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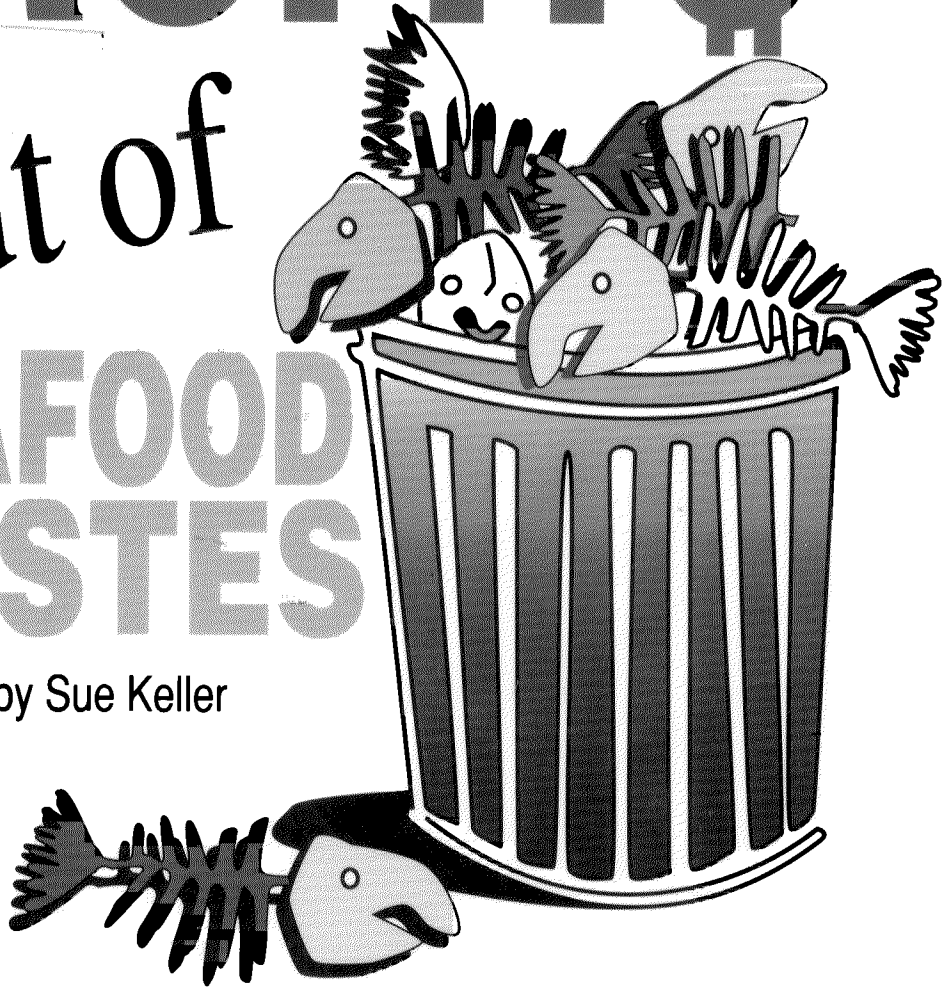
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SEAFOOD WASTES

Edited by Sue Keller



Proceedings of the
International Conference on Fish By-Products
Anchorage, Alaska - April 25-27, 1990



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International Conference on Fish By-Products
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Peter Moore, Conference Chairman
Brenda Melteff, Conference Coordinator

INTERNATIONAL CONFERENCE ON FISH BY-PRODUCTS
PROCEEDINGS
EDITED BY SUE KELLER
ANCHORAGE, ALASKA, APRIL 25-27, 1990
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AK-SG-90-07 1990 Price \$10.00

Elmer E. Rasmuson Library Cataloging-in-Publication Data.

International Conference on Fish By-Products (1990 : Anchorage)

Making profits out of seafood wastes : Proceedings of the International Conference on Fish By-Products.

(AK-SG-90-07)

1. Fishery products—Congresses. I. Keller, Sue II. Alaska Sea Grant College Program. III. Title. IV. Series V. Series: Alaska Sea Grant report ; no. 90-07.

SH335.8.I58 1990

About This Publication

This book was produced by the Alaska Sea Grant College Program and the Alaska Fisheries Development Foundation, primary sponsor of the conference. The Alaska Sea Grant College Program is cooperatively supported by the U.S. Department of Commerce, NOAA Office of Sea Grant and Extramural Programs, under grant number NA90AA-D-SG066, project numbers A/75-01; and by the University of Alaska with funds appropriated by the state.

Cover design and graphics are by Susan Burroughs and text formatting is by Lisa Sporleder. John Doyle and Stephen Sparrow, University of Alaska Fairbanks, helped edit two contributions. Question and answer sessions were recorded and transcribed by Gemini Reporting Services. Printed on recycled paper.

Sue Keller, editor of these proceedings, has edited numerous publications during the three years she has worked at Alaska Sea Grant. Her experience in science editing include a science journal and several proceedings, technical reports, annual reports, and catalogs. Her background is in biology.

Members of the organizing committee and sponsors of the conference, Making Profits Out of Seafood Waste: Alaska's Billion Pounds of Protein, are listed in Peter Moore's Opening Remarks contribution.

This information was produced with funds provided through the Saltonstall-Kennedy program administered by the National Marine Fisheries Service under cooperative agreement NA-89-ABH-00008.

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WELCOME

Robert G. Poe
Governor's Office of International Trade
Anchorage, Alaska

I appreciate the opportunity to speak with you today. Governor Cowper was not able to be with you because he needs to be in Juneau with only 12 days left in this legislative session. The Governor has taken a strong position on international trade, and on supporting the kind of development we're talking about today.

Since 1986, the dollar value of exports from Alaska has doubled. In terms of fish exports, in 1989 the value amounted to 1.096 billion dollars. That number does not account for some of the seafood leaving through other ports. So some of the Alaska seafood that leaves through Seattle is included in that number. Almost all of this went to Asia. Alaska is one of two states in the nation that has a positive balance of trade with Japan. The important thing about this number is that the values increased at a disproportionate level to the increase in volume. That shows an increase in value of the product. The Japanese yen did increase in its strength, but not as much as the value increase.

New markets are opening up before our very eyes, especially in Taiwan and Korea. This year you'll see a big drop in the import restrictions in Korea over salmon, fresh cod, and other kinds of seafood products. All these point to increased value activities. And that is what this conference is really all about. Exporting value-added products is good for Alaskans. It means more Alaskans work; they help produce these products. Most of the money stays in our state, which strengthens our ability to compete on the world market. But value-added products can be found in some pretty unlikely places. We should open up our minds during this conference and take a close look at possibilities for value-added products.

In 1987 the Anchorage International Airport was already one of the two busiest cargo airports in the world in terms of landed weight. The Anchorage airport behaved more like a big gas station than it did any kind of world cargo hub. But 90% of all air cargo going from Asia to Europe, and 70% of all air cargo going from Asia to the lower 48 United States went from Anchorage, Alaska. That's a lot. We marketed to Federal

Express, to UPS, and to Flying Tigers. Now we have Federal Express's world cargo hub. UPS has an important application in for a new Japanese route, and is already serving Seoul and Hong Kong through Anchorage. Federal Express bought Flying Tigers, so the impact of Flying Tigers in the airport is much stronger today. We believe this will continue, and we could see much more export of value-added products as a result. Having those boxes get off the airplane also means that Alaskans and businesses from all around the country can take advantage of cargo moving through the port just as Hong Kong, New York, Chicago, and San Francisco did in their history as ports.

In timber, Chugach Alaska has recently built a large kiln-dried lumber mill in Seward, Alaska. And right now a Korean firm is looking very seriously at using the chips that would be produced from rejected logs from that mill to produce medium-density fiber board for musical instruments. Those are value-added products. In the past, Alaska cut down the logs and sent them to Japan so that somebody else could cut them into lumber, or make them into particle board, or pulp. Today, we're starting to do that ourselves.

I'm not an expert on fish, but I understand a large amount of protein is going right over the side down into the fishing grounds. In some cases, I suppose it feeds other fish. In other cases, it's an overload, and the system probably can't handle it. I think the opportunity to look at value-added products, and to look at the benefits of using our resources through a value-added process means more dollars, more profits for your companies, and less waste.

The opportunities for value-added products are staring you right in the face. You really need to open your minds—to think why not? Why couldn't that be an opportunity? I suggest that as you hear the various speakers during the conference, and you hear about the different innovations, try not to say, "Well, that will never work," or "I can't see how I'm going to make a profit there," or "I can't see that market's really open." But look at the potential. Everyone said we couldn't get Federal Express, and we got it!

OPENING REMARKS

Peter J. Moore
Alaska Fisheries Development Foundation
Anchorage, Alaska

Good morning. I am conference chairman and an Alaska Fisheries Development Foundation staffer. You are probably aware that another fisheries meeting is under way in Anchorage this week. The North Pacific Fishery Management Council is deliberating over the allocation and exploration of the groundfish stocks in Alaska's 200-mile Exclusive Economic Zone. I recommend that you all take an interest in those discussions, now and in the future, because their decisions will directly affect you.

Our gathering of innovators and interested seafood processors represents a hopeful counterpoint to the allocation battles being waged at the council. Full utilization of the harvested resource will be a challenging goal to achieve, but it is one all of us in this industry must strive for. Otherwise, we will see tremendous political pressure exerted on the council to increase the harvest quotas, with potentially dire consequences for the fish stocks. We have a glaring and tragic example of that in the New England and eastern Canadian fishery right now. Your minds, attitudes, and work are in great demand to help solve this pervasive problem—also a promising opportunity. Allow me to make some brief introductions and some acknowledgments.

This conference has been in the planning stage since May 1988. Our first planning committee meeting was held in December 1988. The committee is made up of the following individuals:

Chuck Crapo, Seafood Quality Specialist, Fishery Industrial Technology Center, University of Alaska Fairbanks (UAF), Kodiak

Fred Husby, Associate Professor, Agricultural and Forestry Experiment Station, UAF, Fairbanks

Brenda Melteff, Coordinator, Alaska Sea Grant College Program, UAF, Fairbanks (Conference Coordinator)

Mike Meehan, By-Products Manager, Icicle Seafoods, Seward

Peter J. Moore, Alaska Fisheries Development Foundation, Anchorage (Conference Chair)

Carl Rosier, Chief of Industry Services, National Marine Fisheries Service Alaska Region, Juneau

We have been blessed with the generosity of many individuals and companies who willingly sponsored this conference. These sponsors contributed speakers' travel and meeting expenses, donated seafood and beverages for our receptions and buffet, and gave us cash for unrestricted use in supporting the conference:

Alaska Fisheries Development Foundation

Alaska Fresh Seafoods, Inc.

Alaska Pacific Seafoods

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THE RAVEN, THE BLACKFISH, AND THE FUTURE OF ALASKA

Mel Monsen
Alaska Fisheries Development Foundation
Anchorage, Alaska

We hope this important gathering will be the first step on the path toward full and efficient use of Alaska's fish resources. I begin by telling you an Alaskan story. There is a legend among the local Chugach Indians about the Raven, who was a hero of many Indian tales in Alaska.

One day the Raven was out fishing with his wife and they came upon a Blackfish. The Blackfish was hungry and asked the Raven and his wife for something to eat. The Raven gave him a cod which he had just caught. The Blackfish, who was very clever, said, "Thank you for this cod, but I don't know how to eat it." The Raven said, "Here's how you eat cod fish—you take a big bite, then you close your eyes and chew." And the Raven took a bite and closed his eyes, to demonstrate.

But while he had his eyes closed the Blackfish stole the Raven's wife and dived with her deep into the ocean. The Raven was full of grief, and he vowed to get his wife back. Shortly he found a little songbird, who lifted up the edge of the ocean so the Raven could crawl under the sea to look for his wife. At the bottom of the sea, the Raven met the Halibut. He told the Halibut the Blackfish had stolen his wife and dove with her into the sea.

Then the Halibut told the Raven to follow the road that led up from the bottom of the sea because, he said, that's where all good things come from. So that is what the Raven did. He climbed up to a kelp bed where a Greenling was resting on a kelp leaf. He told the Greenling that he was looking for his wife, who had been stolen from him. The Greenling said, "She was here yesterday. Follow this road up the hill and you will find her."

And so the Raven followed the road from the bottom of the sea up the water column, and each fish told him that he was catching up with his wife, and would soon find where the Blackfish had hidden her. Finally the Raven met the Black Bass, who reached onto her roof where she kept a string of minnows. She fed minnows to the Raven and told him that the Blackfish was hiding his wife in a smokehouse on the shore, and was being guarded by a Crane. She gave the Raven a

spearhead and told him to be careful.

The Raven walked quietly up the road to the smokehouse, but the Crane saw him. Cranes had short beaks then, but they were good watchmen. The Crane started to attack, but the Raven pulled out the spearhead. He said to the Crane, "I will give you this gift if you let me in the smokehouse." The Crane was very happy to have the spearhead, and the Raven was very happy to find his wife. That is why, to this day, cranes have long, spear-like beaks. And every winter, the ravens of this region come down to the sea—some say they come to look for the lost wife of the Raven.

This legend is a little bit like fisheries development in Alaska. Like the Raven, we too often have to start at the bottom and work our way up through a problem. At the foundation we've learned you can't develop one fishery without hearing from another. It seems that we will never find the answer to our fishery problems until we consider every species of fish in the water. And, like the Raven tried to tell the Blackfish, sometimes the only way to begin is to close your eyes and take a big bite.

With this story, I hope to introduce you not only to a bit of local lore, but also to Alaska Fisheries Development Foundation. I'd like to tell you about who we are, how we may help you in the future, and how you can get involved. The foundation is a non-profit industry-built organization that sponsors projects and studies to aid in domestic development of Alaska's fisheries. A group of fishermen and processors started the Alaska Fisheries Development Foundation 12 years ago as a local clearinghouse for federal seafood industry development grants.

The foundation started by helping to fund construction of the largest white fish processing plant on Alaska's shores, now a very successful producer in Akutan. Most of our projects for the first few years focused on developing new harvesting technologies to help make U.S. fishermen more competitive in the groundfish fisheries, which then were dominated by foreign fishing companies.

The fishermen of this region quickly developed the

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capacity to harvest nearly all the total allowable catch, and the foundation shifted its focus to the processing sector.

Our first big processing effort was the Surimi Industry Development Project. For five years we studied surimi production techniques and investigated new food processing technologies that could be applied to improve the surimi process. During that time, AFDF funded the start-up of the first commercial-scale surimi plant in the United States, at Alaska Pacific Seafoods in Kodiak. There are now five shore-based surimi plants in Alaska, and 18 at-sea processors producing surimi. Last year the industry produced 100,000 metric tons of surimi.

From surimi we moved on to our flatfish demonstration project, which is now in its third year. Our goal here is to learn how to efficiently process and market the millions of metric tons of flounder and sole within our 200-mile limit, most of which previously were ignored or discarded. As Northwest Atlantic flounder species diminish, the potential for a profitable Alaska flatfish industry improves. AFDF has been working with Eagle Fisheries, All Alaskan Seafoods, Baader North America, TRIO, and several other companies to improve processing technologies, quality control, and market conditions for Alaska's flatfish.

The foundation has also sponsored a project to help upgrade the rather obsolete meal and oil plant at Kodiak Island—a long struggle that continues even now—well after our involvement. We are also involved in projects to develop new end-products using surimi, minced pink salmon, minced pollock, and other underutilized species or product forms.

The driving force behind all of our projects is the industry's desire to make the best use of the fishery products in Alaska's waters. The fishermen and processors of this region are dedicated to finding the balance between conservative fishing practices and aggressive processing techniques. The industry that supports this foundation is now most interested in learning how to process and market the fish materials that previously were discarded, and that's why 250 of us gathered for this symposium.

To the people of the North Pacific, the ocean has always been a provider of plenty—plenty of fish, plenty of room for everyone, and plenty of time for harvests. Very recently we have begun to learn a hard lesson: That even in the North Pacific, plenty is not enough. Our harvesting technology has exceeded even nature's bounty. Our factory ships and trawl fleets are scooping up the available harvest so fast, processors can't even keep up with the flow of fish. This has led to cost effective but wasteful practices like roe stripping—where processors strip roe from spawning pollock and

discard the entire body of the fish, fillet and all, into the grinder.

The furor that has arisen over roe stripping in the last year or so has caused the Alaska industry to take a hard look at all of its processing practices. The industry is asking itself, is 20% to 40% an acceptable yield for fish processing? Even if we are producing meal and oil, is it wasteful to grind into meal products like livers, cheeks, tongues, and stomachs that can be made into more valuable items? These questions form the structure of this by-products conference. Much of the future of Alaska seafood processing will have its roots in this meeting.

This is a turning point in the history of Alaska seafood processing. From these days forward, we have the opportunity to become a major source of the world's valuable fisheries by-products. With our bountiful resources, our globally centered location, and our history of cooperation with other fishing nations of the world, we can help turn our fisheries into an even greater treasure for the future.

I invite you to become involved in the future of the North Pacific by participating in the Alaska Fisheries Development Foundation. AFDF is a membership organization made up of more than 100 companies from Alaska, the United States, and around the world. Our member companies help guide the foundation's projects, design its goals, target funding sources, and make connections for the foundation's growing network.

The AFDF Board of Directors is made up of 13 members from the harvesting, processing, and supporting sectors of the industry. The Board of Directors meets three times a year and is very active in setting the direction of the foundation.

Projects are administered by the AFDF staff. Right now there are five staff members—two project managers, a controller, our secretary, and myself. Together we work with the companies and contractors who conduct AFDF development projects, and we disseminate information learned from those projects to the industry.

Our communications efforts are part of AFDF's strength in the industry. Through newsletters, videos, reports, and conferences such as this one, we try to create a forum for the free exchange of information. In this way, AFDF acts as a catalyst between suppliers and buyers, between producers and product developers, between the potential of an industry and its fulfillment.

By helping sponsor this international by-products conference, we hope to create the same kind of activity. We hope that here, companies can gain from each other's knowledge, discover solutions to our emerging problems, and find hope in the tangle of ecological, economical, and ethical issues that we are facing in this industry. We in Alaska are dedicated to finding the

methods not just to make more money from the sea, but to act respectfully toward it so the ocean can continue to feed us, and to feed our children.

The Chugach Indian legend I told you a few moments ago tells us something important about the Natives who have lived in this region for thousands of years. They believed there were great treasures in the sea. They believed that by diving into the ocean and

learning about the fish resources that abound in these waters, we will find our way toward our desires. And like the Raven who longed for his wife, they believed that by following the path that leads from the bottom of the sea they would discover something as precious as life itself. I welcome you to Alaska and to the international by-products conference: **Making Profits out of Seafood Waste: Alaska's Billion Pounds of Protein.**

CLINGING TO THE FOOD WEB: THE POLITICS AND PENALTIES OF WASTE AND THE SEA

**Bradford Matsen
National Fisherman
Seattle, Washington**

This symposium is part of an attempt to take one of the most negative wrinkles in our business—waste—and try to set it right, which seems to be what the Alaska Fisheries Development Foundation is all about. I first caught wind of the foundation at a fishermen's poker game in Ketchikan in 1980: one of those mid-winter gatherings of ocean hunters, with a party going on in part of the house and the card game in the kitchen. At some point in the evening, one of the players mentioned that she and some other people were pushing to spring money out of the National Marine Fisheries Service into regional foundations that would use it to develop the fisheries off their own coasts.

At the time, the state of Alaska had just commissioned a study of the potential of the offshore fisheries and declared that we had a billion-dollar bottomfish dream to pursue. So we pumped some petro-bucks into a variety of agencies to encourage the development of renewable resources, to counter the uneasiness just about everybody felt about dependence on oil and the pipeline.

At first, I was skeptical of the value of a fisheries development foundation because it looked for all the world like another government pocket just waiting to be picked. My skepticism was short-lived, though, since even the somewhat controversial and not entirely successful demonstration projects of the early years taught us a lot about production and dead ends. In fairly short order, the foundation had a bottomfish factory up and running in Kodiak, and another in the Aleutians, both in partnership with fledgling white fish companies. One of the companies survived, the other didn't. The foundation also stimulated the development of fishing technology in at-sea projects, and woke us up to one of the toughest games of all, marketing.

Through a substantial part of its existence, the foundation concentrated on introducing Americans to the surimi miracle—until that point a truly mysterious part of the global seafood repertoire. Right now, the foundation is putting a lot of time into finding ways to make flatfish pay—another puzzle. Lots of flatfish that

could be food at a profit aren't getting to market. The foundation has become an institution whose job is to foster creative impulses that don't immediately produce bottom line results for fishermen, processors, or consumers, but give us breathing room to try something different. Now, with that same kind of creative boost, all of you are taking a shot at one of the most nagging and critical pieces of misery in food production from the sea: waste. I applaud the foundation for sponsoring the symposium, and all of you for being here.

The very idea of waste is repugnant to every one of us, and it is beginning to operate as a kind of speed bump in mainstream commerce in our hurtling culture. When the earth was supporting half a million, or a billion, or even two billion people, we could literally hide all our waste, but no more. It's right out there in plain view, and our collective self-esteem is suffering because we now suspect we are the destroyers, though our myth structure celebrates creation. For most of us, one of the earliest moral absolutes of childhood was: Don't waste food. As individuals we cherish that sensibility. I have heard endless variations on why this group or that group of fishermen or processors should get a break on an allocation or a season or a regulation, but everyone unanimously condemns waste, even the people most intimately involved with its practice and outcome.

If you talk to a fisherman about wasteful conduct in the fisheries, he'll tell you he wouldn't do it if his competition wouldn't do it. Though we continue to operate like the waste champions of earth, we are awakening to the truth of a finite ecosystem and the certainty that we must be responsible custodians of our home planet. It is bad enough that we produce a horror show of toxins in the mere process of living and consuming, but we also waste what we could use or re-use. And perhaps most consequential, we are wasting food.

I have had the privilege of writing about fishing and seafood under the covers of a couple of fine magazines for a dozen years. We've all enjoyed the pleasures of a decade of relatively uninterrupted prosperity, at least on

the Pacific. Another part of my good fortune is that I have been tolerated for a long time without laying any real money down to back an idea in seafood commerce. So I'm a little uneasy discussing a topic that translates into hard dollars in the profit and loss statements of many of you.

As a journalist, I am basically in the business of accumulating thoughts, ideas, and tall tales from other people and passing them on. I am, therefore, in a constant state of indebtedness along those lines. I'm grateful to quite a few of you and others for loaning me your good ideas on the politics and penalties of waste and the sea, but I also take full responsibility for the way I string my purloined ideas together. The title of this symposium, Alaska's Billion Pounds of Protein, is an understatement just begging for elaboration.

Here are some numbers: A billion pounds of protein is 500,000 metric tons; that's half a million. Our annual catch off Alaska is about three million tons. On a world scale, however, we land about 100 million tons of protein from the sea each year, and by all the best estimates, 20 million tons—fully a fifth—that could become food is wasted one way or the other. This is important, because just about everybody agrees that we will not see much more than a hundred million pounds of protein annually from the world's oceans, ever. In all likelihood, we will harvest less because of the general destruction we are visiting on the seas.

Without the truth that ocean resources are finite, the notion of waste would be abstract and practically meaningless despite our moral prohibitions. I'm always amazed when the revelation that the ecosystem is finite startles us again and again. Until about 15 years ago, just about everybody figured that food from the sea would banish the conclusions of Malthus and the others who stumbled across the grim mathematics of population growth in the nineteenth century. He demonstrated convincingly that, unchecked, the earth's population is quickly outrunning our ability to produce enough food to sustain that population. That is to say that sooner or later, we will experience famine of hideous proportions and other grim reminders that the earth does not exist just for us.

But like pilgrims, we put our faith in the sea to provide after discovering the amazing bounty of its higher, edible animals. Until 1975 or so, things looked pretty good, and the myth of the inexhaustible oceans took hold. A major human shortcoming seems to be our inability to consider long range threats to existence as anything but abstractions that cannot be incorporated into the daily routines of life. After all, the certain threat of a catastrophic earthquake has not kept us from building a megalopolis on the California coast, and the threat of starvation five or ten generations hence is

likewise beyond our ability to deal with it.

Commerce, with its emphasis on short term returns, certainly isn't going to respond realistically to the global food crisis until a lot of bad things are happening. Large-scale harvesting of seafood did not begin until the 1950s, when we were taking just 20 million tons of food from the sea, coincidentally the same amount we estimate we are wasting now. The first distant water fishing ship capable of catching and processing was a converted British whaler called the *Fair Try*, which started fishing just 35 years ago. She began the shift from essentially artisanal fisheries to industrial fishing, of which we are all a part today.

From the 1950s to the 1970s, we increased the world fish catch from 20 million tons to a phenomenal 70 million tons at a rate that easily exceeded that of population growth. Fat city, right? Wrong. Catches leveled off and the population continued to explode. On that side of the equation, it is valuable to note that when I was born only two and a half billion earthlings were around. Now we are double that number, and by the years 2030, we'll double again to around 11 billion.

Right about the time we got our first look at the earth from an Apollo moon ship as the 1970s began, and saw that the big blue marble is a one-time offer, the myth of endless food from the sea had begun to unravel like a cheap rug. Catches leveled off, humans proved to be not only voracious food consumers but destroyers of the habitat upon which we depend for that food. If that 100 million tons we take from the sea each year is all we'll ever get, we can't waste much and still have a chance at survival. A few days before I came to Anchorage, I asked my daughter, Laara, who is 16, what I should tell you about the ocean. After a long pause, she said, "Tell them that the ocean is our strongest mother and our most fragile child."

So what, in the context of a robust but limited ocean ecosystem, is waste? First, I propose that our definition acknowledge that every food or energy system with which we interact is going to produce at least some waste no matter how good our intentions. Furthermore, we have to consider that some food potential returned in proper portions to the ecosystem is called fertilizer. How much waste we or the oceans can tolerate though, is another question. We wouldn't be here on this fine spring evening if we had the answer or if we didn't suspect we are already wasting too much food to suit our moral and business sensibilities.

It seems to me that we are participating in unacceptable waste production in three ways. Though a solution to each lies within the responsibility of a specific sector of our industry or culture, we should approach them as common challenges rather than as targets for blame or indignation. First, and probably

most approachable, is the waste we produce by failing to use everything but the splash of the fish we actually catch. This is most specifically a consideration for processors and marketers who must not only find ways to extract the protein in palatable form, but then sell it to consumers who are used to salmon steaks, cod fillets, and the like. It is tough because you're asking the consumers to not only start eating seafood that isn't absolutely terrific, but to stop eating seafood that is. Typical samples of this type of waste are before us each season in the roe stripping of herring, pollock, rock sole, and other species, and in the high-grading of fillets and loins.

Second, we waste millions of tons of food because our choice of non-selective, high-volume fishing methods force us to catch creatures we do not intend to catch, don't have the ability to process, and in many cases are prohibited from catching by law. We have to throw them back into the sea, dead or alive. This is most specifically a consideration for fishermen and fisheries managers. It is the famed collection of ongoing debates that we lump together as the Bycatch Dilemma.

All of you who have labored through a decade of attempts to solve the bycatch dilemma are participating in a unique and noble effort, despite the frustration and anxiety. Never before has a fishing nation tried to set policies to mitigate interference with the total ecosystem. The artisanal and largely unregulated fisheries, that existed before the industrial fleets, faced none of the complexities of bycatch management. Artisanal fishermen take everything they catch and sell it or eat it; if the fishing falls off, they just move. Most modern industrial fishermen take what will produce the most profit, and now we don't have the option of moving on.

In these first two categories of waste, we also have to acknowledge the dominant role of the consumer and the political force of economics in the puzzle. Until now, society has basically condoned waste in favor of lower prices. Squeezing the last bit of consumable food from ocean, field, or orchard costs money, which must show an effect in the market. For example, the cost of picking 99% of the world's peaches rather than just 90% would drive the price of a single peach from, say, 25 cents to 50 cents. So far, though, at least in the developed nations, we have never had to worry about running out of peaches and getting down to eating the pits and maybe the bark off the trees.

Third, and most consequential in our consideration of waste, is the destruction of the ocean's very ability to produce food. The key fisheries issues from here on are going to turn more on protecting regional and global environments and less on limitation of our extraction of the resources.

The fact that we once perceived the oceans as

limitless is quite understandable. We didn't even run out of free land until our grandparents' generation. And what's more, the real threat is not so much to the seas, which will survive an enormous measure of abuse and still recover; it is we humans who will not survive if the oceans are destroyed as a food source.

So what do we know about the sea? Not much. One marine biologist I know is fond of saying that we know less about the earth's oceans than we do about the surface of the moon. He is given to hyperbole, but his exaggeration is not far off. We do know a few things about the seas, though understanding how the oceans work is roughly akin to trying to figure out how that magnificent electrical organ, the human brain, works. We can come up with a few facts, but no real answers.

First, fish and other marine organisms have demonstrated a remarkable ability to adapt to the ecosystem of the planet earth, or more accurately, planet ocean, as water forms seven-eighths of everything we know. Over 90% of all vertebrates are fish, the most successful class of creatures, and they have thrived in every body of water on the globe.

The fishes are the creatures most synchronized with the earth's rhythms. Since most living things are more water than not, it is advantageous to live in an environment such as the sea in which an animal does not have to expend much energy to conserve or produce water. This harmony with water, the nature of water itself, and the characteristics of water in great quantities like the oceans offer a framework onto which we can graft bits of knowledge.

We do have some idea of how the marine ecosystem works and how marine organisms have adapted to life on the ocean planet. The governing generalities of the system are a product of nutrients, light, and circulation. Every living creature is both predator and prey, consumer and food. The forms that make up the marine food web have adapted to span levels of complexity from single-celled organisms to the intricate systems of the blue marlin, for instance, that include heating tissue, a brain, and a sophisticated digestive tract.

Many ocean species participate in the nourishment cycle in different ways at different levels of their development from egg to adult. At some point in their life cycles, the higher animals are more prey than predator. Because of these stages of vulnerability, the more complex an organism, the longer it takes to replace it in the sea. Phytoplankton, the microscopic plants that form a huge part of the marine nutrient web, can double in number in a day. Replacing a dead mature marlin, however, requires good genes, many years, and a lot of good luck.

The predator-prey dance that accounts so profoundly for adaptation in the nutrient cycle is performed in a

saline soup, the sea, so the condition of the sea itself is critical. Only certain things can happen in cold water, other things in warm water, and so forth through various conditions of temperature, salinity, and levels of light. Circulation of water and its nutrient packages can be vertical as in the daily movement stimulated by heat and light, or horizontal as in the ocean currents and upwellings over subsurface terrain.

Most photosynthesis that produces the lower trophic orders of the marine food web—like planktons and krill—occurs in the sea's top 300 feet where light can penetrate the water. Without both horizontal and vertical circulation, the ocean below that top layer would be virtually inert except for sinking organic matter that is pulled by gravity to the bottom. Nothing like the earth's fertile seas would exist without circulation.

Though we humans are conversant with the broad concepts of ocean dynamics and the food web, the variables are so complex as to be classed as mysteries. That complexity means that the oceans able to produce foods for humans are very fragile, despite their magnitude, especially when juxtaposed with waste producers like humans.

Most of what has emerged from several hundred years of systematic study of the sea tells us only that our interactions with marine systems will have consequences that extend far beyond our ability to predict them. We can, however, observe the condition of the sea and its ability to produce food as an indicator of the overall health of the big blue marble.

Whether we are in the marine food web as predators, or just living in our urban clusters on the ocean shores, the critters of the seas are like mine shaft canaries for humans and our continued existence. Miners bring canaries or other singing birds with them into the shafts because the more fragile birds expire sooner than humans if the subterranean air becomes unbreathable. When the birds stop singing, the miners beat it for the surface if they can.

In the late 1970s, a profound message on the ocean was delivered to millions of people in a very unlikely bit of Hollywood fluff, a movie called *Oh, God*. George Burns plays the title role as a charming, acid-tongued wit, wearing a white fishing hat with a marlin in mid-leap emblazoned on a patch on the crown. At a particularly critical point in the movie, George tries to convince a produce manager named Jerry, played by John Denver, that he really is who he says he is—God—and that Jerry should carry a message to the world. They play the scene in Jerry's bathroom, where Jerry—in the shower—listens to God in his marlin hat say that everything people need to make a paradise is here on earth and it's up to us to take care of the details.

Then George Burns stabs a finger at Jerry and

says, "And another thing: I look down, and I don't believe the filth; using rivers for toilets; poisoning my fishes. You want a miracle, make a fish from scratch. You can't. You think that only God can make a tree? Try coming up with a mackerel. And when the last one is gone, that will be that. Eighty-six on the fishes, good-bye sky, so long world. Over and out."

I don't know whether George Burns has ever caught a fish, but the message in that speech buried in some light entertainment in 1974 rings louder and clearer as time passes. We all have to summon enthusiasm for what we do every day, whether it is writing my hundredth story on fish politics or running a packing company, and it is good to be reminded that we are involved in matters of consequence that demand the best in us.

Especially those of us who take from finite resources for our own needs and pleasures. So what do we do about waste and the sea? Well, in the matter of the general condition of the oceans, we should work for global policies that protect them. The recent agreements on marine debris are a good example. We are moving into an era of truly international perspectives on fisheries and the seas, probably because 15 years ago we and other maritime nations claimed 200 mile zones off our coasts. Before then, you didn't have to get along with anybody to gain access to the fish; you just sailed in, took it, and left. It is now true that we cannot manage fisheries from a United States or Russian or Japanese point of view in the long run; we have to manage from a North Pacific point of view.

We should insist on more scientific inquiry and bolster our paltry understanding of the marine ecosystem. And we should remember that whatever we do to the sea might not be undone. We might be able to increase the net food tonnage from the sea by harvesting the lower tiers of the food web like krill, but we had better not mess around there until we know for sure what's going on throughout the system. We don't want to make a wrong move in the lower trophic orders.

In the matter of bycatch, the destruction of critters we don't intend to eat, we're just going to have to shake down our politics so we're not always thinking with our wallets. We have a system now in which those outside the law can do better than those inside the law; we are all uneasy with the gap between our moral prohibitions against wasting food and the economic validation of actually doing it. As efficient as our bottom line mentality is in some things, it is playing hell with the condition of our home planet and our vision of ourselves.

And finally, in the matter of using everything but the splash from what we catch and process, the iron, as we say, is hot. The very fact that a conference like this takes place is a note of optimism. We can also look

forward to a new era of selling what we produce to consumers who will respond to ecological positivism.

Last year, when I spent a few weeks as a witness to the aftermath of the *Exxon Valdez* spill, I joined the ranks of the walking wounded in Valdez after sleepless days and nights on the sound. A minor miracle brought me a hotel room and I slept in a depressed haze for about 48 hours. When I finally got up, I went to the coffee shop where I ran into a friend who happened to be working at the otter hospital.

We sat down, and the first thing we did to relieve our emotional tension was laugh. Then we talked, and agreed that though Joe Hazelwood and Exxon had some consequences due for their negligence, ultimately every one of us who had ever put pedal to the metal or turned up a house fire was to blame for consumptive abuse. The only way out of the grim vision of ourselves as destroyers was to envision the spill as a wake-up call, alerting our entire culture to the potential disaster at hand unless we clean up our acts. We dubbed

the tanker's skipper Saint Hazelwood of the Reef, designating him as an ecological martyr, hoping that others like us would accept responsibility for the spill.

So thanks to Saint Hazelwood of the Reef and dolphins and drift nets, American consumers are wide open to ecological marketing. You can't watch a couple of hours of television without hearing the words environment or ecology a dozen times. It shouldn't be too hard to find ways to market fish chunks or meal patties or other by-products by selling their consistency with sound environmental practices.

I'll borrow my last words for you tonight from the old food gatherer, Chief Seattle, who lived in a simpler world when it was probably easier to understand this: Buy low, sell high.

Not really. What he said is this, "The earth does not belong to man; man belongs to the earth. All things are connected like the blood that unites us all. Man did not weave the web of life, he is merely a strand in it. Whatever he does to the web, he does to himself."

WORLDWIDE PROTEIN MARKET DEVELOPMENT

K.R. Ellis
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INTRODUCTION

This reports on the development of the international protein situation—the supply, demand, prices, and dynamics that have an impact on the market. The proteins covered are the major vegetable meals, fish meal, and other major animal meals. In the vegetable category are soybean meal, cottonseed meal, rapeseed meal, sunflower seed meal, peanut meal, copra meal, linseed meal, and palm kernel meal. The major animal proteins are meat and bone meal, poultry by-product meal, and feather meal.

A number of these meals are by-products and their production is governed by supply and demand for the main product. Examples of this are all of the animal protein meals and cottonseed meal. The other proteins mentioned result from the cultivation of oilseeds for their meal and oil.

Alaska's billion pounds of protein is a large quantity of specialized product that will have to find its place in the world market. Perhaps the information that follows will provide an indication of the relative ease or difficulty of accomplishing this task. In order to be consistent we have converted the billion pounds to metric tons; 453,600 metric tons is equal to one billion pounds.

The world production of fish meal for 1990 is estimated at 6.67 million tons, up from 4.8 million just 10 years ago. The fish meal production in 1960 was just under 2.0 million tons. Alaska's billion pounds of protein is 6.8% of the 1990 world production estimate.

Production of animal proteins for 1990 is forecast to be 6.87 million tons. These meals are meat and bone meal, poultry by-products meal, and feather meal. These figures do not include blood meal, bone meal, or hoof and horn meal as there are no data available on these products. It is interesting to compare world animal protein output with Alaska's billion pounds of protein.

The vegetable protein production estimate for 1990 is 111 million tons, compared with 88 million tons in 1980 and 51 million tons in 1970. In 20 years produc-

tion has more than doubled. How does this balance with demand? In 1989 the price average for soybean meal was the highest in at least 20 years. And soybean meal represents over 62% of the total world production of vegetable, or oilseed, meals.

The combined world production total of protein meals is 124.6 million tons for this crop year. Only 3.5% of this is anticipated to be in inventory at the end of the year. This indicates a healthy demand.

The protein supply has doubled in the past 20 years, and after adding Alaska's billion pounds, we have a total of over 125 million tons. This does not include grains, cereals, concentrates, or liquids. This 125 million tons is all protein.

POPULATION INCREASE

Population increase is one of the many forces that has an impact on the supply and demand of protein. Thirty years ago the total population was 3 billion people. In 1990 the estimate is 5.25 billion, and in the year 2000 the forecast is for over 6 billion. In the 40 years from 1960 to 2000 the world will have added 3 billion people, which means population will have doubled in those 40 years. In the late 1960s and early 1970s the rate of increase was fairly steady at 2% per year. In recent years the rate has slowed to 1.6% and is expected to decline further to about 1.3% in another 15 years. However, even with the lower rates, the estimate is for the world to add another one billion people between 2000 and 2010 for a total of 7 billion.

Such an expanded population requires greatly expanded food and feed supplies. The main use for vegetable, animal, and marine proteins is to produce meat, milk, and eggs for the human population. The expanded supplies of protein have been able to keep pace with the demands of an increasing population. Although there has been severe famine in some areas of the world, surpluses of food have existed at the same time in producer countries. The problem is proper distribution rather than inadequate production. You are probably familiar with the recent mountain of butter in the European Economic Community, and the sale of over 150,000 tons to the USSR at \$.12 per pound.

GOVERNMENT PROGRAMS

Government programs are in place in abundance in all major crop producing countries. We have subsidies to encourage production, intervention prices to help the less efficient producer (in the EEC), licensing procedures to control exports, and export promotion arrangements to move out surplus stocks, to name a few.

The United States and the USSR recently signed an agreement that allows the USSR to buy 10 million tons a year of grain, soybeans, and soybean meal. This is a five-year agreement replacing the old one that allowed the purchase of 9 million tons per year. While most of the new agreement covers wheat, corn, and barley, 2 million tons per year can cover soybeans and soybean meal along with wheat and grains. The USSR is expected to buy 4.3 million tons of soybean meal in 1990, in addition to 2.0 million tons of other meals. Consideration is being given to extend credit to the USSR, which should be welcome to them given the current state of their economy.

Brazil, the second largest producer of soybeans after the United States, uses export registrations to balance its need for soybean oil with its need for foreign exchange. When Brazil closes its registrations for export, we can usually expect an immediate price increase for our beans and products. A change in existing government programs, or new ones, by major producers or consumers usually has an effect on world protein prices.

One of our country's programs is the sunflower seed oil assistance program, also known as SOAP. Under this program a bonus is paid in pounds of sunflower seed oil per ton of exports. A total of 100,000 metric tons to Egypt and Algeria was announced and over 60,000 tons has been sold and shipped. One sale to Egypt was for 10,000 tons, and for each ton sold Egypt received a bonus of 730 pounds. This amounted to an additional 3,311 metric ton bonus. This is in addition to our vegetable oil export enhancement program that has 765,000 metric tons registered and 525,000 tons shipped.

PALM OIL PRODUCTION

The largest producer of palm oil in the world is Malaysia. About 20 years ago Malaysia was faced with a sharp decline in export earnings for two of their main products, natural rubber and tin. The development of synthetic rubber had cut deeply into their sales, and the future for natural rubber sales was not good. The International Tin Agreement was beginning to come apart and tin prices were declining. Malaysia decided that the oil palm would be ideal to replace the rubber plantations. They have the acreage and the climate. The

trees begin producing three or four years after planting and continue to produce for another 30 years. Natural rainfall is adequate and the application of fertilizer is the only action that requires labor other than the harvesting of the fruit.

From production of only 431,000 metric tons in 1970, output tripled to 1,258,000 tons in 1975. Malaysia hit the jackpot as prices for vegetable oils tripled in the same time span. Production costs were reported at \$100 per ton and palm oil was selling on the world market as high as \$600 per ton. Buoyed by this success Malaysia rapidly expanded the cultivation of the oil palm, and palm oil production rose from 431,000 tons in 1970 to an estimated 5.9 million tons for 1990. With production also increasing in Indonesia and Nigeria, this year's world production is forecast at 10 million tons. An additional 1.4 million tons of palm kernel oil is expected this year. For producers of protein it is fortunate that the oil palm produces a flesh fruit, similar to a large grape, with very little meal (protein) content. If the oil palm had the same oil and meal content as the soybean, we would be facing over 40 million tons of additional protein meal to affect the world market.

The growth of the oil palm complex has produced a surplus of oil, evident in the fact that Malaysian palm oil delivers to the West Coast for only \$.15 per pound. This growth will also result in a relative deficit of protein meal. Much of the increase in demand for fats and oils will be covered by palm oil and palm kernel oil. The oil palm produces 10 times as much oil per acre than soybeans. The oil palm produces for 30 years, while soybeans have to be planted each year. As a result, oil palm growing is more profitable than soybean growing, and expansion of palm oil production probably can meet increases in world demand for oil.

However South America, in particular Brazil and Argentina, has sharply increased its soybean production over the last 20 years. Brazil's production in 1970 was 764,000 metric tons of soybean meal compared to this year's forecast of over 12 million tons, over 75% of which will be exported. Argentina produced 15,000 tons of soybean meal in 1970 vs. the estimated 5.8 million tons for 1990. Of this, over 90% will be exported. These increases in production resulted in additional quantities of oil on the world market.

Any oversupply of oil results in less incentive to increase soybean production, unless producers can get more money for the meal. With a steadily rising demand for meal (protein), meal prices probably will rise. Meal prices last year were at a 20-year high. While protein prices at this time are below those of a year ago, the oilseed production already in place should favor meal producers in the long run.

POLITICAL CHANGES

In reviewing information for this presentation, I came across some forecasts prepared a few years ago by an organization that collects data on oilseeds, meal, and oil. One of the primary assumptions was that the existing free market economies and centrally planned economies would change little. The events of the last few months in eastern Europe has voided that assumption. Many of those countries will be moving from a strong centrally planned and controlled economy to one with market incentives. Only 10 years ago the USSR was a net exporter of oils and meals. Today they are a net importer of meals, and as mentioned earlier, are expected to import 6.3 million tons of protein meals this year.

Countries in Eastern Europe can be expected to import more protein to produce food for their people. The quantities of imports will depend on the amount of money available and the availability of credit or government programs from exporter countries. There are many communist-socialist countries that have low profitability in their agricultural sector, low yields, and underutilization of resources. These countries represent fully one-half today's world population. Obviously there is great opportunity to provide these countries with the protein they need. Their inability to produce in the past has provided great opportunities for increased production of oils and meal by the United States, Brazil, Argentina, and Malaysia.

CURRENCY CHANGES

Currency changes of the importing and exporting countries also affect the movement of protein. The recent decline of the U.S. dollar has made the purchase of American products less expensive, and thus more attractive. Currency changes can be quick and extreme. An example of an extreme change over time is the Mexican peso. About 20 years ago one dollar would buy 25 pesos. Today one dollar will buy 2,788 pesos. In spite of this decline, last year Mexico was the number one customer for U.S. animal protein, as well as the number one customer for lard, edible tallow, and inedible tallow. Government programs did have a hand in this volume.

Brazil had a 12% devaluation of their currency last year and an additional devaluation is expected, perhaps as much as 30%. Brazil has serious economic problems and its currency is not quoted. Last year, soybean prices rose 850% but inflation rose almost 1,800%.

WEATHER

Weather can be a major determinant of crop prices, mainly when the weather is abnormal. The most recent abnormality was the drought of 1988, which cut grain and corn production by about 25%. In the 3-1/2 months before the expiration of the July 1988 contract, the price per bushel of soybeans increased from \$6.25 to \$10.40, and corn increased from \$2.10 to \$3.30 per bushel. In 1973 above-normal rainfall resulted in a sharp decline in production, and the price for soybean meal doubled from the year before.

Agriculturists continue to look for accurate forecasts of weather but have been largely unsuccessful. Dr. Iben Browning, speaking before a feed industry group in March 1986, predicted plentiful rainfall and bumper crops in 1986. USDA figures show total oilseed production that year to be over 65 million tons, the highest on record and well above the 59 million tons predicted for this year. Dr. Browning also forecast reduced water supplies for the next five years. As far as California is concerned, he was right on. Among his further predictions are that by the year 2010 Canada will grow no grain because the climate will be too cold, and that the growing season in the Corn Belt will shrink to 110-115 days. This is in direct contrast to the reports of global warming that we hear today.

El Niño, which is the periodic warming of the waters along the northwest coast of South America, is blamed for abnormal weather conditions. The last intense El Niño was in 1982-1983 and was responsible for additional moisture that produced bumper crops in Brazil. At the same time Southeast Asia experienced a severe drought that reduced production of palm oil and coconut oil in Malaysia and the Philippines as well as lower corn output in Thailand. A USDA meteorologist notes that the period 1955 through the early 1970s was unique in this century, one in which weather was unusually stable. In the 1980s there have been three major droughts in the United States while Florida has had seven freezes that affected its citrus crops.

The reasons for the higher highs, lower lows in temperature, more droughts, and more flooding? No concrete reasons, only theories, to explain the abnormal weather.

1. This extreme weather may be a return to the type of weather experienced between 1930 and 1955. That theory states that this period was "normal" weather, as contrasted to 1955 to the early 1970s which was described as "unusually stable."
2. El Niño has been fairly frequent and has strongly affected the weather in the subtropics, but also has had an effect in the mid-latitudes.

3. A gradual warming of the earth's climate has received much publicity recently.
4. An increase in volcanic activity affects climate by propelling tons of debris into the atmosphere. Of the earth's 70,000 volcanos, 3% to 5% may be active at any time. After a 1982 eruption in the Yucatan, Hawaii lost 30% of its sunlight through the summer because of the resulting volcanic cloud.

Weather is a major factor in determining crop yield and therefore prices. Unfortunately weather is very difficult to predict, particularly long term. Until prediction becomes more accurate, producers of crops will continue to be victim or beneficiary of weather changes.

ANIMAL PRODUCTION AND PROFITABILITY

Animal production and profitability is a key item for the producers of protein since an increase in animal production requires an increase in feed. The use of feed concentrates in the United States alone this year is expected to exceed 200 million tons. Feed concentrates include fish meal, oilseed meal, animal protein, and feed grains. Keep in mind that total world production of protein meals was put at about 125 million tons.

A major consumer of protein is the poultry industry, which includes the producers of broilers, turkeys, layers, ducks, etc. The U.S. production of turkeys was up 91% in 1989 compared with 1979, and broiler production was up 58%. In contrast, beef production was up only 8% and pork 3%. The large expansion in poultry was due mainly to price and health considerations. Broiler and turkey prices are considered a good value in relation to beef prices. Right or wrong, more people consider red meat unhealthful, and as a result are switching to poultry and fish.

Poultry is an efficient converter of feed to finished product. Broilers require only two pounds of feed for every pound of gain. And broilers reach market weight in only seven weeks for the most efficient producers. Turkeys require 2.5 pounds of feed for each pound of gain and reach a 30 pound market weight in 18 weeks. Production this year of broilers is expected to be slightly over 5.5 billion birds, about one-third of the world's production. Turkey production is estimated to be 267 million birds.

As important as the volume produced is the profitability of the industry. Broilers have been particularly profitable in the past year, which explains the continued expansion. Production in 1994 is forecast to be up 36% over the 1989 output of 5.3 billion birds. Turkey profitability has been spotty over the last few years, but turkey growers are optimistic about the future and plan to expand production.

Exports of poultry are expanding with 15,000 tons of broilers shipped to Romania this year, in addition to 60,000 tons to Russia. Poultry is a relatively inexpensive product to produce as well as being quick. In contrast to the seven week production time for broilers, steers require five to six months in the feed lot alone. A range fed steer would require even more time.

The use of concentrates in the United States in 1987 was 203.7 million tons at a cost of \$15.6 billion dollars. Due to the drought in 1988 the use declined 11% to 181.6 million tons at a cost of \$20.6 billion dollars. Obviously animal producers are very sensitive to any major changes in their feed costs.

At this time very few high-protein ingredients are being used in cattle feed. There is a possibility that animal protein use will increase in cattle feeding due to their bypass characteristics.

An expanding industry is aquaculture, which uses the high-protein feeds. In the southwestern United States, aquaculture is expanding at the rate of 25% per year.

HEALTH AND DIET CONSIDERATIONS

Health and diet are becoming more important to many people. One of the reasons for the increase in poultry consumption and the decline in beef consumption is that people perceive poultry meat as being more healthful than red meat. The main issue here is the saturated fat and cholesterol associated with red meat. The increase in demand for poultry products works in favor of the protein producer since poultry feeding requires a great deal more protein (fish meal, soybean meal, etc.) than does cattle feeding.

From its high point in 1976, consumption of beef has declined from 94.4 pounds per capita to an estimated 67.5 pounds this year. Over the same period, per capita consumption of chicken has increased from 42.8 pounds to 66.1 pounds. As previously mentioned, broiler production is expected to continue to increase steadily for the next few years.

Another aspect of the health question is the use of tropical oils in food products in the United States. Perhaps you will note more advertising stating "no tropical oils" or "no animal fats" in the product. The tropical oils include coconut, palm, and palm kernel oils. Before this became an issue, the United States imported as much as 424,000 metric tons of palm oil alone (1975-1976). This year probably no more than 150,000 tons will be imported. In 1975-1976 we imported 566,000 tons of coconut oil, and this year's imports will be less than half that (estimated 260,000 metric tons). The reduction in U.S. imports of palm oil will be made up by increased imports by India, China,

Pakistan, and Russia.

As mentioned earlier, the large increase in palm oil production does have an effect on the production of oilseeds with a high meal content such as soybeans.

PER CAPITA INCOME

As countries increase their per capita income, they become more able to improve the diet of their people.

As they are able to produce or buy poultry or fish, they will have an impact on the demand for protein.

All of the items discussed will by themselves and jointly raise the demand for all protein—fish, animal, and vegetable. With the world dropping political barriers while trying to improve the standard of living among its people, a substantial increase in the demand for feedstuffs in general, and protein in particular, should be the positive result.

PAST, PRESENT, AND FUTURE MARKETS IN THE UNITED STATES FOR FISH MEAL, FISH OIL, AND FISH SOLUBLES

Thomas J. Starkey
H.J. Baker & Bro., Inc.
New York, New York

H.J. Baker has been involved in the marine protein industry since its founding in 1850. In the early years, the firm was actively involved in the distribution of organic fertilizer products, one of which was fish meal. We carried cargoes of sardine fish meal in sailing ships from California to the East Coast. Baker was also one of the earliest investors in Peru, and at one time produced fish meal in two fish meal plants for world distribution. At present we import fish meal; in fact, we are one of the nation's largest consumers of fish meal. We use it in Propak, a protein concentrate we manufacture. We're also exporting fish meal from Peru, Ecuador, Chile, Canada, and Alaska to consumers in the world markets. Baker is still a major distributor of fertilizer products, as well as a producer of prilled sulfur. We're also importing food products including canned and frozen fish, beef, and fruits.

This report is an overview of the U.S. market for proteins, with special emphasis on marine by-products including fish meal, fish oil, and fish solubles.

PROTEIN USE 1968-1988

Although this report covers recent history, it begins with a comparison of the demand base for proteins from the poultry sector to demonstrate growth from 1968 to 1988. Poultry in 1968 was responsible for about 80% of all fish meal use (Figure 1). We produced about 24 million short tons in 1968 compared to a little over 40 million tons in 1988—an increase of two thirds. In the evolution of fish meal consumption in the United States, 1968 was a key year.

The available supply of fish meal in the United States, both domestic and imported, was 1,127,224 short tons in 1968 and 510,415 short tons in 1988. We had about twice as much fish meal in 1968 as we did in 1988, but only 60% of the poultry feed was produced in

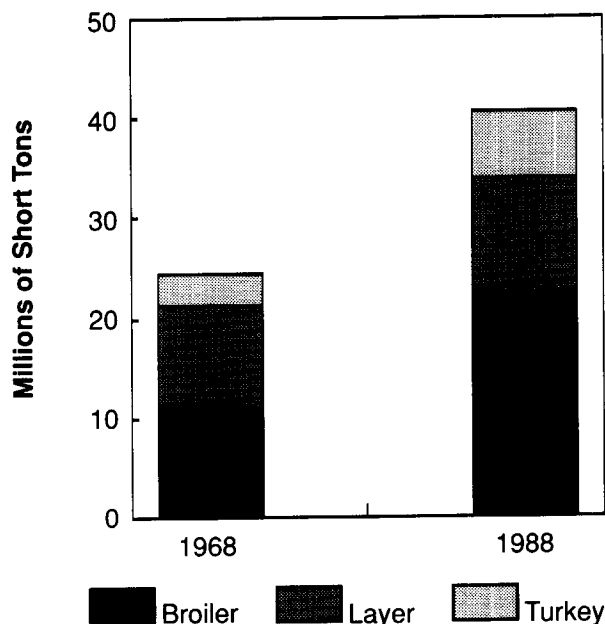


Figure 1. U.S. poultry feed volume, 1968 and 1988.

1988. Why is this? Back in 1968, we had a completely different scenario to justify the heavy use of fish meal. Fish meal was looked at by the nutritionists for its UGF, or unknown growth factors. Selenium content was also an important consideration. It was not uncommon to find poultry feed with 12%–15% fish meal content based mainly on the mystique of UGF. Fish meal producers, importers, and traders in 1968 experienced the peak fish meal demand that the United States could offer, as far as percentage of feed formula was concerned. But times have changed. A growing animal feeding industry outgrew a stagnating supply of fish meal in the years that followed. Since 1968, world production of soybean meal has grown by 176%, but fish meal supplies have increased only 27%. Between now and the year 2000, fish meal production probably will decline about 5% and soybean meal production will

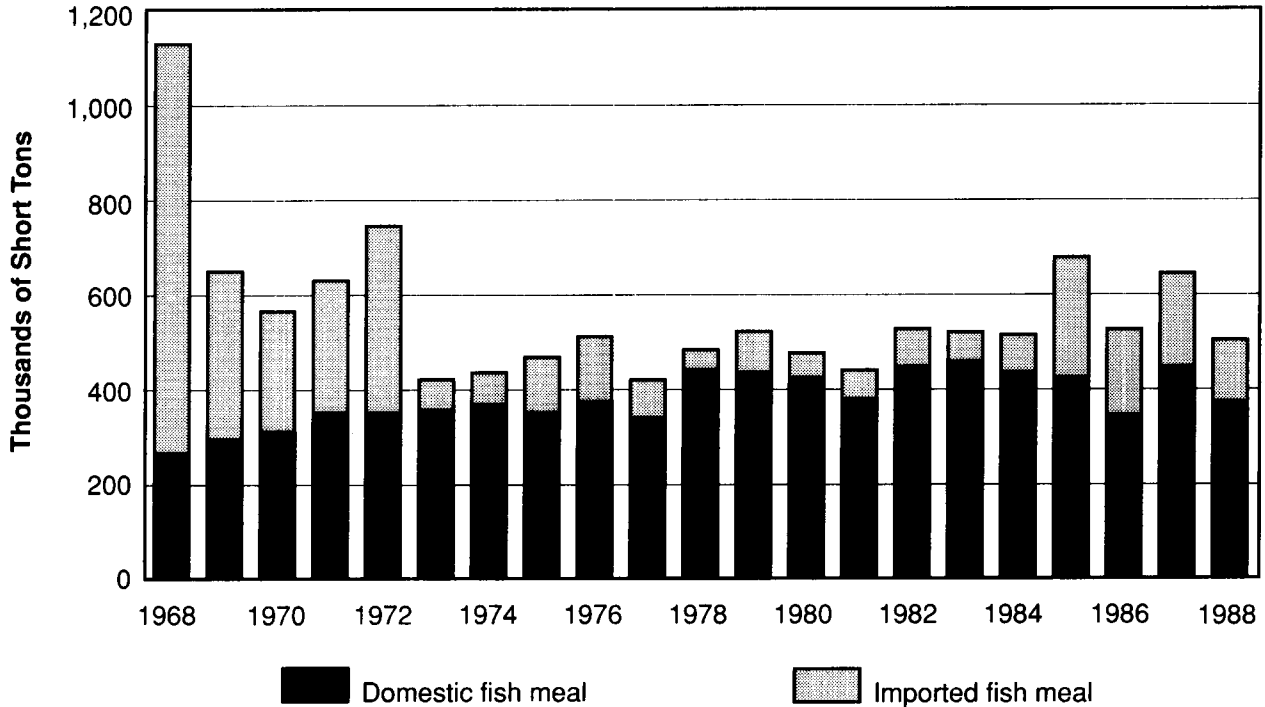


Figure 2. Total U.S. fish meal supply, 1968-1988.

increase by another 37%.

Figure 2 shows the total supplies of fish meal during the 20 years since 1968. Our overall supply has ranged from a low of 425,000 tons in 1973 to a high of 1,127,000 tons in 1968. About 32% of the total supply was imported, mostly from South America. During the last 10 years, we've averaged 547,000 short tons of fish meal supplies per year with little or no growth over that period.

CURRENT USE OF PROTEINS

Let's return to the present and take a look at the overall usage of proteins for the animal, fish feed, and pet food industries in the United States. Figure 3 shows the total usage of major proteins in the United States by type for 1988-89, in metric tons. The dominant protein source is soybean meal, far in excess of all the other proteins combined. It's no secret to the feed industry, or to the traders and distributors, that the direction of protein prices is driven almost solely by the price trend of soybean meal.

To illustrate this point, Figures 4-6 give a comparison of prices between soybean meal and other major by-

product proteins over the last couple of years. Figure 4 is a comparison between menhaden fish meal prices at the Gulf of Mexico and Chicago Board of Trade soy prices based on the nearest option. Figure 5 compares delivered northwest Arkansas prices for fish meal and 48% protein soybean meal, which is used by the poultry industry. Arkansas is the number one broiler-producing state. And Figure 6 compares delivered northwest Arkansas prices for fish meal, meat, bone meal, blood meal, and soybean meal. Among the figures we have some very neat alignments certainly between meat and bone meal, fish meal and soy, and to a lesser extent between blood meal and soy.

This kind of information is important to intelligent buying decisions, because we have a very direct trend relationship between the price of soybean meal and those of other marine and animal proteins.

In order to make a proper judgment, and to make a correct buying decision, all we have to do is guess right on the price direction for soy. Then using historical price relationships between soy, meat meal, fish meal, and blood meal we can arrive at the proper value for other by-products. Of course, this is a lot easier said than done. It is not all that easy to judge the price of soy.

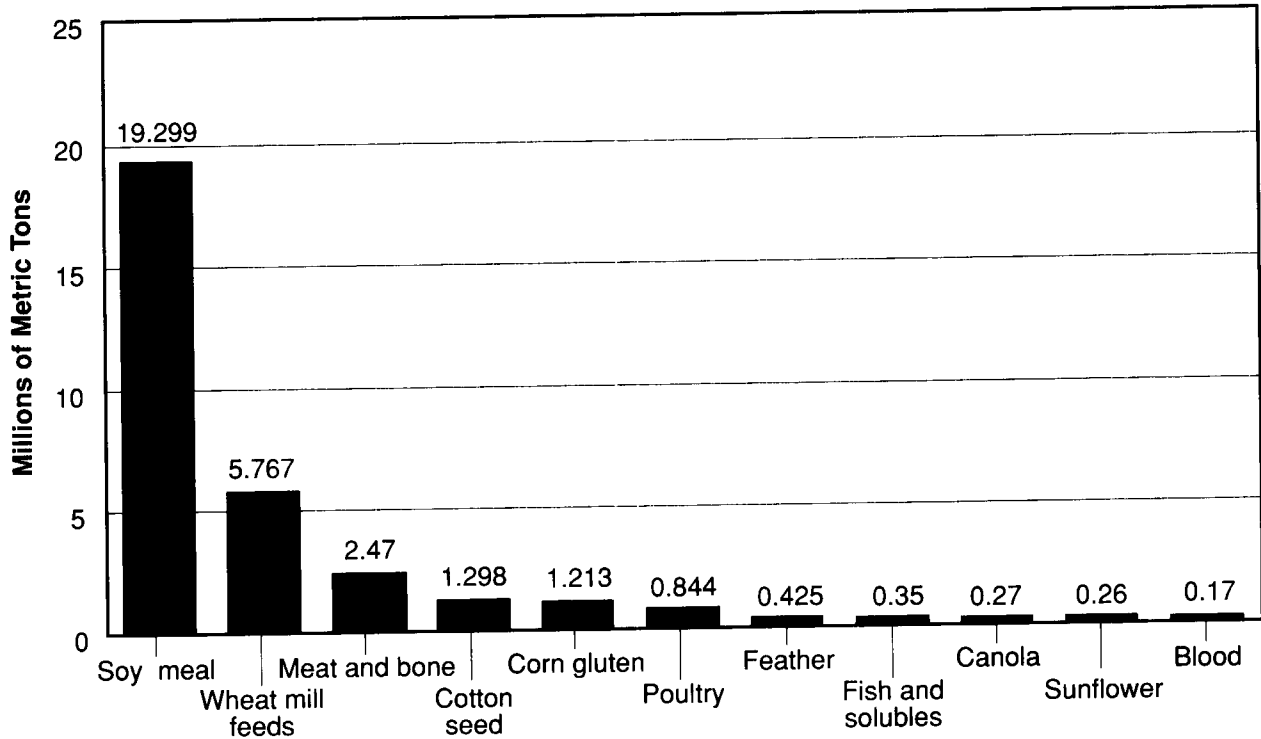


Figure 3. Major supplies of protein for U.S. feeds.

FISH MEAL

In 1989, the U.S. Department of Commerce estimated a total usage of fish meal in the United States at about 350,000 metric tons. For fish meal, 1989 was a high-priced year because of poor fishing in the United States and strikes in Peru over a period of eight weeks. The fish meal to soybean meal price ratio was about 2.0–2.2, which is on the high side. Our best guess on the various percentages used in feeds would be 60% in poultry, 30% in aquaculture, and the balance in pet foods and specialty feeds for swine and ruminants. Although poultry is still the largest user of fish meal, the trend is definitely away from poultry, which represents a more elastic, or price sensitive, demand. That means the computer no longer sympathizes with UGF, and will remove fish meal from the formula unless it's economically priced relative to its amino acids, energy, and vitamin and mineral contributions.

Increasing use is found more in special situations or in elastic areas, such as fish feeds and pet foods. Poultry feeds only require about 21% protein, but a typical fish feed formula such as trout requires almost twice as much protein. Therefore high-quality protein sources,

such as fish meal, allow the fish feeder to pay more for each ton of fish meal to meet feed requirements. In other words, as aquaculture expands, it is gradually buying away supplies from the poultry sector. Aquaculturists use fish meal because it fills protein needs and because high-quality fish meals are well utilized by the fish compared with cheaper plant or animal protein. Of considerable concern to the aquaculture industry is a possible cost-price squeeze, as fish meal consumption increases and world supplies decline. The end result is a higher price for the fish meal portion of the formula.

Figure 7 illustrates the phenomenal growth of U.S. aquacultural production, led by catfish, with about 150,000 tons in 1988. Catfish production showed a sixfold increase from 1980 to 1988.

Another interesting opportunity for fish meal is in dairy feeds. We've seen some studies from Cornell University and a dairy research center in Wisconsin that indicate significant increases in milk production when fish meal was used. Apparently, fish meal holds up very well as it passes the rumen providing the cow with more digestible nutrients. The feeds that were used contained from 1.5% to 3% fish meal. National production of dairy feeds is about 29,500,000 tons, so at a 1.5% usage

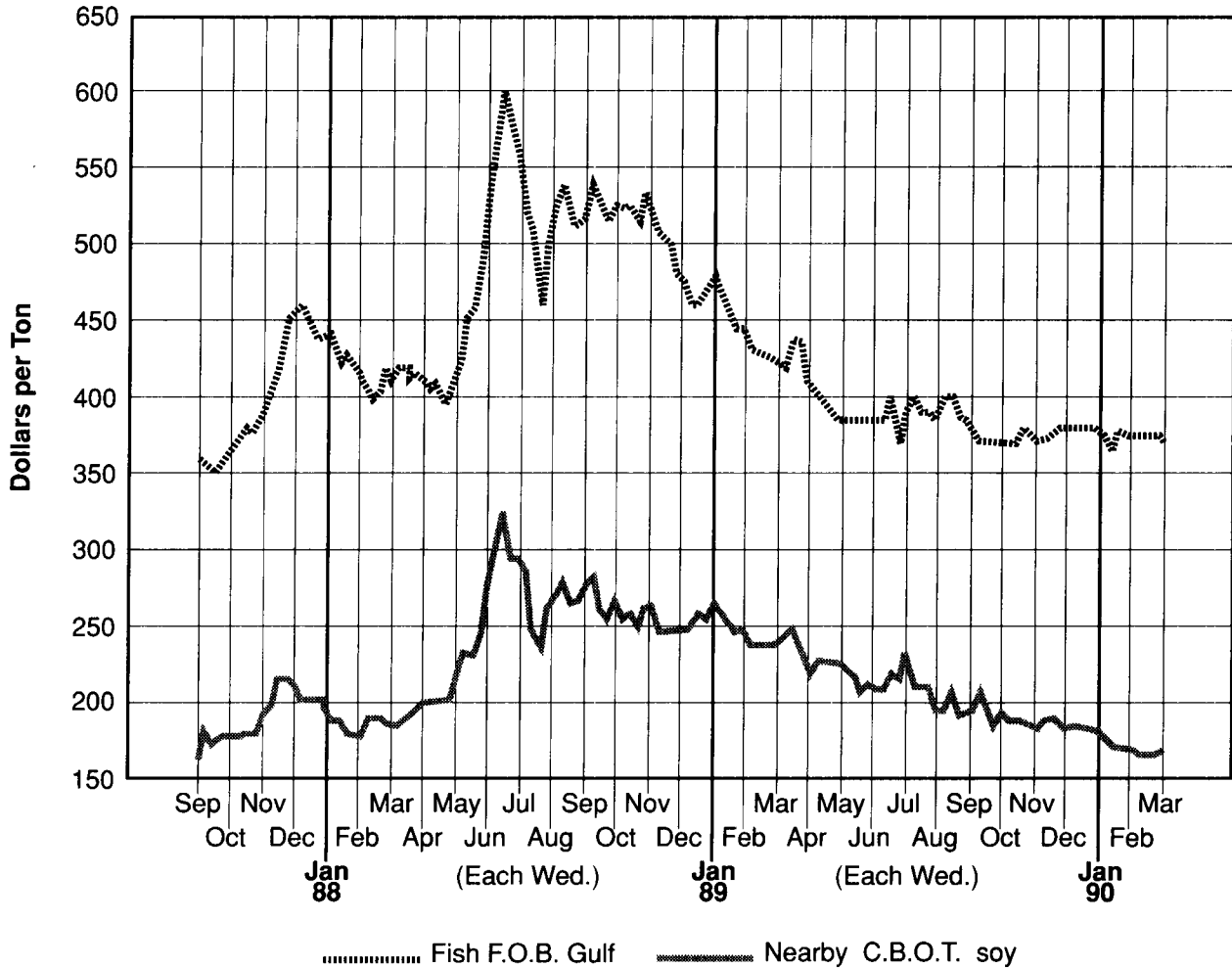


Figure 4. Gulf of Mexico fish meal and Chicago Board of Trade (C.B.O.T.) soy.

level for fish meal, the potential fish meal consumption per year is considerable. However, many dairy farmers are reluctant to use fish meal, fearing possible flavor problems in the milk or palatability problems with the feed. This area is developing slowly, but it shows promise. The same is true for cattle feeds, where fish meal usage has acted as a growth stimulant in feeding operations.

There is certainly a role for fish meal in pet foods, especially cat food, but growth is much less spectacular than in aquaculture. Recent conversations with one of the largest pet food producers in the United States indicate the pet owner plays a major role in determining the use of ingredients in pet food. They prefer to see fish products such as fish meal used in cat foods.

One problem area for fish meal is the lack of sufficient supplies for poultry feed. One U.S. poultry

company in particular could use almost 5,000 tons of fish meal per week, or about 66% of the total supply available. If the entire broiler industry used 2.5% fish meal, annual fish meal consumption at today's rate of broiler production would be 540,000 tons of fish meal. That would be 100% of available supplies over the last 10 years, which would leave us nothing for aquaculture, pet food, or other special uses.

As the U.S. trout, catfish, and salmon industries grow, we feel the use of fish meal will continue to expand in that sector and decline in poultry. But the aquaculture industry probably will reach a point where it too will substitute other proteins. One example is the catfish industry in the southern United States. In 1986 catfish feeds used about 8%–10% fish meal, but today those same feeds are only using 4%–5%. The balance was replaced with other animal protein products, such as

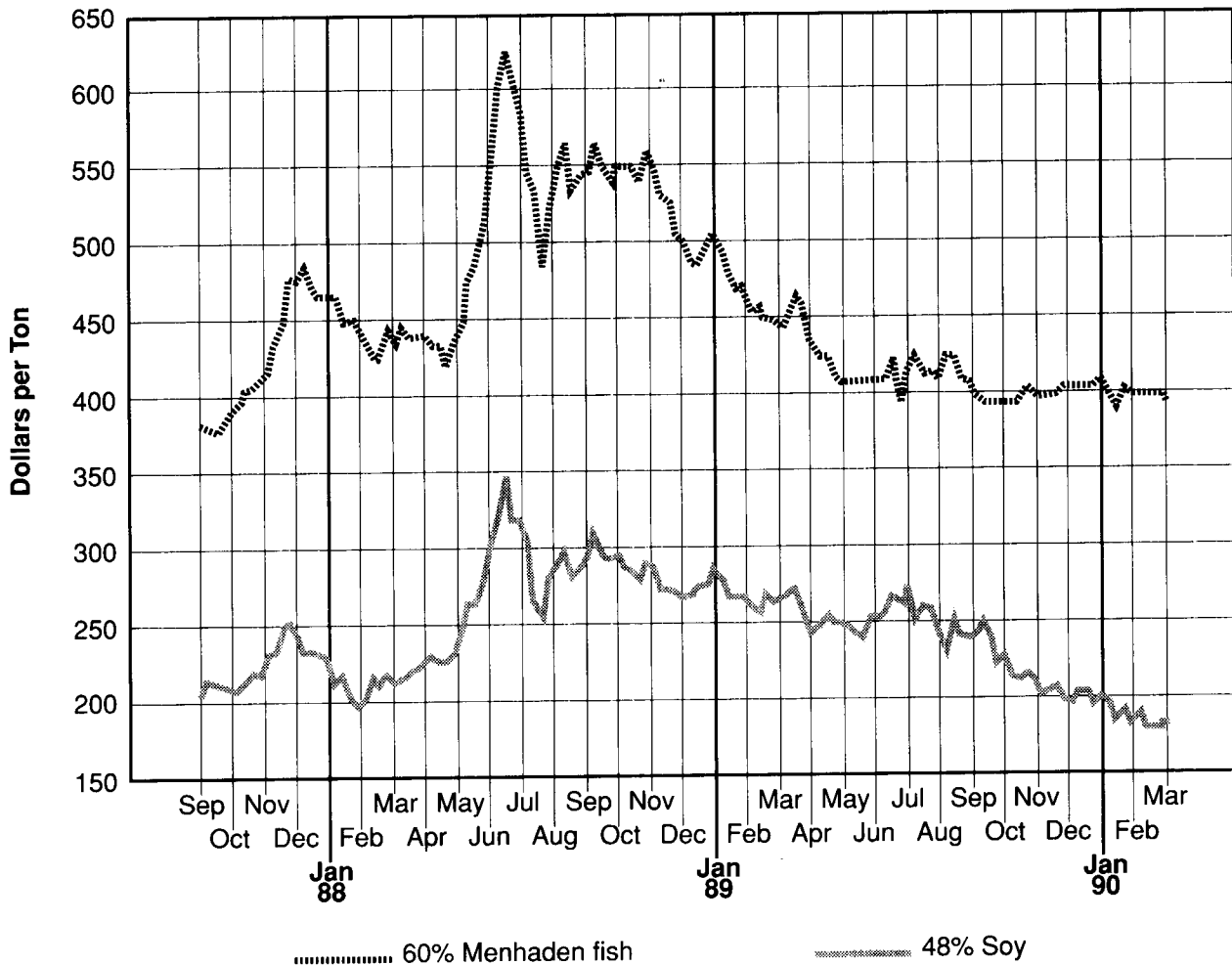


Figure 5. Fish meal and soy meal, delivered northwest Arkansas.

meat meal, bone meal, and blood meal. We've also heard talk that trout feeders have replaced some fish meal with high-protein poultry by-product meal. So we have to be careful not to overprice our goods and suffer the consequences of substitution with other competitive proteins. Once those changes are made, it's usually difficult to reverse them.

At the recent International Fishmeal Producers Conference in Hong Kong, similar findings were revealed. Dr. Ian Pike, director of nutrition for the Fishmeal Association, reported that, internationally, poultry is still the biggest consumer of fish meal, followed by pigs and farmed fish. He told us that five years ago, consumption of fish meal by farmed fish was only 1% to 2% of global fish meal production. Today it's closer to 10%, which is about 600,000 tons. He also pointed out that the global production of farmed fish

will double between 1986 and the year 2000. This also means that fish meal requirements for farmed fish could reach 20% of global supplies by the year 2000 from the present 10%. That's certainly good news for exporters of fish meal such as Alaska.

Twenty years ago there was a much less sophisticated approach to purchasing fish meal. All the buyer wanted to know was protein content and price. Now the purchasing agents might ask:

1. Is it treated with anti-oxidant? If so, how many parts per million?
2. What's the initial peroxide value?
3. What's the amino acid profile?
4. What's the true metabolizable energy?
5. What's the digestible protein?

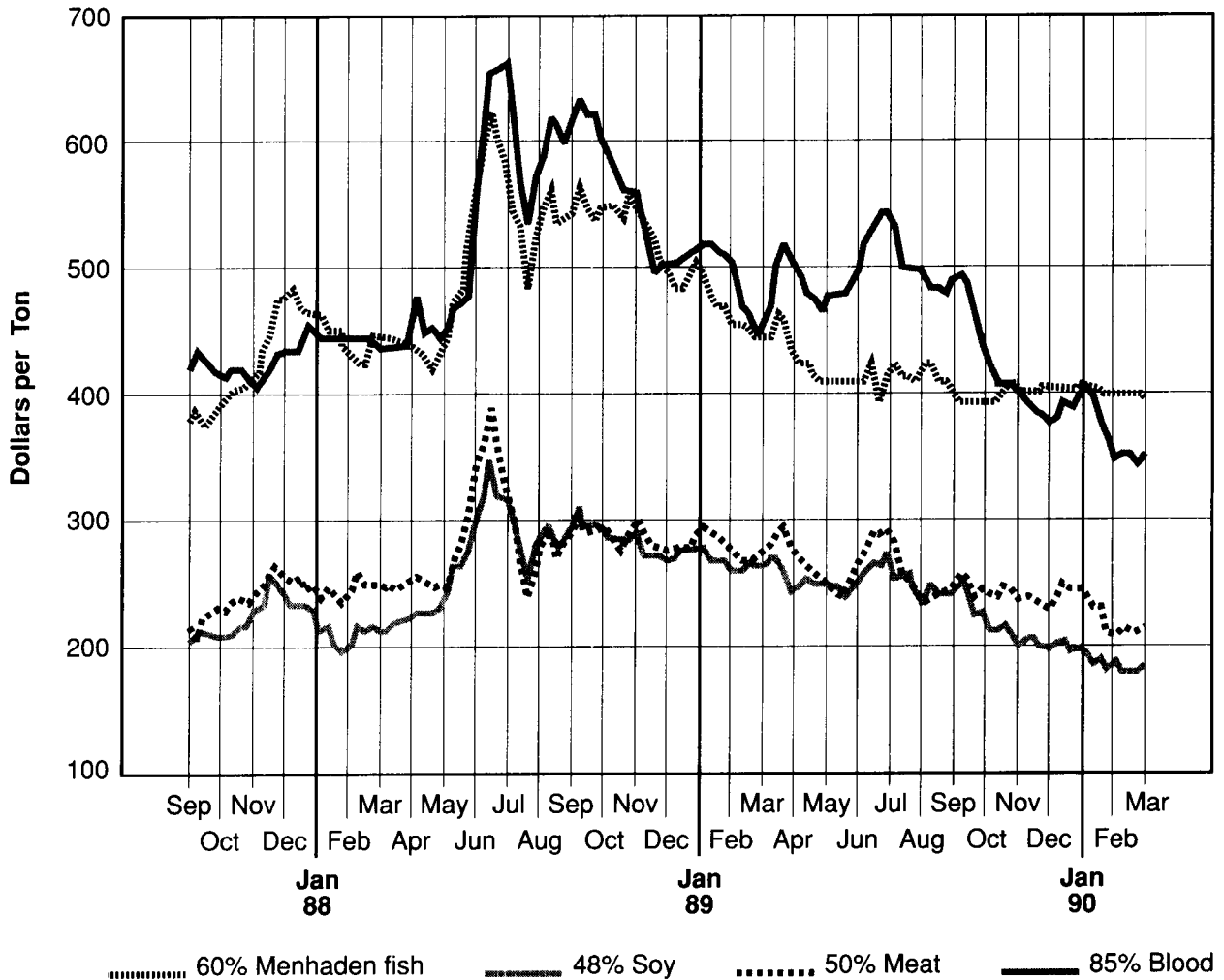


Figure 6. Fish, soy, meat, and blood meals, delivered northwest Arkansas.

6. What's the histamine content?
7. Is it flame-dried or steam-dried?
8. Is it low-temperature dried?
9. What's the total volatile nitrogen?
10. What's the fatty acid content?
11. What's the acid value?

You'll find many of these questions coming from the aquaculture sector, but some will originate with poultry feeders.

We're living in a new and more sophisticated environment, and having the right answers to these questions will make a difference in making a sale or not, or getting a premium or not. We'll have to know the quality of our product. Once the product quality is

established, then the most important question is, is the product consistent? More than anything else, that will govern continuity of business as opposed to a one-time sale.

FISH OIL

The sister fish oil industry in the United States has been suffering these past two years with poor menhaden production, mainly due to poor weather conditions. Landings in the Gulf of Mexico this past season were the lowest since 1981 and 32% below the last five-year average. The outlook for the 1990 season, although improved compared with 1989, is still 5% below the same five-year average. That's not good news, but these forecasts have not been completely accurate, and

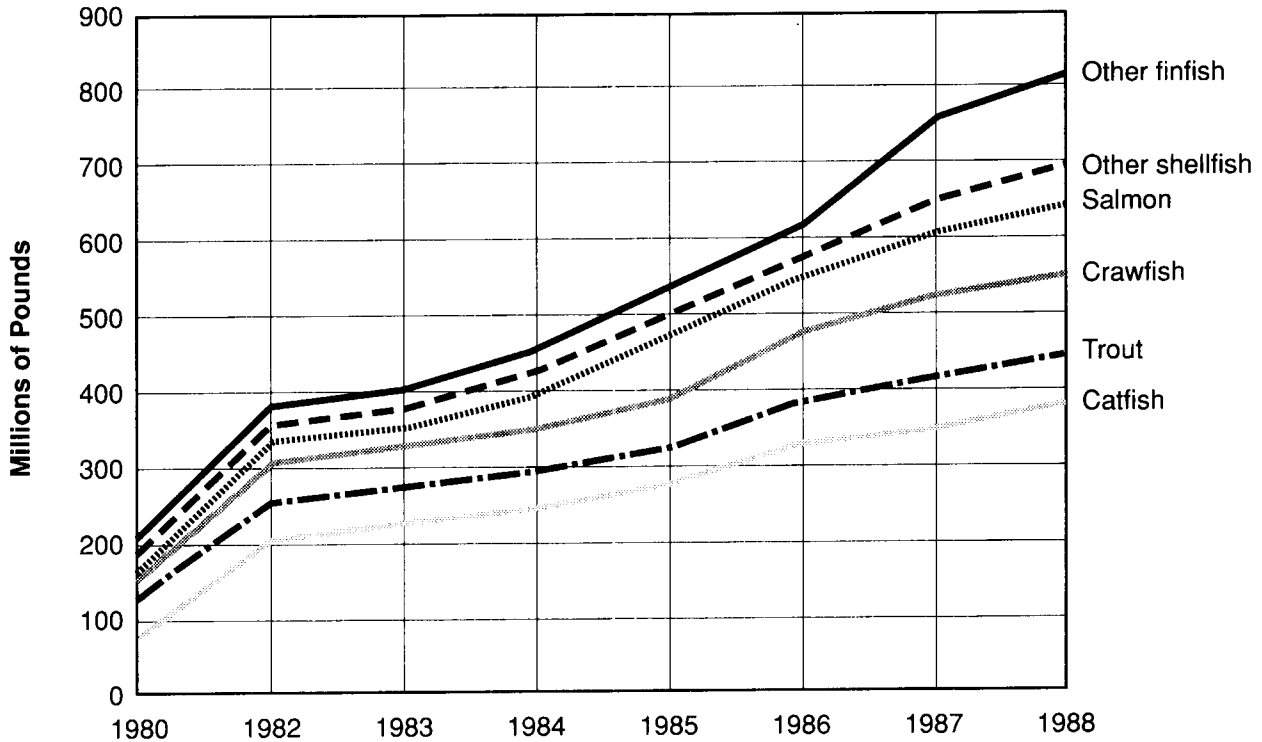


Figure 7. U.S. Aquaculture production, 1980-1988.

given the five-year average catch prior to 1989, we wouldn't be surprised to see a much improved catch in view of the poor results of the past two seasons. Last week's results were poor, mainly due to the weather.

Good news for the menhaden industry is the 1989 approval of a petition filed with the U.S. Food and Drug Administration. This approved petition permits edible use of fully and partially hydrogenated fish oil in the food industry. Most of the fish oil produced in the Gulf of Mexico and Atlantic has been exported to Europe, and mainly to one major consumer. Without alternative users, the industry has suffered with an inflexible position, but the recent approval by the F.D.A. should change things. Up to now about 90% of U.S. fish oil was exported, with the remainder used domestically in industry and in some animal feeds.

Plans to market menhaden fish oil domestically will include the need to find hydrogenators or hardeners willing to participate. We understand this effort may take time as fish oil will require special handling to avoid contaminating equipment handling other types of oils. Partially hydrogenated menhaden oil will be used mostly in specialty margarines, baking fats, and shortenings.

Generally regarded as safe (GRAS) approval for

refined, liquid menhaden oil is also pending. Once approved, refined menhaden oil could be used as an ingredient in salad oils, pastes and spreads, canning oils, sausages, and mayonnaise.

A petition has also been submitted to the FDA requesting an amendment to the standard of identity for margarine. Years ago this standard of identity was established by federal regulations clearly defining oils that could be used to produce margarine. Fish oil was not included. The amendment, if approved, would permit fish oil to be used in margarine. When these petitions will be approved is not known.

FISH SOLUBLES

Fifteen years ago, the United States imported wet solubles from Norway and Denmark, and dried solubles from South Africa. But those supplies disappeared as fish meal producers began adding solubles back in their meal, with technological advances in processing technique. The same thing is happening in the United States. Most of the wet solubles produced are added back to the fish meal. Why sell a wet product for only \$100 to \$150 per ton when it can be dried back on a meal that sells for \$350 to \$400 per ton? When production is heaviest and

plants are unable to add back, then there is a limited market for fertilizer use as well as fish feeds. Poultry feed use of solubles is all but eliminated, except in dry form. I can see a time in the future where all solubles will be added back to the meal, especially since environmental regulations will not permit indiscriminate dumping at sea.

SYNTHETIC AMINO ACIDS

In reporting on the U.S. protein market, the first thing that obviously comes to mind is the abundance of organic protein by-products that are available to the feed industry. But another area of growth should be mentioned, because it will have a direct effect on both the usage and price for organic proteins. This is the area of synthetic amino acids, in particular L-lysine. We are expecting the U.S. production of lysine to increase fourfold over the next three years or so. The lysine producing industry has learned how to be flexible and compete with soybean meal. Lysine prices still remain well above production costs, and it is conceivable that increasing production could replace some soy meal in the formula. It's very easy to replace 100 lb of soy meal with 3 lb of lysine and 97 lb of corn. Obviously, any pressure on soy meal prices will have a direct effect on other proteins as well. For example, at the tail end of last year, we saw prices for blood meal drop \$40–\$50 per ton, as the price of synthetic lysine also dropped 15–20 cents per lb. However, for the short term, we feel that the increasing demand for quality feeding around the world will still seek out soy meal, which is the largest volume protein supply available, and temper the potential price effect lysine might have. As long as lysine can be sold above its cost of production, which is a good bet, there may be longer term considerations for the corn-lysine package.

SUMMARY

Up until this point I've tried to illustrate to you the changing uses for fish meal over the last 20 years, what to expect in the future, how protein prices are influenced by the direction of soybean meal, and that when fish meal prices are economical, there is far more demand potential than there are supplies. Also, purchasing agents have become more sophisticated in what they look for in fish meal quality. It's not just protein. I've given you current information on the menhaden fish oil situation, talked about the trend toward greater domestic consumption for food use and less exports, and mentioned where fish solubles fit into the picture and their eventual disappearance from the marketplace as they are added to the fish meal.

MARKET OUTLOOK

The last topic I'd like to comment on is the present market outlook for fish meal and fish oil. Going back once again to 1968, I remember that it was an exciting event to see on any given day a 1 or 2 cent a bushel change in the price of corn, or \$1.00 or \$2.00 per ton in the price of soybean meal. The markets traded in an orderly manner, stocks of grains were heavy, and one came to expect normalcy in the marketplace. All that changed in 1973—that was the year we exported our surplus grain stock to the Soviet Union.

By the early 1980s it became clear that to deal with the commodity outlook, it was almost mandatory to become an economic analyst. Quite frankly, we haven't found the time to follow that route completely, but we do try to keep our eyes on key areas of concern in order to draw some intelligent viewpoint. The markets are volatile to say the least. Dividing the last three years into six-month sections, I found that the average spread between the highest and lowest price for soybean meal in each of those periods to be about \$74.00 per ton. When markets are swinging that much, it's imperative to keep your eyes and ears open. Besides the supply and demand figures, we also try to watch interest rates, inflation, animal numbers, weather, currencies, per capita consumption of meat, and political events around the world. I'd like to deal today with supply-demand fundamentals to see what might be in store for us for the next six to eight months.

We consider the agricultural year as having two halves: the first half October–March dominated by supplies from North America, and the second half April–September dominated by supplies from South America.

Since I've keyed the price direction of all proteins around that of soybean meal, let's take a look at soy's activity over the last six months. Since last fall's harvest, soybean meal prices dropped about 16%. Since mid-1988, we've had almost a two-year uninterrupted drop of \$180 per ton. The most recent extension of this decline into early March 1990 of this year was not without good reason.

We'd consider these four points as the major reasons contributing to the decline in soybean meal prices into early March:

1. In 1989 the Brazilian farmers held their soybean crop from the market, anticipating another drought possibility in the United States. When the drought didn't materialize, they began to sell practically right on top of the U.S. new crop in late August. U.S. exports of soybean meal suffered, and in spring 1990 we found ourselves with about 18% less soybean meal exports than a year before.

2. USSR imports of soybean meal for the October–March 1990 period are forecast to be down about 500,000 tons. Since we know they need protein to produce an efficient feed, it's assumed their much discussed shortage of exchange has slowed down their purchasing.
3. There's also been an obvious shift in the U.S. soybean crush from meal to oil. U.S. stocks of soybean oil have dropped from 2.9 billion lb in 1989 to 1.7 billion lb in 1990 as of March 1, 1990. This indicated a much improved domestic demand for soybean oil at the expense of palm oil, coconut oil, and other saturated fats. We're seeing more of the fast food franchises switching to vegetable oils and away from animal fats for cooking purposes.
4. Soybean meal's share of the crush has dropped from 67% in January 1990 to more recent figures of about 62% as demand for soybean oil increased.

Since early March, the market has improved somewhat as the long-awaited harvest and export of soybeans from Brazil was delayed, due to weather and political considerations. This is now beginning to swing the other way. It's fully expected that as Brazilian trade normalizes, the U.S. exports of beans and meal will suffer further, and soy meal prices could decline back to low \$60s by June. At least that was the popular view until recently. The U.S. Department of Agriculture planting intentions report of March 30, 1990 indicates a slight decline in the acreage committed to soybeans compared with a year ago, but with a normal growing year we'll have more than adequate supplies. With a record supply of soybeans available in the world markets, it's easy to get bearish and expect further declines in prices, which we expect might happen in the short term. However, we urge some caution be used because there are other considerations that could lead us to much stronger markets.

Even though USSR imports of soy meal are down, we think we'll see a recovery during the second semester. They've just recently reentered the U.S. market for beans, meal, and corn. World crushings of oilseeds

during October–March hit a record high level, and we understand both United States and European feed companies are using maximum levels of soybean meal in their feed formulas.

Overall, world soybean meal demand for the current feeding season could be up as much as 6%. The American Soybean Association believes if the USSR is granted most favorite nation (M.F.N.) status, they would purchase at least 25% more meal from the United States. Eastern Europe is also expected to increase their consumption of soybean meal. We may have some damage to the Brazilian crop. Also, dry weather could develop in the western U.S. corn belt again. Although that's nothing to trade on today, it must be closely watched. We can ill afford a poor corn crop with present stocks at greatly reduced levels. We may even see an increase in planted corn acreage at the expense of soybeans.

We expect to see brown fish meal prices decline further in the short term. Peru and Chile are building stocks now that Chile has returned to a full effort, and Peru has lifted a ban on anchovy catches. Demand from China and Taiwan has been slow—for China, we feel that might be due to a shortage of foreign exchange. The United States will depend on its own production until fall 1990, eliminating possibilities of imports, so we wouldn't be surprised to see values in Peru or Chile drop another 5% from where they are today.

Fish oil is also weakish in the short term. The Japanese Hokkaido Fishery begins in June, and their decisions will largely dictate the direction for oil prices on top of improved production in South America. The Japanese yen is about 25% lower than it was a year ago. Due to the weaker yen, and low prices for fish oil, they may decide to burn some portion of their production rather than sell it. That might help stabilize the market for other origins.

It should be another interesting year for proteins, and we sincerely hope that regardless of the outcome, the fish meal producers of Alaska will be the beneficiary of the expanding demand for quality fish meal in the world markets. We ourselves are receiving more and more inquiries for Alaskan white fish meal and look forward to working with you in the future.

HISTORIC AND POTENTIAL PRODUCTION AND UTILIZATION OF ALASKAN MARINE BY-PRODUCTS

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For centuries U.S. fish processing wastes ("scrap," "pomace," or "offal") were utilized as a fertilizer ingredient. The earliest recorded use of fish by-products as a food for domestic livestock was in 1835. This utilization as a feed increased only slightly in 1864 when part of the oil was removed by pressing. By 1877, Dr. W.O. Atwater, a world-renowned animal nutritionist at the Connecticut Agricultural Experiment Station, recommended the use of fish scrap from menhaden as a source of protein for livestock. With the exception of isolated instances, only farmers near fish processing areas that had access to material in fresh condition utilized the fish scraps or meal for livestock.

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As late as 1916, the utilization of fish meal for feeding purposes was so limited that commercial quantities were scarcely marketed (Weber 1916). The recovery of fish wastes and the production of fertilizer and oil from whole herring in Alaska was initiated by the Alaska Oil and Guano Co. in Killisnoo, Alaska. Industrial development in Alaska had some similarities to the development of the fish-waste recovery industry in the lower 48 states, but it also had some distinct differences. This paper will briefly discuss the historical and potential production of marine by-products from 1882 to 1957 and the current era of production conducted from 1973 to 1989, and will estimate the potential of Alaska's marine by-product industry.

From 1882 to 1903, Alaska Oil and Guano Co. was the only plant in Alaska. The company produced edible oil for the European market and fertilizer for Hawaii's sugar cane fields from whole herring. From 1903 to 1919, the number of plants varied between two and five. The number in business in any year depended on the availability of salmon processing

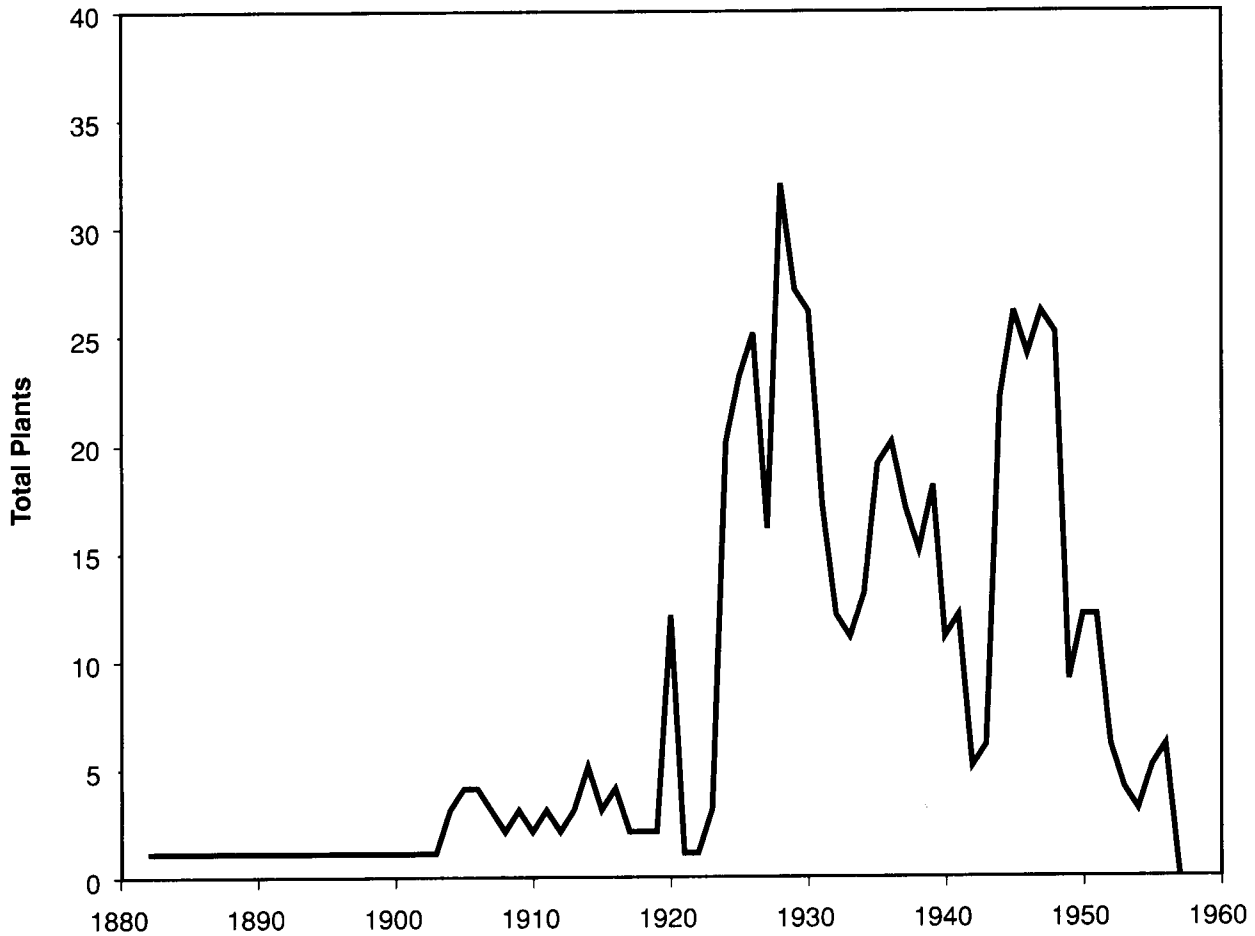


Figure 1. Number of Alaska fish meal and fish oil plants, 1882–1957.

wastes and the limited herring not used for pickled herring. By 1920, the herring catch was mainly small fish, and 80% was utilized for fertilizer. For the next few years, from 1923 to 1928, the small size of herring resulted in an increase in the number of meal plants from 3 to a peak of 32, respectively. Figure 1 shows the number of reduction plants and the wide fluctuation in plant numbers through 1957. Besides body size of the herring, fluctuation in plant numbers was also related to a western movement of the fishery. Prior to 1923 the herring fishery was only in southeastern Alaska, but in that year a reduction plant was constructed in Larsen Bay off Kodiak Island. By 1928, herring reduction plants built in Dutch Harbor were the primary business industry. The number of operating plants declined to a low of five during World War II due to reduced manpower, and by 1957 competition with imported meals brought an end to Alaska's fish reduc-

tion business.

Although efficiencies of operation and recovery have since improved, as early as 1914 the standard reduction methods and equipment were available with both direct-steam and steam-jacketed cookers, hydraulic and screw presses, separators for stickwater and oil cookers, vacuum and direct or steam-rotary driers, grinders, screeners, and automatic weighers and baggers (Weber 1916). The newer steam cookers replaced open-vat cookers, and by the 1930s oil separation and purification was enhanced by centrifugal separation. Therefore, these early Alaska reduction plants had the best available technology. Alaska produced a large number of products. In addition to the main products of oil (human edible, liver oil, pharmaceutical, industrial), fertilizers, and edible meals (first produced in 1914), Alaska produced glue, bone meal, eggs, bait, fresh and frozen feed (fur farmers) and fish

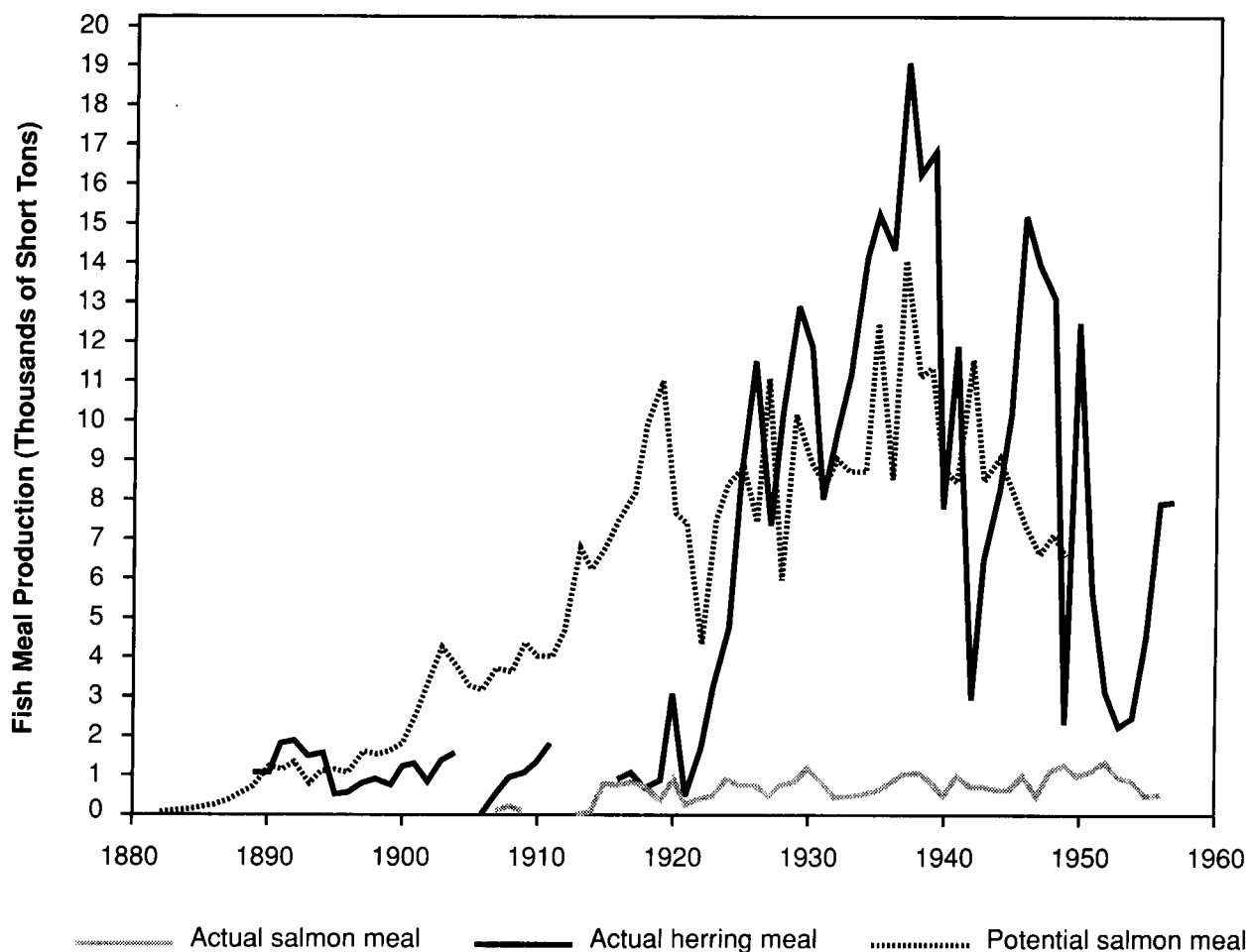


Figure 2. Actual and potential fish meal production, 1882–1957.

skins for the Orient.

In Alaska, plant numbers and total meal production were dependent on the availability of whole herring. Although large amounts of salmon processing wastes were available, economics limited salmon meal production. Fish meal (fertilizer) production from 1882 to 1957 is presented in Figure 2. (Note! Since production statistics often listed fertilizer and meal as one dry product, and meal is the largest volume of today's marine by-products, all totals were calculated as meal equivalents to provide a common reference product for discussion in this paper.) Herring meal production is considered total actual production, because after 1920 herring was mainly caught for reduction to meal and oil. Herring meal production peaked at 19,000 tons in 1936, and total production for the 1882–1957 era was approximately 360,000 short tons. Actual salmon meal production from the early

1900s to 1957 remained relatively constant with an annual average of approximately 1,000 tons. Prior to 1906, whole salmon were fished for reduction, but meal production after 1906 was predominantly from processing wastes. The 1905–1957 salmon meal production was approximately 31,000 tons. However, the potential salmon meal that could have been produced was estimated at greater than 374,000 tons, or 10 times the actual production for the same period. The potential salmon meal production was estimated from the salmon pack statistics (Alaska Dept. Fisheries Rept. 1949) for cases (48 lb) of canned salmon, with 30% of the fresh catch as wet waste and a 16% recovery as dry meal. This waste of a potential resource was based on unfavorable economics associated with salmon meals and a lack of regulations concerned with processing effluents. This poor utilization of a potential resource is still present in Alaska's

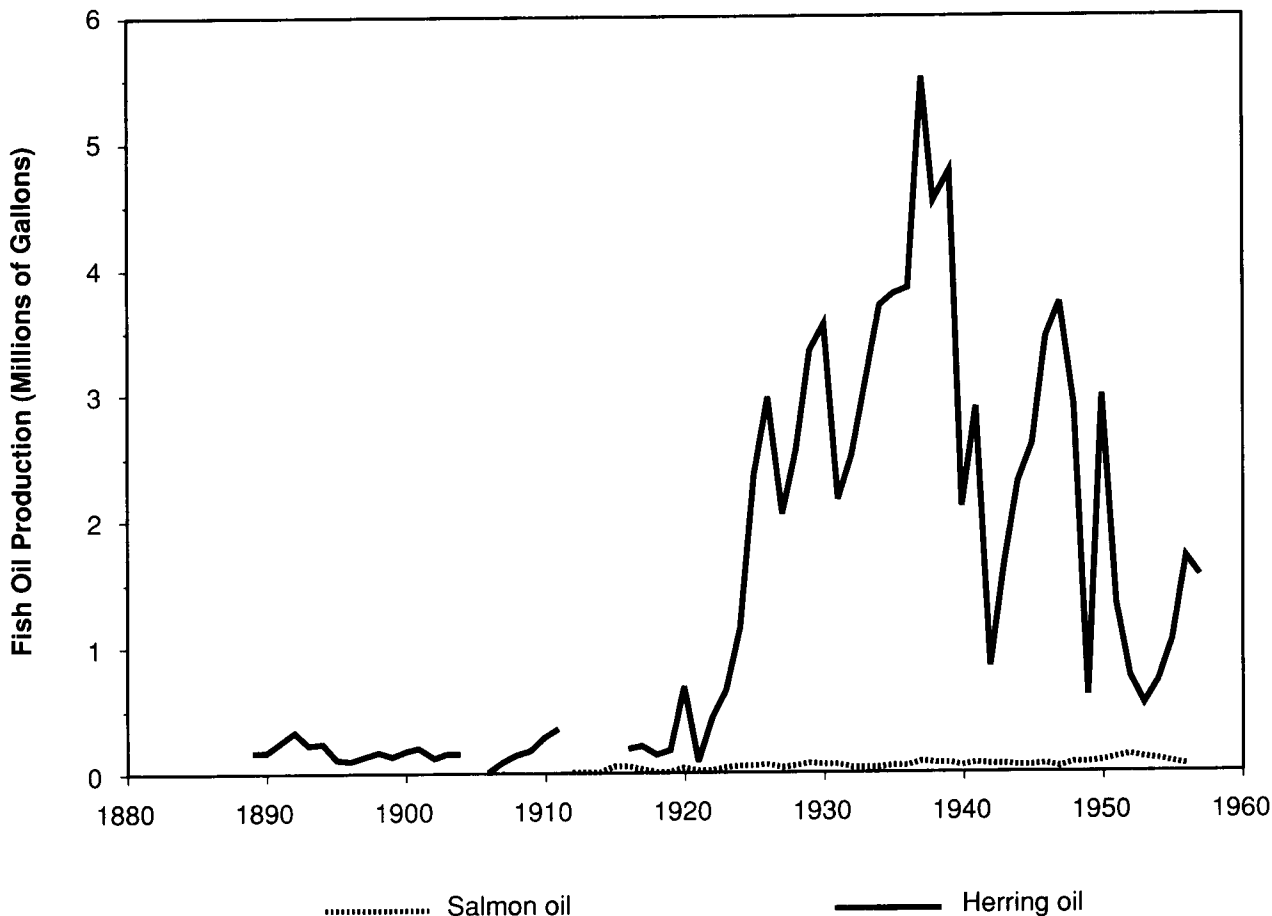


Figure 3. Alaska fish oil production, 1882-1957.

seafood processing industry.

Total fish oil production is shown in Figure 3. From 1882 to 1957, herring oil was the main product, with salmon oil representing the limited amount recovered from the salmon processing wastes.

As previously mentioned, historic production of by-products was highly variable because it was based mainly on the herring resource with some salmon processing wastes. Production levels were affected more by nonregulatory factors—such as exploitation of the resource (herring depletion in southeastern Alaska and small fish body size), economics (decreased demand for edible markets since second generation immigrants reduced herring consumption and imported herring for human consumption was more competitive), labor disputes, low manpower during the war, technology (depth finders enhanced the rate of herring stock depletion after the war), and meals and oil production (reduced to low economics of depression years and poor

economics following foreign competition of imported meals in the 1950s). Salmon meal production declined because of regulations, but rose again due to a lack of tolerance for waste discharge near seafood processing plants.

The reduction industry was affected to a lesser extent by regulations and restrictions. In 1906, the Protection and Regulation of Alaska Fisheries was designed to enhance awareness of the fishery as a human edible market. Caught salmon had to be older than 48 hours before whole carcasses could be utilized for reduction. The White Act of 1924, passed to conserve salmon, established a 50% escapement. The 1939 and 1940 herring fisheries of southeastern Alaska and Prince William Sound were either completely prohibited or restricted to a quota, respectively. During World War II, fishing was restricted in certain waters, and a second herring quota was established in southeastern Alaska in 1954 due to stock depletion.

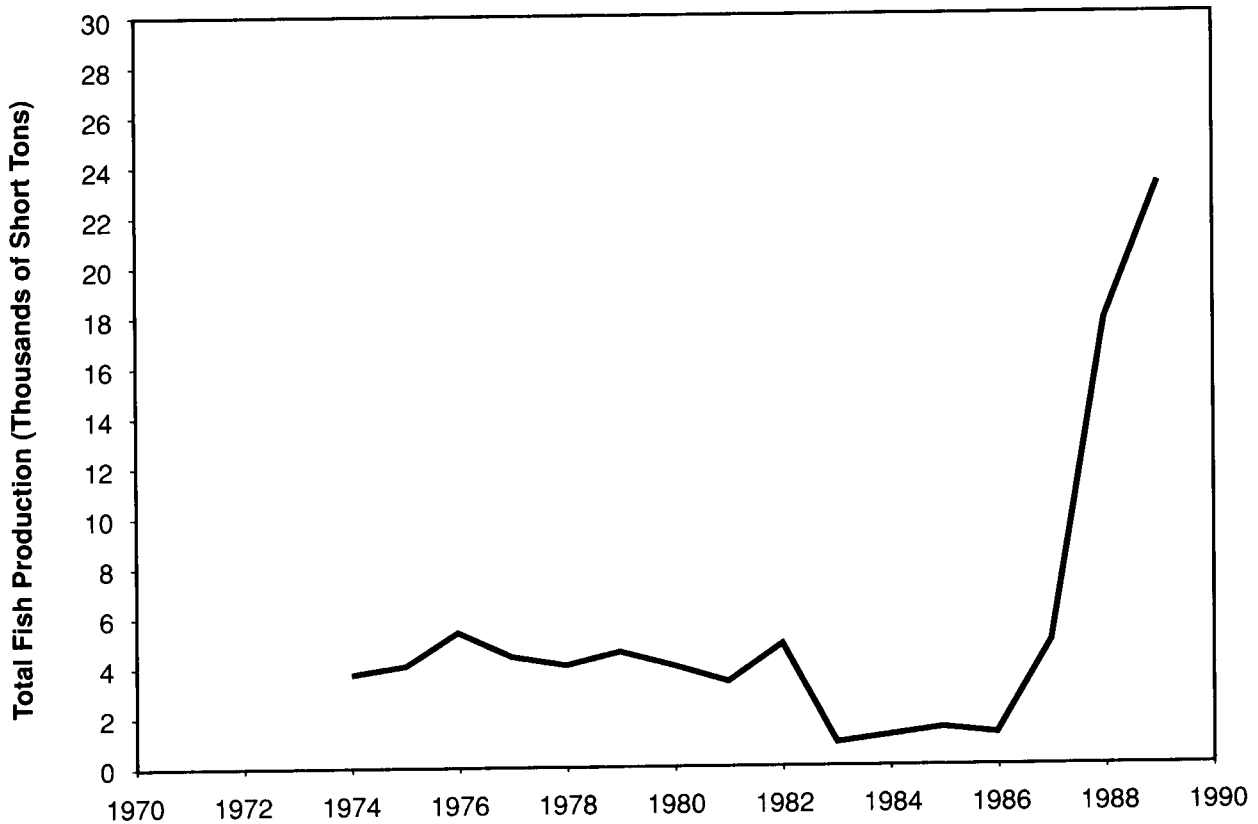


Figure 4. Current Alaska fish meal production, 1974–1989.

Following the 1957 decline of the reduction industry, no government regulations required further handling of fish processing wastes nor were the economics favorable for producing oil and meal from fish or fish processing wastes. However, concern for water quality (Federal Water Quality Control Act of 1972) resulted in Environmental Protection Agency effluent guidelines that initiated a second stage, or the current era (1973–1989), of fish meal production. These guidelines mandated that fish (mainly shellfish) processing wastes in non-remote sites be discharged to or disposed of in tidal flow areas to prevent buildup of seafood processing wastes. In addition to these guidelines, there was an increased world demand for high-quality protein, drastic reductions in South American fish meal production, and proposed in-state development of a bottom fishery. For American processors, the potential for high tonnages (caused by the bottom fishery developed under the Fishery Conservation and Man-

agement Act of 1976) provided positive economic conditions for developing waste reduction plants. In contrast to the past, the current era was initiated by regulation, but the degree of development was limited by economics.

In 1973 and 1974, three meal plants were constructed at Kodiak, Petersburg, and Seward. From 1975 to 1982 (Figure 4), the total annual meal production ranged from 4,000 to 5,500 tons produced from shellfish, salmon, herring, and halibut. Shellfish meals represented a major portion of the meal production, and from 1977 to 1979 Alaska produced approximately 50% of the U.S. shellfish meal. However, this annual tonnage was between 5% and 10% of the potential. For example, in 1979, 2,800 tons of shellfish meal were produced by the three plants. If all the shellfish processing wastes generated in that year were required to be converted to meal, the production would have been approximately 26,000 tons, assuming all the crab was

processed by section-line processing methods (Husby et al. 1981). By 1983, the decline in meal production was related to a decline in the crab and shrimp fisheries, the dumping of wastes in a defined area of Dutch Harbor by Bering Sea crab processors, and the Kodiak plant closure. By 1987-89, meal production increased due to a reopening of the Kodiak plant and construction of shore-based plants in Dutch Harbor and floating processors with meal plants (Figure 4).

Most of the meal (specifically from shellfish) represented products of little-known feeding and nutritional value, and therefore did not demand high prices as protein supplements in "Lower 48" markets. A series of studies were conducted at the University of Alaska to determine the feeding value of shellfish meal for domestic livestock. Briefly, shellfish meals can be supplemented at 6% of swine diets, and the product can be improved by physical separation (screening). Crab meals can be included at 15% of the concentrate mix or 7.5% of total diet dry matter in lactating dairy cattle diets. There was no taste detectable in either pork or milk products. Crab meal could be included up to 10% in beef cattle finishing diets and was a cost-effective protein supplement for calves receiving poor-quality grass hay. Rumen microorganisms can degrade approximately 25% of crab shell chitin. Most of the research has been summarized in papers by Husby et al. (1981) and Husby (1987).

Just about the time that the feeding value was established, the shellfish fishery declined. Little shellfish meal is produced at present. Unfortunately, processing regulations created a situation where the industry produced large volumes of meal with little or no economic value. Finfish meals (salmon, low- and high-salt herring, and cod) have been studied as high-quality protein supplements in early-weaned pig diets. With the exception of limiting salmon meal to 10% of the diet, these meals can replace most of the soybean meal. Additional studies have established salmon meal as a rumen bypass protein (low rumen solubility) in dairy cattle rations. In addition, Alaska salmon meal may only have 50% of the lysine content of salmon meal listed in the National Research Council publication on feedstuffs nutrient composition. Alaska herring meal can make up as much as 25% of high-performance sled dog diets. Some additional uses of Alaska's fish meals are in aquaculture diets (Alaska Dry Pellet from Icicle Seafoods at Seward), eel diets (white fish meal), pet foods (dog and cat), fur animal diets, fertilizers (bone meal) and as omega-3 oils for human consumption. In Dutch Harbor, fish oils are used to fuel boilers. The current era could be characterized as an industry struggling with seasonal production, regulations that are not required for all processors, and processing

Table 1. Potential meal and protein production, assumptions.

Species	Raw waste (%)	Dry meal recovery (%)	Crude protein (%)
Salmon	27.5	16	62
Herring	92	20	70
Halibut	25	16	55
Sablefish	35	16	51
Cod	70	16	57
Pollock	65	15	57
Sole	70	15	57
Flounder	70	15	57
Flatfish	70	15	57
Rockfish	70	15	57
Other	70	15	57
Crab	45	30	57

wastes that may have some inherent, low nutrient value (shellfish meal). All these factors create a marginal economic situation for further expansion in some regions.

What does the future hold for meal production and utilization in Alaska? The future industry in western Alaska currently has four shore-based, 400-800 ton per day meal plants and approximately 11 meal plants on floating processors. This rapid buildup is due to the development and Americanization of the pollock and other white fish fisheries since 1976. The development of these meal plants relates to a premium market for white fish meals that have low ash content, due to screening and to no requirement by the EPA to recover the stickwater and return the solubles to the meal. The resulting meal receives a premium price by Oriental eel and fish farmers. In addition, the large volumes and long seasons allow the processors and meal plants to operate approximately 300 days per year.

The potential meal and protein production for Alaska is estimated in Tables 1 and 2. Table 1 estimates are based on assumptions of raw processing waste and dry meal recovery percentages, and the known crude protein content. For example, approximately 27% of salmon is raw waste. After processing in a reduction plant, about 16% of the wet waste should be recovered as dry meal, and that meal would have a 62% crude protein content. In our estimate perch and rockfish were combined, and turbot was included under flatfish.

Potential meal and crude protein for Alaskan species are presented in Table 2 and Figure 5. The numbers are based on processing and the recovery of processing wastes for the actual catch of salmon,

Table 2. Potential crude protein from Alaskan acceptable biological catch, in tons.

Species	Catch*	Total crude protein	Dry meal	Waste crude protein
Salmon (1988)	264,500	42,320	11,638	7,216
Herring (1988)	56,800	9,088	10,451	7,316
Halibut (1987)	28,300	4,528	1,132	623
Shellfish (1987)	77,400	3,278	10,586	3,278
Pollock	1,848,557	295,769	180,234	102,734
Yellowfin sole	307,431	49,189	32,280	18,400
Rock sole	238,427	38,148	23,035	14,270
Arrowtooth flounder	481,815	77,090	50,591	28,837
Other flounder	207,232	33,157	21,759	12,403
Flatfish	220,350	35,256	23,137	13,188
Sablefish	37,258	5,961	2,086	1,064
Pacific cod	547,843	87,655	61,358	34,974
Rockfish	54,970	9,695	6,326	3,627
Other species	102,711	16,434	10,785	6,147
Total	4,479,219	716,675	447,435	254,075

*Actual catch for salmon, herring, halibut, and shellfish; acceptable biological catch for all other species.

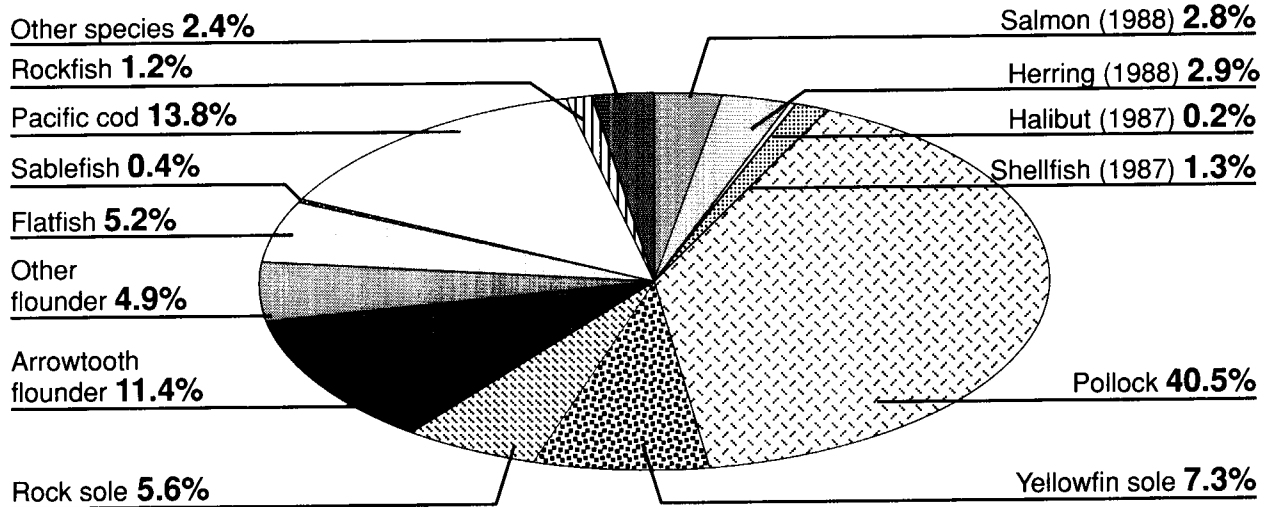


Figure 5. Potential crude protein of waste from the acceptable biological catch.

herring, halibut, and shellfish, and for the current acceptable biological catch for all other species. Table 2 does not include the recent Alaska Fisheries Development Foundation estimate for 2.1 million metric tons of arrowtooth flounder in the Gulf of Alaska. The total catch exceeds 4.4 million tons, with a dry meal recovery of approximately 450,000 tons. This level of production exceeds the 1989 U.S. production of 400,000 tons. The protein recovery on a dry basis exceeds 250,000 tons. In Figure 5, traditional fisheries (salmon, herring, halibut, and shellfish) would represent only 5.9% of the potential if all their processing wastes were recovered as meal. The estimated 24,000 tons of fish meal produced in 1989 is a far cry from the potential that would be realized with an improved recovery of marine by-products.

In summary, our potential resource was and still is underutilized. Potential fish meal could double the U.S. production. If the EPA requires stickwater recovery for shore-based plants in Dutch Harbor, a large volume of meal will enter the U.S. market rather than meet the specifications for the Asian market. With the potential for this meal entering the domestic market, we will be challenged to find alternative markets and uses other than the traditional uses in livestock and aquaculture diets. New and innovative processes may be required to convert this potential resource into edible foods, and it is hoped that other presentations at this conference may stimulate the development of new technology.

ACKNOWLEDGEMENTS

We wish to thank the following individuals for providing material and assistance in developing this presentation: Robert M. Thorstenson, Chairman of the Board, Icicle Seafoods, Inc., for providing historical documents and background; Norma Mosso, U.S. Cooperative Wildlife Unit, University of Alaska Fairbanks, for library search of historical documents; and Heather McIntyre, Agriculture and Forestry Experiment Station, University of Alaska Fairbanks, for data summary and graphics.

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INTRINSIC QUALITY AND SPECIES OF NORTH PACIFIC FISH

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ABSTRACT

The seafood industry is Alaska's most diversified industry with Alaska producing 46% of our nation's seafood. Today, billions of pounds of pollock, cod, flatfish, sablefish and other valuable species are harvested by Alaskan fishermen who either deliver their catch to shore or process at sea. Groundfish contributes about 30% of the total ex-vessel value of seafood off of Alaska. Salmon contributes 42%, shellfish 19%, and halibut 6%. Although Alaska seafood products are of high value, the waste products, if processed using traditional methods to produce fish meal, will be of lower quality and value than fish meals produced from whole fish. However, a tremendous opportunity exists for producing products from Alaska's fishery wastes because of the volume and availability of "fresh" wastes. Information on the type and composition of fishery wastes will be presented and new approaches to upgrade groundfish wastes will be discussed.

The recent interest and investment in fish meal plants, both shoreside and on factory trawlers, illustrate how rapidly the white fish industry has developed in Alaskan waters. The landings of major species in Alaska in 1989 are shown in Table 1 (Talley 1990). When landings for halibut and salmon are also included, there is a tremendous volume of fishery wastes available for meal production. These species of fish are handled very carefully because they are intended for human consumption; consequently, the waste products are "very fresh" and ideally suited for the production of fish meal and other products.

The first step in deciding to produce fish meal

Table 1. Landings of major fish species in Alaska.

Species	Volume (Million pounds)
Pollock	2,350
Pacific cod	255
Black cod	75
Rockfish	67
Dover sole	3
Halibut	57
Salmon	711

from these fishery wastes is to look at what types of fish meal are being produced worldwide, the composition of these meals, and what will the markets look like in the future.

Based on the composition of three major fish meals produced throughout the world (Table 2), the average protein content is about 67%, average ash content is 16%, average oil content is 9%, and average moisture content is 8% (Allen 1979, Windsor and Barlow 1981). Table 3 illustrates the composition of meals produced directly from Alaska's major fishery resources: white fish (cod, pollock) and salmon. The composition of these meals compares favorably with the traditional fish meals. However, the ash content may be slightly higher and the protein content, especially for salmon meal, may be slightly lower. Also, Table 3 illustrates the composition of higher quality meal. The market demand for this type of meal is growing because of the rapid growth of mariculture and aquaculture. Thus, knowing the makeup of the fishery wastes and the composition of each part of the fish may be helpful in selecting those parts of the waste to produce a higher quality meal.

Undoubtedly, the various parts of the fish carcass used to produce fish meal may affect the composition

Table 2. Percent composition of commercial fish meals.

	Herring (Norway)	Anchovy (Peru)	Menhaden (U.S.)
Protein	72	66	62
Ash	12	15	20
Oil	8	10	10
Moisture	8	9	8

Table 3. Percent composition of salmon and white fish meal (Pacific cod and pollock).

	Salmon	White fish	High quality
Protein	61–66	62–64	75–78
Ash	16–22	23–25	12–15
Oil	8–12	6–8	5–10
Moisture	7–9	6–8	7

Table 4. Weight ratios of body parts (percents) for pollock and Pacific cod.

Part of body	Pollock		Cod
	Babbitt (1982)	Kizevetter (1971)	Kizevetter (1971)
Head	22.0	15.6–29.4	15.3–29.6
Gills	–	2.1–4.6	–
Viscera	13.9	8.6–32.4	10.4–28.3
Liver	–	1.6–10.0	3.2–6.0
Gonads	–	3.1–19.6	–
Frame	24.5	6.9–19.1	8.5–24.6
Fins and tail	–	1.3–8.9	2.5–9.2
Column	–	5.6–10.2	6.0–15.4
Skin	9.4	6.5–16.4	4.5–8.6
Fillet	30.2	28.9–38.6	38.7–44.7

Table 5. Weight ratios of body parts (percents) for pink salmon.

Part of body	Kizevetter (1971)	Crapo et al. (1988)
Head	10.9–15.4	14–16
Gills	2.5–3.0	–
Viscera	6.4–16.3	6–16
Eggs	5.0–10.0	–
Liver	1.5–3.8	–
Frame	5.3–9.4	–
Bones	3.3–6.6	–
Fins and tail	2.0–2.8	–
Skin	3.5–9.5	6–12
Fillet	53.4–61.3	41–46

of the meal. Tables 4 and 5 illustrate the parts of white fish or salmon that would be used to produce fish meal. The composition of the meal will be affected by the type of processing being used (i.e., hand or machine filleting, heading and gutting, roe extraction, etc.) and the time of fishing. For example, the liver may make up as much as 10% of the weight of the pollock during the summer months when the fish are actively feeding. During spawning, the gonads (roe or milt) of pollock may make up as much as 19% of the weight of the fish. It is important to note that the wastes from salmon processing, the head and viscera, constitute from 17% to 32% of the weight of the fish.

Table 6 illustrates the proximate composition of the various parts of fish carcasses for Pacific cod, pollock, and salmon wastes. Salmon heads are a good source of oil, and it was common practice until a few years ago to render the oil from the heads and add it back to canned salmon during processing.

Probably the most important factor affecting the composition of the meal is how the fish wastes are processed. For example, if pollock carcass wastes are

Table 6. Proximate composition (percents) of fishery wastes.

	Protein	Ash	Oil	Moisture
Pacific cod				
Crawford et al. (1972) Hand	15.6	4.3	2.1	78.9
Crapo (1988) Hand	14.3	3.9	1.7	79.5
Machine	14.1	3.8	2.0	79.4
Pollock				
Crapo (1988) Hand	11.3	3.6	3.0	81.3
Machine	12.5	3.7	1.9	82.0
Babbitt (1982) Hand	13.8	2.7	8.9	74.8
Head	13.6	4.9	1.4	81.1
Viscera	8.2	0.8	40.1	45.0
Frame	15.9	3.3	0.7	80.4
Skin	18.0	0.9	0.3	81.8
Salmon				
Crapo (1988) Head	13.3	4.2	15.8	67.3
Kizevetter (1971) Head	15.0	3.6	17.5	65.1
Crapo (1988) Viscera	16.2	1.6	2.5	80.5
Kizevetter (1971) Viscera	18.0	2.0	4.0	76.0

Hand = hand filleting; Machine = mechanical filleting.

Table 7. Converting pollock waste directly to meal.

	Fillet waste, 100 pounds	Meal, 28.3 pounds	
	Percent	Pounds	Percent
Protein	14	14	49
Ash	3	3	11
Oil	9	9	32
Moisture	74	2.3	8

dried directly in a drier to a moisture content of 8%, then the meal would consist of 49% protein, 32% oil, and 11% ash (Table 7). Although the recovery is very good, the meal would not be considered of very high value based on the low protein content and high oil content which would be very unstable.

It is difficult to follow the materials flow of reported meal processes because the solids content is not broken down into protein and ash components. However, using a hypothetical case, it is possible to speculate on how processing affects the composition of white fish meal. In Figure 1 pollock fillet waste is ground or broken up and heated (or cooked) to at least 195°F (90°C) to coagulate the proteins. Then, the cooked waste is passed through a screw press or

Table 8. Use of a screening system to upgrade white fish meal.

	Percent	
	Without screen	With screen
Protein	62–64	67–69
Ash	23–25	16–18
Oil	6–8	6–8
Moisture	6–8	6–8

decanter centrifuge or both. In this flow scheme, 28 pounds of presscake with a moisture content of 55% is recovered after centrifugation. Since it is known that the ash content of the meal ranges from 22% to 24%, it is presumed that most of the ash or bone stays with the presscake. Some ash, however, is in the press liquor; Allen (1979) reported that 50% fish solubles contain 10% ash. If the press liquor is discarded, then the recovery of meal from white fish wastes will be 14%. Recovering the press liquor and adding it back to produce meal could theoretically increase the recovery to 20%. This step is expensive because a large amount of water must be removed: 72 pounds of press liquor must be evaporated down to 11.6 pounds to produce 50% solubles. Recent research in this

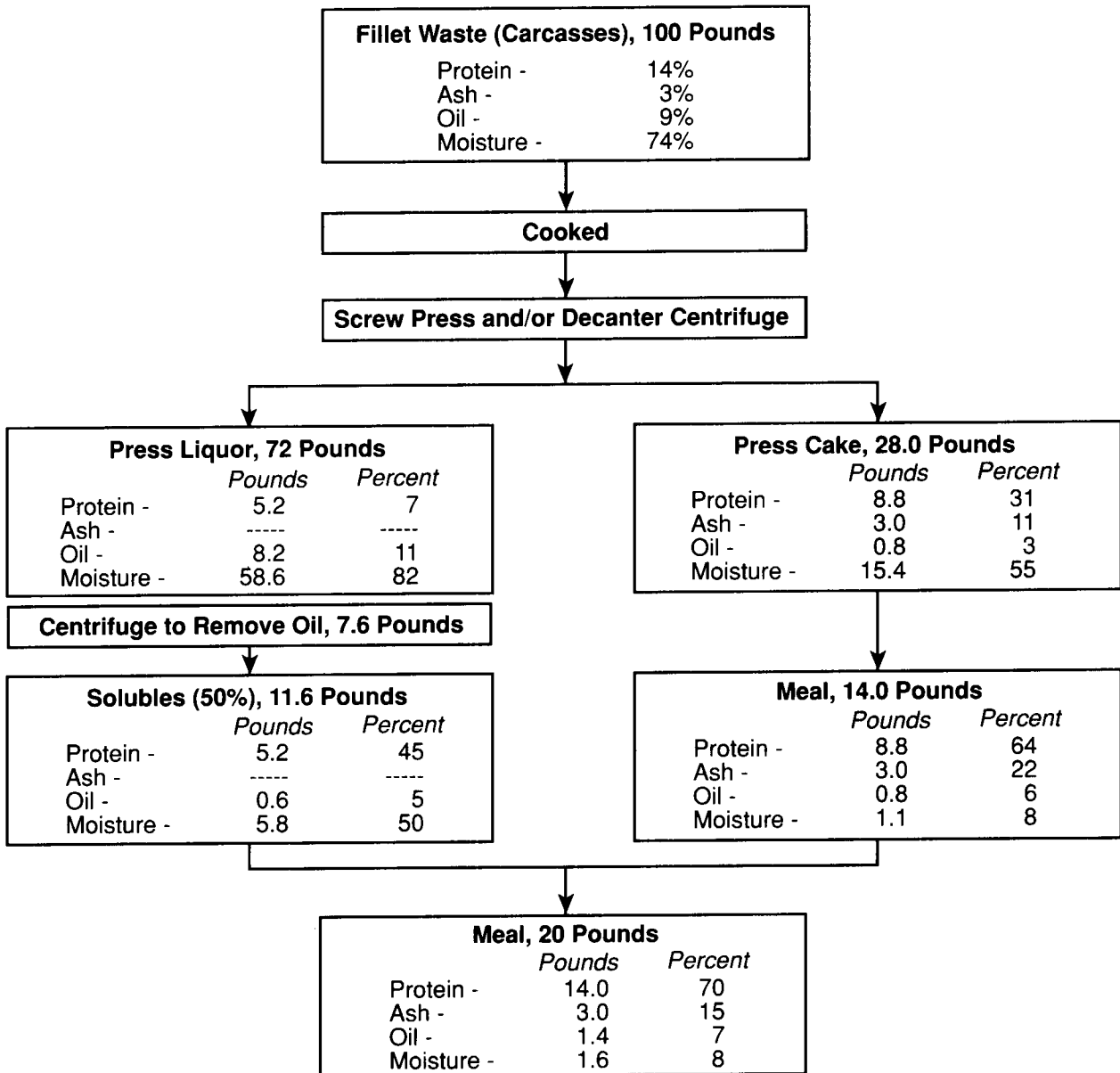


Figure 1. Meal from pollock fillet waste (hypothetical).

area has concentrated on reducing production costs and developing new products for more specialized applications (Fosbol 1988).

In 1988 our staff and Dan James of Kodiak Reduction Inc. looked at the feasibility of using a screening system between the drier and meal grinder to remove some of the bone, thereby increasing the protein content of the meal. A Gyra-Vib vibrating separator was used and, indeed, the composition of the meal was improved (Table 8). Depending on the size

of bone fragments, the screens can be changed to achieve the desired composition of meal. By separating out the bone, a higher quality fish meal can be produced and the bone meal can be sold to targeted markets as well.

In conclusion, I would like to mention that it may be possible to use other techniques to improve the quality of white fish meal. Last year, our staff evaluated the use of a mechanical meat separator to debone pollock fillet waste before processing the

Table 9. Carcass wastes from Baader 182 filleting machine and Model 51 skinning machine.

	100 Pollock, weight = 129 lb	
	Pounds	Percent
Heads, viscera, backbones	93.6	72.6
Skin	2.8	2.1
Fillets	-	25.3

Table 10. Effects of a deboning process on the composition of fish waste.

	Percent	
	Before deboning	After deboning
Protein	13.8 (54.3)	12.0 (48.4)
Oil	8.9 (35.0)	11.0 (44.4)
Ash	2.7 (10.7)	1.8 (7.2)
Moisture	74.8	75.4

Values in parentheses expressed on dry weight basis.

waste into meal. In this study, 100 pollock were weighed and passed through a Baader 182 filleting machine and Model 51 skinning machine. The heads, viscera, backbones, and skin represented 74.7% of the weight of the fish (Table 9). The waste products were ground through a 12.5 mm plate and fed through a Brown finisher with a 5 mm screen opening. The results of the deboning process are shown in Table 10. On a dry weight basis, over 30% of the ash was removed. If the deboned waste material behaves as expected during meal production, then it may be possible to produce a very high quality meal consisting of 75% protein, 12% ash, 6% oil, and 7% moisture.

Mention of trade names or commercial firms in this report does not imply endorsement by the National Marine Fisheries Service, NOAA.

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QUESTION AND ANSWER

- Q. What type of a deboner did you use?
- A. A Brown finisher. It's used in the citrus and tomato industries as a pulper/finisher to remove pulp from the juice. It has two or three blades inside depending on the model, and has a screen on the outside. The rotating blades force the material through the screen. Depending on the size of the screen and the speed of the blades, you can get any type of product you want. It has good application in the surimi process too, being very similar to a Japanese refiner.

OVERLOOKED OPPORTUNITIES: A CREATIVE APPROACH TO SEAFOOD UTILIZATION

Rae McFarland
Diamond Stainless
Herriman, Utah

Why am I doing what I'm doing? First I am a committed, disciplined missionary dedicated to passing on the good message. There is an abundance of underutilized resources from which good food will be produced.

There is little waste; there is only ignorance. Ignorance can be overcome through change. Some of the forces that have an impact on change are: practical experiences first and foremost, though political beliefs, level of education, and religious background are also important. Change is always a challenge to the short term; it has a greater impact on our future.

I have a long history in the meat, poultry, and seafood industries:

- 1937 - Carp rendering plant, family business.
- 1950 - Boned turkey for U.S. government school lunch program.
- 1954 - Made first poultry sausage.
- 1956 - Processed fish meal from mullet (suckers).
- 1969 - Built and sold first seafood processing equipment to Europe.
- 1978 - Processed and sold carp mince to Singapore.

I am fulfilling some of my dreams about having good food for everyone. I first became involved in the meat, fish, and poultry industry in 1950. That was the beginning of the era of further processed poultry. The U.S. government had large surpluses of turkey. Companies contracted to bone the turkeys for the school lunch program. Some turkey loaves, sausages, and ham were produced.

It wasn't until 1954 that I first learned how to make good poultry sausages from a German sausage maker. He produced kosher-style sausages in Israel as early as the 1930s. Later, in the 1960s, my background in food

processing helped me. I built and sold my first Beehive meat separating machine to Findus in Europe. From that early research to the present, I hold 21 patents related to novel food processing. Beehive equipment was sold and installed in more than 20 successful seafood and 3,800 meat processing plants worldwide.

Between 1950 and 1986, I continuously experimented with fish equipment. I came to the realization that meat processing, poultry further processing, and surimi analog all use basically the same technology. By this time, I recovered a wide range of red-meat poultry food materials. Particularly, seafood materials have not been fully utilized by either European or Japanese fish processing systems. I have been working to develop Amerimi technology (full utilization of seafood protein) since that time.

One of my greatest opportunities has been to serve with the Alaska Fisheries Development Foundation. I reached those interested in the Amerimi technology. I have learned much over those many years—and I'm still learning.

The opportunities that I see in the fishery recovery area will require open-mindedness and a new way of thinking. It will require change in our systems and equipment. Space-age technology can convert frames, bones, heads, and other parts and portions of the marine environment.

Chicken salad topping and Chicken Alaska, which use basic Japanese analog technology with poultry ingredients like broth, stocks, and fat, are made with Amerimi. Refined technology now produces pizza sausages and Spicy Bites using the surimi technology. A low-fat, palatable product produced using this technology is now being sold.

Atheresthes stomias (arrowtooth flounder) fillets recovery is one example. We inject enzyme inhibitors into the fillets, derived from meat, poultry, and marine flavorings. Two of the most interesting flavored fillets are the Alaskan Icy White fish fillets—halibut or salmon.

A wide range of foreign seafood processing machines don't process heavy bones successfully. Appar-

ently foreign seafood processors want to develop products they can sell in their markets. To better use these materials, a method of producing high-quality salmon and halibut minces has been developed. A wide variety of products, including paté, is packaged.

Now chicken salad topping, Chicken Alaska, Italian Medallions, Spicy Bites, and halibut injected and marinated fillets are marketed.

To fully utilize any food resource, you must look to many disciplines for knowledge and information. As a director of AFDF, and through other organizations, I have found information making connections between other industries that will broaden our ideas about what is possible. I believe that the basic principles under which we operate are common to all disciplines. These principles are:

1. We must use our resources fully and responsibly.
2. The imagination is the most powerful tool we have.
3. Change! Now.

What opportunities are available for Alaska in by-

product recovery? Using an innovative bycatch and by-product processing system like a Diamond Stainless, Inc. M3 system, more and more surimi and Amerimi will be produced. However, vast quantities of secondary by-products remain to process: bones, heads, etc., which will convert into a number of food products.

CONCLUSION

Beware of feeling that you know anything for sure. You have to discover solutions and keep discovering them. You must recognize that fact and act on your intuition, or your company will die. In 1950 poultry consumption in the United States was lower than seafood is in 1989, but poultry consumption surpassed beef as a muscle food. Seafood passed the 15 lb per person benchmark in 1990. I predict seafood will be the equalizer in muscle food for the next 30 years. Consumption of seafood will be 40 lb per person. Seafood will be eaten as mince, surimi, soup, flavoring, and specialty, red-meat poultry seafood.

ANIMAL, POULTRY, AND MARINE PROTEIN: A COOPERATIVE MARKET APPROACH

Frank A. Burnham
Render Magazine
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This symposium presents you with a multitude of facts and figures about the fish meal industry, the world markets for fish meal, and the competing vegetable animal, poultry and marine protein meals.

My purpose is not to add to this body of information but to discuss a philosophy, which came to mind soon after creating *Render Magazine* 18 years ago and becoming familiar with the rendering industry.

Rendering is what we are all talking about. It makes little difference if the final product is fish meal, meat and bone meal, feather meal, or poultry by-product meal, the process is the same. We grind, we cook, we dry, and we grind again. In fact, much of the technology that has in recent years been introduced into the red-meat rendering plants actually was developed by the fish rendering industry.

Fish oil, edible and inedible tallow, lard, and choice white grease all are rendered products as are fish meal, blood meal, poultry by-product meal, feather meal, and meat and bone meal.

The processes, the plants, the owners and operators, and the regulatory agencies all face the same operational, management, and environmental problems. And they also look to the same marketplace to dispose of their finished products.

As I first became familiar with the red meat segment of this industry—when poultry rendering as a segment was still rather small—I found that a wide chasm lay between the independent renderers, the packer renderers, and the fish renderers. Packer renderers are those slaughterhouses and packing houses that choose to render their own raw material rather than sell to the local independent renderer.

The suggestion that all would benefit if all worked together to find solutions to common problems, to develop new products, and to open up new markets for

rendered products was met by a resounding “hell no!” The packer and independent segments of the industry long had been enemies and the idea of participating in a partnership was foreign to them.

Then came the environmental movement. Suddenly, independents and packers alike were faced with huge capital expenditures for air and water pollution control systems. Public clamor whipped up the specter of regulatory decisions that would not encourage continued profitable business. Under the leadership of veteran Rocky Mountain renderer Jordan Heller—who had succeeded to chairmanship of the National Renderers Association—the NRA closed the breach and actively solicited packer renderers to join the association. The idea was to pool their efforts and financial wherewithal in a cooperative program wherein operational information would be shared, much greater political muscle could be brought to bear in dealing with regulatory agencies, and new markets could be developed, taking the edge off the often bitter competition between the two segments.

The effort had barely gained headway when the poultry industry began its skyrocketing growth, and another major segment was added to the rendering industry. Meanwhile, fish renderers continued to ply their trade as a separate group.

That's where we still find ourselves today—the independent red-meat renderers, the packer renderers, the poultry renderers, and the fish renderers largely going their individual ways, fighting their individual battles with environmentalists and the regulatory agencies, and duplicating efforts in terms of time and money to solve mutual operational and technical problems.

The million dollar question becomes, “Why?” The simplistic answer that will be advanced by many renderers representing the major industry segments is: “We're competitors!” Let us sit back and consider that for a moment.

Do not Boeing and McDonnell Douglas, together

with almost all other major aerospace firms, participate in national associations that work to the benefit of the total aerospace industry? And doesn't this cooperation, in the final analysis, benefit each individual company? Do not Macy's and Gimbel's support the same mercantile associations working to improve that industry and thereby enhance their individual profit pictures?

The fact is that in the twentieth century, most industries cooperate within the framework of a trade association to meet major common challenges and find solutions to common problems.

You might be thinking, this guy doesn't really understand renderers even after 18 years. I don't accept that. In fact, perhaps I understand renderers too well. I know that it is more than possible that my message is falling on deaf ears. I hope that is not the case because the time is long past when renderers of all kinds—both in the United States and worldwide—need collectively to meet environmental challenges and solve the operational problems that sap profitability.

Let's look at the marketplace in the context of a cooperative approach to marketing. It is obvious that such an approach also would pave the way for all segments to focus their attention on common technical and operational problems, and at the same time, present a more formidable front to regulatory agencies.

According to the latest statistics collected from a variety of sources—some official, some industry, and some the result of individual computation—the total world production of animal, marine, and vegetable protein meals for 1989-1990 should be a little over 124.5 million metric tons. That breaks down to 6.7 million metric tons of fish meal, 111 million metric tons of vegetable protein meals, 750,000 metric tons of feather meal, 1.6 million metric tons of poultry by-product meal, 4.5 million metric tons of meat and bone meal, and a relatively small amount of blood meal. It does not reflect negligible amounts of the so-called exotic meals—blood meal, bone meal, hoof and horn meal, and hog hair meal.

Economists from the U.S. Department of Agriculture estimate that major consumers are in Western Europe and the United States and that consumption will increase about 2% a year.

There is no question that the rest of the world needs additional protein. World health and nutrition authorities talk in terms of dietary protein, but for us this translates into more animal, marine, and poultry protein feed ingredients to support the production of more poultry, beef, mutton, and seafood for domestic consumption and export.

While there is a huge untapped market for our products in the undeveloped nations, as well as in more developed ones whose populations rapidly are outgrow-

ing their capability to produce sufficient food, large investments in time, technology, know-how, and hard cash are going to be required before this potential can be realized. Here again is an area in which cooperative efforts of all renderers is needed!

One trend, of which you are aware if you are involved in the Alaska fish rendering industry, is the development of a specialized product for a specialized market. Of course, I refer to white fish meal, which is prized by the Asian commercial eel industry.

There are many existing specialized markets and many more waiting to be developed. For instance, since bypass protein characteristics of feather meal, fish meal, blood meal, and meat and bone meal have been recognized scientifically and commercially as rations for ruminants (cattle and sheep), that market is on the verge of growing sharply.

The aquaculture industry—commercial production of seafood—is growing by leaps and bounds. It may become the principal means for us to provide the urgently needed dietary protein to the peoples of many underdeveloped nations. Fish meal is favored by the aquaculture industry.

Little of the poultry by-product meal gets out of the poultry industry. More than 90% of it disappears right back into poultry rations along with quantities of fish meal and meat and bone meal.

There appears to be a multitude of other potential markets, some that require additional development and others that today only represent a good possibility for rendered products. Each segment and each individual plant of this industry has the opportunity to make a choice:

1. Continue to fight one another for a larger share of the same existing markets, or work together on an international basis to tap the potential represented by the underdeveloped nations.
2. Identify and develop new specialized markets that can best benefit from unique nutritional characteristics of your various products.
3. Through collective research and development, determine where each product best fits, and tailor that product for one or more of those special markets.

In so doing, develop a working interface between the various segments of the rendering industry, nationally and on a worldwide basis. Such an interface would pave the way for cooperation between the industry segments in seeking solutions to mutual technical problems and would organize the individual efforts of the segments into a single, powerful entity to deal with environmental activists and regulatory agencies.

I am aware that what I suggest will not come easily.

At the very least, old antagonisms will have to be forgotten and, of course, there are organizational and logistical hurdles to surmount. Yet, I feel this idea is

worthy of your consideration, and in the end it can only result in great benefit to each and every segment of this essential industry.

WORLD MARKET OPPORTUNITIES FOR FISH MEAL, FISH OIL, AND BONE MEAL

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INTRODUCTION

There are two categories of Alaskan fish meal. I want to concentrate here on the white fish meal market, because the Alaskan brown fish meal (primarily salmon and herring) is not an export product. Brown fish meal is used in the domestic market as animal feed, whereas white fish meal is mostly sold to the growing Far Eastern aquaculture industry.

White fish meal is made primarily from Alaska pollock waste generated from surimi and filleting operations, and to a lesser extent from Pacific cod processing. The traditional white fish meal market has been in Japan and Taiwan, where it gained a very good reputation as a starter feed for young eels. The market was originally developed by the Japanese in the mid-1960s, when they established the standards for eel feed. Recent advances in aquaculture in other Far East countries such as Korea, Indonesia, and the Philippines, have expanded the market for aquaculture feeds, but the high-priced market for Alaskan white fish meal remains small and very specialized. Now more white fish meal is produced than can be consumed by the baby eels, so Alaskan white fish meal must compete with other less expensive fish meals in the general aquaculture market. Accordingly, prices have fallen from the heady days of three years ago.

The specifications of white fish meal in the Far East are generally: minimum 65% crude protein, maximum 20% ash, maximum 8–10% fat, and moisture of 6–8%. The reason for the historically high prices paid for white fish meal is that it is a very palatable product for the eels—it's fresh, it has low fat, it binds well with potato starch and other additives, and the eels eat it easily.

The Alaskan white fish meal produced on factory trawlers and in shore plants tends to have a high ash

content, since it is produced from heads, frames, and skin rather than from whole fish. The ash content must be below 20% to get good prices, so most factory trawlers and all of the shore plants are screening their meal at the end of processing in order to take out enough bone fraction to bring the ash content of the finished meal below 20%.

Incidentally, I recommend that the deboning be done on a vibrating or rotary screen after the drying of the meal, rather than using a mechanical deboner on the raw material before the cooker.

MARKETS

When I was in graduate school years ago I had an economics professor who said that despite all of the intricacies of economic theory, if you understand simple supply and demand, you really understand all there is to economics. This is certainly true in the fish meal industry.

The price of Alaskan white fish meal is dependent on a number of factors. Only one of these factors, supply, is under the control of Alaskan producers. Supply of Alaska white fish meal has increased greatly in the last couple of years, and production capacity is still increasing. However, the prices are affected dramatically by seasonal production of high-quality brown fish meal in Japan, and by production of South American white fish meal, particularly in southern Chile.

We are also affected to some extent by the general worldwide brown fish meal prices. Alaskan fisheries may have a billion pounds of protein, but when you compare Alaskan fish meal production to the annual production throughout the world, we are small players, and we are subject to the swings of the global fish meal commodity markets.

The demand for our fish meal is dependent upon the size of the elver (baby eel) harvest in the Far East. If the elvers are not caught in sufficient numbers in the spring, the demand for white fish meal can be low for the entire year. China is the major source of elvers, and is

trying to develop its domestic eel culture, which is good news. The flip side is that China has legally banned exports of elvers into Taiwan, the biggest present user.

The market depends on shrimp production as well. The price of white fish meal, which is used to an increasing extent in shrimp culture, can be affected by shrimp diseases. In 1988 and 1989 the cultured shrimp industry in Taiwan and other Far East countries was hit hard by disease, and at least in Taiwan the industry was probably permanently damaged. Many shrimp farmers there who have lost money will not be getting back into the industry because of those disease problems.

Currency fluctuations, particularly between the U.S. dollar and the Japanese yen, can make or break deals with the Japanese. I have had orders canceled by Japanese buyers because of quick drops in the value of the yen.

Prices of white fish meal vary considerably depending upon quality. Factory trawler meal historically has commanded a premium over shore plant production, because the raw material is generally fresher. However, even factory trawler product can vary by \$50–\$100 per ton between boats, depending on protein and ash content, and on the grind of the meal. A big factor in the market is consistent quality, and the boats that consistently make a good product get better prices.

Many people in the Alaskan groundfish industry had high hopes for fish meal prices when the first factory trawlers hit the pollock. In 1988 the *F/T Arctic Storm* and the *F/T Northern Eagle* were the first two big factory trawlers with meal plants, and they were getting prices of over \$900 per metric ton for their meal during the last part of 1987 and the first couple of months of 1988. Unfortunately, these prices led people to believe that white fish meal has always enjoyed such a premium. That's not the case, however. The price peak of 1988 was in fact a fairly short spike, corresponding with low South American meal production and high feed commodity prices in general due to the severe drought conditions in U.S. agriculture. Factory trawlers that entered the pollock fishery in 1989 were surprised to find out that they were not going to get these high prices.

The fall in price was rapid, similar to the rapid rise that led to the high prices in 1988. Three years ago the price was lower than it is now, and I see prices dropping further as the supply of Alaskan white fish meal increases dramatically in 1990 and 1991, unless there are measures taken to limit the harvest of the raw material.

Right now the factory trawler meal is going for a little over \$500 per metric ton, f.o.b. Dutch Harbor. I expect this price will move downward somewhat over the next few months. Much of the expected continuing

decline is due to the world supplies of fish meal. South America is producing a lot of meal, and substantial quantities of Chilean white fish meal are being pumped into the Far East. Nearly 20,000 tons went into Taiwan last month at a delivered price of under \$500 per metric ton. That corresponds to an equivalent price of about \$380 per metric ton f.o.b. Dutch Harbor for Alaskan white fish meal. Alaskan meal may be of better quality, but if buyers in the Orient can purchase Chilean white fish meal for a lot less money, that drives down the price of Alaskan meal.

One big disadvantage that Alaskan producers have is that they really don't have the option of storing much of their meal when market conditions are poor, so they tend to be more at the mercy of the spot market. They can go into long-term supply contracts with buyers, but they don't have the ability to stockpile the meal, as the menhaden business does. When factory trawlers come into Dutch Harbor, they have to unload the meal as quickly as possible. The meal generally goes into 40-foot containers, which the shipping lines want to move out within a week. Fish meal buyers know that this meal has to move. They also know that there are many new factory trawlers coming into the industry. They know there's going to be increased production. They know that all of the suppliers are going to be fighting over the relatively small white fish meal market. Prices are going to come down—unless there are quotas established to limit the pollock fishery. If the Alaskan producers were able to form a cooperative to market white fish meal in the Far East, they would take some leverage away from the buyers. But it is unlikely that such an approach will happen, given the history of cooperatives in the fishing industry.

There is going to be drastically increased capacity for fish meal production in Alaska by next year. In 1991 we'll have seven or eight shore plants and at least 16 factory trawlers producing fish meal. Four shore plants are being installed in the Dutch Harbor area with a combined capacity of about 2,000 tons a day of raw material. Three of these plants will be producing LT (low-temperature) white fish meal, with higher digestibility than standard steam-dried fish meal. The owners are hoping that LT meal will be the premium product for the Far East aquaculture market. If that happens, and it really depends on the freshness of the raw material at these plants, it is likely that factory trawler meal will be relegated to a lower price level—just the opposite of what's happening now.

One problem with LT meal is that it is a new meal in the Far East market. The buyers are not familiar with it, and it doesn't smell or look like the steam-dried meal with which they are familiar. They're not going to pay premium prices for LT meal until they have had a

chance to use it in their feed formulations, and see what happens to growth rates of eels over time. It may take at least two years for LT meal to reach the top of the market in the Far East.

The United States is not a market for white fish meal right now, and probably will not be a market factor for the foreseeable future. U.S. buyers are simply not willing to pay the higher prices that are offered from the Far East. Also, most of the Alaskan meal is packed in 35-kg bags, and domestic U.S. users are geared to bulk processing. Handling bags is too costly and time-consuming. The bags are essential for the Far East market where the feed mills are small, the end-users are typically small, and distribution of bagged meal is easier.

Traditionally, Taiwan has been the big market for white fish meal, with an annual consumption of 75,000–100,000 tons. This compares with total fish meal imports of about 400,000 tons per year. Some of this product is re-exported from Taiwan as feed to other countries in Southeast Asia. I estimate that the production of Alaskan white fish meal in 1991 will be about 75,000 tons, assuming unlimited fishing. We would be in a stronger marketing position if Taiwan bought white fish meal exclusively from Alaska, but unfortunately they don't. Consequently, we have to find other places to sell this meal. It also appears that the domestic market demand in Taiwan for white fish meal will be dropping, since eel and shrimp farming are on the decline due to lack of elvers, diseases, pollution, rising land values, and higher labor costs. However, the Taiwanese industry is involved in a growing number of joint-venture aquaculture projects in nearby countries, and will likely be a major source of feed for these ventures, so I expect that Taiwan will continue to be a dominant market for fish meal.

Japan is a market, but is not a big importer of white fish meal. They produce much of their own high-quality brown fish meal, and import most of their Alaskan white fish meal from the Japanese-owned shore plants in Dutch Harbor.

Taiwan and China are by far the two biggest importers of fish meal. People are looking to China as the biggest future market for white fish meal, since China is trying hard to develop both its cultured eel and shrimp industries. Unfortunately, doing business with China is fraught with difficulties, securing payment being the foremost problem. In general, the Chinese are also not willing at this stage to pay the kind of prices that can be obtained elsewhere. They typically want white fish meal for brown fish meal prices. With increased supplies of white fish meal in the future, it is likely that the price differential is going to be smaller and smaller.

Other growing markets include Indonesia and the Philippines, which are expanding shrimp production aggressively, and Korea, which is also trying to develop its aquaculture industry. Thailand is a large shrimp producer, and is beginning to allow imports of fish meal. One of the most interesting future markets is Vietnam, which is ideally suited for shrimp culture. A number of joint ventures are under way or being planned in that country.

CONCLUSIONS

Fish Meal

We are going to have to sell Alaskan white fish meal to expanding markets. There are essentially three tiers to the market in the Far East: the eel market, which pays the highest prices; the shrimp market; and the low market for poultry feed, duck feed, and other animal feeds. In the past, the Alaskan white fish meal has been on the upper tier, despite problems with product consistency, but because of increased production we're now seeing it move down to the shrimp market as well. There is a price drop into that second tier, and it's likely to remain that way.

Only the consistently top quality white fish meal will be in the eel feed market at high prices, but factory trawlers have had problems maintaining consistently good quality. Shore plants have a bit of an advantage over factory trawlers in this regard, as they tend to have more resources to control quality.

The differential between white fish meal and brown fish meal prices will continue to decrease, so be prepared for lower prices over the next year or two. If you could contract to sell your meal for \$500 a ton for the next year, I would advise you to do it.

Of course, the world fish meal supply could change rather quickly. Japan may limit fish meal production from its sardine fishery, which may benefit Alaska. Closures or fishermen's strikes in South America can alter pricing substantially. In 1989, prices went down, then came up a bit, and then continued going down. The brief rise was in large part due to the fishermen's strike in Peru. The strike did not have much of an effect on supplies of fish meal, but it had a big effect on buyers in the Far East who thought that supplies might be tighter, and therefore were willing to pay a little more for Alaskan product.

The biggest issue that directly faces Alaskan producers is the large production capacity, a capacity which will soon outstrip the ability of the resource to sustain it. A forced reduction of fishing effort on Alaska pollock will result in fish meal supplies that are less than anticipated, and prices may then firm upward.

Bone Meal

Although bone meal is not a high value product, there is a market for it. The price varies from \$100 to \$200 a ton out of Alaska. All of the shore plants are making bone meal, but factory trawlers don't keep it. Trawlers that separate bones out just blow them overboard, because they don't have the space to store bone meal.

Fish Oil

The two words that best describe the fish oil situation in Alaska are: Burn It. Because of the logistics and expense involved in storing and shipping fish oil, and the low fish oil prices, you simply cannot make money manufacturing and transporting fish oil out of Alaska right now. To give you an example, last fall I purchased about 30,000 gallons of pollock oil. I paid \$0.025 a pound for it, f.o.b. Dutch Harbor, and it was done basically on a nonprofit basis—I did it as a favor to help the supplier move the oil out. The oil probably cost the supplier about \$0.025 a pound to make.

You are much better off substituting fish oil for diesel fuel in the meal plant, which most producers are doing on shore. If that's not possible, try burning it in a boiler elsewhere in your plant. It's definitely worthwhile using fish oil as fuel, as it has about 80% of the BTU value of diesel. I see no indication in the near future that the fish oil situation will change.

Fish Solubles

Fish solubles are a big problem in Alaska, largely because of high salt content. The shore plants have evaporators which can concentrate the stickwater, and this concentrate can be added back to the presscake in the dryer to make whole meal. However, because of the high salt content in the concentrate, the meal ends up with a salt level well above the maximum 3% allowed in most market specifications. Pollock picks up salt because it is normally stored in refrigerated seawater in the boats or on shore before processing, and is often carried through the surimi plants or filleting plants with seawater. In order to lower the salt content, many processing plants are now trying to use fresh water in their flume transport systems. Dry conveying is also a good alternative.

The shore plants are therefore stuck in a dilemma: If they add all the concentrate back to the meal, they end up with a low-quality meal that is difficult to sell; if they simply make presscake meal and make solubles out of the concentrate, they cannot sell the solubles. Even if the solubles had an acceptable level of salt, the

cost of storing and shipping out of Dutch Harbor makes it uneconomical. We have grappled with the solubles problem for a year with three of the shore plants, but there are no easy solutions right now, and the shore plants are discharging most of their stickwater.

Factory trawlers cannot make concentrate or solubles, because they have no evaporators or storage space. Factory trawlers will continue to make presscake meal.

QUESTIONS AND ANSWERS

- Q. Has anyone done feeding trials to establish the increased quality of LT meals?
- A. Studies have been done with salmon, which indicate high growth rates. And in Norway the LT meal sells for substantially higher than regular steam-dried fish meal because of it. But to my knowledge there were no studies on elvers for the Far East aquaculture market. I know of at least one supplier in Alaska who is going to be involved in this over the next couple of years.
- Q. What's the protein content of the white fish meal?
- A. One figure presented at this symposium is 57%. My experience has been that 57% is a little bit too low. More normal figures are 60% to 62%, from frames. The factory trawlers that don't screen their meal end up with 60% to 62%. But the premium market requires 65%. You have to screen it to get it up to about 65%.
- Q. Shrimp culture, particularly in Asia as well as elsewhere in the world, is becoming more and more competitive, and they're trying to reduce the price of their feeds. The big emphasis on these shrimp feeds worldwide is to reduce the dependency on fish meal. So I would not look upon shrimp aquaculture as a panacea for fish meal marketing. You're going to have economic constraints as they cut down on prices of the shrimp feeds, which comprise about 50% of the cost of the operation.
- A. I agree with you. We're never going to see \$1,000 a ton again for fish meal, and I expect prices to keep coming down. Even if the aquaculture market grows, I don't think Alaskan white fish meal is going to increase in value.
- Q. Do you have a maximum on the amount of oil?
- A. For eel feed, they don't want a fat content above 8%, because it imparts a fishy flavor to the eel.
- Q. Isn't the fishy flavor a function of the quality of the oil rather than the oil per se?

A. Yes. And that gets back to why white fish meal is actually in demand for eel feed. There are many questions as to why it gets a better price. In the Far East the farmers want white fish meal. The Japanese have done a good job over the years of convincing them that's the right product.

Q. In the production of the eel food itself, isn't it true you add oil back to it? I saw them making it back there, and they actually were adding oil back to the diet. That's the reason I asked why they have a minimum in the fish meal. I suspect it's really the quality of the oil that makes the difference. They add at least 5% cod liver oil to the mixtures.

A. Yes, that's true. Eel feed is generally about 70% fish meal, 10% to 20% potato starch, plus vitamins, some gluten meal, and other additives such as beer yeast.

I would like to clarify something about the protein level. On the factory trawlers, they use the waste from the filleting and surimi operations. They also add some whole fish. When a lot of small fish come in, and they can't handle them on the filleting machines, they send them right to the meal plant. So the 60% to 62% protein level probably includes some whole fish.

Q. You spoke to the lower quality of meal coming off the trawlers versus the onshore plants.

A. The reverse is true. In general the quality on the factory trawlers is better than onshore. LT meal production is mostly onshore, and that LT produc-

tion is probably better quality than factory trawler production. There is generally about \$100 differential between shore plant production and factory trawler production right now. Factory trawlers get a higher price. But there is at least one shore plant that gets very high prices because of the quality it produces.

Q. By low temperature rendering do you mean low temperature drying?

A. Yes.

Q. You haven't mentioned opportunities in Ecuador regarding the shrimp culture. Is there any possibility to sell there?

A. I don't know. My experience is not in selling to South America. But I would think that the South Americans would handle that pretty well themselves. Is there an opportunity in Ecuador for Alaskan fish meal?

Q. In reference to the shrimp aquaculture, which has been growing very rapidly: Where do they get their supplies of white fish meal? Is it coming from Uruguay or Argentina?

A. It's probably coming from Chile. I don't think the South American shrimp farms use much white fish meal.

Q. What do they make white fish meal out of in South America?

A. It's a type of whiting from southern Chile. They've been increasing their production of it.

U.S. DEMAND FOR FISH MEAL

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ABSTRACT

Factors that influence U.S. fish meal demand are examined in this paper. Demand for fish meal is price inelastic, as it is for other protein meals. However, the demand elasticity with respect to fish meal prices is a relatively high -0.7, meaning that a 10% increase (decrease) in fish meal prices will lead to a nearly 7% decline (rise) in domestic fish meal use. Therefore, movements in fish meal and other prices may affect domestic use of fish meal more than they do for competing protein sources.

INTRODUCTION

Factors that influence U.S. fish meal demand are examined in this paper. These factors are ranked by making statistical estimates of economic forces that influence the use of fish meal. Specific objectives are: (1) isolate components of U.S. demand for fish meal in a linear regression model, (2) estimate model parameters, (3) examine results for consistency with a priori expectations, and (4) discuss economic implications of the estimated model and its usefulness for evaluating policy questions.

Fish meal demand is affected by prices and quantities of meal and other feeds, livestock markets, and other economic factors. Explanatory variables used in this paper to estimate fish meal demand include prices of fish meal and competing protein meal, prices of corn gluten feed and meal (CGFM), meat prices, and total use of animal protein for livestock and poultry feed. Empirical estimates of explanatory variables for fish meal demand are useful to oil and meal processors and producers, livestock producers, commodity traders, and government agencies.

PROTEIN MEAL MARKETS

Soybean meal dominates domestic protein meal markets. Soybean meal captures more than 90% of the oilseed meal market, and constitutes about three-quarters of all protein feeds. U.S. soybean meal use has risen steadily since 1960-1961 (Figure 1). Much of the decline in U.S. fish meal use is attributable to widely available and lower priced soybean meal.

Fish meal use for feed in the United States has declined substantially since its peak in the 1960s, and its share has been cut to less than half the levels attained 20 years ago (Figure 2). Poultry and livestock feed account for 95% to 99% of total protein meal use in the United States and other developed countries. World demand for protein meal has increased sharply during the same period, and has been met mostly by lower-priced oilseed meals. Lower supplies of fish meal appear to have contributed to the decline in its use.

Virtually all fish meal used in the United States is for animal feed. Fish meal has amino acids that are important for meeting certain nutritional requirements in livestock and poultry rations. Most of these amino acid requirements can be met with other feeds or with synthetic amino acids. Therefore, it is important for fish meal to be priced competitively if it is to effectively compete with other protein sources on a protein content basis.

Demand for dominant protein meals, such as soybean meal and cottonseed meal, is highly price inelastic. This means movements in prices of those meals cause less-than-proportional changes in meal use in the opposite direction; i.e., a 10% increase in the price of soybean meal will result in only a 2% to 6% decrease in use (Houck and Mann 1969, Hull et al. 1984, Meyers and Hacklander 1979, Vandenborre 1966).

An objective of this paper is to compare the demand for fish meal with respect to prices for fish meal and other protein meals. Fish meal demand also is expected to be price inelastic with respect to fish meal price, but considerably less so than for other protein feeds. This is because prices of fish meal per unit of protein are higher than those for other protein meals. As a result, fish meal

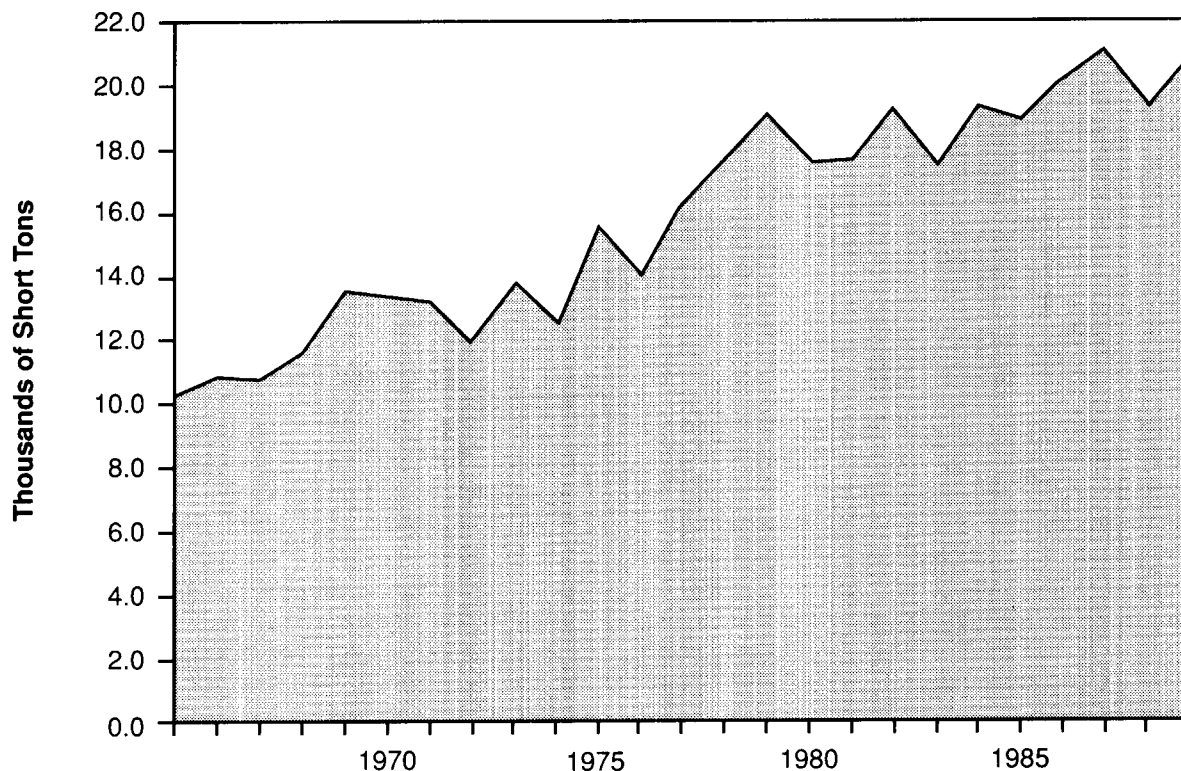


Figure 1. U.S. soybean meal use.

use should be affected more by swings in supply and demand of protein feeds than are other protein feeds.

Corn gluten feed and meal use for livestock feeding was relatively constant during the 1980s, except for a large increase in 1984-1985. Most U.S. CGFM was exported during the 1980s, and rising exports have roughly matched the increased production of CGFM, limiting the amount of CGFM competing for U.S. protein feed market share. The amount of corn that is dry milled to produce ethanol depends on corn prices, tax and regulatory provisions for ethanol and ethanol products, and competition from petroleum and other products, such as methyl alcohol. Prices and use of other protein feeds will be reduced if CGFM production and domestic use grow.

ECONOMIC MODEL OF DEMAND

Domestic fish meal demand is estimated as a function of fish meal prices, major oilseed meal prices, meat prices, CGFM prices, and total animal protein use. Fish meal demand is inversely related to fish meal price, while higher prices for competing oilseed meals positively affect fish meal demand. A positive relationship

exists between meat prices and the use of fish meal. Stronger demand for other animal protein feeds also should exert a positive effect on fish meal demand.

CGFM and other feeds serve as substitutes for protein meal, but the effect of CGFM prices on fish meal demand is indeterminate. Because CGFM is a substitute for fish meal, the cross price elasticity of demand with respect to CGFM could be expected to be positive. However, CGFM is a residual product that is basically "disposed" of at prevailing protein meal prices, so higher prices for CGFM also could indicate higher prevailing prices for fish meal and other protein meals, resulting in less use of fish meal and other higher-priced protein meals in favor of lower-priced protein feeds such as CGFM.

The economic model estimated is:

$$QFMEAL = C - PFMEAL + POMEAL + PMEAT \pm PGLUTEN + ANPROT + e$$

where:

QFMEAL = U.S. use of fish meal (thousands of short tons, 60% protein).

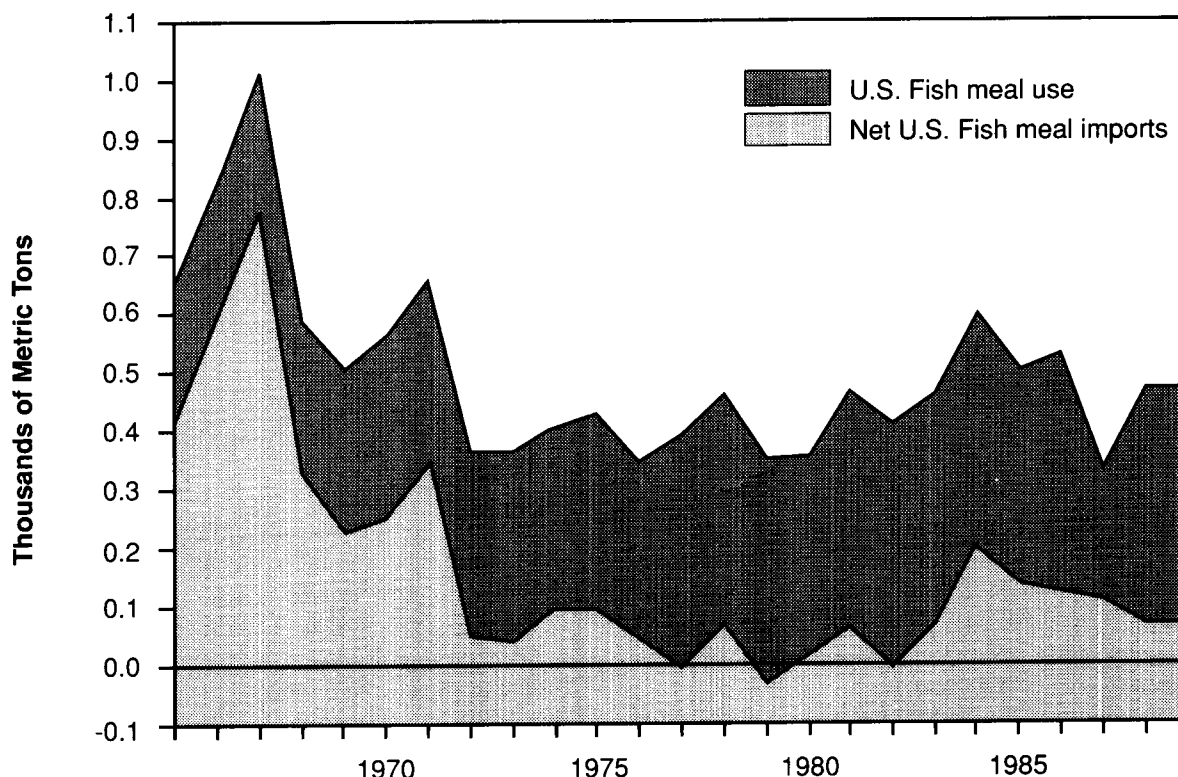


Figure 2. U.S. fish meal use and imports.

C = constant term.

PFMEAL = price of fish meal (60% protein) per ton, deflated to 1982 dollars.

POMEAL = price of oilseed meal per ton, either soybean meal price (PSMEAL) or a weighted average price of the five major oilseed meals (PMMEAL) converted to soybean-meal equivalent (44% protein) prices, weighted by domestic use. Meals include soybean, cottonseed, sunflower seed, linseed, and peanut, deflated to 1982 dollars.

PMEAT = a weighted average of broiler and hog market (farm) prices per hundred-weight, deflated to 1982 dollars.

PGLUTEN = price of corn gluten feed and meal (21% protein) per ton, deflated to 1982 dollars.

ANPROT = U.S. use of animal protein (thousands of tons) fed to livestock and poultry, which primarily includes tankage and meat meal, as well as fish meal and dried milk.

e = stochastic error term.

RESULTS

Annual data are used for the period 1961-1988. The linear model was estimated with a log-log formulation using ordinary least squares. Because equations are estimated in natural logarithms, coefficient estimates in Table 1 are short-run elasticity estimates.

The R^2 in equations 1 and 2 are about 0.88 and t-statistics indicate that all coefficients are significant at the 1% level (Table 1). The estimated fish meal demand elasticity with respect to own price is -0.68 in equation 1 (using PMMEAL) and -0.70 in equation 2 (using PSMEAL), meaning a 10% increase (decline) in fish meal prices is expected to result in about a 7% decline (increase) in use. A strong cross price effect is exerted by prices of oilseed meals (POMEAL); the cross price elasticities of 0.79 (PSMEAL) and 0.82 (PMMEAL) exceed the own-price elasticity estimates. In other words, estimated coefficients indicate fish meal use increases (decreases) slightly more in response to higher prices for oilseed meal than to a decrease (increase) in fish meal prices.

Table 1. Elasticity estimates of U.S. fish meal demand for livestock and poultry feed, 1961-88.

	Eqn. no.	Elasticity of fish meal demand with respect to:					
		Constant	PFMEAL	POMEAL	PMEAT	PGLUTEN	ANPROT
Price of all oilseed meals ¹	1	-3.243	-0.678*	0.816*	0.453*	-0.728*	1.299*
Price of soybean meal ²	2	-3.078	-0.695*	0.794*	0.481*	-0.703*	1.285*

¹R² = 0.879 Adj. R² = 0.859 Durbin-Watson statistic = 1.98.

²R² = 0.873 Adj. R² = 0.853 Durbin-Watson statistic = 2.02.

Notes: * denotes significance at 1% level.

Adj. R² is the coefficient of determination adjusted for degrees of freedom.

The coefficient on PMEAT also is significant. The positive sign indicates that higher meat prices and greater meat production lead to more fish meal use. Likewise, the coefficient on ANPROT is significant and positive, meaning greater use of animal protein feeds is reflected in greater fish meal use.

The coefficient on PGLUTEN is negative and significant. This result implies that higher prices for CGFM lead to less fish meal use in the United States. Higher prices for CGFM could be correlated with strong demand and high prices for fish meal and other protein feed sources, leading to substitution of more competitively priced sources of protein such as soybean meal.

CONCLUSIONS

Results indicate that fish meal demand is highly price inelastic, but more elastic than previous estimates of own price elasticities for soybean meal. Therefore, fish meal producers and processors may be able to capture (lose) a greater share of the protein feed market by lowering (raising) their costs of production and prices compared to soybean meal and, presumably, other oilseed meal processors. Movements in protein meal prices also affect fish meal use significantly, as indicated by the cross price elasticities on protein meals that are similar in magnitude to the own price elasticities.

Other important variables were prices for corn gluten feed and meal, and meat. As expected, higher meat prices encourage greater use of fish meal

for animal feed, with the cross price elasticity on meat price about 0.5. On the other hand, the cross price elasticity on CGFM was a negative 0.7, indicating higher prices received for CGFM can lead to a short-run decline in fish meal use. Substantially increased CGFM feeding in the United States could lead to greater reductions in fish meal and oilseed meal use. Price effects of increased CGFM production could be significant if export growth does not keep pace with CGFM production.

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CHITIN AND CHITOSAN: CRUSTACEAN BIOPOLYMERS WITH POTENTIAL

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ABSTRACT

Chitin and chitosan extracted from the shells of crustaceans have been tested successfully in several applications. Utilization in industrial, cosmetic, medical, and food related areas could require thousands of tons of the products annually.

However, after 20 years of availability from industrial production, the market for chitin and chitosan is still very limited. Hurdles in the commercialization of chitin and chitosan are discussed with regard to supply, lack of application know-how, regulatory requirements, and patents.

INTRODUCTION

The history of chitin and chitosan goes back to the last century, when Bradconnot first described chitin in 1811, and Rouget discussed the deacetylated form of chitosan in 1859.

From 1950 to the present, a substantial amount of work has been published on these biopolymers and their potential use in various applications. As R.A.A. Muzzarelli showed in his 1977 book titled *Chitin* (Pergamon Press), the number of papers published on chitin and chitosan rose from 15 in 1950, to 126 in 1975.

Shells of crustaceans have been the primary raw material for industrial manufacturing, which started in Japan in 1970. Today, Japan is still the world's leading producer and user of chitin and chitosan. However, as

a result of intensive development work by companies outside Japan, chitosan-based products are now on the market both in North America and Europe. The only current manufacturer of industrial quantities of chitin and chitosan outside Japan is Protan Inc., Washington, USA.

POTENTIAL APPLICATIONS FOR CHITIN AND CHITOSAN

The plentiful works reporting on chitin and chitosan show an enormous potential for these natural polymers. Their physical, chemical, and biological properties could be used in industry and in sophisticated medical and biotechnological applications where ultra-pure, well characterized grades are required.

It is not the purpose of this presentation to review all potentials for chitin and chitosan, rather it is to emphasize the uniqueness and advantages in some applications that alone will justify the industrial production of the products.

Industrial Applications of Chitosan

Waste Water Treatment

The polyelectrolytic character of chitosan allows it to be used as a cationic flocculant in waste water treatment (Table 1). With a high degree of deacetylation, the polymer has a relatively high charge density, reacting efficiently with negatively charged waste. In reactions with fat and oil, more hydrophobic properties are required. This can easily be obtained through controlled deacetylation.

The chelating properties are useful in removal and

Table 1. High and low volume applications of chitosan for industry, cosmetics, and medicine.

	Potential	Price (\$U.S.)
Waste water treatment	>1,000 tons	\$5–10/lb
Paper strengthening	>1,000 tons	\$5/lb
Violin varnish	<100 lb	–
Hair and skin care	>100 tons	\$10–20/lb
Toiletries	>100 tons	\$5–10/lb
Nail Polish	low	–
Cholesterol reducing effect	>1,000 tons	\$10–20/lb
Wound treatment	>100 tons	\$20–1,000/lb
Drug delivery systems	>100 tons	\$20–1,000/lb
Bioengineering material	low	high

recovery of toxic and valuable metals respectively, and chitosan can either be applied as a flocculant or as a resin.

Paper Strengthening

During the wet phase of paper production, the addition of small amounts of chitosan can give improved strength to the paper. The best results are achieved with high charge density on the chitosan. Price seems to be a limiting factor at the moment.

Cosmetics

The cosmetic industry has for a long time been involved in development of hair and skin care products containing chitin, chitosan, and their derivatives. Besides being natural products, chitin and chitosan have functional properties of great benefit. Protective films made of chitosan reacted with proteins provide moisture-retention capacity.

In toiletries, chitosan has been found useful as a viscosifier in low pH products. Although the prices of toiletry products are generally lower than those of cosmetics, the potential volume makes such an application worth considering (Table 1).

Feed and Food Applications

The introduction of a new product for applications involving direct or indirect consumption by humans requires substantial documentation regarding the safety and quality control of the grades to be used.

Chitin and chitosan have already been part of human diets. For ages, people have ingested the chitin and chitosan contained in shellfish (as in soft crab), mushrooms, cheeses, and brewers yeast. Despite this fact, Japan is the only country to approve the use of chitin and

chitosan as food additives. Indirect use in animal feed, agriculture, and as a processing aid is, however, approved in several countries. Table 2 lists some interesting uses for chitin and chitosan in feed and food-related applications.

Animal Feed

Chitosan has both environmental and nutritional benefits when used as a flocculant to recover proteins generated in the food processing industry. The biological oxygen demand (BOD) in the waste water effluent can easily be controlled and kept at satisfactory levels, and the disposal of the proteinaceous sludge is easier when a nontoxic flocculant is used.

In raising livestock, problems with digestibility of the feed are often solved by adding antibiotics. Chitin has proven to have prophylactic effects by stimulating enzyme production in the stomach. This could be of great importance in chicken and salmon farming.

Agriculture

The same enzyme-triggering effect described for animal feed is believed to play a key role in the agricultural uses of chitosan. Improved protection of seeds and roots can be realized through the plant's own defense system when the seeds are coated with chitosan. This represents a large potential use of chitosan not only for grains and vegetables, but also in horticulture and forestry applications.

Processing Aid

As in industrial applications chitosan can be used as a flocculating and filtering agent in food processing. As a natural, nontoxic processing aid, concerns about carry over into the final food products should be minimal.

Table 2. Examples of feed and food related applications of chitosan.

Animal feed	Protein recovery
	Fish feed
	Chicken feed
Agriculture	Seed coating
	Fruit and vegetables
	Horticulture
	Forestry
Processing aid	Juice clarification
	Wine clarification
	Potable water
Food additive	Thickener
	Stabilizer
	WOF

Potential for use: >1,000 tons; price: \$5–\$20/lb.

WOF = warmed over flavor.

Food Additives

Compared with other hydrocolloids, chitosan has some unique properties in acting as a viscosifier at low pH, and in reacting with negatively charged ingredients like proteins. Such capabilities open up many application possibilities in the food industry. A very promising use is in reducing bad flavor in precooked meat (warmed over flavor, WOF). Because it can chelate iron that would otherwise catalyze reactions producing bad flavor components, chitosan has a great potential use in precooked meat.

Medical Applications

Cholesterol Reducing Effect

It is estimated that as much as 60% of the adult population in the United States and Western Europe should lower their cholesterol levels for medical reasons. Of this group one-third can significantly reduce cholesterol levels by adjusting their diet. Another third has high cholesterol levels because of a genetic biochemical disorder in their cholesterol metabolism, and treatment with ordinary hypocholesterolemic agents is not effective.

The remaining third is the target group for a chitosan hypocholesterolemic treatment. They are people who are aware of their cholesterol problems, yet have not been able to successfully control the level by adjusting their diet. If all individuals in this group were under chitosan hypocholesterolemic treatment, approximately 200–300 tons of chitosan a day would be

needed in the United States alone, based on a dose of an estimated 5–10 grams per person per day.

However, only some of the group will ever be under hypocholesterolemic treatment. Furthermore, there are other well established hypocholesterolemic agents like cholestyramine and colestipol. Unlike these agents, chitosan can be used in a soluble form. Cholestyramine and similar prescription drugs can typically cause side effects such as constipation, flatulence, nausea, heartburn, irritation of intestinal mucosa, and a certain risk for tumor growth as observed in animal studies. Chitosan, in addition to binding a wider spectrum of lipids, is devoid of such adverse effects.

The primary binding of lipids with chitosan occurs through ionic bonds between the positively charged amino groups of chitosan and the negatively charged carboxylic groups of free fatty acids and bile acids. The secondary binding can be of hydrophobic nature, and it includes neutral lipids such as triglycerides, cholesterol, and other dietary sterols. The latest studies indicate that the whole lipid micelles are subsequently entrapped totally during the precipitation of chitosan in the small intestine (pH approx. 6.5). No other hydrocolloids precipitate at this pH.

The final formulation and administration of a chitosan hypocholesterolemic product would determine whether it would be a prescription drug or an over-the-counter product. The market for the latter category would be considerably larger than for the former.

People who pay attention to the health aspects of their diet certainly will appreciate chitosan for several reasons. In addition to being a nontoxic, biocompatible, and biodegradable natural polymer, its dietary fiber properties create a “negative” caloric value due to its hypolipidemic ability. As much as 5–10 grams of fat can be excreted in addition to normal fat excretion (3–5 grams per day).

Wound Treatment

Chitosan has some interesting applications not only in wound healing, but also as a hemostatic agent. Artificial skin and wound dressings made of chitosan already exist as commercial products.

For topical applications, regular pharmaceutical grades of chitosan are normally acceptable, while internal use requires special grades—extremely pure and with a high degree of chemical and physical characterization. The technology applied to develop and manufacture wound treatment products is often sophisticated. Even though the volumes may never reach really high levels, the potential for such products from chitosan is very promising (Table 1).

Table 3. Pink shrimp landings in millions of pounds.

	Alaska	British Columbia	Washington	Oregon	California	Total
1989	1.6	3.4	15.6	49.1	13.2	82.9
1988	2.1	4.5	18.1	41.5	11.1	77.3
1987	2.0	4.7	16.0	45.0	8.0	75.7
1986	4.7	2.2	17.3	34.0	6.7	64.9
1985	4.2	3.0	9.1	14.8	3.3	34.4
1984	9.5	2.0	3.4	4.8	1.5	21.3
1983	7.4	1.2	5.7	6.5	1.1	22.0
1982	17.0	1.2	5.0	18.5	4.6	46.4
1981	28.0	1.8	10.1	25.9	3.7	69.5
1980	52.6	1.5	12.6	30.2	5.1	101.9

Source: 1990 *Pacific Fishing Yearbook*.

Drug Delivery

The use of chitosan in drug delivery systems would be as a vehicle for the active principle. In such formulations the goal is to ensure optimum bioavailability of the drug through sustained, controlled, or targeted release.

Sustained release systems are characterized by retarded release of the drug over a 24-hour period. The simplest way of applying chitosan is as a matrix in tablets, where a coating can be achieved by solubilizing the chitosan through a wet granulation process. In the acid stomach environment, the chitosan coating dissolves and the matrix erodes to give the expected sustained release.

Controlled release systems are capable of regulating the release of the active component for an extended period of time (e.g. days). Utilization of the bioadhesive properties of chitosan in binding the product to mucosae is one proposed concept for controlled release. A more sophisticated method would be to immobilize living cells in beads for implantation as artificial "organs." Use of chitosan as a coating agent for the beads has been investigated by several laboratories.

By controlling the site of release and adsorption of a drug, undesired side effects can be avoided. Drugs can easily be linked with the reactive groups in the chitosan molecule, and the release controlled by later enzymatic activity or changes in the chemical environment.

Technology Applications—Derivatives

The main objective in making derivatives of chitin and chitosan is to overcome the problem of limited solubility while retaining the unique properties of the polymers. In some cases improved functionality has

been obtained, and making derivatives with active ingredients can give added benefit to the product.

Gels

Cross linking chitosan with multivalent anions will form a network structure able to hold large amounts of water. Low molecular weight counter-ions like phosphates as well as polymers like alginate have been shown to work successfully. Gels in the form of beads are currently used as matrixes for immobilization and as erodible sustained release vehicles.

Films and Fibers

In principle, films and fibers can be considered as thin gels with extremely low water content. In addition to cross linking, chelation with metals, precipitation at basic pH, and evaporation of the water from pure chitosan solutions are methods used in film and fiber manufacturing.

HURDLES IN COMMERCIALIZING CHITIN AND CHITOSAN

Quantity

The total available quantity of chitin from today's landing of crustaceans is estimated at approximately 40,000 tons yearly. This quantity exceeds the amounts of other marine hydrocolloids currently consumed, like alginate (25,000 tons), carrageenan (12,000 tons), and agar (7,000 tons). In addition, another 100,000 tons of chitin could be extracted from other easily available sources. However, even with the seemingly large amount of material available, reliable supply seems to be a concern among many large potential users.

Table 4. Dungeness crab landings in millions of pounds.

	Alaska	British Columbia	Puget Sound	Washington	Oregon	California	Total
1989	5.0	2.6	1.9	21.9	11.2	9.7	52.3
1988	10.4	2.6	1.6	16.3	8.6	8.7	48.2
1987	9.4	3.3	1.5	3.2	4.7	8.4	30.5
1986	5.7	2.4	1.5	4.0	7.1	5.9	26.6
1985	9.6	2.6	1.3	2.9	4.9	4.8	26.1
1984	9.4	2.5	1.4	4.7	4.7	5.6	28.3
1983	11.5	2.1	1.2	4.0	4.1	5.3	28.2
1982	16.2	2.2	1.3	2.6	8.7	10.5	41.5
1981	15.6	2.9	1.8	2.6	9.5	11.8	44.2
1980	5.9	3.8	1.8	6.5	18.3	13.7	50.0

Source: 1990 Pacific Fishing Yearbook.

The yearly and regional variations in catching and landing of shellfish represent an uncertainty in raw material supply, if this supply is not covered by sufficient and independent suppliers. Tables 3 and 4 give numbers for the landing of pink shrimp and Dungeness crab by region for the Pacific Coast of the United States and Canada over the last decade. For both species, important variations are found in landings over time and between regions. The most dramatic change is seen for pink shrimp—the landings in Alaska in 1980 counted for more than a half the total, but a decade later landings were down to less than 2%.

Quality

The functional properties of chitin and chitosan are influenced by the raw material used to produce them. Not only can different species cause variations in these properties, but also the same species caught at different times of the year.

Since chitin chemically is characterized as a homopolymeric material, the variations in properties are most likely attributed to either residual non-chitinous material interacting with the chitin or chitosan, or physical differences such as particle structure. To be successful in getting rid of non-chitinous material and manufacturing reproducible qualities, it is essential to have expertise in adjusting processing conditions when using different kinds of raw materials.

While the main concern in producing chitin is to remove proteins, minerals, and other minor ingredients contained in the shell to obtain the purest possible product, successful production of chitosan relies on a controllable deacetylation and depolymerization process (Figure 1). Almost all functional properties of chitosan are either a function of chain length or charge

density and charge distribution. The structures of chitin and chitosan are shown in Figure 2.

The last quality aspect to be addressed is purity. In addition to the aforementioned influence that impurities have on functional properties, regulatory agencies will be concerned about contamination from toxic elements and compounds in the raw material. The exclusion of such components will have to be confirmed in order to satisfy standards set by regulatory agencies.

Price

Most feasibility studies on chitin extraction from crustacean waste include extraction of other components like astaxanthin, flavors, proteins, and minerals. Since a combined production is rarely realized, production cost easily exceeds those forecasted. Quality aspects and regulatory requirements also add cost to the manufacture of chitin and chitosan and limit applications, markets, and profit.

Application Know-How

Sales and market development for a new product normally requires more than just a capability to produce. Even customers with expertise in their own fields of applications will need technical and product support to successfully include chitosan in their formulations and applications.

Simple information like the difference in solubility of chitosan in various acids can help avoid problems with compatibility in formulations. Viscosity differences indicate differences in chitosan solubility in 1% solutions of acetic, adipic, and citric acids, as shown in Table 5.

Solubility differences are even more pronounced in

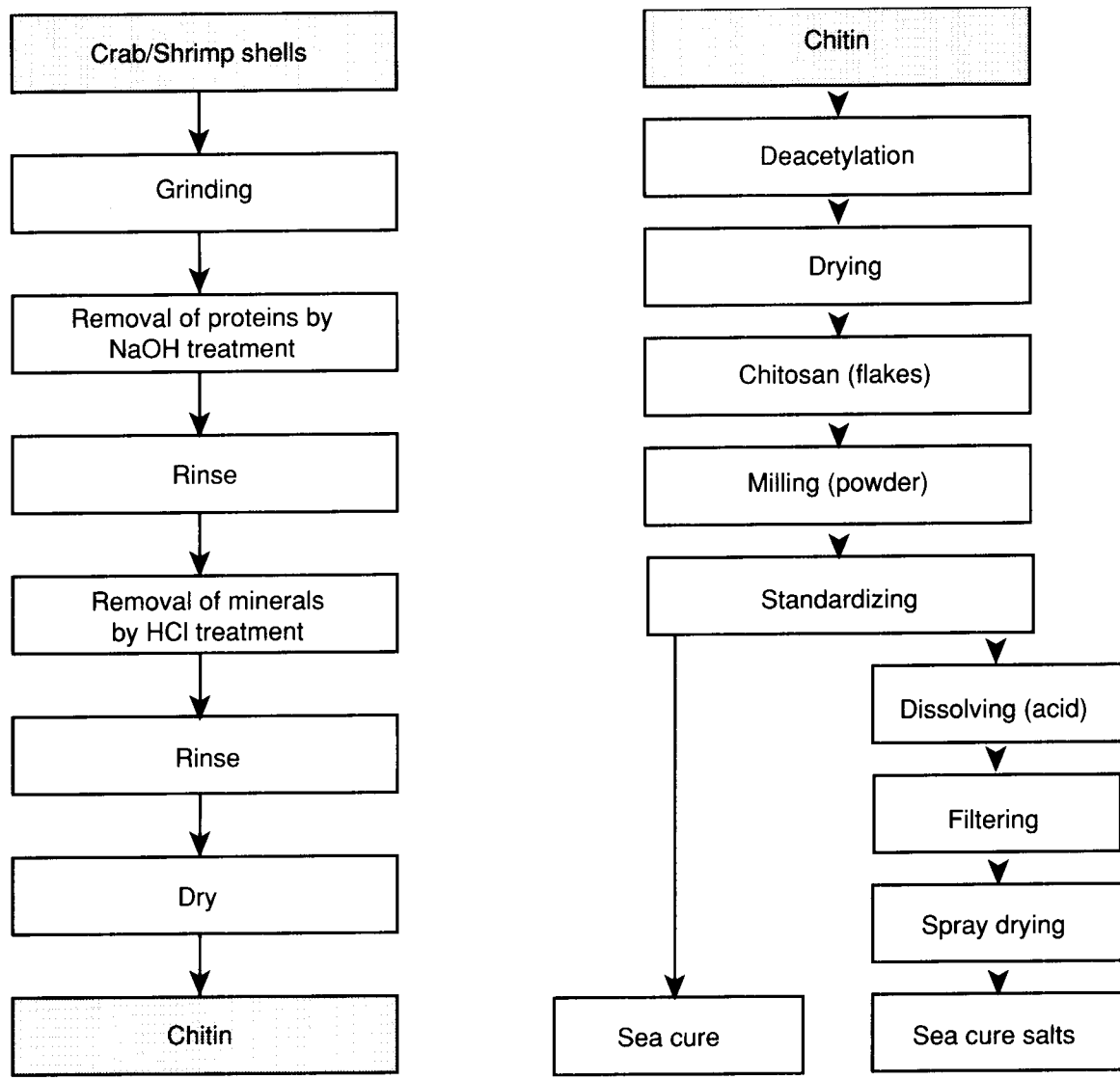


Figure 1. Chitin and chitosan processes.

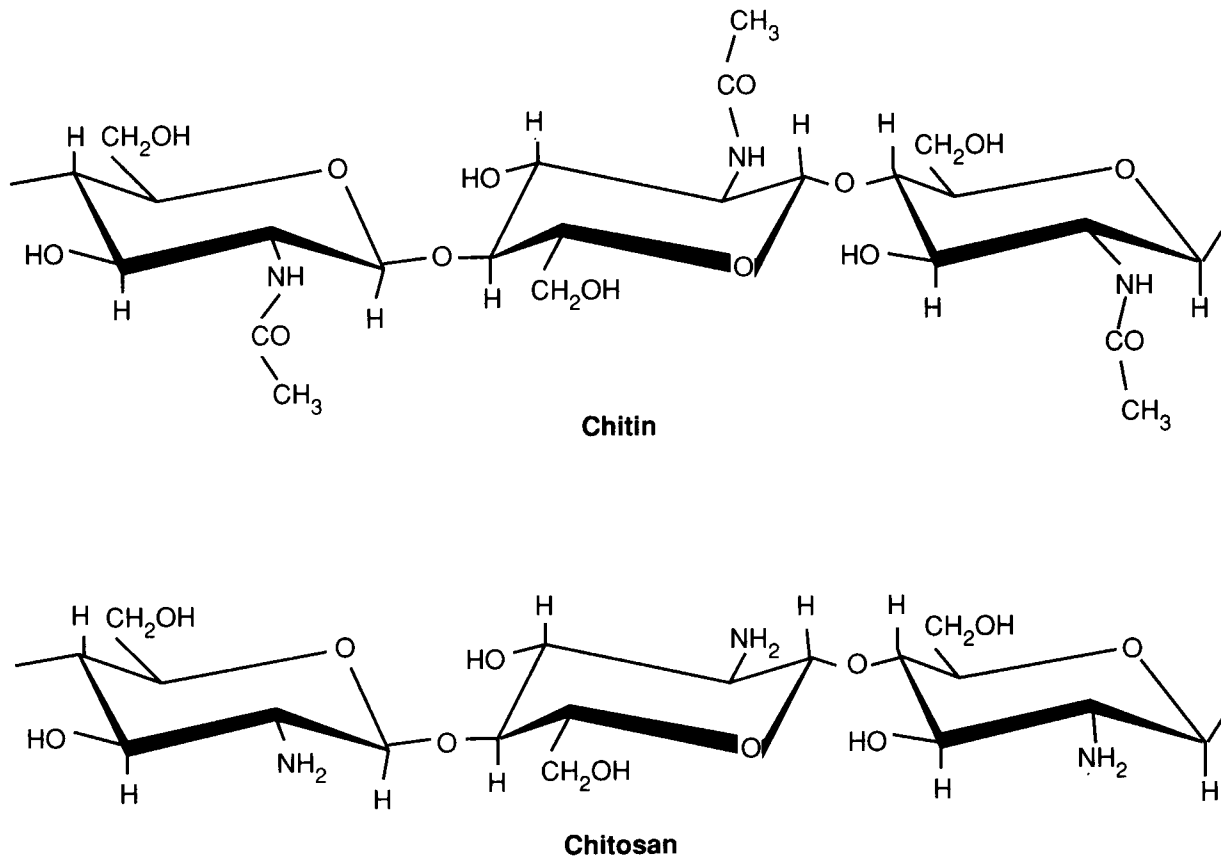


Figure 2. Chemical structure of chitin and chitosan.

the mineral acids. With mineral acids, chitosan solubility is further limited because of high ionic strength, as seen for hydrochloric acid in Figure 3.

Figure 4 shows the relation between viscosity and concentrations of strong electrolytes. The decrease in viscosity as the salt concentration increases is due to a change in the molecular conformation of chitosan, from an extended rod through a random coil to a completely collapsed (salted out) structure.

Regulatory Requirements

Requirements related to utilization and those dealing with manufacturing of chitin and chitosan need to be considered.

Effluent Regulations

Use of shells from crustaceans as raw material in production of value-added biopolymers is a positive

way of handling a waste that otherwise creates environmental problems for the shellfish processing industry. However, restrictions by regulatory agencies, such as the U.S. Environmental Protection Agency, on the disposal of the proteinaceous material remaining after chitin extraction can cost-wisely limit such production. Even though the BOD load to the environment will not be increased, and the location of a chitin production facility will most likely be in the same area as the shellfish processors, more strict requirements often apply to a newly established industry.

Handling Regulations

Introduction of new products will require filing of a pre-manufacturing notice (PMN), and a material safety data sheet (MSDS) will have to follow all products to assure safe handling. Preparation of necessary documentation will require investigations of environmental as well as technical aspects, such as measurements of heavy metal levels and determination of flammability.

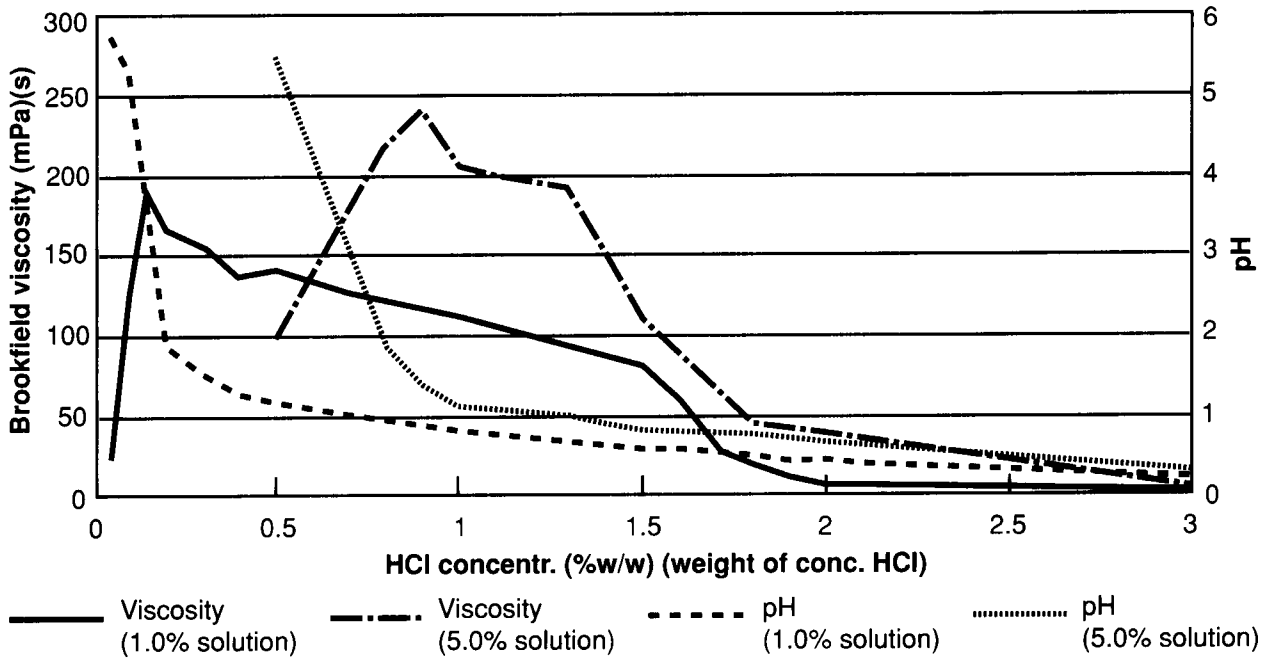


Figure 3. Chitosan solubility in HCl.

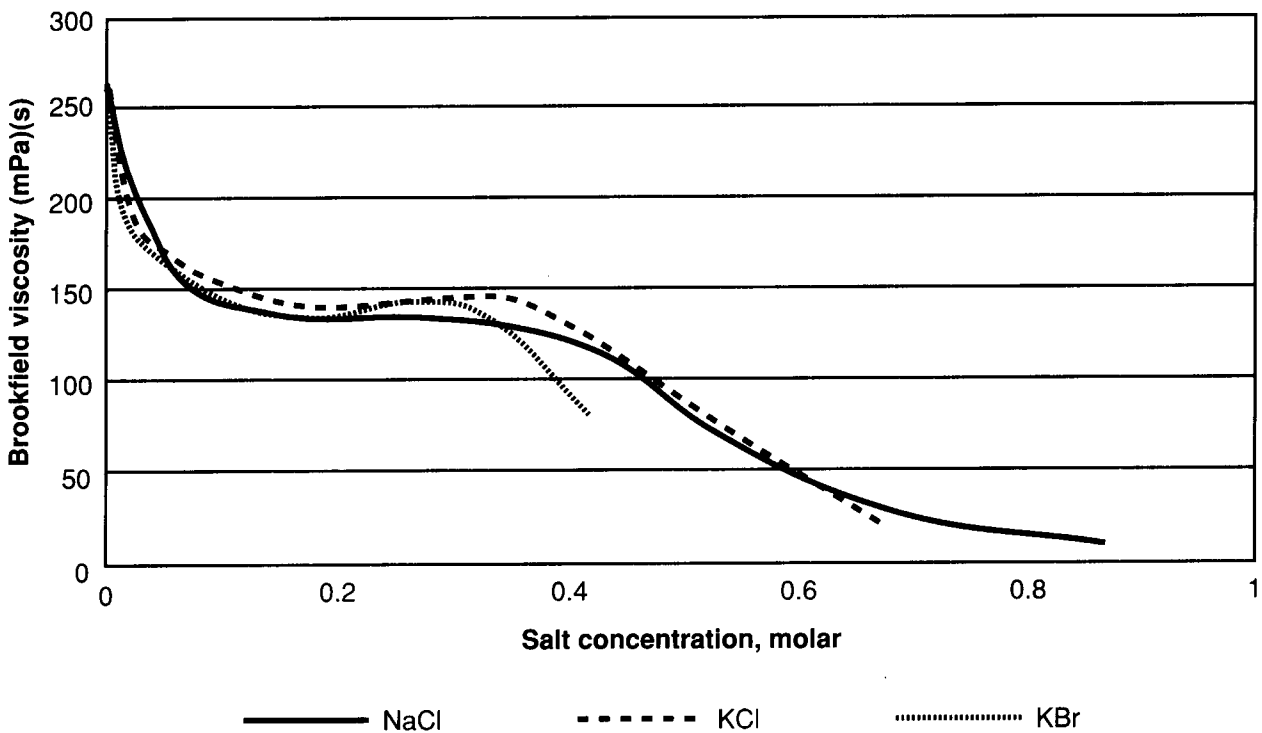


Figure 4. Chitosan solubility in presence of salt.

Table 5. Chitosan viscosity and pH in acid solutions.

	1% (w/w) acid		5% (w/w) acid		10% (w/w) acid	
	Viscosity (mPa)(s)	pH	Viscosity (mPa)(s)	pH	Viscosity (mPa)(s)	pH
Acetic acid*	260	4.1	260	3.3	260	2.9
Propionic acid*	260	4.3	—	—	—	—
Formic acid*	240	2.6	185	2.0	185	1.7
Lactic acid*	235	3.3	235	2.7	270	2.1
Pyruvic acid	225	2.1	—	—	—	—
Malonic acid	195	2.5	—	—	—	—
Adipic acid	190	4.1	—	—	—	—
Malic acid	180	3.3	205	2.3	220	2.1
Succinic acid	180	3.8	—	—	—	—
Tartaric acid	52	2.8	135	2.0	160	1.7
Citric acid	35	3.0	195	2.3	215	2.0
Oxalic acid	12	1.8	100	1.1	100	0.8

*weight of acid as 100%.

Table 6. Papers published on chitin and chitosan 1988-1990.

	Application related	Others	Total
Japan			
Total	257	145	402
Patents	193	62	255
USA and Western Europe			
Total	107	119	226
Patents	44	9	53
Others			
Total	76	44	122
Patents	9	4	13

Use Approval

The safety and toxicological documentation required will increase as human consumption is realized. Studies involving exposure times and quantities, as well as internal and external use, will be important.

While necessary investigations to cover environmental and handling safety should require investments less than \$100,000, toxicology documentation for medical, pharmaceutical, and food approval will probably be in the range of \$1 to \$10 million. Manufacture of food and pharmaceutical grade products will mean that the production facilities will have to operate according to good manufacturing practice (GMP) requirements, and this will have an impact on the production costs.

Patents

The wide interest in chitin and chitosan has resulted in a large number of patents from both academia and industry. From a general literature search for the years 1988 and 1989, a total of 750 publications were found. More than 40% were patent applications (321) (Table 6). If the application-related papers are considered alone, patent applications count for close to 60%.

The number of patents is particularly high in markets where the polymers have the longest traditions. This could mean a hurdle in further development of applications and markets, and could also limit the interest among new companies to start manufacture of chitin and chitosan. These companies may perceive a problem with commercializing their own development work due to potential infringement of some of these many patents.

UTILIZATION OF SELECTED FISH BY-PRODUCTS IN ICELAND: PAST, PRESENT, AND FUTURE

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INTRODUCTION

Iceland is a sparsely populated volcanic island on the middle of the Atlantic ridge. The country enjoys very rich fishing grounds mainly due to the mixing of the warm gulf stream coming from the south and cold currents from the polar region (Figure 1).

Being by far the most important natural resource of the country, fisheries traditionally play a very important role in the economy of Iceland. In 1989 the total catch was around 1.4 million tons, accounting for 73% of the country's merchandise exports (Figure 2) and 54% of the foreign currency earnings. The most important fish species in Icelandic waters belong to the gadoids, i.e. cod, haddock, and pollock. Ocean perch, Greenland halibut, herring, capelin, and pink shrimp also play a major role (Table 1). The fishing fleet and the processing plants are relatively highly mechanized as seen by the fact that only 13.1% of the work force is employed in fishing and fish processing. The main Icelandic fishery products are shown in Figure 3 and the main markets in Figure 4.

From early days Icelanders have realized that their fish resources are limited and that a collapse of any of the major stocks would be economically disastrous. The latest measures for controlling exploitation of the fish stocks took place in 1984, when fixed quotas for each vessel were introduced. Major objectives of the quota legislation were to prevent overfishing, and to stimulate full utilization of all catches and exploitation of underutilized marine life. There is no doubt that the quota system has had a major effort in changing the attitude toward full utilization of the catches. The fishermen and the processing industries are more aware than ever of the possibilities of making marketable products from raw materials that currently are either used for fish meal or discarded. Official institutions and a score of private firms and sales organizations are

Table 1. 1989 Icelandic catches.

Species	Metric tons (x 1,000)
Cod	336
Haddock	55
Pollock	74
Ocean perch	85
Greenland halibut	56
Herring	88
Shrimp	23
Capelin	658
Other species	55
Total	1,430

involved in the effort of better utilization and product development.

THE PAST

Icelanders always have eaten a lot of fish, and today they are among those nations with the highest fish consumption per capita in the world. In times when only small-scale fishing existed, all the traditional methods of preservation were used, such as drying, salting, and smoking. Even today dried fish is considered a delicacy in Iceland and is very expensive. Constant shortage of food throughout the centuries developed a food culture which fully utilized the catch. Dried fish heads were softened in dairy whey and eaten, livers and roe were delicacies, and sharks were (and still are) ripened for a few weeks prior to drying. Fish was in early times praised as health food, especially liver or fish oil. Shark liver was considered excellent against hay fever, dog-fish liver was used for healing wounds, and cod liver was used against swellings. For intestinal disorders swim bladders from cod were considered the best medicine. A popular dish was cod stomachs filled with a piece of cod liver.

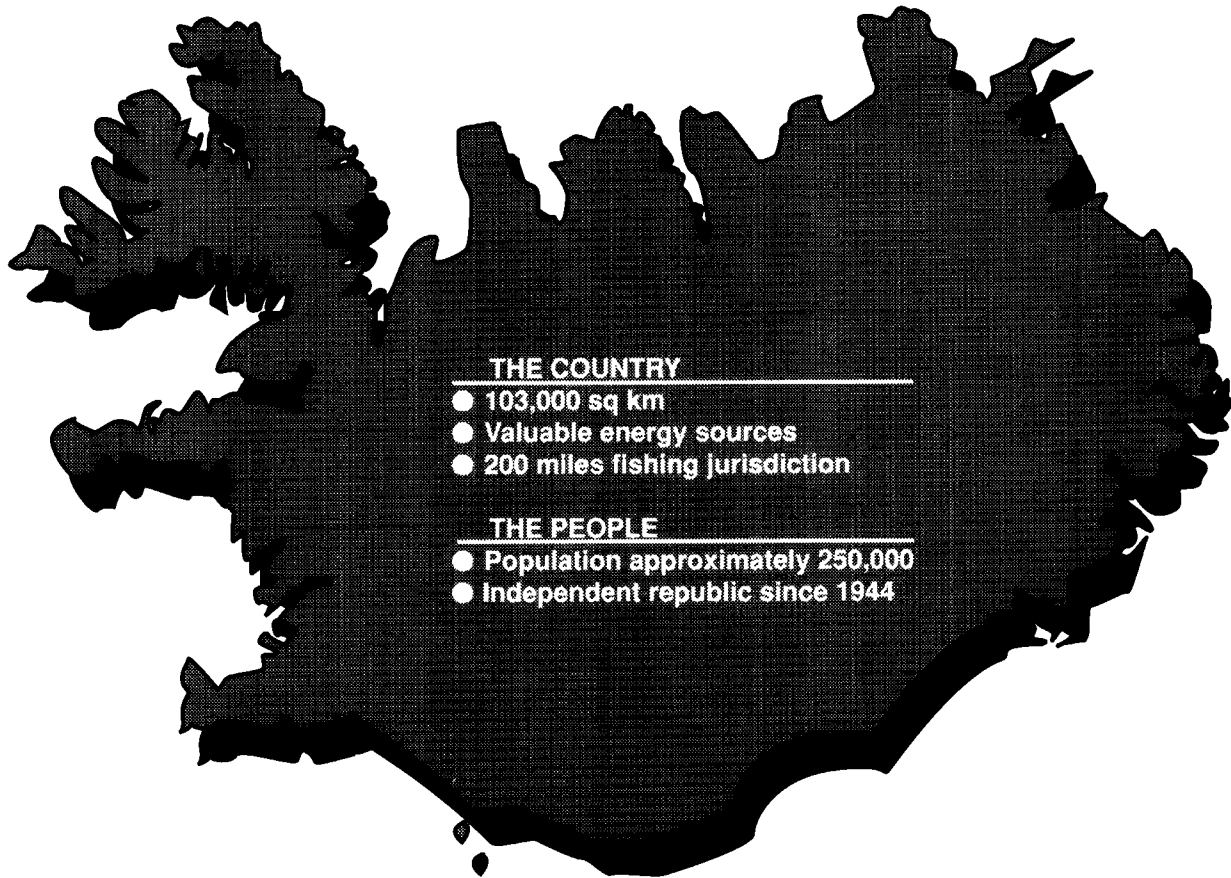


Figure 1. *Basic facts about Iceland.*

When Icelanders started industrial fisheries, they discovered that many new species can be eaten, such as shrimps and lobsters. After the turn of the century cod fisheries predominated, and such species as pollock and ocean perch were considered a bycatch and discarded at sea. The best known Icelandic fish by-product is undoubtedly cod liver oil and cod roe. From 1901 to 1950 the annual production of cod liver oil was 2,000–7,500 tons per year and around 2,000 tons of salted cod roe. In 1935 research by the Icelandic Fisheries Laboratories on the vitamin content of ocean perch liver resulted in high quantities of this fish being caught. The liver was the main product, and the by-product—the fish—was reduced to fish meal. Prior to 1950 all viscera from fish gutted on land was discarded, but gradually all such material became processed to fish meal. After the collapse of the Atlanto-Scandian herring stock in 1967, capelin became the main raw material for fish meal production. In 1978 production of capelin roe became a large by-products industry, partly helped by an Icelandic technological innovation in separating and

cleaning the roe for the demanding Japanese market. Since 1977 the annual production of capelin roe has been up to 6,600 tons.

PRESENT

Presently a number of projects are being carried out in Iceland aimed at better utilization of catches. However, a rapidly changing pattern of processing and marketing is greatly influencing the amount of by-product raw materials available. This is caused by the recent advent of the freezer trawlers, which only use 40%–45% of the catch, and the increased sales of fresh iced fish to the European market. Last year freezer trawlers caught some 107,000 tons of demersal fish, and over 100,000 tons of whole iced fish were sold abroad.

Prior to these changes, we estimated the amounts of by-products and their use. The results are shown in Table 2. Almost 100,000 tons of fish material is discarded annually, 63,000 tons from the conventional

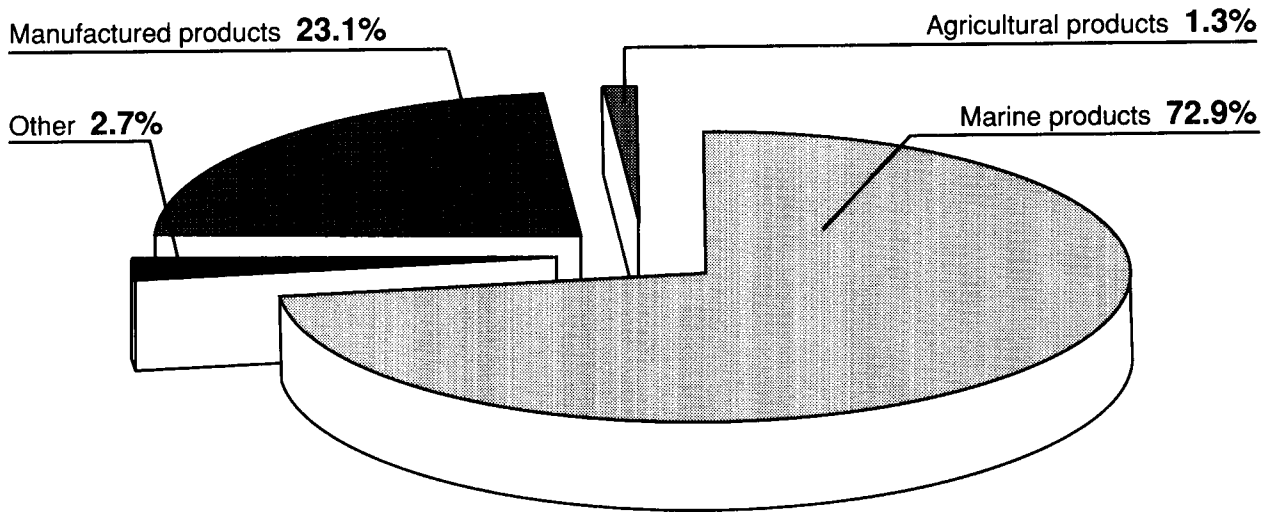


Figure 2. Merchandise exports from Iceland in 1989, by value.

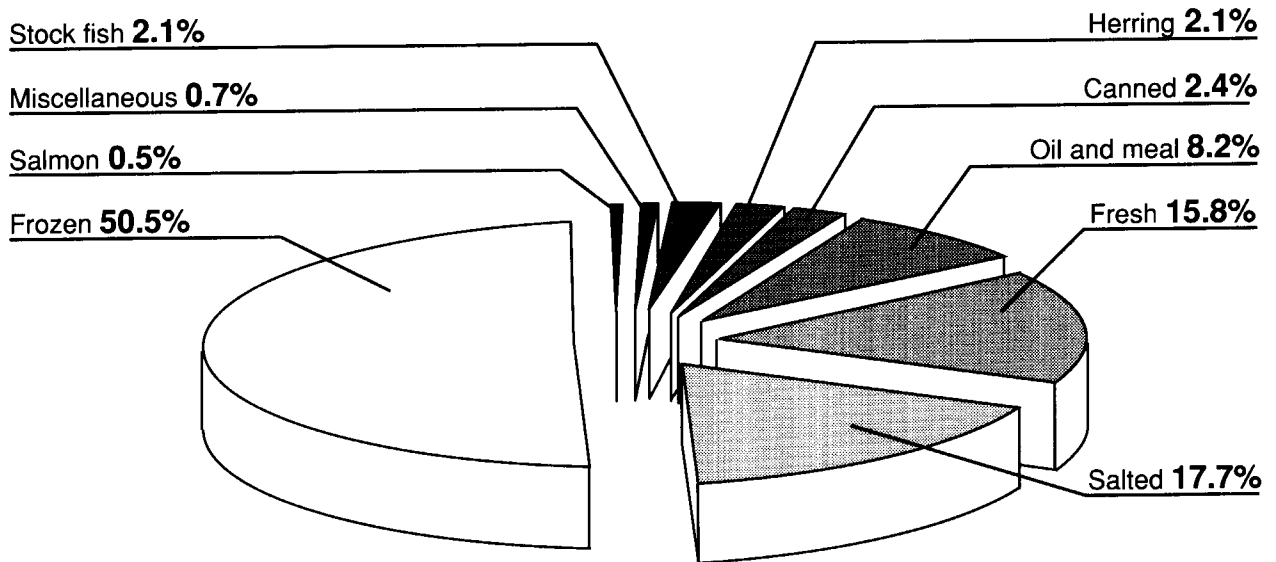


Figure 3. Fish commodity exports from Iceland in 1989, by value.

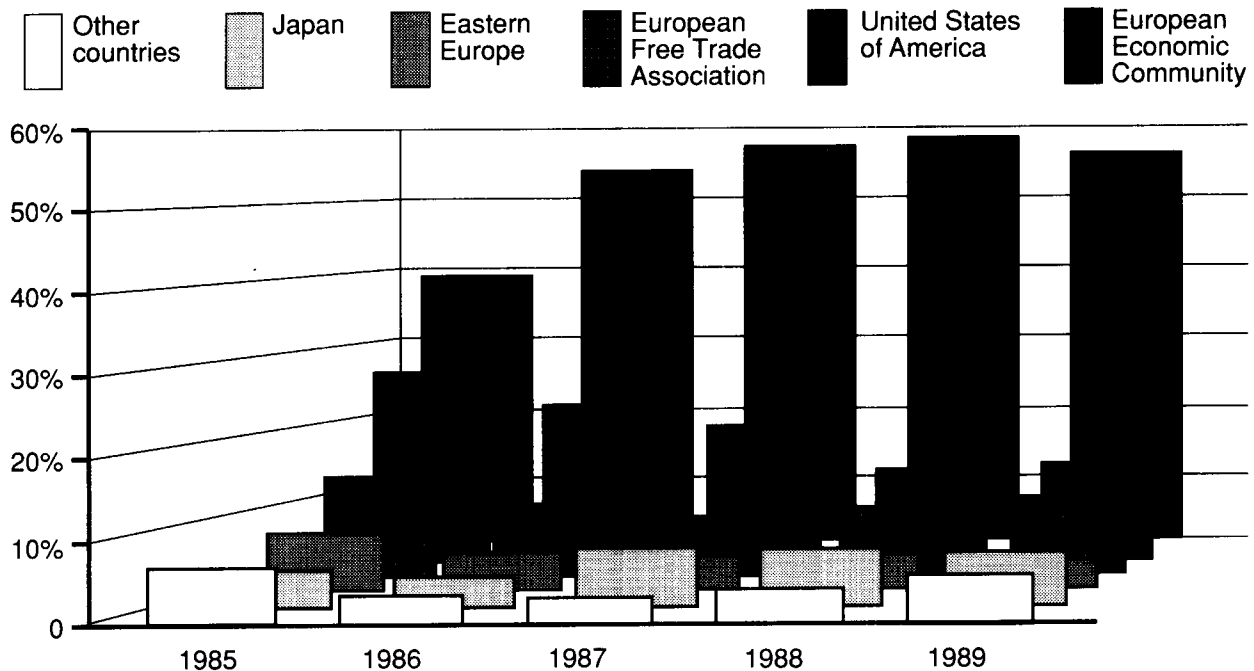


Figure 4. Marketing area percents of total worldwide exports, 1985-1989.

catches plus at least 30,000 tons of noncommercial species and juvenile fish bycatch.

The easiest method to utilize scrap fish and fish offal is to preserve this material by adding 2%-3% formic acid. The resulting liquid silage can then be pumped, the fish oil can be separated easily by centrifugation, and the fat-free silage concentrated by evaporation in stickwater evaporators. This method is dealt with in the paper by Arason et al. in this proceedings.

ICELANDIC EXPERIMENTS ON BETTER UTILIZATION OF FISH BY-PRODUCTS

Shrimp Offal

Shrimp offal constitutes about 50% of the shrimp. It contains protein, chitin, and the coloring agent astaxanthin which is a necessary ingredient for salmon feeds. We have done several experiments with shrimp meal processing. As astaxanthin is very heat-labile, it is necessary to use low-temperature driers. We have made business plans for a shrimp meal factory in northwestern Iceland where some 5,000 tons of shrimp offal are available within a 20 km radius of the factory. Despite these favorable conditions, our calculations show that such a factory would be operated at very low profits. A shrimp meal factory is now being built in the

area, primarily because of increased costs in getting rid of the shrimp offal due to new more strict regulations on dumping offal near the shore.

Roe

Frozen and salted cod roe is in good demand for smoking, canning, and making various kinds of spreads, such as "caviar" spread or the Greek tarama salad. The roes from cod, haddock, and pollock are only available for a period of three months each year. The ripening stage is very important in terms of product quality.

In Iceland all iced fish must be gutted at sea except fish landed daily from November to April. Traditionally only roe from fish landed ungutted have been taken for salting or freezing, and the same is true for collecting the liver. Recently, however, vessels eviscerating the fish at sea have started collecting roe in insulated plastic tubs, using salt for preservation. On land the roes are sorted and brine salted in barrels.

It is time consuming for the fishermen to eviscerate the fish carefully enough not to damage the roe sack, which would reduce the roe prices significantly. At least three producers of eviscerating machines, one of them Icelandic, now claim that their equipment does not damage fish roe or liver.

The lumpfish roe industry is now well established

Table 2. Utilization of the Icelandic demersal catches and shrimp 1982–1985 (averages in metric tons x 1,000).

Demersal species	Total catch	Total available by-products	For human consumption	For fish meal and oil	Total utilized	Discarded
Cod, haddock, pollock	436,200					
Heads		74,200	10,400	47,000	57,400	16,800
Frames		54,100	1,600	51,000	52,600	1,500
Viscera		39,200	–	16,600	16,600	22,600
Liver		25,600	4,800	4,400	9,200	16,400
Roe		11,000	3,400	–	3,400	7,600
Ocean perch, Greenland halibut	145,000					
By-products		75,400	–	72,800	72,800	2,600
Shrimp	18,000	9,000				9,000
Total	599,200	288,500	20,200	191,800	212,000	76,500

Bycatches estimated to be 30,000–50,000 metric tons.

in Iceland, and most of the roe is packed as caviar under various foreign labels and sold in Europe. We have been experimenting with direct salting of the fresh roe, leaving out the stage of primary salting and storing in barrels (Magnússon et al. 1984).

Capelin roe has almost exclusively been sold in Japan, but some producers are now producing caviar or spreads for the European market.

Liver

Traditionally cod liver has been used for making medicinal cod liver oil. Significant product development has been made by the University of Iceland, Lýsi Ltd., and our institute. The main effort has been toward producing cod liver oil with a higher proportion of omega-3 fatty acids. Icelanders always have been large consumers of cod liver oil, and since the news media started reporting the alleged beneficial effects of the omega-3 fatty acids on human health, the local consumption has increased fourfold. Generally there is now more demand for cod liver than can be supplied from the unviscerated catch alone. Therefore fishermen increasingly have started to collect cod liver at sea in specially designed plastic tubs.

Canned cod liver has always been in good demand, but for the last few years only 100–200 tons have been produced annually. One reason this is considered difficult business is that the operating period is only about three months per year. Also the liver is very perishable, it has a maximum keeping time of 4–5 days at 0°C, and

its preparation prior to canning is very labor intensive because the membrane surrounding the liver has to be removed. We have been running experiments on storing the liver frozen, carefully protected from oxidation. The results show that good-quality canned liver can be produced if the freezing, storing, and thawing processes are carefully controlled (Steingrimsdóttir 1988). At the Icelandic Fisheries Laboratories we also have developed a process by which the cod liver membrane can be dissolved by using hydrolytic enzymes, but this process has not yet been employed in the canning factories (Steffánsson and Steingrimsdóttir 1990).

Fish Viscera

Viscera (including liver and roe or milt) constitute about 15% of the net weight of fish. In Iceland, most of the intestines are discarded at sea. It is well known that the intestines, the stomachs, and the pyloric caeca contain large amounts of digestive enzymes. These enzymes are responsible for the disintegration of fish left unviscerated for too long, and for liquefying fish when mixed with formic acid for silage production. For a number of years the University of Iceland and the Icelandic Fisheries Laboratories have worked toward producing crude enzyme mixtures, containing high amounts of cod enzymes. A pilot-scale process that produces the crude enzyme has been run for three years (Benediktsson 1987). It involves homogenization of the viscera followed by extraction using a neutral or a weakly alkaline pH. After filtration, precipi-

tation, and centrifugation, the liquid containing the enzymes is ultra-filtered in order to reduce the volume and remove low-molecular-weight impurities. After freeze-drying, the mixture contains enzymes such as trypsin, chymotrypsin, elastase and other proteases (Steingrimsdóttir 1988), and amylases. At the university further work is carried out for purifying the specific enzymes, especially trypsin and chymotrypsin (Ásgeirsson et al. 1989; Ásgeirsson and Bjarnason 1988b).

The use of industrial enzymes in the world is growing. Of about 200 thoroughly investigated enzymes, around 20 are used for industrial processes. These include additives to laundry detergents and animal feeds, and enzymes for tenderizing meats, clarifying beverages, etc.

At the Icelandic Fisheries Laboratories we have been experimenting with using industrial hydrolytic enzymes for various purposes in fish processing. The projects include removing skin from skate, membrane from fish liver, black membrane from swim bladders of cod, and scales from fish skin. In most of these processes the enzymes from cod viscera have proven to be at least as effective as some of the other industrial enzymes tested. However, the cod enzymes are at present more expensive than most of the other preparations. One of these processes is now being used commercially for removing black membranes from swim bladders, a specialty item in southern Europe (Stefánsson and Steingrimsdóttir 1990). Further research is needed to find specific users for fish enzymes, but no doubt users will be found. For example there is a growing market for fish hydrolysates, i.e., enzyme-digested fish proteins with defined qualities. This is one area where fish enzymes might become valuable in producing a variety of fish protein hydrolysates from scrap fish.

Fish Frames and Collars

After filleting or splitting groundfish, a considerable amount of fish flesh can be recovered from the remaining collars and the frames. The technology, using a bone separator, is well known and widely used in many countries. In Iceland practically no fish mince is produced except from the V-cuts rendered by the production of boneless fillets. The mince from the collar and the frames is darker in color than the V-cut mince and therefore sells at lower prices. By splitting the frames, using the attachment supplied with the Baader 184/185 filleting machine, a mince of relatively good quality can be made from the upper part of the frame. In our opinion all fish frames should be processed in this way.

From one ton of cod some 20–30 kilograms of

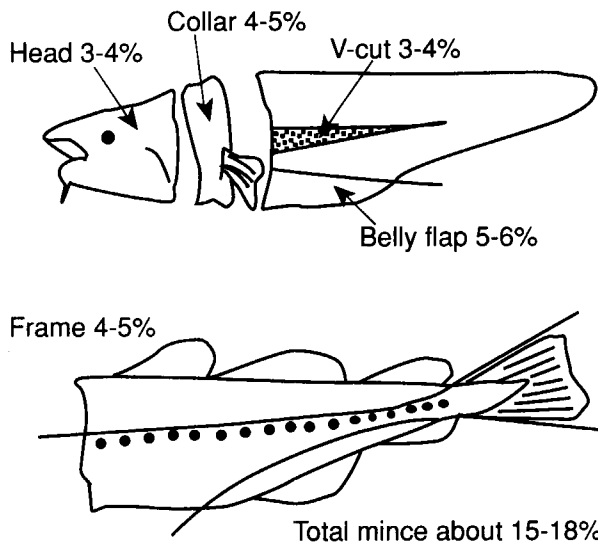


Figure 5. Possible mince quantities from various parts of the cod.

mince can be made from the upper section of the frame alone and 40–50 kilograms from the collars (Figure 5) (Arason 1988).

Mince is a very difficult product in terms of bacteriological quality and limited keeping time. Good-quality mince, however, can be used for various excellent products. In my view we need to improve production technology, and we can learn a lot from the surimi industry about this. We especially require economical ways of washing the mince and making washed mince a commodity subject to specified industrial standards.

In this area research and development is needed. There is a lot of interest in Iceland concerning better utilization of fish frames and collars, and a few companies are now working in that area.

Fish Heads

In Iceland, as in many other countries, fish tongues and cheeks are considered delicacies among the local population. Some cheeks and tongues also are exported. The bottleneck for processing is the high manpower requirement. Even though some 10,000 tons of fish heads are processed in Iceland for human consumption, mostly by drying, almost 50,000 tons are still processed to fish meal.

Therefore, the development of a head splitter by the Kvik company was a major development toward better utilization of the flesh from fish heads (Figure 6) (Gudmundsson 1989). As the product of the machine is

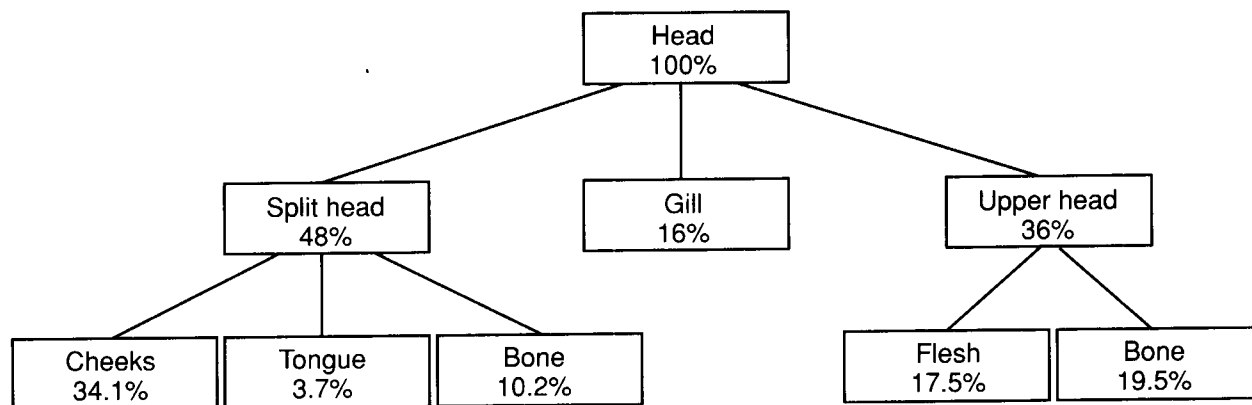


Figure 6. Recovery of flesh from cod heads using the Kvikk 205 head splitter.

new on the market, time has to be allowed for product development. In Iceland tongues and “double cheeks,” products of the head splitter, have mostly been salted and sold on the salt fish markets in Portugal and Spain. Little yet has been done in exploring the potential of producing mince from the “double cheeks” but we know that such material could have value as an additive to other minces because of its high binding properties.

THE FUTURE

I am optimistic regarding future utilization of fish by-products. In fact I am convinced that the day soon will come that no parts of the fish will be discarded.

In my view there are three major components in successful utilization of all by-products. First is technology. In most cases we are trying to utilize a small portion of a large mass of material. Doing this manually requires a lot of labor. We need new equipment that can reduce the labor cost. Examples include small automatic fish meal plants or silage units that can continuously process all material not suitable for human consumption. These should be made in a size that will fit processing plants or freezer trawlers.

Second, quality of products is a determining factor in the market value of such by-products as fish mince. The fact is that large quantities of poor-quality fish mince is on the world market. With better quality management, it is possible to make immense improvements in this area. New technologies are emerging that will allow a new range of products to be made from fish mince or washed fish mince.

Third, research is needed for new uses for the various by-products from fish. We all know about the continuing research on the apparent beneficial effects

of the omega-3 fatty acids. There are many unknowns about fish consumption. For example a search of the available literature on the composition of fish roe reveals that very limited research has been done on the subject. In the animal feed area, questions are still unresolved regarding the existence of “growth factors” in fish meal which make it superior to other animal feeds of apparently similar composition. We are just beginning to scratch the surface regarding research on the range of enzymes found in fish viscera in great quantities. The same holds true for fish hydrolysates.

There could be large markets for various fish hydrolysates, both as special feed components and as natural stabilizers for protein foods, fish, and meats. There are numerous possibilities for fish oils. One area of research relates to akyl glycerols in shark fats. These compounds have the effect of protecting living beings from radiation, thereby decreasing the chance of cancer.

The increased prosperity of the Southeast Asia region, where the richest fish-eating culture exists, opens various new possibilities in better utilization of bycatches and by-products. Already the fish-eating habits of Asia are influencing western societies.

We must admit that in relation to other food industries the fish industry is underdeveloped in many ways. However, it holds a great promise in terms of variety and development of products.

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QUESTIONS AND ANSWERS

Q. How about the utilization of blue whiting?

A. The Faeroese have been utilizing blue whiting, unfortunately at a great loss. They made the surimi plant, but as far as I know most of the surimi vessels have been sold. We have been waiting in Iceland. We could catch some 100,000 to 200,000 tons of blue whiting, but it is still swimming in the sea waiting. It's quite difficult to process economically.

Q. Is that because of the recovery of the blue whiting?

A. It's a small fish. Using filleting and skinning machines, the yield is quite low. But the determining factor is that the market value of bulk blue whiting is lower than for pollock. It's a bit lower than was anticipated when the plans were made for this type of processing.

THE PRODUCTION OF SILAGE FROM WASTE AND INDUSTRIAL FISH: THE ICELANDIC EXPERIENCE

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INTRODUCTION

For many years there has been interest in Iceland for finding new ways for utilizing pelagic fish, fish waste, and fish viscera as an alternative to fish meal. The main emphasis has been on a cheaper process that could work aboard large and small fishing vessels or in small isolated places with too little fish production for operating a fish meal plant economically. One of the processes that has been considered is conservation by acids or bases, with or without hydrolysis (Arnesen et al. 1981; Raa and Gildberg 1982).

Research on fish silage began in Iceland about 20 years ago. At that time it was mainly focused on preservation with addition of ammonia to the fish and keeping the pH above 10. This silage was separated and dried or concentrated. Feeding trials on calves were reasonably successful but due to lack of interest in the method, these tests were soon abandoned. For the last 10–15 years, the Icelandic Fisheries Laboratories have intermittently been running trials and experiments on silage production using various organic and inorganic acids. Many different aspects of fish silage have been considered such as different raw materials, reclaiming of acids, corrosion of metals in contact with silage, processing methods, methods to control the level of hydrolysis, etc.

Today there are five companies that produce silage on a commercial basis in Iceland, one from viscera and bycatches on board two trawlers, two from fish offal, and two that produce silage from capelin. The total production of fish silage during the last two years was about 10,000 tons each year (Arason et al. 1984; Arneson et al 1981; Dagbjartsson et al. 1976).

Today the main effort is to find new users for silage and/or silage concentrate and to make it economical for

factory trawlers to use their offal for silage instead of discarding it.

RAW MATERIALS

The available raw material for silage production in Iceland can be divided into three categories.

1. Viscera and bycatches.
2. Filleting operations.
3. Pelagic fish.

Today most of this is used for fish meal production. Yearly some 100,000 tons of offal and bycatches are discarded that could have an export value of about eight million U.S. dollars if all of it were used for producing animal feeds. For silage production, raw material freshness is of as great importance as for the production of other animal feeds from fish.

PRODUCTION METHODS

Producing silage is simple. The fish material is finely comminuted and mixed with formic acid 2%–3% (w/w) depending on the material.

The types of equipment for producing silage differ, however, from one raw material to another:

1. When producing silage from viscera, one can use high-speed, low-quantity mincers and keep the silage moving with a circulation pump or other inexpensive equipment. The pump can be any acid-proof, low-speed, positive-displacement pump.
2. When producing silage from filleting waste, the machinery must be more rigid, and the mincer has to be a low speed type that can handle fish skin and bones and will not break down even if foreign objects get into it. The pumps also must be very rigid. We have found that piston pumps or force-

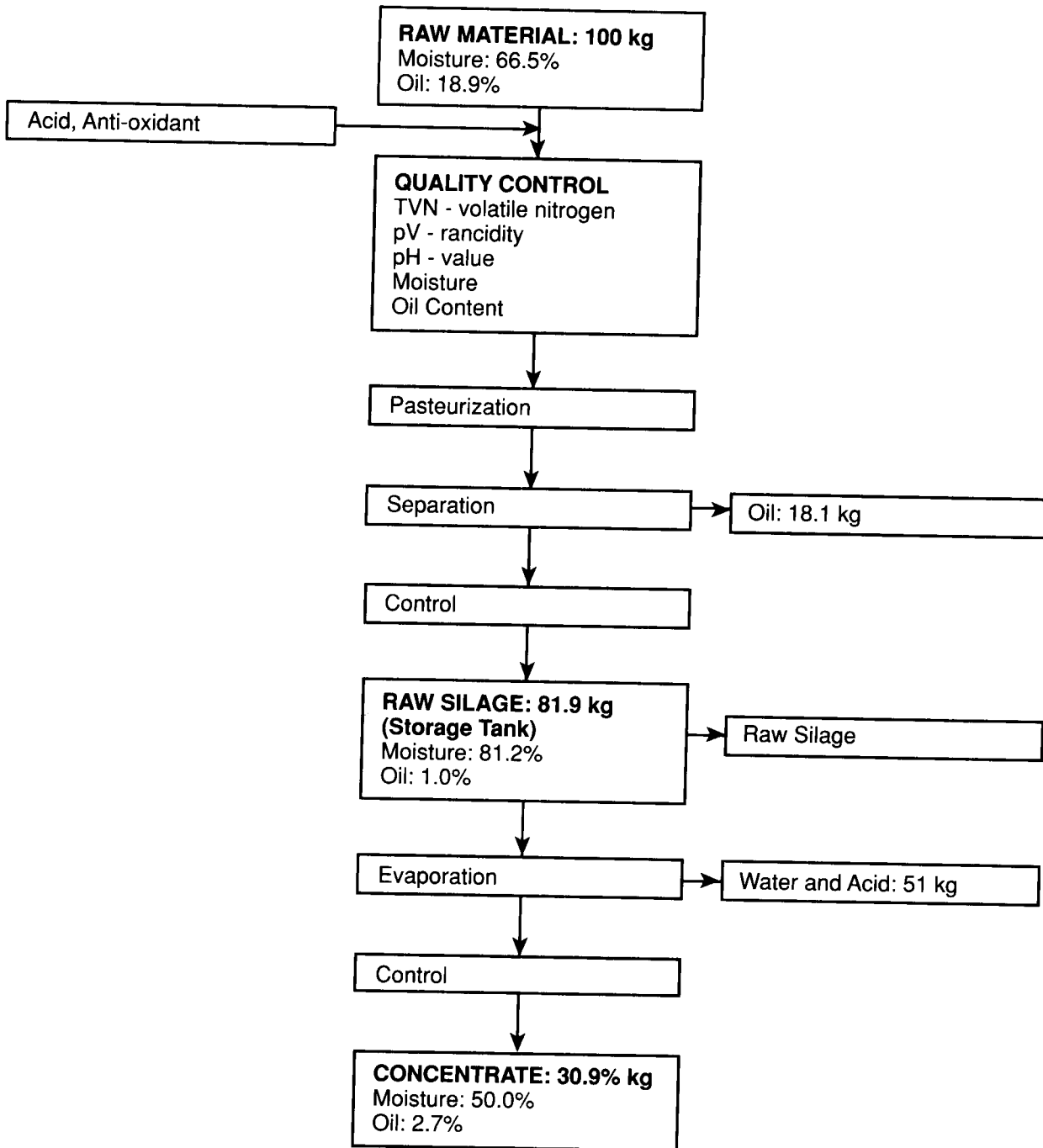


Figure 2. Flow diagram for processing fish silage offal from trawler.

diagram of such a process is shown in Figure 3.

Various experiments have been done to make direct use of the silage concentrate instead of processing it into fish meal along with conventional raw material. The concentrate contains about 60% dry matter and has a

syrupe consistency (Arason et al. 1984).

The silage concentrate has been used as an additive in grass pellets for feeding ruminants. The pellets contained 15%–20% silage concentrate, which increases the protein content of the pellets and acts as a binding

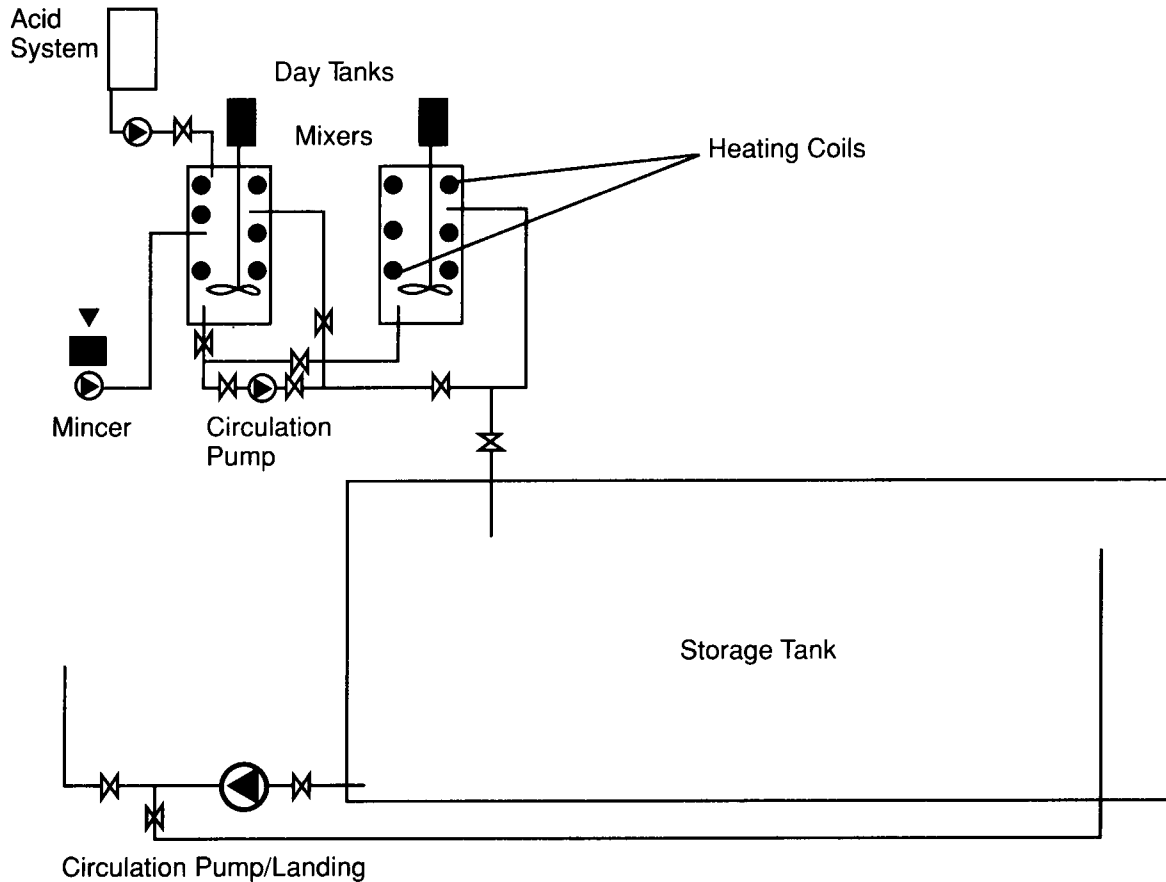


Figure 3. Fish silage process for factory trawlers.

agent (Arason and Guðmundsson 1984; Arason et al. 1984).

In Iceland, some 2,000 tons of semi-moist fish feeds containing 45% unconcentrated silage have been produced using formic acid. The silage is made from whole fish and is subsequently mixed with grains to form semi-moist pellets (Arason and Guðmundsson 1984).

The corrosive effects of silage were studied with respect to acid type, concentration, temperature, and fat content. The results indicate that low-fat silage is more corrosive than silage with about 10% fat content. Silage can be stored in ordinary steel tanks if the temperature does not exceed 20°C. Above 20°C the silage must be stored in tanks made of stainless steel or plastic (Figure 4)(Arason et al. 1984).

Considerable work has also been carried out to evaluate the main physical properties of fish silage, i.e., the viscosity, heat convection coefficients, and the rate of autolysis (Figure 4)(Arason et al. 1984).

NUTRITION

Composition of the silage depends on the type of raw material used. In Table 1 we can see a typical composition of the main silage products.

It is possible to standardize the fat and protein content during processing. The fat and water content can be changed by separation and evaporation. The hydrolysis can be stopped any time, and we can thereby influence the types of proteins in the product.

Hydrolyzed silage with short peptides has mainly been used in feeds for fish, mink, fox, chicken, and pigs, and silage with less broken down proteins has been fed to ruminants (Guðmundsson et al. 1979).

The silage is pasteurized when the desired degree of hydrolysis is attained, measured by viscosity. The silage can be stored again for later use or processing.

Many different kinds of acids have been tried for making silage. The most popular one is formic acid, which is organic and penetrates well into cells. In low

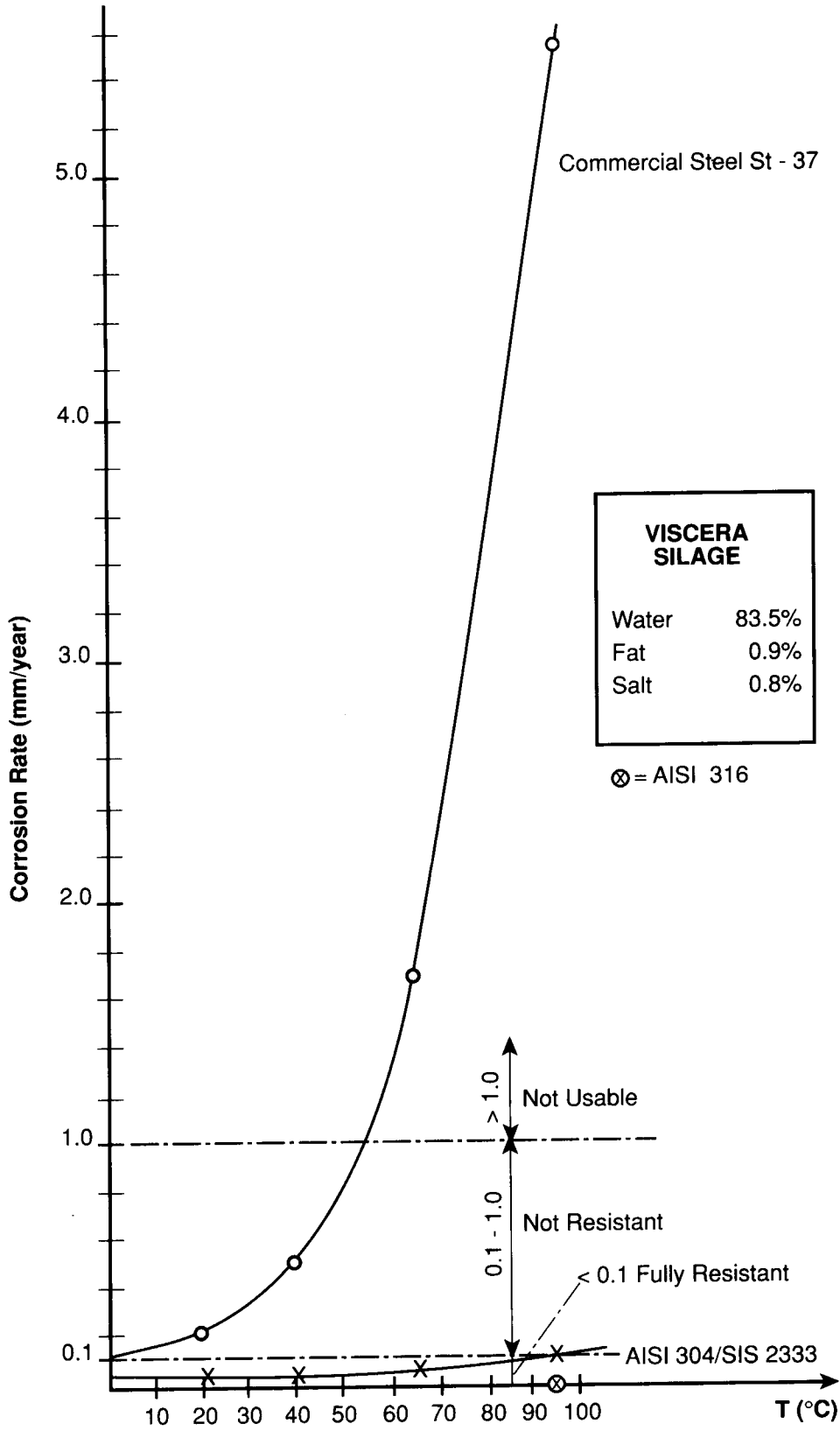


Figure 4. Corrosion of containers for viscera silage.

Table 1. Proximate analyses of different silage types.

	%		
	Dry matter	Protein	Fat
Silage—Icefish trawler	14.6	12.5	18.9
Silage—Factory trawler	18.0	14.5	10.7
Whole capelin	15.0	13.0	15.0
De-oiled viscera silage	18.0	15.0	1.0
Concentrated silage	47.5	40.5	2.5

concentrations formic acid has no harmful effects on animals. A blend of acetic acid and sulfuric acid, as well as blends of propionic acid and formic acid, also have been tried in Iceland. The latter mixture is more economical than formic acid alone but has the limitation that it cannot be used for salmon feed. Today full-strength formic acid is the most popular for making silage 2%–3% (w/w). The cost of the acid is about 25% of the sales price of the silage. It is possible to reclaim up to 50% of the acids when concentrating the silage, and this is a way to lower the acid cost.

MARKETING

Fish silage has not been an easy commodity to sell for some of the reasons listed below.

1. Silage is competing with known and well-established products like fish meal, soya meal, and other products.
2. It is not a known product.
3. Feed producers are generally not equipped to handle the liquid material.
4. Customers are not willing even to try silage or silage concentrate unless they have guarantees of constant deliveries and a stable product.

There has been a steady market for silage from whole capelin for many years, particularly in Denmark which annually uses about 60,000 tons, of which Iceland has supplied 3,000–5,000 tons per year. This silage has mainly been used for feeding pigs, chicken, and fur animals.

In Iceland there have been several outlets for silage over the years: as an additive into grass meal pellets, and as a feed for salmon, fur animals, pigs, and sheep. It also has been used as an additive in fish meal production for some special meals.

The fur industry in Scandinavia has shown some interest in the product, but so far the actual sales have been limited. The feed industry in Norway increasingly

has been using silage concentrates as a component of semi-moist pellets for salmon and fur animals.

ECONOMICS

In our opinion the method can be used economically in the following situations:

1. Where small quantities of fish offals do not justify investment in a fish meal plant or small-scale transportation. We consider silage production more profitable than fish meal plants for places with less than about 5,000 tons per year of fish waste.
2. Conventional trawlers. Silage production is a very cheap way to increase profits if tanks are already on board that can be used to hold the silage. If tanks have to be built specifically for the silage, the profitability becomes almost nil.
3. Factory trawlers. Both fish meal and silage production are marginal. Silage production costs less in investments but the fish meal is a well-known product and in big demand.

CONCLUSION

Our work on fish silage in Iceland mainly has been concerned with the technology and economics of making silages out of fish offals that otherwise would have been discarded. Apparently simple operations, such as mincing fish offals, adding acids, and ensuring thorough mixing, are not so simple after all. Our trials with marketing fish silage or fish silage concentrates as a special commodity to the feed market show that we need more experience in handling silages on a routine basis and we should introduce detailed product specifications.

To gain this experience we are now attempting to process more fish waste as silage, and to use it as an additive in fish meal production. While doing this we will continue to specify the silage concentrates as feed

components and continue our efforts to make this product a commercial one in its own right.

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QUESTIONS AND ANSWERS

- Q. You indicated that capelin silage is exported from Iceland to Denmark.
- A. (Dr. Valdimarsson) Yes. It's not concentrated. It's simply minced, mixed with acid, and shipped directly. In fact, Denmark is the only large-scale user of fish silage. They use about 60,000 tons a year.
- Q. What quality control parameters do you have on the solids? I presume it's sold from one organization or company to another, and the variation in quality could be quite large.
- A. (Dr. Valdimarsson) We have been measuring total volatile nitrogen, pH, trimethylamine, and the viscosity of the silage. It has been increasingly common to stop the hydrolysis by heating, and the viscosity has been used as a parameter.

CREAMY FISH PROTEIN

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ABSTRACT

Although fish such as pollock, pink salmon, and menhaden are valuable resources obtained in large quantities, effective food engineering processes for these fish on a large scale at a reasonable cost are not available yet. At this time only pollock surimi is used for boiled fish paste. Furthermore, in order to maximize gelling, most of the soluble proteins, minerals, fish oils, etc. have to be removed. Thus, surimi has a low yield, on the order of 20%, and requires large amounts of salt, sugar, or phosphates to be added to prevent a decrease in gelling.

Recently we reported on a newly developed method of treating whole fish meat, including the bones, with enzymes, thus retaining the effective contents of the original fish in an emulsified protein mixture. We have investigated the functional characteristics of the enzyme-treated fish meat mixture as food material. In addition, we are developing new processing methods that will overcome decreased gelling due to enzymatic treatment, and we are elucidating methods that process foods in emulsified, solid, or gelled forms. Finally, we are clarifying application of this technology to fish heretofore unrecognized as useful, and to specific parts of ordinary fish and shellfish for their processing.

Pollock, pink salmon, and snow crab are skinned, eviscerated, finely ground, and treated with protease enzymes to form an emulsified protein mixture (creamy fish protein, CFP) mainly consisting of peptides of 40,000–70,000 molecular weight. CFP does not coagulate upon heating. The enzyme-treated proteins retain the amino acid profiles and mineral content of the processed fish, and do not contain preservatives or additives. By blending with vegetable proteins, eggs, and edible oils, CFP can effectively create digestible, smooth-textured food preparations which have a potentially large application as new food material.

INTRODUCTION

I am reporting here on the manufacturing and uses of a new food product produced from marine protein by enzyme processes. The fish protein produced by this enzyme process is a completely new, creamy-textured fish product. We call it creamy fish protein (CFP).

Creamy fish protein uses the fish in its natural state, without loss of any components of the fish. Its outstanding nutritional value and unique properties make it well suited to a wide range of uses, such as processed food, pet food, and feed applications. Also, the manufacture of creamy fish protein is an extremely efficient use of marine resources.

This report contains the background of creamy fish protein and a basic description of research on the enzyme process. The CFP production method is discussed, as well as the characteristics and applications, markets, and future uses for CFP.

SCOPE OF TECHNOLOGY

Marine products are used as food, and also as feed and fertilizer components, but a large portion is also discarded as waste. Our research is directed at developing new manufacturing technologies to make more efficient use of these resources, especially by the use of enzymes. Enzyme process technology can be applied both to edible and nonedible uses, and can enable the use of all material components.

This report is about the creamy fish paste used for edible food products. However, there is also an application in the feed and fertilizer field, which we call bio-flour. This is a new, high-quality fish meal with high nutritional value.

Pollock, pink salmon, menhaden, and sardines are valuable food resources that are harvested in great quantities. There has been considerable research aimed at making the most efficient use of these fish in such products as FPC (fish protein concentrate) and marine beef (sardine powder produced by an ethyl alcohol extraction process). Unfortunately, these have not yet

Table 1. Nutritional information for creamy fish protein and meat for three species (per 100g).

	Red salmon		Pollock		Snow crab	
	Meat	CFP	Meat	CFP	Meat	CFP
Protein (g)	18.7	16.9	15.7	14.1	14.8	8.7
Fat (g)	11.2	10.8	0.7	0.2	0.5	0.2
Carbohydrate						
Sugar(g)	0.1	0.1	0	0	0.1	0.1
Fiber (g)	0	0	0	0	0	1.8
Ash (g)	0.7	1.4	0.9	1.7	1.8	6.8
Calories (kcal)	184.7	173.3	72.9	61.4	68	46
Calcium (mg)	14	183	42	158.9	90	18,500
Iron (mg)	0.5	1.2	0.6	1.0	0.5	4.05

succeeded as industries. Only surimi technology has become established as an industry, and it is limited to pollock and a few other fish. In particular, surimi technology relies on heat-induced gel production. In order to produce a stronger gel in surimi, most of the water-soluble protein, minerals, and fish oils are washed out and lost.

Fish protein processing with enzymes is widely used; however, most products such as liquified fish protein are used as flavorings. Food protein products have not yet been developed.

Our enzyme process technology can be applied to all types of fish, making maximum use of all components, and increasing the fish use in food. The nutritional value of all components is preserved and even increased. CFP can be used in a wide variety of food applications.

After adding various types of protease in a 30-minute reaction at 104°F (40°C), we heated the pollock meat to 194°F (90°C) for one hour to harden the gel. Gel strength was then measured. In all cases, gel strength rapidly decreased at low protease densities, but stabilized at a certain density level even if density increased.

In order to study the residual levels of actomyosin, which has a strong effect on the gelling of treated pollock meat, we studied the activity of ATPase as an indicator. ATPase activity is sharply reduced at low protease density levels. However, it changes very little as protease density increases, which closely resembles our gel strength data.

Selective use of small amounts of protease enzyme can have a strong effect on gel formation in pollock meat. By establishing the proper conditions, we can make pollock meat products with very different consistencies.

CFP MANUFACTURING

As a result of detailed research, we were able to develop creamy fish protein as a new, paste-type material which does not require thermal hardening. For the CFP manufacturing process, raw materials may be any type of fish, including shellfish or a wide variety of marine resources.

After removing viscera, skin, and fins, wash lightly. Bones and shells are rich in important nutritional minerals such as calcium, iron, and also chitin and chitosan, and may be used as ingredients. If bones and shells are not used, they are removed. After this process, the materials are ground to a size of 100 microns or smaller. Next, protease is added and allowed to work under moderate, carefully controlled conditions. Then the product is briefly heated to deactivate the enzyme. The protein has now been broken down to the point that it will not coagulate when heated, so it is possible to thermally sterilize the product to provide longer life. This produces a creamy-textured fish protein. CFP needs no preservatives, and when refrigerated or dried will remain stable for a long time.

Pollock meat primarily consists of large-molecule protein with molecular weight above 100,000. In CFP, however, the large molecule protein appears to be broken down by hydrolysis into peptide molecules with molecular weights of around 40,000 and 20,000.

For food products for which creamy consistency is well suited, CFP may be made from any type of fish or shellfish. Fish and shellfish that have been tested and used as CFP include pollock, cod, salmon, trout, capelin, hake, herring, sardines, whiting, tuna, eel, crab, shrimp, lobster, and scallops. CFP has a moderate fish taste like the original fish, and often it is a desirable flavor. Fish taste of CFP can be reduced by using

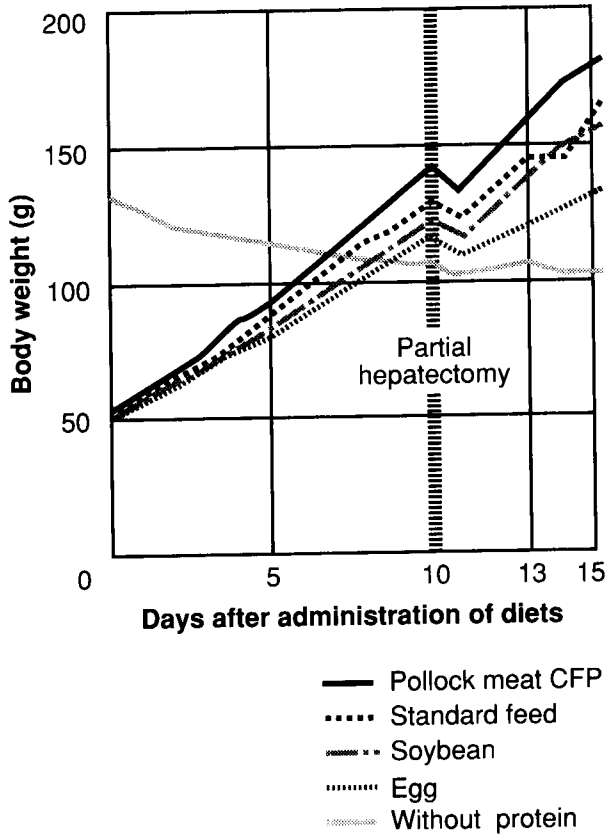


Figure 1. Growth test of rat before and after liver removal, fed different diets.

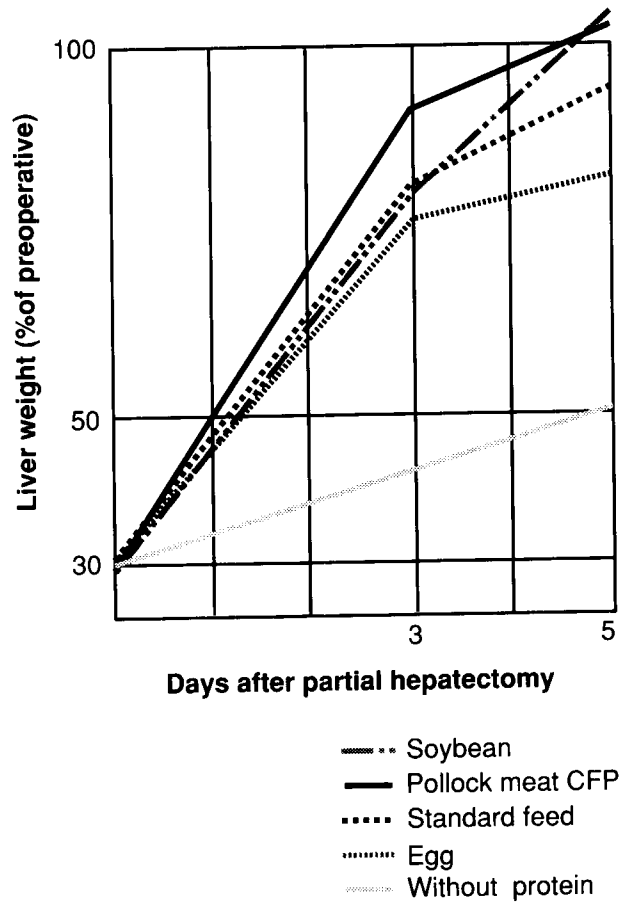


Figure 2. Liver restoration in rat after hepatectomy, fed different diets. Partial hepatectomy was done at 10th day of growth test shown in Figure 1.

treated fish meat, if necessary. We can also obtain odorless CFP using treated white flesh such as pollock meat.

NUTRITIONAL PROPERTIES OF CFP

Pollock, red salmon, and snow crab CFP are generally lower in fats and protein and higher in minerals such as calcium and iron than fish meat CFP, because CFP contains both soluble fractions and bones (Table 1).

The amino acid patterns are unaffected by enzyme activity. Both pollock and red salmon have an exceptionally good amino acid balance. The higher concentrations of lysine and threonine in CFP may compensate for the lower levels of these amino acids in vegetable protein, providing greatly improved nutrition.

To further study the nutritional characteristics of

CFP, we did a growth test using rats. As protein sources, our feed with CFP made from pollock showed better growth than standard feed, and feeds with soy protein and egg protein (Figure 1). In this test, we performed a partial hepatectomy on the tenth day of the study. This was to observe the recovery of the rats after the operation, and also to study the regeneration of the liver. The results show that CFP provided the best weight gain after the operation, suggesting that it may be an excellent nutritional source for convalescents. A partial hepatectomy by Higgins and Anderson (1931) involved removal of two-thirds of the rat liver. They reported 75% of the original liver weight had been reached after one week, and normal liver weight was reached after two to three weeks.

Our research shows that CFP made from pollock provides the best results in terms of liver weight at three and five days after hepatectomy (Figure 2). This

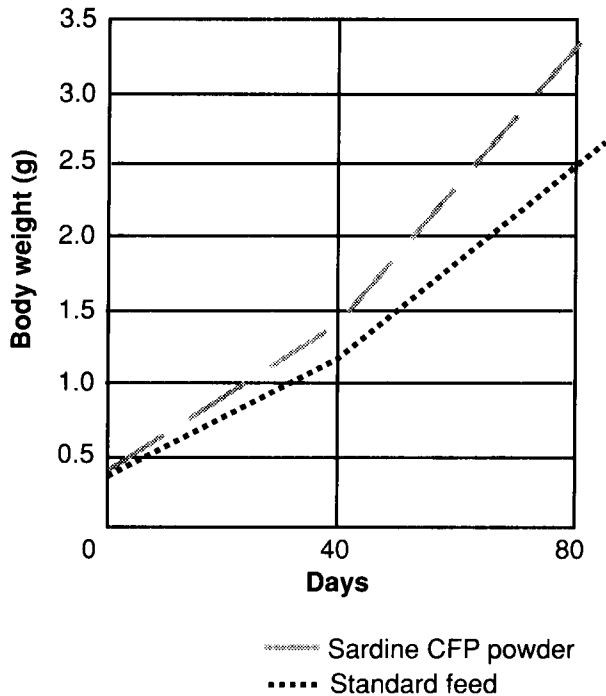


Figure 3. Salmon body weights, fed different diets.

demonstrates that CFP is an excellent nutritional source, with the necessary nutritional components in good balance, for liver regeneration. However, our rat experiment did not show any difference between normal pollock meat and pollock CFP. Possibly this is because the absorption rate of digested fish protein is fairly high, so that no difference appeared between enzyme-treated protein and untreated protein.

To test the absorption rate of enzyme-treated protein, we did a growth test on young fish with undeveloped digestive organs. One-week-old salmon were fed with standard feed and with sardine CFP. The CFP-fed fish were 27% larger after 40 days, and 80% larger after 80 days than those on the standard feed (Figure 3). Salmon, trout, eels, red sea bream, and other fish showed the same excellent results. This confirms that CFP has excellent digestive absorption, because it is enzyme-processed protein.

The high nutrition level of CFP appeared again in a high blood pressure control experiment. When a 5% CFP powder supplement was added to the diets of rats with naturally high blood pressure (SHR rats), the blood pressure of all CFP rats decreased greatly over 15 days, whether on pollock, salmon, sardine, crab, or shrimp CFP. After 15 days, the CFP was removed, and the rats returned to standard feed. The blood pressure of all test groups increased. These results show that CFP

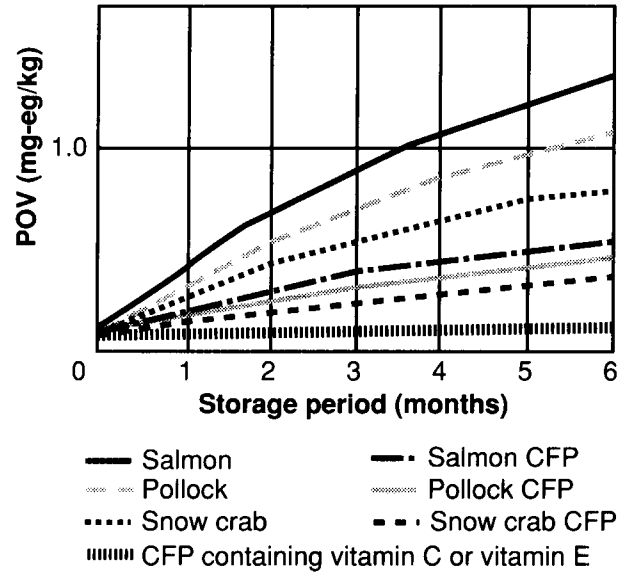


Figure 4. Fatty acid oxidation in frozen storage at -20 to -25°C. POV = peroxide value.

is effective in controlling increases in blood pressure.

The effectiveness of peptides derived by enzyme action from fish protein in controlling high blood pressure has recently been reported, and the effectiveness of CFP is thought to be due to its peptide component. We suppose that calcium absorption is also enhanced because the calcium in CFP is in very small grains and dispersed with the peptides in the form of an emulsion. Calcium is also known to be effective in controlling high blood pressure, so the remarkable effect of CFP in blood pressure control is probably caused by the combined effect of peptides and calcium.

Calcium is important not only for bone formation, but also for controlling arteriosclerosis, heart disease, and psychological stability. It is also a nutrient in which many Japanese are deficient. The potential for calcium supplements from fish and shellfish in the form of CFP is a significant development which has attracted considerable notice. Because of nutrient content, CFP-containing foods are recommended and are used in Japanese school lunch systems.

APPLICATIONS OF CFP TO FOOD PRODUCTS

As a food base, quick-frozen CFP has no character change after thawing, and there is also no large character change with repeated freezing and thawing. In the

Table 2. Comparison between creamy fish protein and surimi.

	CFP	Surimi
Raw material requirement	Fresh, frozen, or steamed	Fresh
Oil in raw material	Adjustable	Removed
Minerals	Unchanged	Almost lost
Additives	None	Saccharides and sodium polyphosphate
Taste	Moderate taste	Almost none
Frozen stability	Better than surimi	–
Refrozen	Possible	Impossible
Bacteria count (per gram)	Less than 10 ³	Less than 10 ⁶
Compatibility with other food	Very good	Limited
Heat coagulation in fish protein	Small	Large
Powder form	Possible	Impossible

case of slow freezing, small viscosity changes do occur; however, the original consistency returns by stirring. In surimi and ordinary fish meat, refreezing causes abrupt texture deterioration, so CFP appears to be an easier-to-handle food base.

As explained earlier, because CFP has become emulsified by the enzymatic hydrolysis of high-polymer proteins, protein coagulation through heating is minimal. Furthermore, combining CFP with vegetable oil yields minute grain sizes, and the dispersion is stable. Thus, applications to fluid or flowing food products are quite suitable.

Generally oils and fats in fish are high in polyunsaturated fatty acids; therefore they are prone to oxidation even when frozen. CFP, however, does not oxidize and deteriorate as readily as ordinary fish meat. The addition of vitamin C or vitamin E inhibits most oxidation (Figure 4).

In CFP, fats and oils are surrounded by protein layers in an emulsion which inhibits oxidation. Also, a deactivation process in making CFP contributes to a deactivation of oxidase in fish. Furthermore, such antioxidants as vitamin C and vitamin E become more effective because they are uniformly dispersed in CFP due to its emulsified character. Thus, CFP is a superior material for ingesting stable fatty acids such as EPAs (eicosapentaenoic acids) and DHAs (docosahexaenoic acids) in fish.

For forming solid foods, it is possible to prepare a material that retains its shape and has gel strength by combining CFP with a variety of food bases that promote gelling. In this way, you can alter gel strengths to prepare foods with completely new characteristics and textures.

CFP can be mixed with surimi to form many new

types of products:

- Various sheet products can be made by using different kinds of CFP. The texture is softer, and closer to a seafood texture than if surimi is used also.
- By adding CFP made from real crabs, we can obtain a flavor and texture close to real crab meat as in crab kamaboko.
- Imitation scallop is made like a hamburger patty. We have high hopes for this seafood product as a healthy food source with lower saturated fat and cholesterol.
- Imitation smoked salmon is made by mixing smoked salmon CFP and pollock surimi. The product has a taste and texture close to real smoked salmon.
- A chip-type product is made to have a fiber-like texture that is totally different from surimi. We are looking at various ways of using it to produce meat-texture seafood, such as a meat-texture sausage. These are healthy foods with lower fat and cholesterol.

CFP is also mixed with food products such as starch, egg, dairy products, vegetable protein, oils, etc.:

- A fish tofu steak is made with a mixture of soy protein and CFP. This combination of vegetable protein and fish protein provides a desirable amino acid balance.
- We can make cheese-like products by mixing milk protein with CFP.
- We can make a custard with 10% pollock CFP, with almost no trace of fishy smells.

Other applications include CFP as an additive in many types of frozen products, a seafood cup soup with CFP, and CFP-added snacks that have been introduced in markets by a major consumer group in Japan.

Following is a summary of the nutritional features of CFP:

1. CFP retains the nutritional balance of fish and shellfish.
2. It is rich in digestible protein, and low in fat, especially saturated fatty acids and cholesterol.
3. It needs no chemical preservatives or additives, and is an extremely nutritious seafood. CFP may be helpful in controlling high blood pressure.

Table 2 summarizes some comparisons between CFP and surimi. The CFP process is superior to the surimi process in several ways:

1. Product yields differ by type of fish, but in general CFP with bone yields 60% to 65%, and CFP without bone yields 30% to 35%. Both are much higher than the surimi process.
2. The CFP process is economical because it consumes less energy. For example, surimi products require 5 to 10 times the weight of water, but CFP uses one to two times the weight of water.
3. The process equipment required is not as expensive as for surimi.
4. Frozen stability is good, and the products can be refrozen after thawing. This greatly expands the product's use as a food material.

FUTURE USES FOR THESE PRODUCTS

CFP, when used in making bread, could help alleviate the worldwide food problem. CFP made of pollock and cod will work very well in bread because no fishy odor is detected even if 10% to 30% is replaced by CFP. CFP in dry powder form can be stored at room temperature and can be easily blended with flour in bread recipes.

Bread is low in lysine, an essential amino acid. About 30% pollock CFP paste (or 6% pollock CFP powder) doubles the nutritional value of bread. This fact is extremely important in our search for the solution to the world food supply problem occurring now and into the twenty-first century. I expect CFP to be a valuable contribution to the problem because of its unique features.

ACKNOWLEDGMENTS

I wish to express my appreciation to Dr. Keisuke

Tsuji, of the Japanese National Institute of Health and Nutrition, for his dedicated research on the effect of CFP lowering blood pressure using the SHR rat.

REFERENCE

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QUESTIONS AND ANSWERS

- Q. I'm curious where CFP is being produced today?
- A. Our first plant was built in western Japan in Tottori Prefecture. As much as 3,000 metric tons can be produced there.
- Q. Usually when you apply hydrolysis on fish material you have bitterness, and you haven't mentioned any bitterness. How do you explain this problem? And I have the same question concerning fish taste. And my last question to you is, what is the dry matter content of paste form CFP?
- A. Selection of an enzyme depends on the kind of fish, the particular CFP used as an ingredient, and how the final product is used. Peptides with a medium molecular weight should be the main component. Endo-peptidases are suitable, and we get better results with exo-peptidases.
- CFP from refined pollock meat does not have fish taste; CFP from salmon, crab, etc., usually has moderate and desirable fish taste.
- The powder product from paste is about 20% to 25%.
- Q. Can you use fatty fish for producing creamy fish protein?
- A. Yes, we can remove fats in the centrifuge, if necessary.
- Q. What is the cost?
- A. Material cost for CFP without bones is nearly 40% less than for surimi. If bones are used as well, the cost should further improve.
- Q. I'm not a surimi man, but from what you say this industry has invested hundreds of millions of dollars into surimi production. And it sounds like your product is a better product. It can be made more cheaply, and has more uses. Did I miss something somewhere?
- A. We suggest that under the same production scale, the cost is lower than surimi. But we have only a small plant in this state. Scale is very important I think. In the same conditions, same volume, the

CFP product is better than surimi.

CFP does not compete with surimi, but complements it because CFP can be produced from many kinds of marine resources not suitable for surimi production. Combinations of CFP and surimi can be very useful for new food applications.

- Q. Do you find it necessary to have a very special size reduction process for the CFP with bones to avoid a gritty mouth feel from the bone? Does it have to be extremely finely divided? Does the product, the raw material, have to be ground very finely in

order to avoid bone crunch?

- A. Under 100 micron powders we can't detect it. We can obtain such a product by grinding and enzyme treatment in the CFP production process.
- Q. How do you explain the very white color of your product? Usually hydrolysates of seafood produce a brown color. And I have been very surprised by the very white color.
- A. CFP has a color from the fish. Refined pollock meat has no color; it is very white. But we usually use backbones, so CFP with bones has a slight color.

BIO-FISH FLOUR

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ABSTRACT

The biotechnological fractionation method is a new process developed to maximize the value of fish components. The method consists of enzyme reactions and the separation of the mixture into components.

The conventional fish meal process involves cooking, pressing, and drying at high temperatures. In contrast, the biotechnological fractionation method is characterized by mild processing conditions; the temperature is kept under 75°C throughout processing. As an improved process for fish meal, a low temperature drying process has been developed.

In the low temperature process, a cooking method is used. In the biotechnological fractionation method, instead of cooking, an enzymatic reaction at low temperatures is applied. Bio-fish flour is a product of the biotechnological fractionation technology. Controlled enzyme reactions and mild processing conditions, along with strict quality control, assure high digestibility and excellent nutritional value of bio-fish flour.

The high protein digestibility and richness in essen-

tial fatty acids of bio-fish flour meet the requirements of animals and fish with immature digestive systems.

INTRODUCTION

We believe that the biotechnological fractionation method, which we have developed using enzyme technology to produce a high-quality fish flour, is well suited to this conference's theme, the use of "one billion pounds of protein." We believe this method will become a means of maximizing the hidden nutritional value of fish.

The enzyme process described in the "Creamy Fish Protein" paper by Y. Shoji, in this proceedings, is the same as that used to produce bio-fish flour. The application of the product is as a feed and fertilizer. This enzyme-processed marine product was developed to maximize the nutritional value.

SCOPE OF THE TECHNOLOGY

The biotechnological fractionation method is used to produce the following fish flour products:

- Bio-fish flour is the general name for fish flour made from fresh fish.
- Brown bio-fish flour is a trade mark for our new fish flour made from fresh sardines.
- White bio-fish flour is a trade mark for our new fish flour made from fresh pollock waste.

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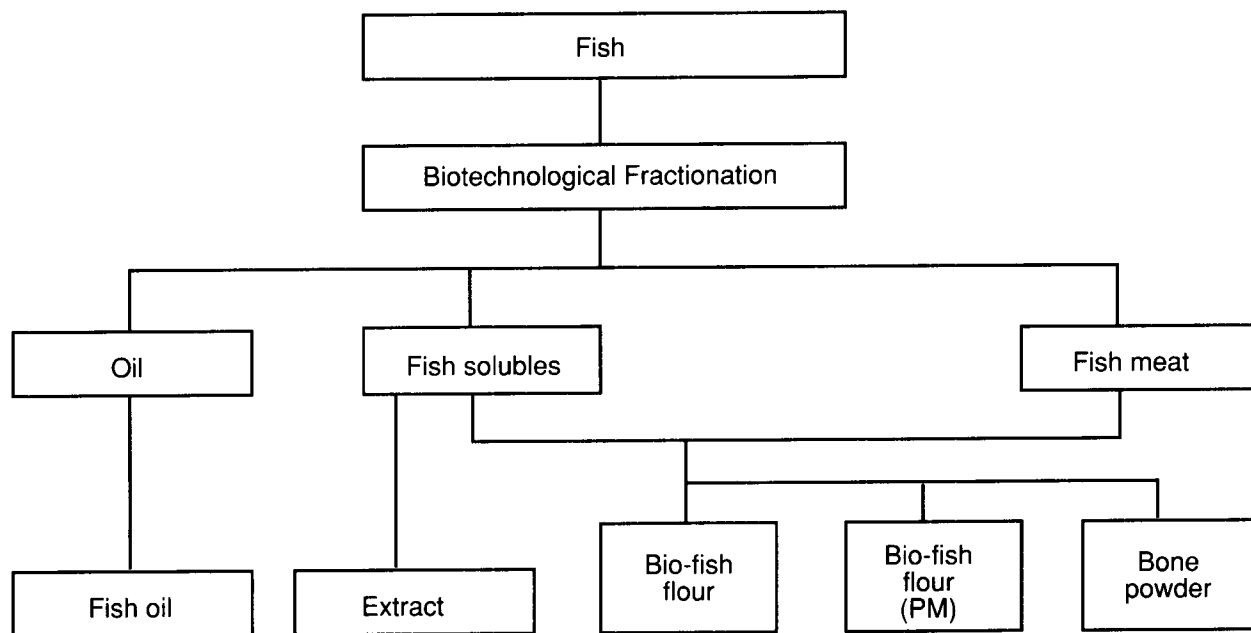


Figure 1. Products from biotechnological fractionation.

Table 1. Specifications for bio-fish flour.

	Brown bio-fish flour	Brown bio-fish flour (PM)*
Crude protein	65% min.	70% min.
Crude fat	12% max.	12% max.
Crude ash	16% max.	12% max.
Moisture	6–9%	6–9%
Pepsin digestibility	98% min.	98% min.
NaCl	3% max.	3% max.
Volatile basic nitrogen	0.15% max.	0.15% max.
Soluble N/Total N x 100	35% max.	–
Anti-oxidant (Ethoxyquin)	100–150 ppm	100–150 ppm

*High protein grade made by partially removing ash.

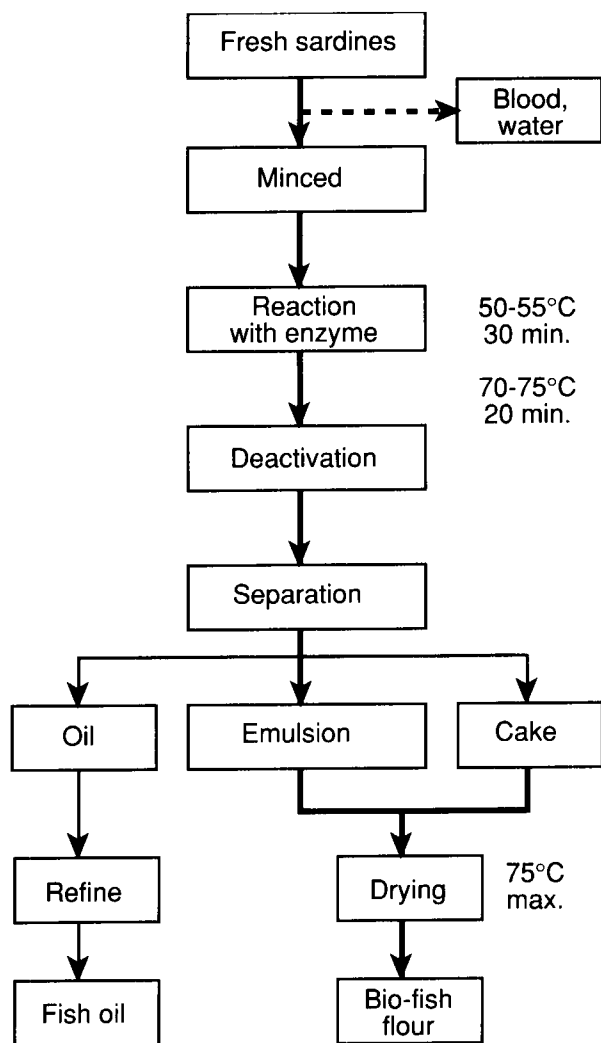


Figure 2. Biotechnological fractionation process used in manufacturing bio-fish flour .

The biotechnological fractionation process uses a partial hydrolysis of fish protein with protease enzymes under controlled conditions. The entire process takes place at mild temperatures of less than 167°F (75°C). As a result, the nutritional value of all components of the fish are maximized in producing a new high-quality fish flour.

During the biotechnological fractionation process, the fish is separated into fish oil, soluble components, and fish meat with bone. Each of these components has high nutritional value and is refined and mixed for various application purposes. Bio-fish flour is produced by drying fish solubles and fish meat, and can be separated into bio-fish flour PM (high protein) grade and bone powder by sifting (Figure 1).

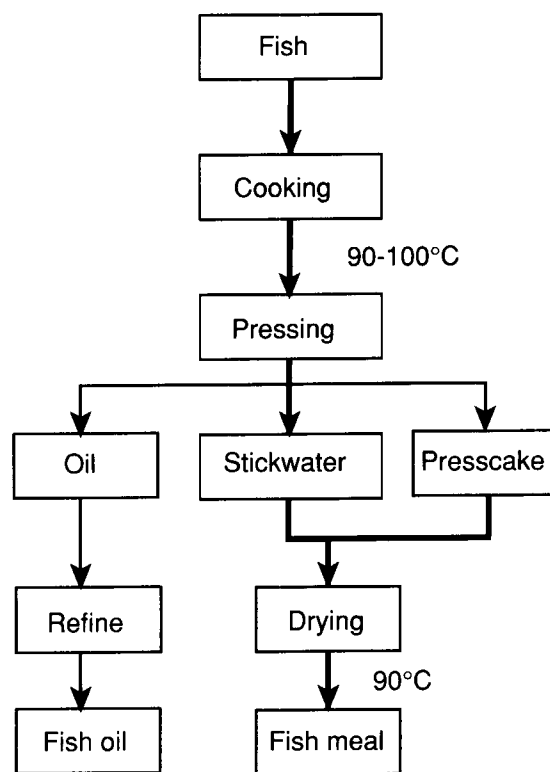


Figure 3. Conventional manufacturing process used in manufacturing fish meal.

During the process for producing bio-fish flour from sardines, enzymes are added to fresh sardines and allowed to react at temperatures between 50° and 55°C for 30 minutes, after which the mixture is briefly heated to deactivate the enzyme. The components are separated into oil, emulsion, and cake in the centrifuge. The cake and emulsion are mixed and then dried at a maximum temperature of 75°C or 167°F (Figure 2).

The specifications for bio-fish flour are shown in Table 1. The high-protein PM grade is suitable for fish fry and milk replacement for piglets and calves.

A conventional process for manufacturing fish meal is shown in Figure 3. The biotechnological fractionation method is different from the conventional process in that an enzyme reaction is used in place of the

Table 2. Measurement of residual sulfhydryl group in model experiment and commercial samples.

	Free sulfhydryl (mM/100g)
Minced sardine samples	
Freeze-dried	3.5
90–100°C x 2 h coagulated, then freeze-dried	0.45
90–100°C x 2 h coagulated, then dried 2 h at 100°C	0.22
Commercial samples	
Bio-fish flour	0.97
Brown fish meal	0.74

Table 3. Effect of extracted lipids on the growth of eel fry.

	Brown bio-fish flour	Brown fish meal
Start		
Number of fry	70	71
Average weight	0.24 g	0.25 g
After 31 days		
Number of fry	63	64
Average weight	0.83 g	0.68 g

cooking stage, and the product is dried at a low temperature. By using this method, we try to avoid the loss of nutritious components and prevent deterioration of protein and oil through thermal chemical reactions, which was the major weakness in the traditional method of processing fish meal.

The protein in bio-fish flour shows evidence of better *in vivo* absorption, and it suffers less heat denaturation. Lipids in bio-fish flour are heat-stable omega-3 fatty acids. Bio-fish flour has a high vitamin content and has a growth-promoting effect.

The results of protein heat denaturation measured in residual amino acid sulfhydryl groups, in a model experiment and in commercial samples, are shown in Table 2. There is a correlation between sulfhydryl group reduction and drying temperature. The residual amounts of sulfhydryl groups in bio-fish flour are higher than in brown fish meal, demonstrating that bio-fish flour protein shows less denaturation during heating.

In bio-fish flour, extracted lipids have high iodine

Table 4. Vitamin and mineral content of brown bio-fish flour.

Vitamins	
B ₁	Non-detectable
B ₂	1.06 mg/100 g
B ₆	0.52 mg/100 g
B ₁₂	37 µg/100 g
Choline	0.44%
Niacin	23.4 mg/100 g
Folic acid	16 µg/100 g
Pantothenic acid	3.19 mg/100 g
Biotin	44.0 µg/100 g
Minerals	
Phosphorus	2.65%
Iron	31.9 mg/100 g
Calcium	3.65%
Sodium	776 mg/100 g
Potassium	1.40%
Magnesium	204 mg/100 g
Cadmium	0.47 ppm
Copper	0.57 mg/100 g
Zinc	14.2 mg/100 g
Manganese	0.79 mg/100 g
Cobalt	0.01 µg/100 g
Total chrome	0.7 ppm
Aluminum	44 ppm

Source: Japan Food Research Laboratories

value, low peroxide value, and low acid value, which indicates that deterioration by oxidation is low. The extracted oil contains polyunsaturated fatty acids rich in omega-3 fatty acids such as eicosapentaenoic acid and docosahexaenoic acid, and has a high concentration of phospholipids. Cholesterol and phospholipids play important roles in the growth and development of shellfish and fish fry. The stability of brown bio-fish flour lipids over time shows that there is good stability in storage. We used an emulsion-type ethoxyquin as an anti-oxidant.

The effect of oil extracted from bio-fish flour and brown meal on the growth of eel fry shows approximately 35% better weight gain with brown bio-fish flour than brown meal (Table 3). In this experiment bio-fish flour lipids and brown fish meal lipids were extracted with ether, then the solvent was evaporated. One part lipids was added to 100 parts feed. Fat quality in brown bio-fish flour is higher because it is processed at lower temperatures than in traditional methods. The

Table 5. Results of digestibility test of brown bio-fish flour and white bio-fish flour on piglets using the Cr₂O₃ method.

	Digestibility		Nutritional value			
	Crude protein (%)	Crude fat (%)	Dry matter (%)	D.C.P. ¹ (%)	T.D.N. ² (%)	D.E. ³ (10 ⁶ cal/kg)
Brown bio-fish flour	95.7	97.3	93.1	64.8	88.1	4.58
White bio-fish flour	95.1	100	89.5	62.1	76.4	4.26
White fish meal	91.0	91.0	92.8	59.5	72.0	3.18
Brown fish meal	87.0	78.0	92.1	58.6	73.2	3.23

Source: Japan Scientific Research Institute

¹Digestible crude protein.

²Total digestible nutrient.

³Digestible energy.

improved growth rate of the eel fry verifies the higher quality of extracted lipids.

Table 4 shows that brown bio-fish flour is rich in essential vitamins including the vitamin B group. This is because lower temperatures control the loss of those vitamins. The mineral content of brown bio-fish flour is not different from ordinary fish meal (Table 4).

In a study of the effect of bio-fish flour on the growth of *Lactobacillus*, the addition of brown bio-fish flour shows a 3% increase in protein and a 30% increase in *Lactobacillus* over the levels produced with the standard diet. Bio-fish flour is 10 times more effective than the standard diet. This was more than expected and shows the existence of an "unknown growth factor."

We tested the digestibility of brown bio-fish flour and white bio-fish flour using piglets (Table 5). In this experiment 10 piglets weighing 33.4–40 kg were tested for 16 days. Both brown bio-fish flour and white bio-fish flour showed better protein and lipid absorption than conventional white fish meal or brown fish meal, indicating that digestible crude protein, total digestible nutrients, and digestible energy of bio-fish flour are higher.

We conclude that bio-fish flour contains oligopeptides with good absorption, good amino acid balance, omega-3 fatty acid-rich lipids, and highly absorbable minerals and vitamins. It is highly digestible, nutritious, and is an excellent feed material for piglets, chicks, juvenile fish, etc. The new fish meal produced by the biotechnological fractionation method has great practical value.

PRODUCTION

There are about 120 conventional fish meal plants in Japan, and their total capacity is 38,000 tons per day.

Our bio-fish flour plant is located on the Pacific coast of Japan in the Kashima area near Tokyo. It has a production capacity of 150 tons per day, and has been operating since January 1987. Sardines are the raw material, caught in fishing grounds within 50 km, or 31 miles, of the coast. The raw material has a TVN (total volatile nitrogen) of 10% to 20%, and is stored between 5° and 10°C, or 41° to 50°F. In other words, we are careful to use fresh sardines as raw material.

Our creamy fish protein plant for food application is located in southwestern Japan in Tottori Prefecture. At present, our creamy fish protein and bio-fish flour plants are in separate locations, but we are planning to construct a joint creamy fish protein and bio-fish flour plant so we can utilize the resources better. We are now researching the best location, not only in Japan, but also overseas.

APPLICATION

The Japanese domestic market for bio-fish flour for fish feed includes sweetfish, rainbow trout, eels, sea bream, and yellowtail. It is sold as a milk replacement for piglets and calves, and it is also used as a growth factor for fermentation.

The high digestibility of brown bio-fish flour makes it well suited to animals with underdeveloped or weak digestive systems, such as fish fry, juvenile fish, piglets, or calves, and it can be used with better results than regular fish meal. Brown bio-fish flour is also suitable for chicks which require highly digestible protein.

The concept of "bio-fish flour" is well suited to the efficient use of Alaska's underutilized protein resources. It is one means of utilizing the many fish species, a blessing of nature we receive from the ocean.

THE AQUATIC LEATHER INDUSTRY: OPPORTUNITIES FOR SMALL MANUFACTURERS IN ALASKA

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In the subsistence economic system of Alaska, there is no classification for waste. Every group of coastal people has a use for fish skins. Food is the primary use, and secondary uses include clothing, household goods, and harvesting equipment. Since the cash-demand market system has spread in Alaska, the secondary uses of skin have been disappearing gradually. As the market system responds to consumer demand for boneless and skinless products, millions of skins are being wasted. Three years ago the cash-demand market system began to identify a new and growing demand for Alaskan aquatic leather. In response to the demand, two Alaskan companies collaborated to place the wasted skin by-product of the canned salmon industry back into the flow of commerce. Aquatic leather is a new industrial material with commercial application and consumer appeal that will support a statewide manufacturing industry. Alas-Skins, Inc., an aquatic leather tannery, and Alaskans Leather Product Manufacturing Co., Inc., an aquatic leather sewing factory, both located in Juneau, are the pioneers of that industry. Together they produce "Alaskins" products.

Subsistence technology, access to resource, applied science, accurate market analysis, and a supportive retail sector have been combined to make Alaska an international aquatic leather industry leader in 1990. The leadership is founded and sustained by the tourist industry. In 1985 the Alaska Association of Manufacturers estimated that only 5% of shelf space in Alaska's gift shops held products made in Alaska. The marketing strategy that has driven Alas-Skins leather is focused on the remaining 95%. Wholesale manufacturing of finished goods bought by Alaska gift shops has sustained a doubling of gross sales of aquatic leather goods for three successive years. The domestic markets for aquatic leather will continue to sustain industry growth into the foreseeable future. The limits to industry

growth will be defined by product development and production capacity over the next five years, rather than by access to resources or limits in the domestic market.

To a large extent, the aquatic leather industry is developing outside of the focus of state and federal economic planning. The public sector economic model is based on a history of resource extraction and external demand for raw material. State tourism promotion is designed to increase service sector jobs, while export of value-added products is a secondary effect of foreign trade.

The Alaskins model views tourism as the market element for in-state, value-added manufacturing. To the aquatic leather industry, the primary motivation for international trade is technology transfer and a market for excess factory capacity. The difference in focus has effectively made the Alaska aquatic leather industry irrelevant to the public planning process at this time, and has restricted access to in-state public and private capital sources. Production financing will remain the primary expansion mechanism for the aquatic leather industry until the public economic planning process gains experience and understanding of the role of manufacturing in a fully diversified economy.

Wasted fish skin is available on every continent in quantities to sustain a fully developed aquatic leather industry. The Alaskins model is a fully integrated factory replication plan that can be applied profitably in a wide variety of business environments. The plan was developed in response to business inquiries generated by national and international publicity of our industry. In the current period of political and economic realignment, there is a great demand for small-scale, owner-operated and production-financed manufacturing models. The demand seems to be greatest for turn-key factories using simple, low-energy methods to make consumer goods from local fish species sold in tested markets.

Environmental and social considerations enhance the marketability of a model for any location. Because

the Alaskins model was developed on green principles and practices, it shows more promise of easy integration into a wider variety of economic systems and management structures than other models. Corporate planning and development strategies of growth by replication appear at this time to be equally applicable to domestic and foreign markets for industrial material, finished goods, or technology transfer. But the Alaskins model remains untested. The first domestic replication will be completed this year, and the first foreign application of the model will probably be completed in 1991.

Alas-Skins leather was the first integrated aquatic leather tannery and product manufacturer to enter the marketplace. Eel leather, developed in Hawaii, opened the market and established a worldwide reputation by Korean manufacturers. The eel success prompted other Korean firms to tan and manufacture salmon leather from Alaska cannery waste. Canada developed a salmon leather tannery that failed to attract product manufacturers until a joint venture was entered with manufacturers in Thailand. In 1989 an Australian firm initiated a venture to tan several species in Nova Scotia. Numerous other countries are now involved in aquatic leather research and development. In 1989 Alaska lost development momentum through failure to fund and build a leather science laboratory in Juneau. The opportunity loss has been more than compensated by aggressive public relations efforts that stress the environmental soundness of replacing "exotic" leathers of endangered reptiles with a salmon look-alike that would otherwise be a polluting cannery waste. Made in Alaska USA adds a valuable media and market dimension that elevates our label over similar and even superior foreign-made goods.

It is an unfortunate business reality that specific information on tanning formulas and production techniques are proprietary information that cannot be made public. Each species has associated development costs that exceed \$50,000, and when products are developed, they represent a corporate asset of \$100,000. Development of formulas under contract to parties with access to wasted skins of foreign species is a maturing profit opportunity that will spread the use of aquatic leather beyond Alaska. To our knowledge, Alas-Skins, Inc. is the only tanner offering that service. It is our intent to spread the use of "aquatics" as rapidly as possible and to profit both ourselves and Alaska's fisheries.

QUESTIONS AND ANSWERS

Q. Have you tried shark and dogfish?

A. We can tan the leather, but we can't get the material. We have to do it in about 60 pound lots, and we've got our hands full. We'd like to try it, but every time we bring in a new species, it costs about \$50,000 to

perfect it, to turn it into leather we can sew and make products out of. Unless we already know it's sellable, and that we can make things out of it ourselves, we can't afford to take on new species. We'd like to do be able to work with every species in Alaska, just in case the industry for that particular kind of fish says, "We don't want the skins anymore."

Q. Does the way the salmon is skinned affect the quality?

A. It does. It affects our consistency. Some canneries skin them and leave a quarter inch of meat, because that's what the particular client wanted. Others just want to get the skin out of the way, and they use a machine that catches it at the tail and rips it off. Those are real good. The weight we're getting is 4 to 12 hides per pound. The ones that have no meat on the back we have to treat a little differently, because some are too thin. With those we have a problem we call window shading. It means that when you're done, you hold it up to the light and you could read a paper through it. We have to throw those out.

There's no consistency in the product coming from the canneries. Because we have to take what they've got, we have to be able to sort and use all of it that we can. If we get hides with holes and nicks, that have been treated badly, we don't get full use. We use a lot more skins to make the same amount of products. Fortunately the end products go in at a price that's comparable to snake and lizards. We could not compete with cowhide.

Q. What kind of skinner is best to use?

A. We don't use a skinner. We buy skins in 50 to 100 pound wet lock boxes from the canneries. They skin all of them. Right now we have to take what they've got. We hope at some point to skin them ourselves and offset some of the cannery costs of skinning. Sometimes we buy the skin for more than what they're getting for the meat.

Also, a lot of water comes in the package. We'd like to get a closer handle on that. As we get bigger and the market improves, we hope to get much more consistent hides and get a lot more use out of the hides. We may identify what kind of machine skins them best and gives us the best product. But as a wasted by-product, we really don't have much control.

Q. Do you make other products besides wallets?

A. Yes. That's product development. We have briefcases. We started using the wasted by-prod-

ucts of the herdsmen up north, combining arctic reindeer with fish skins. It looks like a very successful product line. And we do have halibut. There's nothing in the world to say you can't make skirts and leather jackets, and leathers for motorcyclists. Boots are going to be the next big hot one.

We can make salmon leather inlays from three different colors of salmon. Natural colors are black, white, cream color, and gray. And we dye the salmon. We can combine salmon and reindeer, because they're more expensive than any other kinds of skins. The more you can combine aquatic hides with other kinds of mammal leather, and still

get the bang for being an exotic salmon leather product, the better you are in the market.

Footwear, boots, are going to make us rich, I'm convinced of it. We've had a lot of calls for boots, and we don't produce boots because that's a different game. That requires a cobbler, and that's a trade and a craft. Boot makers are not easy to find, especially to bring up to Alaska to make things out of salmon leather. We've not had a great deal of success in that, although we have over 300 standing orders for boots at \$300 a pair. We hope to attract a boot manufacturer once we have enough standing orders.

EFFECTS OF PROCESS PARAMETERS AND RAW MATERIAL FRESHNESS ON FISH MEAL QUALITY

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Production of fish meal and fish oil is technically a process in which the water phase, the oil phase, and the protein phase are separated by several unit operations. The raw materials are fish or fish offal, such as heads, frames, liver, and viscera.

The main design of the fish meal process has changed very little over the last decades (Figure 1). The five steps of the process are:

1. Heating to coagulate or denature the proteins. The fats and water are hereby released, and the digestibility of the protein is somewhat improved.
2. Mechanical liquid-solid separation by twin screw pressing. The oil and water phases (containing water soluble proteins as well) are separated from the solid phase (presscake). The presscake will contain 40%–55% of the solids.
3. Separating the oil and the particles from the liquid phase by subsequent treatment in decanter centrifuges and centrifuge separators. The water phase is now called stickwater and contains 6%–10% soluble proteins, minerals, salt, etc.
4. Evaporation of the water from the stickwater in evaporators, which normally are multi-stage or mechanical vapor recompression (MVR) evaporators. Energy sources might be live steam, waste heat, or electricity.
5. Drying of presscake and stickwater concentrate. The drier is normally an indirectly heated steam drier, direct flame drier, or indirectly heated air drier.

The selection of equipment and process parameters in the different steps will, along with the raw material quality and utility or energy supply, decide the product quality and the production costs. The optimum conditions vary from processor to processor.

Table 1. Influence of refrigerated seawater and handling of fish with seawater on fish meal composition.

	Fish offal 65 kg		Fish offal 65 kg plus RSW, seawater	
	kg	%	kg	%
Raw material				
Protein	9.5	14.6	9.5	14.5
Fat	4.9	7.5	4.9	7.5
Ash	2.1	3.2	2.5	3.8
Moisture	48.5	74.7	48.5	74.2
Whole fish meal (presscake and solubles)				
Protein	9.5	70.0	9.5	66.9
Fat	1.0	7.4	1.1	7.7
Ash	2.1	15.6	2.5	17.6
Moisture	1.1	8.0	1.1	7.7
Total	13.7		14.2	
Presscake fish meal				
Protein	6.9	67.0	6.9	65.7
Fat	0.7	6.7	0.7	6.7
Ash	1.9	18.1	2.0	19.0
Moisture	0.8	8.0	0.8	7.6
Total	10.3		10.5	

Drying is the process step that most affects the protein quality. Fish proteins, as other proteins, are affected when exposed to high temperatures for long periods. This affects the nutritional value, especially important when fed to fry and juvenile fish and other animals. Extensive work has been carried out by the Norwegian Herring Oil and Meal Research Institute (SSF) to establish the relationship between the biological values of the fish meal and drying conditions. A condensed conclusion of their work follows:

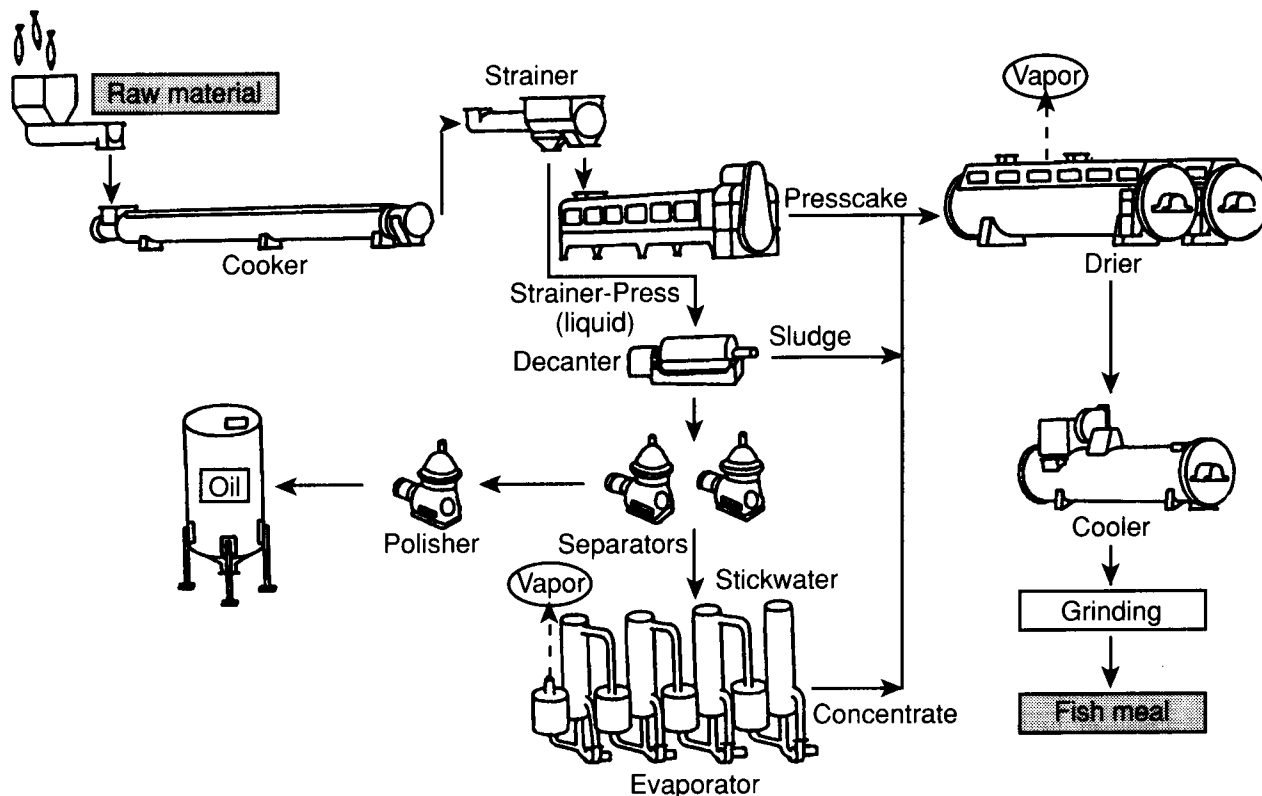


Figure 1. Basic process for producing fish meal.

- When the product temperature can be kept below 70°C during the drying process, long drying time affects the protein quality very little.
- Very short drying time (1–10 minutes) allows exposure to high temperatures without significant reduction in protein quality.

Raw material freshness is a factor of the greatest importance if a producer wants to make premium-quality fish meal and fish oil. Enzymatic and bacteriologic activity in the fish and fish offal can rapidly decrease the content and quality of the protein and oil. High content of free fatty acids in the fish oil reduces the price. Protein decomposes to amines and ammonia, and both reduce the protein value and recovery of protein. Freshness of raw material for fish meal production is normally measured in total volatile nitrogen (TVN). Premium quality fish meal requires raw material with less than 40 mg TVN per 100 g going into the process.

Handling of raw material is a very important step in preserving freshness. The biological activity in the fish depends on the season—during the feeding season the activity is high, and it will continue post mortem and lead to rapid decomposition and quality decrease of the raw material. Mincing of the raw material prior to storing should therefore be avoided. Cooling and icing of raw material will normally slow down the biological decomposition. Handling of fish and fish offal with seawater and refrigerated seawater storage will increase the salt content in the raw material going to the fish meal plants, as seen in Table 1. Table 2 shows raw material and fish meal composition at different recoveries.

Conversion of heads, frames, etc. into fish meal and fish oil can represent a 100% utilization of fish processed for human consumption. Between 30% and 40% of the fish is utilized for fillets, surimi, etc. The rest is raw material for fish meal and fish oil . . . or pollution potential!

Table 2. Composition and recovery of raw material and fish meal, based on 100 kg pollock.

	Whole fish 100 kg		Fish offal 70 kg		Fish offal 65 kg		Fish offal 60 kg	
	kg	%	kg	%	kg	%	kg	%
Raw material								
Protein	16.0	16.0	10.5	15.0	9.5	14.6	8.6	14.3
Fat	5.0	5.0	4.9	7.0	4.9	7.5	4.9	8.2
Ash	2.4	2.4	2.1	3.0	2.1	3.2	2.0	3.3
Moisture*	76.6	76.6	52.5	75.0	48.5	74.7	44.5	74.2
Whole fish meal (presscake and solubles)								
Protein	16.0	78.0	10.5	70.8	9.5	70.0	8.6	69.0
Fat	1.4	7.0	1.0	6.9	1.0	7.4	0.9	7.0
Ash	2.4	11.7	2.1	14.2	2.1	15.6	2.0	16.0
Moisture	1.6	8.0	1.2	8.1	1.1	8.0	1.0	8.0
Total	20.5		14.8		13.7		12.5	
Presscake fish meal								
Protein	12.0	71.4	7.6	67.2	6.9	67.0	6.0	63.8
Fat	1.2	7.0	0.8	7.1	0.7	6.7	0.6	6.4
Ash	2.3	13.4	2.0	17.7	1.9	18.1	2.0	21.3
Moisture	1.3	8.0	0.9	8.0	0.8	8.0	0.7	8.5
Total	16.8		11.3		10.3		9.4	

*Includes process water and refrigerated seawater (RSW).

Note: 65 kg of offal means that 35 kg is recovered for fillet, surimi product, etc.; 60 kg of offal means that 40 kg is recovered.

QUESTIONS AND ANSWERS

Q. How do you measure the effect of drying temperature and time on fish meal quality? I mean the nutritional factors.

A. With trace materials added with the fish into the drier, and then measuring concentration and time. Digestibility has been measured using salmon and also mink.

Q. You mentioned that the use of less than good raw material is undesirable. What's the consequence of using lower quality raw material and then feeding it to fish, or to other animals? Are there any health consequences?

A. No, it's mainly the consequence of a lower biological value. You have a lower digestibility of fish meal when the raw material quality is low. The digestibility of the protein is lower when you are using bad raw material.

Q. Do you have the same information that you gave us on pollock for herring?

A. Yes, of course. But I didn't bring it with me.

Q. You showed data on pollock held in refrigerated seawater. It looks like the ash content was only increased 1%. Could we just assume then that 1% was attributed to the sodium chloride in the bottom?

A. Sodium chloride, yes.

Q. Would some of the soluble ash go over into the stickwater, and more of the salt go into the meal made from the presscake, and make the salt content higher? Can we assume that you're just going to get 1%?

A. In the presscake, no, the salt content is not much higher. It's just slightly higher.

Q. You mentioned that the direct flame drier may be damaging to some of the protein content. If you had a plant using a flame drier at one stage, and followed

it with a lower temperature drier, would the flame drier do as much damage if the raw material in that stage was staying at a higher moisture content, and then doing the finishing stage in a low temperature drier, or an indirect heated drier?

- A. I don't think so. I don't think the flame drier will harm the protein much, as long as the moisture

content is high. The finishing stage would be the stage influencing protein quality. The only risk is when you have amines like trimethylamines, or dimethylamines. With the flame drier you will have nitrogen oxides. It will go into a reaction with the amines and produce undesirable nitrosamine components.

SPECIFICATIONS FOR MARINE BY-PRODUCTS FOR AQUACULTURE

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ABSTRACT

Fish meal, fish oil, and novel fish by-products, such as fish silage, are marine by-products upon which the aquaculture feed industry depends. Aquaculture produces approximately 18% of the global production of seafood and a growing percentage of that production is from semi-intensive and intensive production, which require substantial amounts of feed.

In 1988, aquaculture used an estimated 700,000 mt of fish meal and 190,000 mt of fish oil, which represented 10% and 6% of world production, respectively. By the year 2000, the needs of aquaculture for fish meal and fish oil are expected to double, while world production is expected to remain constant. Demand for high-quality marine products in aquaculture feeds is expected to increase, as economic and environmental concerns will demand more efficient conversion of feeds to fish production.

Several quality indices are currently used to differentiate various marine by-products in the marketplace, but the relevance of many of these indices to nutritional value in aquaculture feeds is questionable. These indices, which are often used to develop specifications for marine by-products, are reviewed and discussed in relation to their real or imagined value for predicting nutritional quality. Problems and pitfalls in evaluating marine by-products by laboratory and field testing in feeding trials are also discussed.

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INTRODUCTION

Aquaculture feeds represent a growing market for marine by-products, primarily fish meal and fish oil. Approximately 700,000 mt of fish meal and 190,000 mt of fish oil, representing 10% and 6% of world production, respectively, were used in fish feeds worldwide in 1988. By the year 2000, the consumption of fish meal and fish oil by the aquaculture industry is expected to double, while world production of fish meal and oil is expected to remain constant (Barlow 1989). Thus, in 10 years, aquaculture feeds could consume 20% of the world production of fish meal and 12%–15% of world production of fish oil. Substitution of plant protein sources for fish meal in poultry feeds and more efficient utilization of fish processing waste are two ways that a shortage of fish meal might be avoided. Another possibility is an increase in the use of alternate protein sources for fish feeds, although use of plant protein sources will result in an increase in solid waste output of fish farms, and this may be an unacceptable practice in some areas. The types of fish meal used by the aquaculture industry are also expected to change during the next decade. Demand for high-quality marine products in aquaculture feeds is expected to increase, as economic and environmental concerns will require more efficient conversion of feeds to fish production.

Fish meal and fish oil are the principal ingredients in feeds of many important species of farmed fish and shrimp. Carnivorous finfish raised in aquaculture require feeds containing more than 40% protein (Wilson 1989). Commercial salmon feeds contain approximately 50% protein, while the diets of eel and yellowtail contain 45% protein.

Trout feeds contain 35%–44% protein. Trout feeds

generally contain a minimum of 25% fish meal, while the feeds of salmon, yellowtail, and eel contain over 50% fish meal. In terms of worldwide use in 1988, shrimp feeds accounted for 28% of the fish meal used in aquaculture feeds, while feeds for the carnivorous finfish accounted for 68% of the fish meal used in aquaculture feeds. Geographically, Asia consumed 55% of the fish meal, North America consumed 10%, and Europe consumed 31% of the fish meal used worldwide in aquaculture feeds in 1988 (Barlow 1989).

Fish oil consumption in aquaculture feeds follows a pattern similar to that of fish meal consumption, with the exception that very little fish oil is used in feeds for omnivorous fish, such as catfish and shrimp. Fish oil is an excellent source of concentrated dietary energy and also contributes essential fatty acids to the diets of the fish. Omnivorous fish do not require high levels of energy in their diet, possibly because their dietary protein requirement is also low in comparison to that of carnivorous fish. The dietary protein to energy ratios for carnivorous and omnivorous fishes are similar, but the dietary levels of each are different. Feeds for Atlantic salmon typically contain fat levels over 22%, while feeds for Pacific salmon generally do not exceed 18%. Fat levels in trout feeds are usually kept below 14% to prevent accumulation of fat in the viscera of the trout. Catfish feeds contain 2%–3% added fat. In Japan, dietary fat levels of over 30% are being tested with yellowtail with good results. Eel diets generally do not contain fat levels above 15%–16% (Arai 1989).

The purpose of this paper is to discuss trends in the use of marine by-products in aquaculture feeds and to review the specifications used to select suitable marine by-products for use in various aquaculture feeds. The relevance of the specifications used to establish grades of fish meal to the actual nutritional value of the meals, and the problems and pitfalls associated with field testing in fish feeding trials are also discussed.

TYPES OF FISH MEAL

The major fish meal manufacturing countries in the world are Peru, Chile, Norway, the United States, Japan, Iceland, Denmark, and South Africa. In some countries, fish meal is made from whole fish, while in other countries, fish meal is made from fish processing waste. The leading fish meal exporting countries in recent years have been Chile, Peru, and the United States. Many countries with growing aquaculture industries, such as Norway, Japan, and Canada, use more fish meal than they produce and have become importers of fish meal. The types of fish meals produced by the major exporting countries are listed in Table 1.

Fish meal production varies from year to year in

Table 1. Types of fish meals produced by fish meal-exporting countries.

Country	Type(s) of meals
USA	Menhaden, mostly FD, in South SD available at a premium Pollock (white fish meal) in Alaska
Canada	Herring, mostly SD
Peru	Anchovy
Chile	Anchovy and horse mackerel, FD and SD
South Africa	Pilchard
Norway, Iceland	Herring and capelin, all LT
Japan	Sardine

FD = Flame-dried, SD = Steam-dried, LT = Low-temperature dried.

various countries. Chilean fish meal production increased 23% from 1988 to 1989, although worldwide fish meal production increased only 3%, according to the International Association of Fish Meal Manufacturers. During the same period, production increased in Norway, remained constant in Peru, and decreased in Iceland, Denmark, South Africa, and the United States. Despite increases and decreases in fish meal production in various countries, worldwide production is expected to remain relatively constant during the next decade.

Fish meal is categorized in most countries based on protein content, with higher value going to fish meals with higher than average protein contents. In Norway, a system of fish meal grading has been in existence for about 20 years (Opstvedt 1989). This system grades fish meals into six categories, five of which are used in animal and fish feeds. Of the five fish meals used in feeds, four are considered special quality fish meals. The specifications of three of them are shown in Table 2. The production of special quality fish meals in Norway during the past decade has increased greatly, with most of the products being used in salmon feeds. The price differential between the three grades of fish meal used in fish feeds is about 12% for each increase in quality. In other words, the highest grade of fish meal used in fish feeds, Norse LT-94, costs about 25% more than regular fish meal, and about 12% more than NorSeaMink. Differences in manufacturing procedures and quality of the raw material used to make fish meal, plus the results of chemical tests done on each batch of fish meal, determine the grade the fish meal receives. Obviously in Norway there is an economic incentive to produce the higher grades of fish meal.

The quality of fish meal produced in the other major

Table 2. Specifications for Norwegian special-quality fish meals.

Category	NorSeaMink ^R	NorseEel ^R	Norse LT-94 ^R
Moisture (%)	5–10	5–8	6–10
Protein (%)	70	66	68
Fat (%)	–	–	11.5
Ash (Max. %)	–	20	–
Salt (Max. %)	3.0	–	3.0
Water-soluble protein (g/16gN)	–	12	32
NH ₃ -N (g/16gN Max.)	0.18	0.18	0.18
Protein digestibility (%) ¹	–	–	90.0
TVN (mg/100g)	<90	<90	<40
Approximate price (NKr/kg) ²	4.10	–	4.60

¹Measured using adult male mink.

²NKr = Norwegian kroner

exporting countries has been variable in the past, but efforts are now under way in all of these countries to increase the quality of their meals. In Chile, for example, most of the fish meal made in the past was flame-dried, and emphasis in the plants was placed on percent recovery from the landed amount of fish. In other words, managers were paid more if they increased the amount of fish meal they made from the starting material. This operating practice sometimes resulted in an inferior quality product due to the poor-quality raw fish, the use of blood and other spoiled material found in the bottom of fish pits, the use of “aged” fish solubles, and the improper operation of the flame dryer. Today, most Chilean fish meal manufacturers are producing high-quality fish meal. Changes in equipment and operating practices and aggressive quality control practices have all contributed to the improvement in fish meal quality. The other fish meal exporting countries have, for the most part, made changes similar to those in Chile. Nevertheless, it is still possible to purchase inferior-quality fish meal on the world market.

OTHER MARINE BY-PRODUCT PROTEINS

In Alaska, those wishing to produce protein sources from marine by-products must confront the problems of a high bone content in the starting material, which is often filleting waste, and a variable supply of raw material throughout the year. Producing fish hydrolysates is one way to overcome these problems. Once hydrolysates are produced, they can be stabilized, and concentrated or dried, depending upon their intended use. Products made from fish hydrolysates include fish silage, liquefied fish, and their concentrated, dried, or

co-dried derivatives (Hardy et al. 1983; Hardy et al. 1984; Stone and Hardy 1986). The value of fish hydrolysates and their derivatives depends upon their nutritional quality and protein content, both of which are subject to variability depending upon the production steps used in their manufacture (Hardy 1987; Stone and Hardy 1989; Stone et al. 1989). Potential uses of these products are as ingredients in aquaculture feeds, pet feeds, in starter feeds for swine, and in milk replacers for cattle.

COMPETING PROTEINS IN AQUACULTURE

Products that can be used as protein supplements in animal and fish feeds must have nutritional or price advantages over competing alternative ingredients, most of which are established articles of commerce. Generally, competing protein supplements are produced from animal processing by-product or from the oil seed residue remaining after oil removal (Table 3). There are good reasons why these feed ingredients are competing alternate protein sources rather than commonly used feed ingredients, and most of these reasons involve nutritional value. However, the situation with these ingredients is not static, and new manufacturing methods coupled with advances in research may change the relative nutritional value of alternate feed ingredients, making them more competitive with fish meal and protein supplements of marine by-product origin.

PROTEIN SPECIFICATIONS

Specifications for fish meal and protein sources made from marine by-products used in aquaculture

Table 3. Alternate protein supplements to fish meal for use in aquaculture feeds.

Ingredient	Comments
Poultry by-product meal	High protein digestibility in best quality Variable quality among producers
Meat and bone meal	Variable quality among products Sometimes high in ash
Soybean meal	Palatability problem in Pacific salmon fry and fingerlings Must be heated sufficiently to destroy trypsin inhibitors
Canola meal	Acceptable up to 15%–20% of the diet of Pacific salmon Contains high levels of phytic acid
Fish silage	Variable quality depending on manufacturing conditions Palatability problem with some products in fry and fingerlings High moisture content prevents long-distance shipping

vary with the country importing the product and with the intended use. For example, a major manufacturer of fish feed in Japan uses the specifications in Table 4 for white fish meal used in their products. Contrasting these brief specifications with those required to produce quality fish meals in Norway shows that these specifications are not very detailed. The specifications given by one of the major trading companies in Japan for imported white fish meal is slightly more detailed as in Table 5.

In addition, the specifications read that meal should be packaged in 35 kg bags, with an over-pack of 150 g. As much as 60% to 70% of the meal must be in the particle size range of 30 to 60 pieces (grains) per square inch. Anti-oxidants must be added to the product prior to drying to ensure a level of 150 ppm in the final meal. How do these specifications compare to white fish meal produced at sea by one American surimi vessel? Testing of eight batches of meal from a vessel showed that some variation existed from batch to batch (Table 6).

Obviously, this meal (Table 6) would not meet the specifications for ash listed in Tables 4 and 5 for white fish meal destined for use in aquaculture feeds in Japan. Screening the product coming out of the dryer will reduce the ash content by at least 4%–5%, thereby opening up the possibility of placing this meal into markets that would otherwise be closed.

Specifications for fish meal used in aquaculture feeds in North America are of a similar nature to those of Japan, although the absolute values vary somewhat depending upon the size and species of fish for which the feed is intended. For example, Pacific salmon hatcheries operated by the federal government use specifications for fish meal in their feeds as in Table 7

Table 4. White fish meal specifications used by a major Japanese fish feed manufacturer.

Moisture	<10 %
Protein	>65%
Fat	>10%
Ash	<10%
Total volatile nitrogen (TVN)	<130 mg%

Table 5. Imported white fish meal specifications used by a major Japanese trading company.

	Minimum	Preferred	Maximum
Moisture	--	<10%	10%
Protein	65%	67%	--
Fat	--	5–6%	10%
Ash	--	18%	20%

Table 6. Variation in batches of white fish meal from an American surimi vessel.

	Average ± SD
Moisture	6.4±1.0
Protein	64.9±2.1
Fat	7.6±0.7
Ash	18.9±1.9

Table 7. Specifications for fish meal used in feeds in Pacific salmon hatcheries operated by the U.S Government (%).

	Starter feeds	Crumbles	Pellets
Moisture	<10	<10	<10
Protein	>70	65-67.5*	65-67.5*
Fat	8-12	8-12	8-12
Ash	<15	<17	<17
Salt	<3	<4	<4
Pepsin digestibility	>92.5	>92.5	>92.5
Ethoxyquin (Anti-oxidant)	0.025	0.025	0.025

*Depends upon species of fish used to make fish meal.

(Anonymous 1990).

Specifications established by the Department of Fisheries and Oceans in Canada for Atlantic salmon diets (Lall 1988) are similar to those of the United States federal hatcheries (Table 8). In addition, the Canadian specifications call for the fish meal to be preferably steam-dried, and ground finer than 0.25 mm.

There are no specifications for fish meals used in catfish feeds, but fish meals make up less than 7% of most catfish formulations, and the contribution of the fish meal protein to the overall protein content of the diet is relatively low. There are also no set specifications for fish hydrolysates and their derivatives used in aquaculture feeds or in other animal feed applications. However, later in this document, recommended specifications are presented for these products based on recent research in our laboratory and others.

FISH OIL

Fish oils are important constituents of aquaculture feeds, contributing low cost energy to the diet and contributing essential fatty acids needed by fish for normal growth, health, and reproduction. Fish oils do not differ among species in caloric content, but they do differ substantially in the content of essential fatty acids, which for fish are the omega-3 fatty acids (Table 9). Fish cannot synthesize omega-3 fatty acids and therefore require a dietary source. In nature, fish obtain omega-3 fatty acids from their diet; all omega-3 fatty acids in the marine environment have their origin in plankton.

The main quality considerations with fish oils are oxidation and enzymatic hydrolysis. Fish oils contain a relatively high concentration of long-chain, polyun-

Table 8. Specifications established by the Department of Fisheries and Oceans in Canada for Atlantic salmon diets.

Moisture	< 10 %
Protein	>68%
Fat	<10%
Ash	<12%
Salt (NaCl)	< 3%
Ammonia nitrogen	<0.2%
Anti-oxidant	500 ppm

Table 9. Omega-3 fatty acid levels (%) in herring oil, menhaden oil, and pollock waste oil.

Fatty acid	Herring oil	Menhaden oil	Pollock waste oil
C20:5n-3 (EPA)	5.5	10.2	13.1
C22:6n-3 (DHA)	3.9	12.8	6.8
Total n-3	12.4	25.8	25.4

Notes: First number describes the number of carbon atoms in a fatty acid chain, the second number describes the number of double bonds, and n-3 = omega-3.

EPA = Eicosapentaenoic acid.

DHA = Docosahexaenoic acid.

saturated fatty acids which oxidize upon exposure to oxygen, producing a number of unwanted and potentially harmful compounds and accelerating the oxidation of ascorbic acid and vitamin E in the feed.

Oxidation of lipids can be prevented by limiting exposure to heat, air, and pro-oxidants, and by adding anti-oxidants. Hydrolysis of fish oils produces free fatty acids, which are not necessarily bad from a nutritional perspective. However, elevated levels of free fatty acids generally indicate abuse of the oil during processing, and serve to alert buyers that the quality of the oil might be reduced in other ways. Therefore, the specifications for fish oils used in aquaculture feeds often include a maximum level of free fatty acids, usually about 3%. For Norwegian special quality fish oil, called NorSalmOil, a maximum level of 4.5% free fatty acids is allowed. Other quality indices for fish oil that are often specified for product used in aquaculture feeds

Table 10. Specifications for fish oils used in aquaculture feeds.

Category	Recommended value
Free fatty acids	< 3%
Moisture	< 1%
Nitrogen	< 1%
Totox*	< 20
Anti-oxidant addition	250-500 ppm

*Totox = 2 x PV (peroxide value) + AV (anisidine value).

concern the addition of anti-oxidants, the amount of oxidation that has occurred in the oils, and the presence of other impurities or contaminants. Some of these specifications are listed in Table 10.

NUTRITION IN HIGH-QUALITY FISH MEALS

Feeding trials conducted in Norway with Atlantic salmon in a variety of settings have shown that the substitution of Norse LT-94 fish meal for NorSeaMink in production feeds results in a 14%–17% increase in weight gain (Opstvedt 1989). Similar tests with rainbow trout have yielded a weight gain increase of approximately 4%. Differences in weight gain between groups of fish fed diets containing Norse LT-94 and regular fish meal ought to be even greater. It is difficult to evaluate these reported values and determine the degree to which they might predict increases in weight gain of Pacific salmon or rainbow trout reared in North America if a similar substitution were made in North American aquaculture feeds. Among the difficulties in making such an evaluation are differences between Norwegian and North American salmonid aquaculture in diet formulations, types of fish meal used, species of fish, and types of feeds.

Recently, two feeding trials were conducted at the Northwest Fisheries Center, Seattle, Washington, to evaluate the nutritional value of various fish meals in juvenile Pacific salmon diets, and to evaluate the effect of feeding practices on the rankings of the fish meals. In each of the feeding trials, various fish meals were substituted for herring meal, which is the standard fish meal used in juvenile salmon feeds. The proximate composition of the fish meals is shown in Table 11. In the first feeding trial, a moist diet formulation, the Oregon moist pellet, was fed to juvenile chinook salmon (initial weight 2.2 g) five times per day to apparent satiation at each feeding (Table 12). After

eight weeks of feeding, significant differences were observed in average weight of fish in the various dietary groups. Fish fed the standard Oregon moist pellet containing herring meal weighed 9.7 g, while fish fed the diet in which Norse LT-94 was substituted for herring meal weighed 10.1 g (Table 13). This difference was approximately 4% and was not statistically significant ($p > 0.05$).

The diet containing white fish meal produced on board a Japanese processing ship supported the highest final average weight of the fish, 11.9 g. This value was significantly different from the average weight of the fish fed the diet containing herring meal ($p < 0.05$), despite the fact that the Japanese white fish meal had the highest ash content of all of the tested meals. Differences among dietary treatments in average final weight of the fish had to be caused by either higher feed consumption (since fish were fed to apparent satiation), or by an improved feed efficiency ratio. The results of this study indicate that both factors influenced average final weight of the fish, but that feed intake was the most important determinant of weight gain. In other words, the juvenile chinook salmon consumed more of the diet containing the Japanese white fish meal and, as a consequence, gained more weight.

The second feeding trial was conducted with juvenile coho salmon (initial weight 6.1 g) and was designed to measure nutritional value of the fish meals in a dry, pelleted feed. The amount of feed given to the groups of fish was controlled by following a feeding program that gave the tanks of fish a fixed amount of feed each day, based on a percentage of the body weight of the fish. The amount fed was increased each week to take into account weekly growth. The diet formulation was similar to that used in federal salmon hatcheries, and the percentage of fish meal and fish oil used in each diet was adjusted slightly to make each diet identical in protein and energy content (Table 14). After 12 weeks of feeding, there were no significant differences in average fish weight among the dietary treatment groups (Table 15). Fish fed the diet containing herring meal weighed 57.6 g, while fish fed the diet containing Norse LT-94 weighed 63.1 g, a 9.5% difference. Feed intake was slightly different among dietary groups, but did not significantly influence average final weight. The conclusion drawn from this feeding trial was that the nutritional value of the Norse LT-94 was slightly higher than that of herring meal, supporting the claims of scientists from Norway.

The most interesting aspect of the feeding trials was the degree to which feeding practices influenced the relative ranking of the diets containing the various fish meals (Table 16). Feeding to apparent satiation resulted in the groups of fish fed the diet containing

Table 11. Proximate composition (%) of fish meals used in the experimental diets

Fish meal	Moisture	Protein	Lipid	Ash
Herring meal	7.5	69.2	8.1	14.0
Bio-fish flour, white	10.5	67.4	12.0	10.0
Bio-fish flour, brown	8.9	60.6	16.2	14.4
Norwegian LT-94	8.9	70.7	8.9	12.4
Danish 999	9.3	71.4	6.7	11.9
Japanese white fish meal	6.5	66.3	7.7	19.7

Table 12. Composition of the diets used to measure palatability of fish meals for chinook salmon fry.

Ingredient	Diet 1 (g/kg)	Diets 2-6 (g/kg)
Herring meal	300.0	0.0
Cottonseed meal	80.0	80.0
Poultry by-product meal	70.0	70.0
Wheat germ meal	69.0	69.0
Dried whey	50.0	50.0
Corn distillers dried solubles	40.0	40.0
Vitamin pre-mix	15.0	15.0
Trace mineral mix	1.0	1.0
Choline chloride (70%)	5.0	5.0
Herring oil	70.0	70.0
Wet fish hydrolysate	300.0	300.0
Alternate fish meals	0.0	300.0
Total	1,000	1,000

Japanese fish meal averaging a higher weight than fish fed the diet containing herring meal. Feeding all groups of fish the same amount resulted in the groups of fish fed the diet containing Japanese fish meal averaging a lower weight than fish fed the diet containing herring meal.

Palatability differences among diets masked the apparent nutritional differences among fish meal sources in the first trial. Apparent protein digestibility coefficients, measured in fish, were not helpful in predicting the nutritional value of these fish meals in that meals with high digestibility did not necessarily support high fish weight gain. This point illustrates the differences in fish meal evaluation that can result from just one experimental variable in a feeding trial, and the pitfalls of relying on summary results of feeding trials designed to evaluate feed ingredients without knowing the way in which the trial was conducted.

SPECIFICATIONS AND FEEDING VALUE IN AQUACULTURE

Current fish meal specifications are based on the results of chemical analysis, rather than on the results of biological evaluation, with several exceptions. Proximate analysis, which yields the percentage of moisture, protein, fat, and ash, partitions nutrients and non-nutrients into categories based on common chemical properties. For example, the protein level is determined in proximate analysis by chemical analysis of the nitrogen level of a sample and by multiplying the percentage of nitrogen by 6.25 to obtain the percentage of protein. Most proteins contain 16% nitrogen, on a molecular weight basis, and 100 divided by 16 equals 6.25. For most uses, protein levels determined in this fashion are sufficiently accurate. However, any compound in a sample that contains nitrogen will be counted as protein in proximate analysis.

Most products do not contain appreciable quantities of nonprotein nitrogen, but some others contain non-protein nitrogen in sufficient quantities to significantly alter the accuracy of protein levels determined in this way. Examples of marine by-products that contain relatively high levels of nonprotein nitrogen are dogfish, shark, and ray waste which contain appreciable levels of urea (46.65% nonprotein nitrogen), and shrimp and crab waste which contain appreciable levels of glucosamine (9% nonprotein nitrogen). Any product containing large amounts of nucleic acids will also reduce the accuracy of the protein level determined by proximate analysis. The other categories of proximate analysis are also subject to problems that confound their accuracy, but, in general, these categories are more likely than percentage protein to be accurately determined when marine by-products are the tested materials. The most important fact to remember is that proximate analysis is not a nutrient analysis. It is a chemical analysis that partitions nutrients and non-nutrients into categories depending upon their chemical properties.

Table 13. Average final weights (\pm SD), feed conversion ratios,¹ and feed intake of chinook salmon fed the experimental diets for 8 weeks.²

Dietary treatment	Average final wt (g)	Feed conversion ratio	Feed intake (g/fish)
Herring meal	9.69 \pm 0.56 ^b	1.34 ^{ab}	10.0
Bio-fish flour, white	9.61 \pm 1.35 ^b	1.39 ^{ab}	10.2
Bio-fish flour, brown	8.97 \pm 0.94 ^b	1.44 ^b	9.7
LT-94	10.09 \pm 0.8 ^{ab}	1.29 ^{ab}	10.1
Danish-999	9.51 \pm 0.37 ^b	1.37 ^{ab}	10.0
White fish meal	11.90 \pm 1.50 ^a	1.23 ^b	11.9

¹Feed conversion ratios = feed fed (g)/weight gain (g).

²Values with same letters within a column are not significantly different ($p > 0.05$).

Table 14. Composition of the diets used to measure nutritional value of fish meals in practical diets for juvenile coho salmon.

Ingredient	Diet 1 (g/kg)	Diets 2–6 (g/kg)
Herring meal	530.0	0.0
Poultry by-product meal	70.0	70.0
Wheat middlings	193.0	193.0
Dried whey product	70.0	70.0
Vitamin pre-mix	15.0	15.0
Trace mineral mix	1.0	1.0
Choline chloride (70%)	5.0	5.0
Vitamin C	2.0	2.0
Fish oil	112.0	112.0
Permapel pellet binder	2.0	2.0
Alternate fish meals*	0.0	530.0
Total	1000	1000

*The actual levels of alternate fish meals and fish oil in the diet were modified slightly to make the diets isonitrogenous and isocaloric.

Pepsin digestibility is another chemical test that is found in the specifications for fish meal used in aquaculture feeds. Pepsin digestibility is used to measure the percentage of protein that is released into solution when a sample is mixed with bovine or porcine pepsin at a given concentration for a given period of time under defined conditions (AOAC 1975). Presumably, fish meals that are heat-damaged during production are less digestible to pepsin than are fish meals that are not heat-damaged and thus give a lower value when tested.

Through the Western Regional Aquaculture Consortium, we have been examining alternate protein

sources for aquaculture feeds and evaluating ways to predict the nutritional value of ingredients and batches of ingredients for salmonids using chemical tests. We have found that while we can distinguish poor protein sources from excellent ones using a pepsin digestibility test, we cannot distinguish between good protein sources and excellent ones, as determined by the performance of fish in feeding trials (Dong and Hardy, unpublished results). One of the goals of this research is to develop chemical tests for protein sources that accurately predict the nutritional value of the products to salmonids.

Other specifications in use in Norway include those that measure the freshness of the raw material (total volatile nitrogen, or TVN), ammonia nitrogen in the product, cadaverin level, and true protein digestibility measured using adult male mink (Opstvedt 1989). The specified levels of these quality indices for the varieties of fish meal produced in Norway were shown in Table 2. While there is no doubt that these specifications are relevant to the production of high-quality fish meal, the direct and indirect importance of each index to the nutritional value of fish meals to fish has not yet been determined.

RECOMMENDED SPECIFICATIONS

Specifications for marine by-products used in aquaculture should include chemical tests that predict the nutritional value of the product. It is widely believed that the quality or freshness of the raw material used to make fish meal and other marine by-products limits the quality of the product. In other words, good-quality products cannot be made using poor-quality starting material. As is the case with other fisheries products, processing cannot improve the freshness of a product.

The chemical test conducted in Norway on high-

Table 15. Average final weight (\pm SD), feed conversion ratios,¹ and feed intake of coho salmon fed the experimental diets for 12 weeks.²

Dietary treatment	Average final wt (g)	Feed conversion ratio	Feed intake (g/fish)
Herring meal	57.6 \pm 2.2	0.85	43.9
Bio-fish flour, white	54.5 \pm 1.3	0.88	42.2
Bio-fish flour, brown	54.9 \pm 6.3	0.87	42.4
LT-94	63.1 \pm 1.8	0.79	45.0
Danish 999	57.8 \pm 3.2	0.83	43.1
White fish meal	55.0 \pm 0.9	0.86	42.3

¹Feed conversion ratios = feed fed (g)/weight gain (g).

²No significant differences ($p > 0.05$) were found among dietary treatments.

Table 16. Ranking of the fish meals evaluated in the feeding trials.*

Fish meals	Proximate composition	Palatability	Nutritional value
Herring meal	1	3	2
Bio-fish flour, white	1	3	3
Bio-fish flour, brown	3	3	3
Norse LT-94	1	2	1
Danish 999	1	3	2
Japanese white fish meal	3	1	3

*Relative ranking based on 1 = high, 2 = medium, 3 = low.

quality fish meals, TVN, is recommended. The recommended procedure for this chemical test is that described by Woyewoda et al. (1986) under Total Volatile Base. Other chemical tests that measure the quality of the raw material are those that measure the concentration of putrefactive amino acids. In Chile, the fish meals are often tested for the presence of gizzerosine, a product that is formed from histamine and lysine in the presence of heat (Castro 1988). This compound is toxic to poultry, causing gizzard erosion, and fish meals are tested for the presence of gizzerosine using a chick bioassay. The effect of this compound on farmed fish is not known.

Specifications for marine by-products used in aquaculture should include proximate analysis, despite its limited value. Proximate analysis is not particularly useful in predicting nutritional value of products, but the results do indicate poor-quality meal, i.e., products containing high ash and low protein. When these products are found using proximate analysis, other chemical tests can be used to further evaluate the product and determine if the high ash is caused by the

presence of bone, salt, or sand.

Efforts funded by the Western Regional Aquaculture Consortium (WRAC) are under way to develop chemical tests that accurately predict the nutritional value of protein sources for fish. Improvements in the pepsin digestibility test are one aspect of that effort. The improvements that are being tested include the use of salmon enzymes rather than bovine or porcine pepsin as the enzyme used to digest the protein, and the use of the pH-Stat procedure rather than the pH-Shift procedure now employed. Conducting the enzyme tests at different temperatures is another variable that is being tested (WRAC 1989). If these improvements are successful, they will be used to show the effects of processing, primarily drying temperature and time, on the nutritional value of fish meal and other protein sources in aquaculture feeds.

Norwegian high-quality fish meals contain added anti-oxidants to prevent oxidation of the fish oil remaining in the meal. In the highest quality Norwegian fish meal, LT-94, anti-oxidants are added both before and after the meal is dried. This is a specification that might

be more widely called for in meals used in aquaculture feeds in the future.

Hydrolysates present a different set of quality problems from fish meal for producers and aquaculture users. During hydrolysis, proteins are hydrolyzed to soluble peptides and free amino acids. This process is time, temperature, and enzyme-activity dependent (Stone and Hardy 1986; Stone et al. 1989). The inverse correlation between degree of hydrolysis and nutritional value is well-established (Hardy et al. 1983), and appears to be the result of conversion of a portion of the protein to nonprotein compounds through deamination of specific amino acids (Stone and Hardy 1986) and premature absorption of free amino acids in the hydrolysate that reduces their availability for tissue protein synthesis (Stone and Hardy 1989; Stone et al. 1989). There are many ways to limit protein hydrolysis in marine by-products by stopping enzymatic activity at the desired degree of hydrolysis, and producers should employ them.

Specifications for products made from fish hydrolysates should include those used to detect putrefactive amino acids and a chemical test to establish the degree of hydrolysis in the product. At present, these chemical tests are beyond the level of routine chemical analysis. Another potential problem with fish hydrolysate products is that the lipids rapidly oxidize during hydrolysis and subsequent storage (Jackson et al. 1984a). Allowed to proceed unchecked, this may lead to destruction of polyunsaturated fatty acids and pathological changes in fish fed such products (Jackson et al. 1984b). Addition of ethoxyquin to the silage effectively prevents these changes.

One emerging issue relevant to specifications for marine by-products involves regulations on the phosphorus content of freshwater hatchery effluent. Uneaten fish feed and undigested phosphorus in fish feces are the major sources of phosphorus in hatchery discharge water. In Europe, strict regulations are being enacted that will progressively lower the allowable phosphorus discharge of hatcheries for the next few years. These concerns will soon begin to affect North American hatcheries, and demands will be made to fish-feed manufacturers to reduce the amount of undigestible phosphorus in feeds. Fish-feed manufacturers will in turn demand lower ash products from producers of marine by-products, and this situation may result in new specifications for allowable phosphorus levels in fish meal and other protein supplements. Fish meal producers and others would be wise to plan in advance for this situation to avoid being the "bad guys" in the battle against water pollution in North America and Europe.

ACKNOWLEDGMENT

This material is based upon work supported by the Cooperative State Research Service, U.S. Department of Agriculture to the Western Regional Aquaculture Consortium under agreement No. 87-CSRS-2-3219.

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QUESTIONS AND ANSWERS

Q. The measure of TVN on the meal itself would be a measure of the way in which it had been stored, or the amount of anti-oxidant that had been put into it. Can you tell what the TVN was, what the quality was, before the meal was produced?

A. No, it's a volatile. It will go out with the drying. My specification was for the raw material, not for the meal.

Q. As a fish meal producer in the three different countries, I did not understand one of the issues on the comparative studies. In the specifications for the Norse LT-94 meal we mentioned the TVN, and the protein, all these different things, and we said the process conditions are supposed to produce the great quality of the LT meal. An important issue to me would be, what was that LT meal? Was it capelin, was it herring, was it fish gurry—what was it made of versus the herring meal?

A. It was made from herring.

Q. You had mentioned at the end something about fish hydrolysates—the less hydrolytic activity the better, yet we heard a paper yesterday saying the nutritional value was improved via proteolytic activity on fish material. I wonder if you'd expand on that.

A. I think the speaker yesterday had a very good point when he said that they control the degree of hydrolysis very carefully, both the time and the enzyme they use. In our production of fish hydrolysates, generally we rely on the endogenous enzymes in the fish itself. When we do that we've found again and again that it's important not to let the material go to completion, which means eventually you end up with around 70% of the intact protein in the form of amino acids. When we feed a product carefully spray dried, freeze dried, anything, what we do after that doesn't seem to matter. We just have too high a level of free amino acids for effective or efficient conversion into fish protein. We get a lot of deamination and other metabolic changes.

Q. But that doesn't necessarily apply if one is using a prescribed proteolytic enzyme for treatment of the material.

A. That's right. But most producers—at least those I've seen in Norway—don't do that. They rely on the endogenous enzymes. At one place they grind the stuff, and put it into a tank, and it may sit there for three or four months before they use it. That's a long time. At that point most of the intact protein is going to be gone. They restrict the level in the diet to around 15%, and may minimize the effects in feeding.

Q. I don't want to leave people with the impression there are protein hydrolysates, and the type that you're referring to were using the endogenous enzymes and letting it ferment in its own juice.

A. Thanks for clarifying that.

Q. Has it been proven that it is the amino acid, or that it's the release of bittering in the refusal of them to accept it?

A. We've just completed a bunch of trials looking at plasma amino acid levels and changes in urea cycle enzymes and I think we're pretty confident that what you're saying is correct. You can get bitterness and feed rejection by certain processes. But in our case, we've been very careful to avoid that and look at the nutritional value. And I'd bet my pay check that the differences we have are truly caused by metabolic differences rather than feed refusal.

Q. Do you know at what temperature or by what process the white fish meal was dried?

A. No, I don't really know anything about it other than it was made on a vessel, and probably steam dried, and it was probably very fresh because you're not going to have a lot of room on the vessel to let stuff

pile up. So very fresh probably, and it may or may not contain solubles. That's another thing that may make a difference—no solubles.

A feed manufacturer in our area talks about what he calls "snap factor." What he means by that is, some feeds the fish snap up; they really like it. Something that really surprised me is that the feed we made from this meal had a lot of snap factor; they loved it.

- Q. In an attempt to make vegetable meals more nutritionally sound, they are adding various amino acids. Your comment was that the free amino acids apparently aren't as well received. Does this have any bearing on the future of the fish meal industry?
- A. I didn't mean to imply that addition of free amino acid to a formulation to make up a deficiency would be a bad practice. What I was saying was, when 70% of the protein is in the form of free amino acids, you've got a problem. I can't really say that addition would be a problem. Obviously properly made fish meals are the standard. They're the ingredient to beat. So in that sense I think the

fish meals do have a leg up.

- Q: How serious is that palatability factor? There are many materials now that we may be able to add that can mask or overcome the palatability.
- A. This is a relatively new development. He is referring to the recent development of a number of compounds that we call gustatory stimulants. Which means we can add them to a feed and increase the snap factor. And it very well may be that palatability will be a less important issue. But these things cost money. And so it's going to come down to economics. Is it cheaper to use a lousy fish meal and add the additive, or use a high quality fish meal? I don't really know.
- Q. Looking at the Alaskan problem, what is the time limit you would set having fish waste exposed before it is processed? We're talking about the freshness factor.
- A. I don't know. So many things might enter into something like that—how long it's been on the vessel before it's landed, the temperature. Up here it's cold most of the time. So I don't know.

UTILIZATION OF MARINE BY-PRODUCTS IN PET FOODS

Tom Willard
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PET POPULATION AND TRENDS

In 1985 the number of cats surpassed the number of dogs in the United States for the first time. As of 1989, there were 58 million cats and 52 million dogs in over 55 million households in the United States. In 1988, 30% of U.S. households owned cats and 37% owned dogs (1989 SAMI overview of Pet Food Sales through food stores presented at the 1989 PFI). In Europe, though there are still more dogs than cats, the trend is similar to that of the United States. Australia and Asia, including Japan, Singapore, Taiwan, Hong Kong, the Philippines, also have a growing dog and cat population, but size is not readily available. The level of dog and cat ownership throughout the world has dramatically changed in the past 10 years.

SIZE OF PET FOOD MARKET

Table 1 shows the breakdown of dog and cat food sales in both tons and dollars by type (dry, canned, semi-moist, snacks, and treats) and by sales outlet (grocery and feed mill). The feed mill portion is often referred to as "non-grocery." SAMI or Sales Area Market Information measures the pet food sold through the grocery distribution system but not what is sold in feed mills, hardware stores, pet stores, pet food stores, or farm feed stores and other non-grocery distribution. Until 1987 there was no reliable way of determining the sales volume through the non-grocery distribution system, partially because it was considered insignificant. Since 1982 this non-grocery segment has been responsible for over 95% of the total growth in dollar sales in the United States, and all of the tonnage growth. (The total tonnage of pet food sold in the grocery store has decreased nearly 10% in tons since 1983, while the total dollars has increased by 5%.) In 1989 the non-grocery sales accounted for clearly one-third of the total tonnage of dog and cat food sold, whereas in 1984 it represented less than 10%. The non-grocery segment has been growing by about 30% to 35% per year since 1984, while the

grocery tonnage has actually decreased.

In 1989, the dollar sales from the non-grocery segment represented 18% of the market or over \$1 billion, as seen in Table 1 and Figure 1. By 1993 the segment should double to over \$2 billion, which could represent nearly one-fourth of the total dog and cat food sales of \$8 billion, as seen in Table 2. The non-grocery pet foods are generally higher quality and higher nutrient density and contain higher quality raw ingredients such as fish meal, poultry by-product meal, chicken, eggs, animal fat, and rice. The grocery store products contain meat meal, soy protein, wheat middlings, and beef tallow.

A price check in early March in the Dayton, Ohio, area on the leading grocery store brands showed that the average price of dry dog food (90% dry matter) was 44¢ per pound, whereas the price of the two market leaders in the non-grocery stores was 84¢ per pound. The gross energy level is about 25% higher on the non-grocery products or between 4,700 to 4,800 kcal per kg, compared to 3,600 kcal per kg.

The cat food sold in grocery stores averaged 85¢ per pound, while the non-grocery sold for \$1.16 per pound. Twenty-five percent of all grocery store dry cat foods contain fish meal or fish hydrolysate. The dry fish meal is usually used at the rate of 5% to 10% of the formula, plus 3% hydrolysate applied to the outside to improve palatability.

Canned cat food represents over 50% of the total tonnage of cat food sales in the United States as of 1989 (see Table 1) with over 200 varieties of flavors, can sizes, and brands to choose from. About 25% have some type of seafood in the product. Some examples are tuna, mackerel, sardines, crab, shrimp, white fish, cod, fish by-products, sole, mixed fish, and ocean fish. All the red meat tuna caught and canned in Thailand and Puerto Rico goes into canned cat food, which represents about 60,000 tons per year. Another 13,000 tons of mackerel goes into canned cat food as well. Overall, fresh fish and fish by-products will continue to go into canned cat food and hydrolysate, whereas fish meal and fish oil will go into dry, canned, semi-moist, and snacks.

As the pet food market continues to change, the non-grocery segment will continue to lead the growth

Table 1. U.S. dog and cat food sales (52 weeks ending June 16, 1989).

	Tons (as sold)	% %	% Dry matter	Dry matter basis		Dollars (millions)
				Tons	%	
Dog food¹						
Grocery						
Dry	2,148,500	66.14	90	1,933,650	83.3	\$1,847.0 ¹
Canned	856,500	26.36	22	184,430	8.1	905.0
Semi-moist	104,500	3.22	70	73,150	3.2	155.2
Snacks and treats	139,000	4.28	90	125,100	5.4	417.0
Subtotal	3,248,500	100.00		2,316,330	100.0	\$3,324.2 ²
Non-grocery						
Feed mills ³						864.6
Total dog						\$4,188.4
Cat food¹						
Grocery						
Dry	560,000	42.4	90	504,000	70.8	\$836.0 ¹
Canned	678,000	51.3	22	149,160	21.0	1,237.0
Semi-moist	77,500	5.9	70	54,250	7.6	207.0
Snacks and treats	4,500	0.4	90	4,050	0.6	38.7
Subtotal	1,320,000	100.0		711,460	100.0	\$2,318.7 ²
Non-grocery						
Feed sources ⁴						231.9
Total cat						\$2,550.6
Misc. foods ¹						120.0
Dog and cat food						
Grocery total ²	4,568,500					
Feed mills ⁵	1,949,500					
Total	5,949,000					\$6,859.3

¹From presentation by Rich Paesh, ARBITON/SAMI report of 52 weeks ending June 16, 1989, Warehouse, Withdrawals. Pet Food Institute, September 14, 1989, Chicago, Illinois.

²SAMI (Sales Area Market Information).

³Estimated to be equal to 23% of value of sales through "food" outlets.

⁴Estimated to be equal to 10% of value of cat foods sold through "food" outlets.

⁵Feed mills include sales through feed stores; pet stores; veterinarians; direct sales to larger kennels, some large retailers, and research facilities; plus export. They are estimated to account for 30% of total dog food production.

Table 2. Projected sales growth rate of dog and cat food, total market 1989–1993.

	Growth rate/yr	Dollars (millions)				
		'89	'90	'91	'92	'93
Non-grocery dog and cat	20%	1,217	1,460	1,752	2,103	2,524
Non-grocery cat	30%	352	458	595	773	1,005
Snacks and treats total	8.1%	456	493	533	576	623
Grocery cat	2.8%	2,280	2,344	2,410	2,477	2,546
Grocery dog	-2.0%	2,907	2,849	2,792	2,736	2,681
Total		6,860	7,146	7,487	4,892	8,374

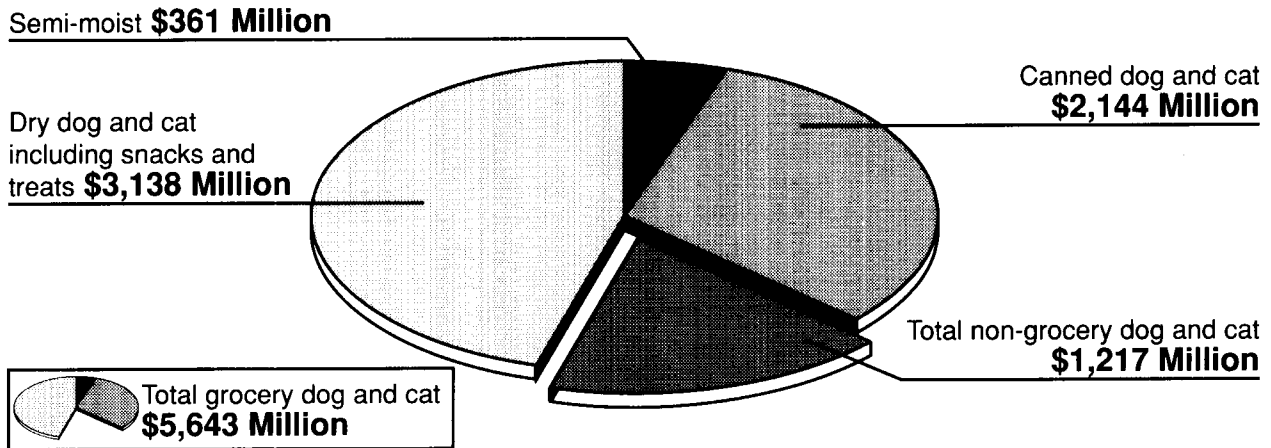


Figure 1. Total sales for dog and cat food, 1989.

and offer better foods to the consumer while using higher quality ingredients at a premium price over the grocery store products. It is to this non-grocery segment that the Alaskan seafood processors would have the best opportunity to supply consistent, high-quality, competitively priced fish and fish by-product meal and oil.

BY-PRODUCTS AVAILABLE FOR USE IN HIGH-QUALITY PET FOODS

By far, dried fish meal or fish by-product meal has the greatest appeal to the manufacturers of dry pet food because of its ease of handling and cost per unit of protein. As the non-grocery segment becomes more price competitive among brands, there will be greater pressure to reduce manufacturing and ingredient cost. The challenge for the manufacturers will be to find a reliable source of high-quality meat protein at a price competitive with other available protein sources, such as poultry by-product meal, dried egg, herring, menhaden, and catfish meal. High protein quality and ash levels below 15% will be a factor in the value of this meal, especially in cat foods for the higher quality non-grocery segment. There is also an opportunity to provide a whole fish or mixtures of whole fish that can be sold to the canned pet food manufacturers. Again, a high-quality, fresh fish by-product with reduced ash would also be a potential market for the Alaska fish processors.

Fish oils, either in blends or individually from fish like salmon or white fish, have market potential in pet foods as well as in human foods. People are continually looking for alternatives to high-cholesterol saturated

fats in every day use. With the recent research data indicating the health benefits of high omega-3 fatty acids, there is an opportunity that could be a major market for the fishing industry.

FINISHED PRODUCT REQUIREMENTS

Regardless of the type of products produced, quality and consistency will be the key to creating the demand for Alaska marine by-products. After visiting a number of the processing plants in Kodiak and Dutch Harbor a year ago, I realized the enormous size and equally large potential for meeting a specialized pet food market demand. In order to meet this demand and create new demands, the processors must look at further processing their waste as a market opportunity to provide a value-added product, rather than just getting rid of waste.

What are some alternatives to conventional processing? Traditional rendering by high temperature degrades the protein and oil quality of fish meal as it does with other animal proteins. There are alternatives that would (1) produce higher quality value-added products, (2) be more energy efficient to produce, and (3) provide greater market opportunities:

- Hydrolysis
- Low temperature rendering

Of the two, the latter holds the greatest potential for development in the Alaska seafood processing industries. This can produce a high-quality protein meal and oil and can be designed to reduce ash. Protein quality must be maintained during processing because if it is damaged during rendering, it cannot be reversed. The

quality of protein determines its relative value in a feed formulation, thus establishing its market value. Palatability is a major concern for manufacturers of the specialty dog and cat foods. Cats are particularly sensitive to “off” flavors caused by over-processing, rancidity, or non-fresh ingredients. These foods often use little or no palatability enhancers to keep the food as high quality as possible, thus making it even more critical to use consistent quality ingredients.

In closing, the use of Alaska fish by-products in the pet food industry has been greatly enhanced by the emergence of the high-end, nutrient-dense foods sold outside the traditional grocery trade. By 1993, it could account for nearly one-fourth of the total pet food sold or as much as 9 million tons total dog and cat food sold in the United States alone through all distribution means. This could represent as much as 300 million pounds of fish meal that would go into dry dog and cat food by 1993. Another 100 million pounds of fresh fish or fish by-products could go into canned pet foods by that same year. However, consistent high quality at a reasonable price will be the key to the success of any products sold to the non-grocery pet food market.

QUESTIONS AND ANSWERS

- Q. I have two very expensive cats at my home. It occurred to me in hearing your talk, and also during the excellent paper presented yesterday from Iceland, that we do an injustice to these fish by referring to their innards as offal. One of the most expensive items that we buy for the cats, which they get very excited for, are what we call liver yum-mies. These are expensive.
- A. They're about \$8 a pound.
- Q. Why are we treating fish offal as waste product and as a total composite material? A possible approach—a not too sophisticated approach—would be to separate out the livers to develop a good fish liver yummy specifically for cats. Cat food is in the same category, if you'll pardon, as baby food. It is not necessarily the taste to the cat; it is the attitude of the consumer.
- A. Exactly.
- Q. If the consumer sees the cat eating that particular food, he or she will buy it. Maybe a little more sophisticated look at these so-called waste products can result in some very high priced consumer cat food. Cats and dogs love fish products.
- A. Absolutely.
- Q. You bring up a very good point. We could learn from the poultry industry in this area. They do cater quite heavily to this non-grocery market. And the reason they do is that it's profitable. They can afford to separate the livers. The money in the pet food industry is in the specialty market. The grocery store market is based on least cost formulations, not unlike your poultry rations, not unlike your swine, beef, and dairy rations. The higher end is not that way. It's an entirely different market. When you sit behind interview groups and hear people talk about their cats and dogs as if they are family, then you start to listen to them, especially when you see an \$8 billion industry.
- Q. On the question of drying temperatures, you mentioned 190 and 275. Would you just elaborate on those temperatures?
- A. We ran several tests over the last several years. We use a chick bioassay, or PER, protein efficiency ratio. They're repeatable, they're accurate, and they do a good job of measuring quality. We have rendered poultry meal at low temperatures. You break your fat, protein, and water bonds very nicely. Of course, you have to go through the same several steps as you would in other rendering—polishing the fat, and separating, then you dry it on a fairly non-sophisticated forced air drier. You come up with a very nice high-quality product because you've never exceeded the higher temperature. Even if you go to 275 or 300, or 350, as long as you cool it down fairly rapidly after that, it doesn't damage the protein.
- Q. Do you mean your heating medium is 275, or the product itself?
- A. The product itself is 275.
- Q. A few years ago we were doing a lot of work on canned cat foods. Cats are very susceptible to kidney stones and other problems based on minerals. We were making canned diets, but we were adding different types of fish meal and other products, and we found that the scrap meals high in ash content actually formed kidney stones in cats. It's a caution when you start putting fish meal into cat food, particularly from scrap and not from whole fish.
- A. Absolutely. A lot of work has been done in this area, especially in the specialty market. But it's not really the ash level. We're talking about the physiology of the cat, and the dog. The ash content is not nearly as important as the level of magnesium in combination with phosphorus and the other minerals. Magnesium has been found to be the major culprit in most of the urethritis-type problems in cats. And they're starting to see some of the same

type of problems in dogs. As dogs become more confined, less free running, the diet becomes more critical. When we do formulations in this area, we're very careful not to let the magnesium level exceed 0.1%. If you have a product that goes in at greater than 12% ash, and you include it at higher levels than 15% to 20% of the diet, you will exceed 0.1% magnesium.

We did low-temperature rendered fish, and we improved the protein quality in a very high-quality white fish meal from Alaska. (This was in Dutch

Harbor.) We compared it to the traditional rendered method, and it had a protein value of approximately 90% of whole egg. In animal nutrition, egg is as close to ideal as one can get as a single source of protein. The white fish meal was traditionally rendered, but it was not open-flame dried. So the protein quality is there if it's handled properly. The potential is here. It's a tremendous opportunity, not just for pet foods, but for the whole world. The amount of protein that could come out of Alaska could about feed the world if it were all utilized.

QUALITY FISH MEAL: SPECIFICATIONS AND USE IN AQUACULTURE AND FUR FARMING

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INTRODUCTION

Esbjerg Fiskeindustri was founded in 1989 through a merger of Andelssild and Vestjysk Fiskemelnsfabrik, and is owned by the suppliers. More than 130 fishing vessels ensure an annual supply of about 750,000 metric tons of fresh raw materials. The daily production capacity is 7,000 metric tons of raw materials and the production is carried out in four independent process sections. Esbjerg Fiskeindustri is the world's largest single producer of quality fish meal and fish oil and handles half the total Danish production of fish meal and oil. The products are marketed under the trademark 999.

The raw material consists of small fish normally not used for human consumption, such as sand eel (*Ammodytes* sp.), Norway pout (*Trisopterus esmarki*) and sprat (*Sprattus sprattus*). During the sand eel season, from April to July, 70% of the annual catch is landed.

PRODUCTION OF FISH MEAL AND FISH OIL

Immediately after catching, the fish is cooled by measured quantities of ice, which ensures that the raw materials are absolutely fresh when landed.

Before landing, reports are submitted concerning the nature and freshness of the catches. On this basis the factory evaluates which product can be made from the raw materials and which process section is best suited. When the ship arrives, efficient suction equipment ensures prompt unloading, and the fish are then passed on for direct processing.

Representative samples are drawn from each cargo and analyzed for freshness of raw material, expressed by the TVN value (total volatile nitrogen) in milligrams nitrogen per 100 grams of fish. A low TVN indicates fresh fish. The pricing system rewards fresh raw mate-

Table 1. Percent composition of fish meal.

	Average	Minimum	Maximum
Protein	72	68	74
Oil	8	5	10
Ash	14	11	18
Water	7	4	10
Salt	2	1	3

rials and contributes to the landing of top quality fish. For the fishermen, there may be an economic gain of up to 50% by landing fresh fish. Fresh fish is a must when producing quality fish meal for aquaculture and fur farming.

The raw materials are processed by boiling, pressing, separation, evaporation, and drying. The processing generates about 22% fish meal and 6% fish oil. During all key stages of the production, quality is controlled and samples are drawn for laboratory tests. Analyses on final products are also performed.

The composition of fish meal depends on the raw material; a general composition of fish meal is shown in Table 1. Fish meal protein contains all the essential amino acids. The fish meal has a high content of lysine, methionine, and cysteine, and a high digestibility and biological value, which makes it a well suited ingredient in diets. The oil in the fish meal is protected against oxidation by 150 ppm ethoxyquin.

The Danish Association of Fish Meal and Fish Oil Manufacturers has sponsored several experiments at the National Institute of Animal Science and the Danish Trout Culture Research Station to develop new products.

The research involves different process conditions, mixed feeds, and different species of animals (ruminants, mink, piglets, and trout). The experiments have proved that there can be a great difference in the feed utilization and daily gain response depending on the quality of the raw material used for the production of

Table 2. Feed evaluation of different fish meals.

Drying method	TVN in raw fish	High feed intake		Low feed intake	
		BVa	WG %	BVa	WG %
Indirect steam drier	30	0.49	1.42	0.50	1.17
	130	0.46	1.42	0.46	1.05
Freeze drier	30	0.52	1.45	0.51	1.07
	130	0.45	1.34	0.42	1.11
Roller drier	30	0.56	1.46	0.53	1.06
	130	0.46	1.28	0.44	1.14

TVN = Total volatile nitrogen. BVa = Biological value. WG = Daily weight gain.

fish meal (Danish Association 1983). The overall conclusion is that fish meal produced from fresh raw material is a highly nutritional product.

THE INFLUENCE OF RAW MATERIAL QUALITY AND PROCESS ON THE FEED VALUE

To prove the effect of raw material quality on fish meal feed value for trout, the Danish Trout Culture Research Station carried out a series of tests in collaboration with the Technological Laboratory, Ministry of Fisheries (unpublished data).

In four repeated experiments with different raw materials, fish whole meal and presscake meal produced in a pilot plant were compared in feeding tests with rainbow trout (*Salmo gairdneri* Richardson, 1836). The fish meals were produced from fresh raw materials (TVN less than 50 mg N per 100 g) and stale raw material (TVN greater than 150 mg N per 100 g). The stale raw material was from the same batch of fish as the fresh, but stored for some days at ambient temperature.

The same conclusion can be drawn from the four tests. The best daily gain response is obtained with fish whole meal produced from fresh raw materials, followed by presscake meal from fresh fish, presscake meal from stale raw material, and whole meal from stale raw material.

The difference between the presscake meals is minor compared with the difference between the whole meals. The solubles from fresh fish contain a lot of nutrients, whereas the solubles from stale fish contain water-soluble toxic compounds. This explains the difference between the whole meals and why the presscake meal from stale fish is better than the whole meal from stale fish.

To prove the effect of gentle drying and quality of raw material on fish meal quality for trout, Esbjerg

Fiskeindustri in collaboration with Atlas Industries and the Danish Trout Culture Research Station have done some experiments (Fosbøl 1985, Jensen 1986).

In the tests, various methods of drying were compared and the feed value of the fish meals was determined by growth experiments with rainbow trouts in aquaria at 12°C. The pilot plant drying methods comprised normal industrial indirect steam drying, freeze drying, vacuum drying, hot-air drying, and roller drying.

The experiments show that gentle drying does not produce quality improvements over drying performed in a steam heated disc-drier operated under normal conditions.

The quality of the raw material is probably the most important parameter. It has the greatest influence on the fish meal quality, particularly when good production practice is established. Some of the results are shown in Table 2. (Details from the experiments are presented in Jensen 1986.)

The experiments were planned as factorial experiments with the following factors :

Quality of raw material. Two levels: TVN 30 mg N per 100 g and 130 mg N per 100 g.

Drying method. Three levels: Indirect steam heated disc drier (conventional process), freeze drier (low temperature process), and roller drier (high temperature-short time process).

Feed intake. Two levels: High (0.45 g protein and 0.21 g oil per day per 100 g trout), and low (0.45 g protein and 0.13 g oil per day per 100 g trout).

The raw material with TVN 30 was fresh, and the raw material with TVN 130 was deteriorated but was not putrid. The feeding levels were low to show differences (if any) in the feed utilization. The feed was produced as moist pellets and consists of fish meal, fish oil, starch, blood meal, whey, lecithin, alginate,

Table 3. True digestibility of fish meal to mink.

Drying temperature °C	TVN mg N/100 g in raw material		
	22	53	93
	60	94.5	94.3
95	94.8	94.0	93.8
140	93.0	91.7	88.9

vitamin mix, and water.

The feed evaluation including the apparent biological value (BV_a) and the daily weight gain (WG %) is shown in Table 2. There are no practical differences related to the drying methods in the utilization of the experimental diets based on fish meal produced from the same raw material. This means that gentle drying does not produce quality improvements over drying performed in a steam heated disc-drier operated under normal conditions.

The quality of the raw material had an influence on utilization; the value of the diet decreased with increasing deterioration of the raw material.

Gulbrandsen and Hjertnes (1986) have carried out similar tests with mink. They tested the true digestibility of fish meal to mink as a function of drying temperature and raw material quality. They concluded that fish meal temperatures of over 100°C during drying reduces the quality of the fish meal (see Table 3). There is also a slight decrease in true digestibility with increasing TVN in the raw material.

Pike et al. (1990) refer to other Norwegian experiments with temperature exposure of fish meal and true protein digestibility in adult male mink, with the same conclusion: fish meal temperatures of over 100°C during drying reduces true digestibility.

A common conclusion concerning fish meal for aquaculture and fur farming can be drawn: The best products are obtained with fish whole meal produced from fresh raw materials that have been processed under conditions where the temperature in the product have been below 100°C.

FISH MEAL FOR AQUACULTURE

Production of fish in aquaculture is increasing worldwide with an increasing demand for quality fish meal.

Environmental problems caused by nitrogen and phosphorus from fish farming will in the future put demands to the fish farmers and feed producers to minimize this pollution. At that time there will be a

Table 4. Composition of dry pellets for trout.

	Protein %	Fat %	Carbo- hydrate %	Metabolizable energy kcal/kg
1950–1960	35	5	30	2,200
1960–1970	40	7	23	2,500
1970–1980	53	11	12	3,100
1980–1987	50	20	10	3,800
1987–	42	24	19	4,300

Table 5. Composition of wet mink feed.

Fish offal	50%–60%
Fish silage	5%–10%
Industrial fish	0%–10%
Poultry offal	5%–10%
Fish meal	0%–6%
Vitamin mix	5%
Barley	5%
Metabolizable energy	1,000 kcal/kg

need for a highly digestible fish meal with a low phosphorus content.

In Denmark the composition of dry pellets for trout has changed during the last years to reduce the pollution problems: The energy content has increased because the protein level is lower and the fat content is higher (Table 4) (Alsted 1990). The latest types of feed are produced by extrusion.

The dry pellets are based on fish meal and fish oil and the demand for highly digestible protein (fish meal) increases with decreased protein level in the dry pellets.

FISH MEAL FOR FUR FARMING

In Denmark there are two types of feed for minks: wet feed, based on fish offal and whole fresh industrial fish; and dry pellets based on fish meal. The wet feed also contains up to 6% fish meal (see Table 5), while the dry pellets contain up to 50% fish meal. The composition of the dry pellets is 30%–45% protein, 15%–25% fat, and 3,000–3,850 kilocalories per kilogram metabolizable energy.

The Danish mink feed producers prefer presscake meal both for wet feed and dry pellets, to guarantee the feed value. They know they never will get the best fish meal—a whole meal produced from fresh fish,

Table 6. Percent composition of different types of 999 fish meal.

	Standard fish meal	Presscake meal	Whole meal aquaculture
Protein	71.4	74.1	72.2
Fat	8.0	6.5	8.2
Moisture	6.4	6.1	9.5
Salt	2.8	0.9	1.0
FFA of oil*	21	12	12
Lysine	5.0	5.8	5.8
Methionine and cysteine	2.2	3.0	2.9

*Free fatty acids.

which is preferred by the mink feed producers in Finland.

FISH MEAL SPECIFICATIONS

An example of the composition of a standard fish meal, a presscake meal, and a whole meal recommended for aquaculture and mink feed is shown in Table 6. The content of selected amino acids in standard fish meal—produced from unspecified raw materials—is lower than in the presscake meal and the aquaculture meal produced from fresh raw materials.

The raw materials that Esbjerg Fiskeindustri uses for production of fish whole meal for aquaculture and fur farming have an average maximum TVN of 60 mg N per 100 g, and no fish has TVN over 80 mg N per 100 g. The digestibility of whole meal is greater than presscake meal.

In conclusion, quality fish meal ideal for aquaculture and fur farming can be specified as whole meal made of fresh raw material produced under mild conditions.

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QUESTIONS AND ANSWERS

- Q. What does your specification of multi-enzyme at 88% refer to?
- A. This is a three enzyme mix. You can compare it with TORRY-pepsin. The Danish regulation requires that chemical analysis. With a very fine ground fish meal, your enzyme digestibility will increase and you have to be very specific about chemical analysis.
- Q. Are medications added to fish meal or fish oil, and if so, what kinds and how much?
- A. No, we don't add medication.
- Q. There's no disease problem with it?
- A. It's a problem in the industry, especially in Denmark. In Denmark most of the farming is fresh water trout. And of course there are diseases. When you take these trout to seawater, 99% run into disease, but you can cure them.
- Q. This morning we heard that you get the best quality when you have warm temperature in the drier as low as 70. Now you say up to 95 you still have good product. Who is right and who is wrong?
- A. I would say our trial and the Norwegians' trial with mink digestibility show the same results. When the Norwegians compare the LT 94, the Norse mink, you can see a difference—but you also have two quality differences, such as the LT meal is produced from fish with TVN below 50. The Norse mink is produced with TVN below 90. So two parameters change, both the raw material quality and the temperature. The quality of the raw material is the most important factor. Second is how you process it. Of course, if you aren't right you destroy the protein. But as long as you have water in your product, and evaporate water, you don't exceed those temperatures.

NEW PRODUCTS, PROCESSING POSSIBILITIES, AND MARKETS FOR FISH OIL

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Although fish oil has been used as a fuel in some parts of the world for centuries and has been commercially available since the beginning of the century for industrial purposes, it was only 50 years ago that it became a commercial source for human consumption.

When we refer to fish oil we usually mean oil produced from fatty pelagic fish. Today fish oil is a by-product of the fish meal industry. In production, the main emphasis is on fish meal, which is still more valuable and more in demand than fish oil.

Fish liver oil, on the other hand, is produced only from the liver of the fish. In some cases it has therapeutic value and is an important source of vitamins A and D. Documentation from 1657 indicates that cod liver oil was helpful against night-blindness, and in 1770 Dr. Samuel Kay, a physician at Manchester Infirmary in England, gave a lecture on his studies of how cod liver oil helped against rheumatism. In 1920 it was discovered that cod liver contained vitamins A and D (Anonymous 1984). After the Japanese started production of synthetic vitamin D, cod liver oil lost its identity and did not recover until 1979 when the discussion of the health benefits of omega-3 fatty acids began.

Because of its physical characteristics, fish oil was at first mainly used for industrial purposes, such as in the leather industry, for making soaps, and in the manufacture of paints. As processing technology became more sophisticated, a new possibility emerged for the food manufacturers to use fish oil in shortenings, margarine, and fats for the baking and confectionery industry. Margarine was invented in 1869 because of the shortage of butter in Europe. In the beginning rendered beef fat was used, but in the early 1900s after the hydrogenation process was developed to produce hardened fat from liquid oils, a huge new market for fish oil opened. Since then the market for fish oil

has developed slowly. During the last decades we have also seen immense changes in the world oil and fat production where both soya oil and lately palm oil production has increased considerably. Today fish oil accounts for only 2% of the total world market for edible fats and oils. Although a number of countries produce fish oil, there are only seven major producers: Chile, Denmark, Iceland, Norway, Peru, the USA, and Japan. Japan is the largest single producer of fish oil (Figure 1).

Commercial fish oil is usually composed of over 90% triglycerides, each usually containing three different fatty acids. An additional 8% consists of mono- and diglycerides and other lipids such as phospholipids. The unsaponifiable portion that accounts for an additional 1.5% to 2.0% consists principally of sterols, glyceryl ethers, hydrocarbons, and fatty alcohols, along with the fat-soluble vitamins A, D, and E. The residue contains other components in small quantities. Fish liver oil has the same characteristics, but usually contains more unsaturated fatty acids and a higher amount of the vitamins since the liver acts as a vitamin reservoir for fish.

What makes fish oil different from other oils is mainly the unique variety of fatty acids it contains (Table 1). Another factor is the high degree of unsaturated fatty acids. The amount and variety of the fatty acids in fish oil varies from one fish species to another, and also with the season of the year, fish diet, fishing location, ocean temperature, nutritional and spawning state, etc. Only eight to ten fatty acids make up 85%–90% of the total. Also of interest is that fish oil contains a high amount of fatty acids with the first double bond between the third and fourth carbon atom, counted from the terminal methyl group. This family of fatty acids is called the omega-3 fatty acids and is found primarily in oil of marine origin. In contrast, vegetable oils contain mainly unsaturated fatty acids from the omega-6 family and animal fat from the omega-9 family. Human metabolism differentiates between the position of the first double bond, i.e., omega-3,

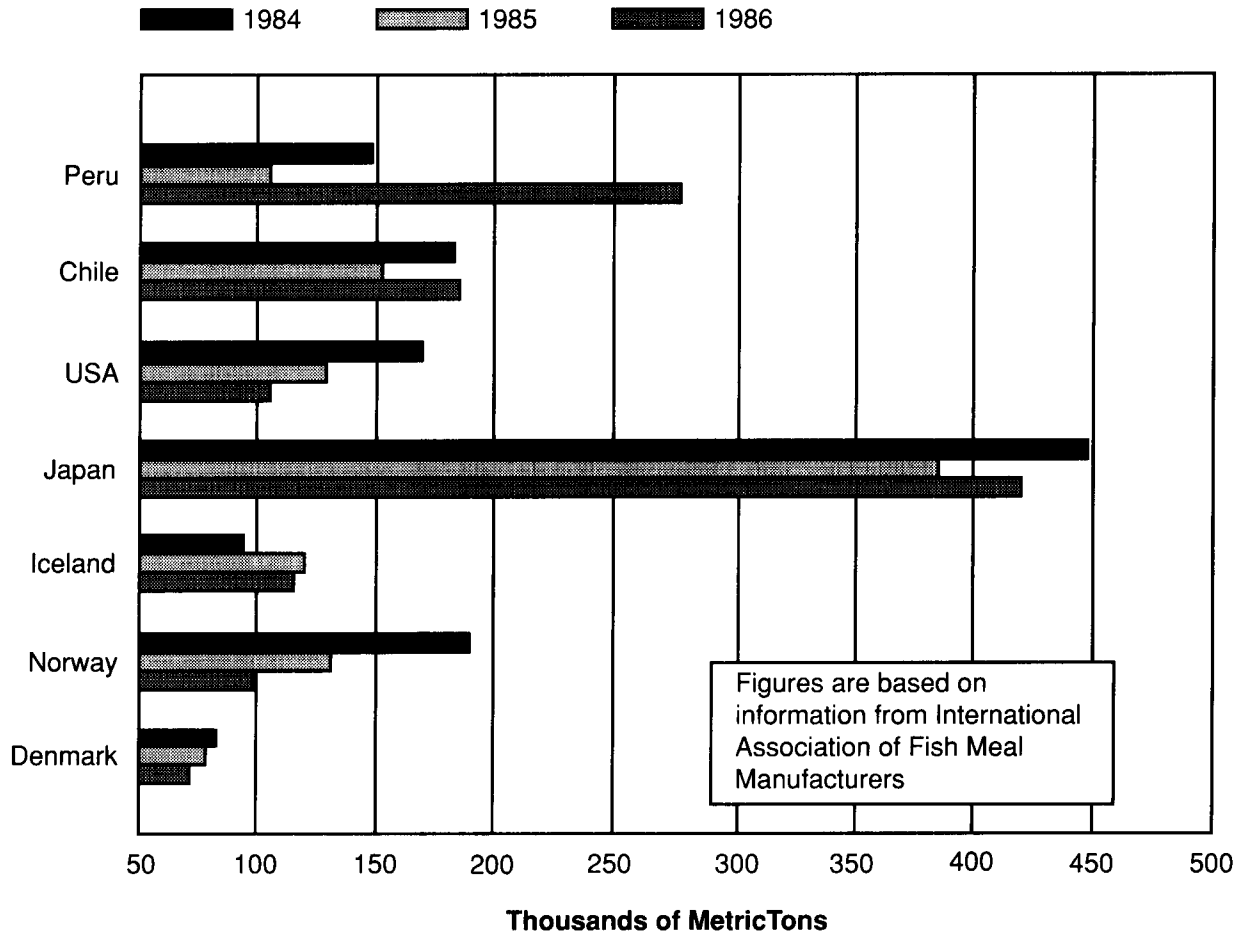


Figure 1. Fish oil production in seven major fish-producing countries, 1984–1986.

omega-6, or omega-9.

As far back as 1956, data were published showing that intake of fish oil had a cholesterol-lowering effect for humans. This was the first indication that fish oil and fish diet guard against coronary diseases (Nelson 1972). In 1972 Dyerberg and co-workers published findings that the low incidence of coronary heart disease in Greenland was related to their diet, and especially to their high intake of the eicosapentaenoic polyunsaturated fatty acid (EPA) of the omega-3 family (Bang and Dyerberg 1972, Dyerberg et al. 1978). Only then did the scientific community become aware of the health-related roles of the omega-3 fatty acids. At first, researchers studied the hypolipidaemic and anti-thrombotic effects of EPA, but after the discovery of prostaglandins and the extensive work on metabolites, it had become apparent that omega-3 fatty acids played an important role in inflammatory diseases and the immune system of the human body (Lands 1986, Kinsella

1987). Results now indicate that consumption of omega-3 fatty acids can help people suffering from arthritis, asthma, and certain types of cancer. Research is also being conducted on the role played by omega-3 fatty acids in the central nervous system and in growth and development (Simopoulos 1986, Horisberger and Bracco 1987).

The Second International Conference on the Health Effects of Omega-3 Polyunsaturated Fatty Acids in Seafood, held in Washington, D.C., March 1990, concluded that all human diets should include omega-3 fatty acids, and a concern was expressed that steps should be taken to stop marketing enteral and parenteral formulas that fail to include any omega-3 fatty acids. Furthermore, new evidence with an extremely high level of statistical precision, from the NHLBI study (National Heart, Lung and Blood Institute), suggest that the daily dietary intake of 0.5 to 1.0 grams of long-chain omega-3 fatty acids per day reduce the risk

Table 1. Fatty acids found in fish oils.

12:0	17:Branched	19:0	22:0
14:0	17:0	19:1	22:1 n-11
14:1	17:1	20:0	22:2
15:Branched	18:Branched	20:1	22:3 n-3
15:0	18:0	20:2 n-9	22:4 n-3
16:0	18:1	20:2 n-6	22:5 n-3
16:1	18:2 n-9	20:3 n-6	22:6 n-3
16:2 n-7	18:2 n-6	20:3 n-3	23:0
16:2 n-4	18:2 n-4	20:4 n-6	24:0
16:3 n-4	18:3 n-6	20:4 n-3	24:1
16:3 n-3	18:3 n-3	20:5 n-3	
16:4 n-4	18:4 n-3	21:0	
16:4 n-1	19:Branched	21:5 n-2	

Source: Leatherhead 1986.

n = position of first double bond counted from methyl group.

of cardiovascular death in middle-aged American men by about 40%.

These findings have been published in the scientific press and have been taken up by the commercial media. This caused a sudden interest in high-quality fish oil, high in omega-3 fatty acids. The fish oil producers and the processors were not ready for such a demand, since up to now almost all fish oil had been hardened. During hydrogenation, polyunsaturated omega-3 fatty acids are partly saturated and their health benefits ruined.

Fish oil today is produced in fish meal factories as a by-product. After the fish are landed, they are stored in holding pits at the factory until they are fed into the cooker. Steam is used for cooking, and the temperature rises to 100°C while the raw material goes through the cooker. In the next step the liquid is removed, consisting of water, oil, and fine solids, usually in a twin screw press. Then the decanter removes small particles before centrifugation where the oil is separated from water. Finally, the fish oil is cooled and stored. The oil from this process is defined as crude fish oil. Guidelines for crude fish oil characteristics are shown in Table 2 (Young 1986).

Figure 2 is a flow diagram for the classical processing of crude fish oil. The acid pretreatment step is intended to remove any gum material or phospholipid that might interfere with the quality of the final product. Usually acid pretreatment is not needed for fish oil. The second step is refining. Crude fish oil always contains some amount of free fatty acids that can have deleterious effects on the final product. The amount of free fatty acids varies mainly in accordance

with the freshness of the raw material used in fish meal production. The most common way to remove the free fatty acids from the oil is to saponify them by adding diluted caustic soda to the oil. They are easily removed afterward with water in a centrifuge. The caustic soda also reacts with the triglyceride but at a much slower rate. Finally the oil is dried before the bleaching process (Proceedings Lipidforum Symp. 1986, Griffith 1986).

Usually, fish oil has a rather unattractive dark reddish color. This can be removed by adding powdered clay or earth that absorbs the color components. Then the oil is filtered to remove the bleaching material.

At this stage the oil is ready for hydrogenation. Hydrogen is added to fish oil in the presence of a catalyst to reduce the number of double bonds and saturate the fatty acids. The melting point is controlled by the degree of saturation and is checked by measuring the iodine value or refractive index. After the desired melting point is reached, the catalyst is removed from the oil by filtration.

It is sometimes necessary to repeat the refining and bleaching steps. After a second bleaching, the color of the final product can be more easily controlled and it is also beneficial to remove traces of impurities that might be left in the oil. The second refining removes the free fatty acids that formed during the bleaching and hydrogenation process.

The last step is deodorizing, which removes the volatile compounds that are the main cause of the strong fishy odor and flavor. Among the known compounds removed by deodorizing are aldehydes, ketones, alcohols, hydrocarbons, and compounds formed by heat decomposition of peroxides and pigments (Griffith 1986). The concentration of these compounds is usually between 200 and 1,000 ppm before deodorizing. During deodorizing the oil is heated to 200°–250°C in a vacuum of 1–3 mm mercury and then stripped with steam, which removes the unwanted components. The oil then is cooled and is ready for use in the food industry.

Due to the health benefits of omega-3 fatty acids, there is increasing interest among food manufacturers to start using liquid fish oil instead of hydrogenating it. So far unhardened fish oil has few applications because of its fishy flavor and stability problems. The highly polyunsaturated omega-3 fatty acids can be easily oxidized if not protected against oxidation and handled with care. If fish oil is used in the food industry as a source of omega-3 fatty acids, the producers must guarantee a certain shelf life. The oil must also be able to endure baking and cooking procedures without deterioration. This creates a certain dilemma for the fish oil producers, since the fish oil is a by-product.

Table 2. Guideline values for crude fish oil characteristics.

Moisture and impurities	Usually 0.5%, but sometimes 1%
FFA (as oleic acid)	Ranges from 1% to 7%, but more usually 2% to 5%
PV	3 to 20 meq/kg
AV	4 to 60
IV	Capelin 95–160
	Herring 115–160
	Menhaden 150–200
	Sardine 160–200
	Anchovy 180–200
Color	Up to Gardner 14
Iron	0.5 to 7.0 ppm
Copper	Less than 0.3 ppm
Phosphorus	5 to 100 ppm
Sulfur	Levels of over 30 ppm will usually result in difficulty with hydrogenation

Source: Young 1986.

FFA = free fatty acids; PV = peroxide value; IV = iodine value; AV = anisidine value.

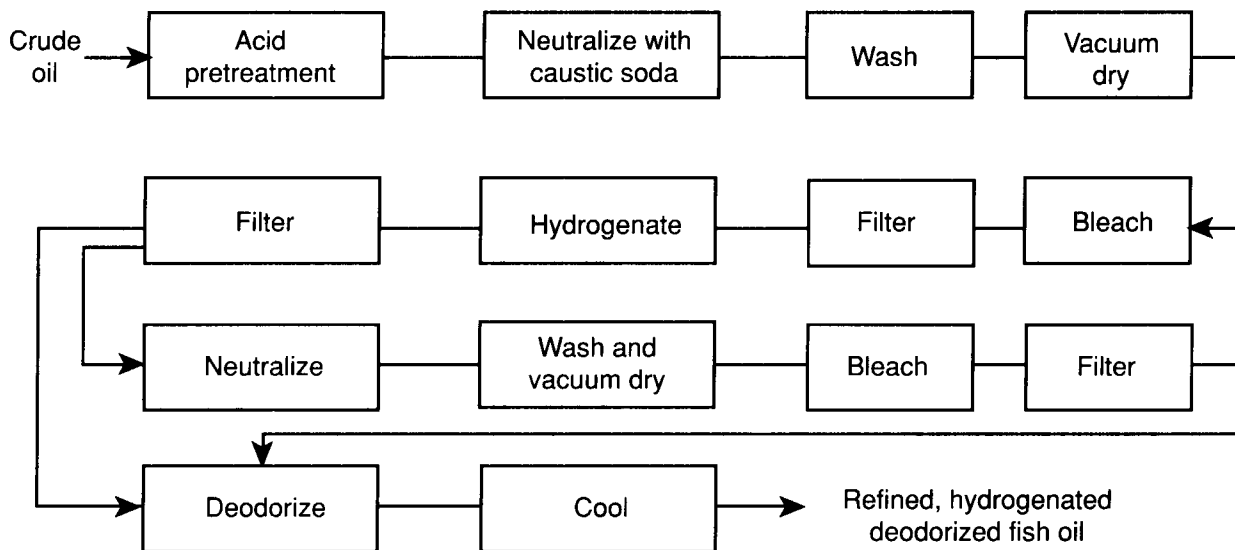


Figure 2. Flow diagram for processing crude fish oil.

Table 3. Partition of lipids in capelin into fish meal and oil.

	Capelin, whole	Meal	Oil
Total lipids (TL), % of dry matter	32	13	100
Percentage of TL in whole fish	—	40	60
Neutral lipids, % of TL	77	60	97
Phospholipids, % of TL	16	24	1
Fatty acid			
14:0	6.7	4.5	8.1
16:0	11.3	15.9	9.0
18:0	1.3	2.0	1.1
16:1	8.2	7.6	8.7
18:1	17.3	16.0	17.4
20:1	20.5	10.0	24.9
22:1	15.6	7.1	19.5
20:5 n-3	5.3	10.5	2.9
22:6 n-3	7.4	17.9	1.7
Total n-6	1.5	2.0	1.4
Total n-3	15.3	31.6	6.3

From N. Urdahl and E. Nygaard (1970) (unpublished data).

Source: Opstvedt 1985.

When the raw material arrives at the factory, it is usually several days old, and a few more days may go by before it is processed. This means that the raw material used is not fit for human consumption, and therefore the oil is often of low quality. When the fish oil is hydrogenated, the crude oil quality is not so crucial since by hardening the oil, the polyunsaturated fatty acids are saturated. This means that oxidation problems are more or less eliminated, so we should not get an offensive flavor in the fully processed oil. But if the fish oil is not hydrogenated, higher-quality crude fish oil is needed. This means it is necessary to look into other production possibilities besides improving the process.

It is worth noting that the oil part of capelin fish meal contains higher amounts of EPA and DHA (docosahexaenoic acid) of the omega-3 family than unprocessed capelin fish oil. The reason is that most of the phospholipids that contain EPA and DHA are still in the fish meal, while the fish oil consists almost exclusively of mono-, di-, and triglycerides (Table 3) (Opstvedt 1985). The conclusion is that in order to obtain the highest-quality fish oil, preferably with the same composition as in the fish, the emphasis must be on the production of fish oil, with fish meal treated as a by-product.

In the vegetable oil industry, oil is the main product and meal is a by-product. By using fresh fish as a raw material and appropriate solvents, the mono-, di-, and triglycerides and phospholipids can be extracted from

the fish. The greatest disadvantages of this method are the high cost, limited number of food-grade solvents that can be used, and the large volume of solvents needed. However, high-quality oil can be obtained with this method.

Recently another extraction method has become commercialized. This is Supercritical Fluid Extraction (SCFE), which has been applied to several processes in the food industry. SCFE utilizes the special properties of gas above its supercritical temperature and pressure to extract or fractionate compounds (McHugh 1986). Partly due to economics, this method has been used only to remove undesirable components from fish oil or to separate EPA and DHA from fish oil (Northwest and Alaska Fisheries Center 1985).

Fish oil producers today have many possibilities to improve the quality of crude fish oil. Improved processing technique and better stabilizers offer higher-quality oil to the food industry.

In all fish oil production, the quality and freshness of the raw material is of greatest importance. After being caught, the fish should be kept on ice until it is processed. Chemical parameters such as TVN (total volatile nitrogen) should be monitored to check the freshness. During processing, heating should be kept to minimum. In the presence of water and pro-oxidants such as copper and iron, fish oil can be easily oxidized. Heat accelerates the oxidation process to a great extent and can also cause isomerization, polymerization, and

loss of essential polygenic fatty acids.

The use of anti-oxidants early in the process is also of great importance. Low-quality fish oil can never be upgraded by adding anti-oxidants, but high-quality crude oil with anti-oxidants is much more stable during processing and less prone to oxidation than fish oil with no anti-oxidants. Tests in Iceland have shown that the processing of fish oil—such as refining, bleaching, and deodorizing—reduces its stability if no anti-oxidants are added to the crude oil and after each processing step (Thorison 1990).

When liquid fish oil is used for human consumption, it is often necessary to add a winterization step to the process. During winterization the oil is cooled to remove solid fat fractions that would normally cloud, at refrigerator temperature, oil that is liquid at room temperature. This also increases the amount of omega-3 fatty acids in the oil.

Due to increased ocean pollution, fish oil produced from fish caught in polluted waters contains some pesticides, polychlorinated biphenyls, and other undesirable contaminants. This is now a problem for the fish liver oil producers since the liver collects these contaminants. During deodorizing some of the components are removed. Deodorizing can hardly be called a gentle process, especially for highly unsaturated oil. Therefore, oil processors have started to use a high-vacuum, molecular distillation apparatus to remove impurities. The high-vacuum, molecular distillation process also removes the vitamins, some cholesterol, and some oxidation products, and therefore purifies the oil and makes it more stable against oxidation.

Let's now look at the markets. The market for liquid fish oil for human consumption can basically be divided into three areas.

- As a commodity for the food industry.
- As a health food.
- As a pharmaceutical.

From a theoretical point of view, fish oil may be used in any food item that contains fat. The problem that must be solved is how to introduce fish oil into food products without making them taste fishy. The most promising food application seems to be in margarine, salad oil and salad dressing, mayonnaise, and several types of spreads and pastes. The International Association of Fish Meal Manufacturers (IAFMM) started trials in the United Kingdom in 1985 using fish oil from different sources at different levels in several foods. The products included were French dressing, salad cream, frankfurters, salami, margarine, and mayonnaise (Table 4). The trials in general were successful since they show it was possible to produce food

Table 4. Tasting results for foods prepared with refined fish oil.

Food type	Food made	Taste comment
Spreads and pastes	Fish spread	Acceptable
	Cheese spread	Good
	Peanut butter	Acceptable
Salads and salad dressings	Salad cream	Acceptable
	Mayonnaise	Production problems
	Coleslaw	Poor
Dairy products	Yogurts	Poor
Oils and oil blends	French dressing	Good
	Canned fish oil	Good
Sausages, smoked and spiced foods	Salami	Good
	Pork sausages	Good

Source: Young 1990.

acceptable flavor that contains fish oil. In Denmark this past year, a commercial margarine product was launched containing 20%–25% unhydrogenated fish oil and 75%–80% vegetable oil (Barlow and Young 1988).

In order to include fish oil in infant formulas and in baked products, processors have been looking into the possibility of using microencapsulated fish oil in order to solve the stability problem of the oil. The microencapsulation technique offers a very promising solution. It is based on forming sub-miniature capsules or microcapsules consisting of a shell and fill material. Typical microcapsules are small enough to be used as a free flowing powder or suspended in water. The disadvantage is that the volume of coating material is still very large compared to the fill material. This is now a commercial product.

In the fats and oils industry, intensive research work is in progress in the field of enzymatic modification, such as interesterification. Cocoa butter equivalents are now produced by interesterifying mixtures of oils and fats (Posorske et al. 1987). Besides making triglycerides high in omega-3 fatty acids, enzymatic modification opens up the possibility of modifying fish oil as a replacement for more expensive fat and oil sources, or even to tailor-make triglycerides for specific uses.

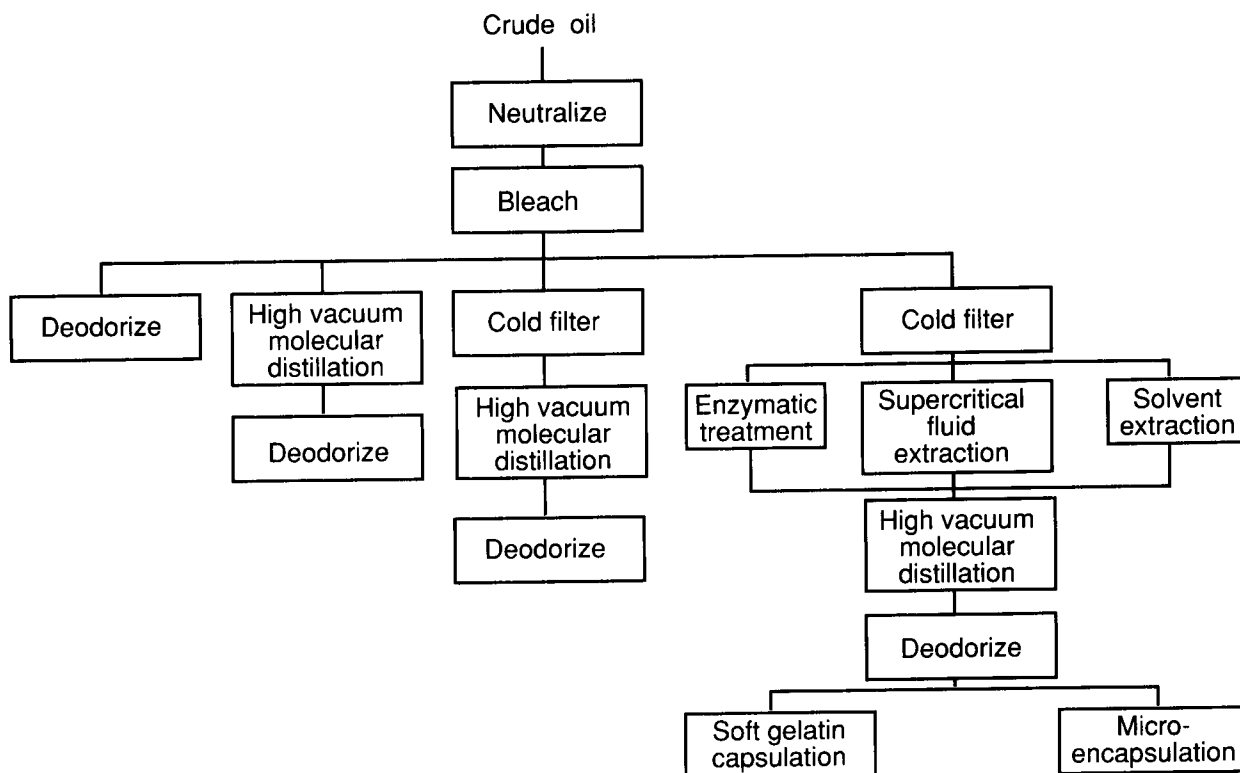


Figure 3. Processing possibilities for unhardened fish oil.

Figure 3 shows some processing possibilities for unhardened fish oil.

It is very difficult to estimate the market for unhydrogenated fish oil. But it would not be unreasonable to estimate the U.S. and European market, based on fish oil as a supplier of omega-3 fatty acids at 150,000 tons per year. This is based on daily dietary intake of 1.0 gram of long-chain, omega-3 fatty acids.

Although cod liver oil has been sold for many years as a health food, a great demand has developed in the last few years from the health food industry for fish oil containing high amounts of omega-3 fatty acids, especially EPA and DHA. Several fish oil products are now on the market. Most of them are based on fish oil in which the omega-3 content has been increased with cold filtration, solvent extraction, SCFE, enzymatic treatment, or a combination of these. There are also on the market omega-3 fatty acid mono-esters and free fatty acids produced from fish oil. Most of these oils are highly unstable, and although anti-oxidants and vitamin E have been added, the oil must be specially protected. Most of these products are encapsulated in a soft gelatin capsule that protects the oil.

It has been proven that fish oil dramatically affects the biological activities in the body (Galli 1988). Many clinical tests are under way, and the pharmaceutical industry has shown interest in the therapeutic application of fish oil concentrates. Whether the results can be harnessed into useful specific therapies remains to be seen. At least one company has registered encapsulated fish oil as a drug in Europe for lowering blood fat. Many patent applications have been approved making claims that omega-3 preparations act as anti-cancer agents, and that they could be used for prophylaxis or treatment of vascular disorder, or even treatment of disorders like Raynauds disease. How big the pharmaceutical market will be depends on the results of the tests. The drug companies will always demand the most purified, highest-quality fish oil from the fish oil industry, and therefore has set standards for the fish oil processing industry.

During the last ten years, we have seen a new market develop in aquaculture for fish oil as an ingredient in fish feed. Lipids from wild fish contain comparatively high levels of omega-3 fatty acids. The marine species that are farmed today must get their omega-3

Table 5. Potential use of fish oil in fish feeds, 1990.

Fish species	Area	Fish production (metric tons x 1,000)	Dry feed (metric tons x 1,000)	Fish oil inclusion in diet (%)	Fish oil amount (metric tons x 1,000)
Salmon	W. Europe	135	225	15 ¹	34
	Far East	30	50	15 ¹	8
	N. America	25	40	15 ¹	6
	S. America	7	12	15	2
Trout	Europe	182	328	10	33
	N. America	80	145	10	15
Catfish	N. America	150	300	2.5	7
Shrimp and prawns	Far East (intensive)	120	240	5	12
	Far East (semi-intensive)	180	180	5	9
	S. America (semi-intensive)	30	30	5	2
Eels	Far East	100	200	15 ⁵	30
	Europe	8	16	15	3
Yellowtail	Far East	150	150 ³	12 ⁵	20
Milkfish	Far East	300	150 ⁴	10	8
Crayfish	N. America	50	10 ³	5	1
Total			2,076		190

¹ Diets produced by cooker extrusion, allowing oil content of finished diet up to 25%.

² Only a small proportion of crayfish produced likely to receive mixed feed.

³ Some fish oil likely to be used in moist feeds. Also will move to dry feeds because of pollution problems caused by moist feeds, especially in Japan.

⁴ Low-cost, carbohydrate-rich diet fed to milkfish with 10% to 15% fish meal in dry diets. However, maybe fish oil will also be included in the diet. Amount of mixed feed used is limited; also use waste products fed directly.

⁵ Watanabe 1988.

Source: Pike 1990.

fatty acids in the diet. Since the omega-3 polyunsaturated fatty acids are an important part of the marketing image of fish as a healthy food, fish oil has become a vital feed ingredient. Recent studies also indicate that omega-3 polyunsaturated fatty acids from fish oil protect the fry from various diseases by improving the immune system.

Production of farmed fish and crustaceans is currently over five million metric tons annually, but only part of this production receives mixed feed. The estimated dry feed requirement in 1990 is 2,076,000 metric tons. The amount of fish oil needed in the feed is in the range of 190,000 metric tons and will likely continue to grow in the coming years (Table 5) (Pike 1990).

Although the emphasis has been on the marketability of the health benefits of fish oil, it is known that fish oil and fish liver oil contain other interesting com-

pounds. With improved separation techniques and more gentle processing methods, these oils might play an even more important role in the pharmaceutical and health food industry in the near future.

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QUESTIONS AND ANSWERS

- Q. When Joel Cowger spoke yesterday on white fish meal production, he said to burn the pollock oil you produce, or any fish oil you produce in Alaska for fuel because you can't make any money from it.
- Is the process used here to produce fish meal and oil damaging to the oil in any way, or is it simply a matter of economics? I noticed on one of your graphs that the omega-3 content in Alaska pollock liver oil is quite high.
- A. In producing crude oil and raw material, freshness is the most important thing. When you start processing the oil after that, then you have to be very careful about the processing techniques. Pollock oil also contains some vitamins, and it has been sold as a very good omega-3 source in fish feed, especially eel feed in Taiwan. It is very possible to use that oil for human consumption as a food ingredient. One has to be careful to keep the oil separate, have everything clean around it, and treat it very gently. But you need to process further than crude oil.
- Q. Is the production of fish meal and oil in Alaska a problem of oil quality, if they do not separate the livers out on pollock?
- A. Fish liver oil contains vitamins, and it is not logical to include it in food simply because you would get an overdose of vitamins. You can add it effectively only up to a certain point. In order to collect liver oil you must separate it by hand, and process it separately. The cost is prohibitive because fish liver oil must compete with vegetable oil prices. I am convinced that food processors will not be able to, or be willing to, pay any high premium for fish oil. It has to compete with soybean oil, corn oil, etc.
- Q. Almost all the pollock landed in Alaska is held in RSW vessels, refrigerated sea water, and delivered at most within two days of catch, more like 24 hours of catch. Do you know of any effect on the raw material that might have? What about salt uptake in

the livers?

- A. The problem with collecting livers at sea is that most of the bottom trawlers, factory trawlers, are now mechanically gutting the fish, and that means that a special person separates the liver. The best thing is to put the liver into a plastic cube and ice it, and if you process it within four or five days, you will be able to get quality fit for human consumption.
- Q. I'm referring to the trawlers that deliver whole fish to shore-based plants where the pollock has been in RSW tanks for 24, 30, to 36 hours.
- A. If it is well cooled, you could get the liver. If you get it out within 24 hours, you would be able to process with good quality. The condition of the fish is also important. If it is close to a spoiling stage, etc., the liver deteriorates fast.
- Q. Is there a market for fish oil in the manufacture of soaps?
- A. Not any more. Now there are cheaper sources of oil. Fish oil is not competitive in most of the industry any more. Today we have only limited use for fish oil—in the margarine and shortening industry as hydrogenated oil, and also in fish feed. There is a good possibility in the near future that food manufacturers will use fish oil in blends with vegetable oil. The dietary recommendation is that you should have approximately the ratio of 4:1 vegetable oil:fish oil.
- Q. I am from a developing country. If fish oil is used in the manufacture of soaps, is there a problem with deodorizing? Or is the manufacturing process a deodorizing process as well?
- A. If you use it as a soap, you would first partly hydrogenate it in order to get the right saturated state of the fatty acids. When you do that, you solve most of your off-flavor problems.
- Q. In an early slide, you showed a specification that listed a tolerance for sulfur. What's the source of that sulfur? It shouldn't be in refined fish oil unless you have contamination from protein.
- A. Some proteins contain sulfur, and when the protein deteriorates and breaks down, some of the sulfur is released to the oil, I believe.
- Q. Was that specification for hydrogenated oil?
- A. Yes. Sulfur affects the catalyst in the hydrogenation process. The cost of hydrogenation increases because you have to add an extra dose of metal catalysts.
- Q. (Mr. Nelson) At our laboratory we've been doing extraction work in fish oils. We're now able to obtain esters at 95% purity of both EPA and DHA.
- Q. (Mr. Goddard) In our salmon processing plants in Kenai we have available to us on the order of one million pounds of salmon heads a year. Is there any economically viable application for extracting omega-3 oils from salmon heads that could be done in a small application without an attendant meal plant?
- A. There is already a small market for salmon oil in capsules as a health food. And also from a marketing point of view, people prefer to have omega-3 oils from salmon to other types of fish. So that is an advantage. But I have seen nothing of the salmon oil—maybe it's not so different in fatty acid composition from other modified oils. This comes around again to the cost of producing it. Is your oil competitive with other oils similar in composition? There is a market for this; I would estimate 50 to 100 tons a year.
- Q. Out of a million pounds of salmon heads, how much oil do you think could be produced?
- A. Fifteen percent.
- Q. That would be substantial. That would be something on the order of 50 to 70 tons.
- A. In our company, we have looked at the fatty acid composition of the salmon viscera, and we found the oil very disappointing in omega-3 fatty acid content. But the oil from the head must be very interesting.
- Q. As a commercial application from a processor's viewpoint, it would be a lot easier to segregate the heads and to deal with them than the viscera. I'm assuming that a simple boiling process would be sufficient for extracting most of the oil and then follow with some sort of crushing.
- A. Yes. Also I think it would be very interesting to look at the composition of the oil. How much is phospholipid, how much is triglyceride; if you could get some of the phospholipids out, you would have much stronger marketing potential. So you should look at your method of producing with this in mind. Not only look at triglycerides, but look at the type of fat left in the head after boiling and separating the oil.
- Q. Boiling and separating is probably the simplest.
- A. Yes, that's the simplest, to grind it very well, and then to boil it and press it out. I'm certain you will get all the oil you would like to get out of the flesh of the head.
- Q. What do you estimate for the commercial value of

something like that in raw form?

- A. I estimate you would get \$2,000 to \$3,000 a ton.
- Q. If we can produce 50 tons a year, that makes it interesting.
- A. You have to be very careful to have a balance between the demand and the supply, because you could overflow the market.
- Q. I have a question about environmental contaminants in fish oil. I'm wondering whether you regularly analyze your products or your crude oil.
- A. Yes, we do.
- Q. Is it a consumer issue?
- A. No, we do it on a regular basis because with this modern analytical technique you can detect pesticides and some foreign bodies in almost any oil, to one part per trillion. We monitor the levels, although they are far below any legal limits. This

is a routine analysis, and I am pleased to confirm that we have a reduction of compounds like DDT and PCBs. The contaminants are usually in very closed areas such as fjords, and they are far below the legal levels. On the other hand, consumers are scared if they know there are even small traces of any contaminants in the oil. Therefore one has to be very careful about removing contaminants in order to state that the oil is contaminant free.

- Q. And are they actually removed, or are they altered by the processes?
- A. Removed. They are absorbed through the bleaching clay, and then during the deodorizing process most of the volatile compounds are distilled off. Further removal occurs if we use supercritical extraction, or high-vacuum molecular distillation. We use the latter processes mainly for special health products and for pharmaceutical products because they must be completely free of any contaminants.

WHAT DO I NEED TO KNOW ABOUT GETTING A PERMIT TO DISCHARGE SEAFOOD PROCESSING WASTES IN ALASKA?

Valerie J. Haney
United States Environmental Protection Agency
Anchorage, Alaska

ABSTRACT

It is common knowledge that the seafood industry is a major factor in the health of the Alaskan economy. Many seafood processing facilities have been in existence since the 1950s. However, aside from canning, the nature of processing has changed dramatically. This change results from the shift to bottomfish processing after the decline of the shrimp and crab harvest.

The emphasis on bottom fishing is changing the face of the seafood industry in Alaska. Bottomfish such as cod and pollock are in popular demand. The cod is frequently made into fillets, resulting in about 80% waste. The pollock is often made into surimi, also resulting in about 80% waste. The disposal of "billions of pounds of protein" in accordance with the federal and state regulations requires a well designed waste-handling system. This translates into a significant commitment of time and money by the seafood processor. It follows that if money can be made by further utilizing the resource, then that is the preferable course of action to simply dumping the unprocessed waste back into the water. Hence, there has been an increased interest in fish meal plants recently, especially since the white meat of the cod and pollock make a high-value meal.

Many of the companies that utilize the by-product are large processing vessels which operate at sea. These companies are able to obtain coverage under the "Authorization to Discharge Under the National Pollutant Discharge Elimination System for Alaskan Seafood Processors" general discharge permit (the Seafood GP) for disposal of their waste water. Shore-based facilities may also be able to obtain coverage under the general permit, but many require an individual permit. Both general permits and individual permits are good for a maximum period of five years.

INTRODUCTION

Currently, there are about 325 permits allowing seafood processors to discharge waste water in Alaska. Of those, five shore-based, meal-making facilities are covered by individual permits and at least a dozen meal plants on board processing vessels are covered by the General Permit for Alaskan Seafood Processors. The EPA's Operations Office in Anchorage has seen an increased interest in new processing facilities, which include meal plants to be located in Dutch Harbor. I have also had one inquiry about requirements for obtaining a permit to discharge waste water from a new meal plant in Kodiak, a company not already doing business there. The purpose of the following paper is to provide prospective applicants with an understanding of the permitting program and its requirements.

ABBREVIATED HISTORY OF THE WATER POLLUTION CONTROL REGULATIONS

The Rivers and Harbors Act of 1899

The root of the water pollution control regulations is the 1899 Rivers and Harbors Act, which was passed for the protection and preservation of navigable waters of the United States. It states in Section 13, "That it shall not be lawful to throw, discharge, or deposit, or cause, suffer, or procure to be thrown, discharged, or deposited either from or out of any ship, barge, or other floating craft of any kind, or from the shore, wharf, manufacturing establishment, or mill of any kind, any refuse matter of any kind or description whatever other than that flowing from streets and sewers and passing therefrom in a liquid state, into any navigable water of the United States, or into any tributary of any navigable water from which the same shall float or be washed into such navigable water; and it shall not be lawful to deposit, or cause, suffer, or procure to be deposited material of any kind in any place on the bank on any tributary of any navigable water, where same shall be liable to be washed into such navigable water, either by

ordinary or high tides, or by storms or floods, or otherwise, whereby navigation shall or may be impeded or obstructed . . .” The sentence is finished with a description of lawful deposits in connection with public works and provision for authorization to grant discharge permits.

The Water Pollution Control Act of 1948

The Rivers and Harbors Act was a start at limiting pollution into the waters of the United States, but it did not go far enough. Furthermore, less than a dozen permits were issued under that act. The pressure mounted on Congress to help the states control the growing pollution. The first comprehensive statement of federal interest in, and financial commitment to, clean water programs came from the Water Pollution Control Act of 1948. The responsibility for carrying out its provisions fell to the surgeon general of the United States Public Health Service, and his power of enforcement was limited to problems involving “interstate waters . . . which endangers the health or welfare of persons in a state other than that in which the discharge originates, and is . . . declared to be a public nuisance.”

The Water Quality Act of 1965

In 1965 the Water Quality Act initiated the development of water quality standards for interstate and coastal waters. While this enabled the determination of pollution, enforcement was a problem. It had to be shown the wastes discharged reduced the quality of the water below established standards (some of which were nonexistent and some were not specific), or that health and welfare was endangered.

The Federal Water Pollution Control Act Amendments of 1972

In order to establish legislation effective in reducing or eliminating the nation’s water pollution problems, the Federal Water Pollution Control Act Amendments of 1972 was passed. It was a turning point and laid the foundation for subsequent legislation via the following national policies:

1. No one has the right to pollute the navigable waters of the United States.
2. Permits shall limit the composition of a discharge and the concentrations of the pollutants in it.
3. Some permit conditions require the best controls technology can produce, regardless of the receiving water’s ability to purify itself naturally.
4. Any limits or control higher than the minimum

federal requirements must be based on receiving water quality.

The passage of the Federal Water Pollution Control Act Amendments essentially established the National Pollutant Discharge Elimination System (NPDES) program. It allowed the federal government, through EPA, to assume the dominant role in directing water pollution control programs across the country. Its well-known goals, listed in Section 101 (a), were to:

1. Eliminate the discharge of pollutants into navigable waters by 1985, and
2. Achieve an interim water quality level that would protect fish, shellfish, and wildlife while providing for recreation in and on the water wherever attainable.

In addition, Section 101 (b) made it a policy to preserve the states’ primary responsibility to meet these goals. Further sections describe how this will be done, including the state’s certification requirement, Section 401; and the mechanisms by which the state can obtain full administration of the permit program, 402 (b).

The act required EPA to issue permits to every point source discharger in the country by December 31, 1974. Thus, the “first round” of permits was issued in 1973 and expired in 1978. We are currently in the “fourth round” of permit issuances. Since the turning point, additional amendments have been passed to further reduce the effects of pollution. The result of adjustments to the regulations is a permitting approach which utilizes a combination of technology-based and water quality-based tools to control the pollution, and permits that are often 30 pages long.

THE LEGISLATION BEHIND THE PERMITS

Sections 301 and 402 of the Federal Water Pollution Control Act as amended by the Clean Water Act of 1977.

The requirement, authorization, and general guidance for discharge permits is referred to in the title of a discharge permit. The permit is titled:

“Authorization To Discharge Under the National Pollutant Discharge Elimination System”

In compliance with the provisions of the Federal Water Pollution Control Act, as amended, (33 U.S.C. 1251 et seq.; the “Act”),

[Your Company]

is authorized to discharge from a facility located in [Somewhere,] Alaska

to receiving waters named [Beautiful Bay]

in accordance with discharge point(s), effluent limitations, monitoring requirements and other conditions set forth herein.

Section 301 of the act says, "Except as in compliance with this section and sections 302, 306, 307, 318, 402, and 404 of this Act, the discharge of any pollutant by any person shall be unlawful."

We will focus on Section 402 of the act which is the NPDES program. The other sections referenced are Water Quality Related Effluent Limitations, National Standards of Performance (for various industry categories), Toxic and Pretreatment Standards, Aquaculture, and Permits for Dredged or Fill Material.

NPDES

Section 402 of the Clean Water Act states all "point sources" "discharging pollutants" into "waters of the states" must obtain an NPDES permit from EPA or an approved state. Waters of the states basically means anything that is wet or may get wet! An approved state is one which has been granted the authority by EPA to administer the NPDES program in that state. A permit can be either an individual permit or a general permit.

The General Permit

"Authorization to Discharge Under the National Pollutant Discharge Elimination System for Alaskan Seafood Processors." EPA has authority to issue a general permit under certain parameters.

The Seafood GP is a grind and discharge permit and is applicable throughout the state except in Dutch Harbor-Unalaska, Akutan, Kodiak, and the Kenai, Kasilof, and Alsek rivers (previously excluded also Cordova, Petersburg, Finger Bay in Adak, and Anchorage area). In some cases, a processor may receive a waiver to operate in Unalaska Bay or Akutan Harbor.

Other exceptions from the Seafood GP are:

1. Discharges into area of concern, such as areas where the water depth is less than 42 feet, that are likely to have poor flushing.
2. Discharges within one-half mile of area of special concern.
3. Discharges to fresh water in the vicinity of drinking water sources.
4. Discharges to lakes.
5. Minor (less than 1,000 pounds) discharges at sea.

The following are the Seafood GP criteria:

1. Same geographic area warranting similar pollution control measures.
2. Involve substantially similar operations.
3. Discharge same types of wastes.
4. Require similar monitoring.
5. Director feels they are more appropriately controlled this way.

The Individual Permit

An individual permit is issued to a "person," rather than a category of discharges, and authorizes the discharge into water. In cases where a general permit is not applicable an individual permit will be written. "Person" means an individual, association, partnership, corporation, municipality, state or federal agency, or agent or employee thereof.

There are two types of facilities requiring an individual permit:

1. Existing source, i.e., expansion of an existing meal plant such as Alyeska Seafoods, Inc. in Unalaska.
2. New source, i.e., "its processes are substantially independent of an existing source at the same site" (40 CFR 122.29) such as Westward Seafoods, Inc. in Captains Bay or Trident Seafoods in Akutan Harbor.

THE APPLICATION PROCESS

Before proceeding, make sure your facility cannot be covered by the Seafood GP. It is the easiest permit to acquire. However, if you are a shore-based meal plant located in a processing center such as Dutch Harbor, you will need an individual permit.

The initial application is in three parts and must be submitted 6-12 months in advance, though 12-18 months in advance is preferable. The three parts are:

1. The State Coastal Project Questionnaire;
2. The EPA Application Form 1, General Information to the Seattle EPA Region 10 Office (EPA Form 3510-1) and;
3. Existing source, the EPA Application Form 2C, Wastewater Discharge Information (EPA Form 3510-2C); or new source, the EPA Application Form 2D, New Sources and New Discharges: Application for Permit to Discharge Process Wastewater (EPA Form 3510-2D).

The following actions result from the application package:

1. Whether you are an existing source or a new source, the following actions will result upon receipt of the application package. Your submittal of the Coastal Project Questionnaire to the State of Alaska's Division of Governmental Coordination (DGC) sets the wheels in motion to:

- A. Identify permits required by the state resources agencies as well as the federal agencies, and
- B. Determine the project's consistency with the Alaska Coastal Management Program.

The DGC reviews your project for consistency with the state's Coastal Zone Management Program. If you are an existing facility this questionnaire will probably be a mere formality.

2. After EPA has received the application package you will receive a form letter stating whether or not your application package was complete; your status as a major or minor discharger; the permit action, i.e., issuance, re-issuance, or modification; and the permit processing decision which will give you a general idea of the processing schedule. Shortly thereafter, a priority status will be assigned to your permit as well as a writer in EPA's Region 10 office to draft the permit.

At the time of public notice of the final draft permit, EPA initiates the state certification actions. If the Alaska Department of Environmental Conservation (DEC) concurs with the permit as written, then the state issues a Certificate of Reasonable Assurance that the permitted discharge(s) will comply with the appropriate sections of the Clean Water Act, as required by Section 401. Thus, the certification is referred to as the "State's 401 Cert."

If the state concurs with permitting the discharge, but feels additional requirements are necessary in order to certify the permit, stipulations will be added to the certification that become part of the permit. It should be noted that if your company plans to discharge in an area of marginal flushing capabilities or the nature of your discharge is such that you may require a mixing zone in order to comply with the foreseeable permit limitations, then it would behoove you to contact the regional DEC office as soon as possible—before a lot of money is spent on consulting fees for plant design and application preparation.

3. If you are a new source, there are additional considerations. First, the Coastal Project Questionnaire may indicate the need to coordinate with the Alaska Department of Natural Resources (DNR) if state

tideland leasing is required, or the U.S. Army Corps of Engineers (COE) if dredge and fill is necessary. The questionnaire may also trigger strict local-area requirements if the project is located in an Area Meriting Special Attention (AMSA), e.g., Kenai.

A new source necessitates that an environmental assessment (EA) be done to determine the potential impacts of the project's alternatives on the environment. When the regional administrator has determined the facility is a new source, a public notice shall be issued to that effect, which includes a statement that the applicant must comply with the environmental review requirements of the National Environmental Policy Act (NEPA) as set out in 40 CFR 6.600 et seq. [40 CFR 122.21(e)]. The EA will require a lot of information before either a Finding of No Significant Impact (FONSI) or determination of the need for an Environmental Impact Statement (EIS) can be made.

TECHNICAL REQUIREMENTS AND TIPS TO MINIMIZE THE PAIN OF THE PERMITTING PROCESS

Tips

To obtain a discharge permit for either an existing source or a new source, it is important to submit a complete application. Include all the information you have to clearly identify and quantify the various waste streams. Include the attachments such as water use diagram and the topographic and bathymetric map. Also, include the State Coastal Zone Questionnaire in your packet to EPA.

Remember, if you are likely to be considered a new source, an environmental assessment will be required in order to comply with the NEPA regulations. At this point, you may need to hire a consultant, unless you've already retained one to help locate a suitable site. The more information and the better the information you provide to EPA, the sooner your EA will be completed.

Effluent Limitations Guidelines

The effluent limitations are arrived at by referring to the effluent limitations guidelines for your particular category, which for seafood processors is found in 40 CFR 408. The new source performance standards apply to all facilities for which national standards of performance have been established, the canned and preserved seafood category being one of many. However, there are no effluent guidelines for the subcategories of

meal plants or surimi processing in Alaska.

Since the effluent limitations guidelines cannot be applied directly to a meal plant operating in Alaska, best professional judgement (BPJ) is used to apply limitations the regional administrator feels are appropriate. Meal plants in Alaska are usually assigned the East Coast limits for Biochemical Oxygen Demand (BOD), Total Suspended Solids (TSS), and Oil and Grease (O&G): 6.7, 3.7, 1.4 lb per 1,000 lb for all the meal plant waste water except stickwater. Since EPA has had trouble determining the best conventional pollutant control technology (BCT) for stickwater, the approach taken to limit the associated pollutants is to limit the flow and to require a stickwater recovery plan. The goal of the stickwater recovery plan is to achieve complete recovery of stickwater through the use of in-plant modifications.

Sometimes the permit limits may need modifying to protect the state's water quality standards, or a zone of deposit or mixing zone must be established. These additional requirements are stipulated in the "State's 401 Cert." It should be noted that the State favors a policy of "no new, persistent (year-round) waste piles."

CONCLUSION

It is often heard that EPA is too strict in regulating the seafood waste water discharges in Alaska. The seafood waste makes a good meal for sea life just as it is produced, without grinding. One look at the thousands (millions?) of sea gulls around the Kodiak and Dutch Harbor processors verifies that statement. In addition, there are sea lions, flatfish, crab, etc. to utilize the by-product.

Therefore, if the pressure of the federal regulations

seems too great, then remember these two important points:

First, it is well known that in addition to being a major factor in the Alaska economy, the seafood industry is a major discharger of seafood wastes into Alaska waters. When "billions of pounds of protein" are discarded in relatively few locations there will be a significant impact, primarily because the waste will smother portions of the sea floor, and foul fishermen's nets.

Second, the EPA strives to apply the effluent limitations guidelines as equitably and as reasonably as possible, while still protecting the receiving water. As the industry changes this makes the permit limits in some areas seem too lenient and in others, too strict.

It is a fact of life in today's world that you will be regulated. The best way to ensure receiving a reasonable discharge permit is to cooperate fully in sharing information with the EPA. There is room for negotiation in the early stages of the process.

Be alert to when the guidelines are published for your industry category. If you feel they are inappropriate, take the time to argue your case then, so you will not have to spend time fighting them later.

REFERENCES

- Code of Federal Regulations Title 40, Parts 100-149, July 1, 1989. U.S. Government.
- Code of Federal Regulations Title 40, Parts 400-424, July 1, 1989. U.S. Government.
- The Clean Water Act of 1987, Second Edition. PL 100-4. Water Pollution Control Federation, 601 Wythe St., Alexandria, VA 22314-1994. WPCF Order No. P00 70JR.

EXPORT AND FOREIGN INVESTMENT OPPORTUNITIES FOR ALASKAN PROCESSORS

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In 1986 a key part of Governor Cowper's platform was a commitment to diversify Alaska's economy. After he was elected, he gave a direct charge to our office to increase export opportunities for Alaskan products, and also search for foreign sources of capital for investment in Alaska.

We do this through a main office in Anchorage, and we have foreign offices in Tokyo, Seoul, and Taipei. We lead trade missions, we sponsor trade fairs, we host foreign trade delegations in Alaska, and we provide international trade information to the Alaska business community through a quarterly newsletter, a biweekly fishery mailing, and co-sponsorship of trade seminars with the University of Alaska. My current trade mission consists of polling the Alaska fishing industry to see if there is interest in a tour of Japanese and Korean fish markets this fall. That may provide an opportunity.

I've taken some trade statistics from the Bureau of the Census, export statistics. Alaska has doubled its exports between 1985 and 1989, with a substantial increase in fishery products. Fish exports in 1985 accounted for approximately 34% of the total exports. In 1989 that had increased to over 42%. Our major fish markets are the Pacific Rim, Western Europe, and the Americas. The Americas include Canada and Latin America, but most of the fish products go to Canada. Very little now goes to Central or South America.

In fish by-products export, we've gone from approximately \$121,000 in exports of inedible fish meal in 1985 to total fish meal exports of over \$33 million last year. Basically there are four markets for those fish by-

products: Japan, Taiwan, Korea, and Indonesia.

We see some opportunities to significantly increase fishery exports, particularly in Korea and Taiwan. The standard of living in those two countries is increasing, and the people are looking for sources of protein other than rice, such as fish and meat. Last year Korea initiated a three-year trade liberalization program on food products. On the schedule for tariff decreases are 95 fish products. In 1991 edible fish meal is included on that schedule. So we hope that will provide some opportunity for this emerging by-product industry in Alaska.

We are currently hosting large parties of foreign buyers for fishery products. They have contacted our office here through our overseas offices. Some have not bought products from Alaska before, and some have worked through brokers based in Seattle. They're interested in buying products directly from Alaska. We have scheduled appointments around the state in our major fishing ports to discuss opportunities with fish processors.

We also initiated discussions between a foreign investor and an Alaskan fishing company recently. This involves the formation of a joint venture for seafood processing and marketing. It will combine Alaskan expertise and foreign capital.

So if you develop wonderful new products from fish by-products, how can we help you sell them? All you have to do is contact our office by telephone or telefax, or stop by the Anchorage office, tell us what you have to sell, and give us a simple proposal. We will shop that proposal through our foreign offices to potential buyers.

We're very easy to deal with. We're not a regulatory agency; we're there to assist businesses.

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ECONOMICS OF FISH BY-PRODUCT UTILIZATION FOR SMALL PROCESSORS IN ALASKA

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We have seen that there are economic benefits in worldwide by-product processing of fish waste. Producers are putting forth effort and money to get hold of by-products to be processed. What are the possibilities here in Alaska, where processors already have the by-products in their hands and do not know what to do with them?

We have been looking at this problem with regard to:

- Product compositions
- Seasonal variations in amounts of by-products
- Shore- or ship-based installation
- Factory and storage space requirements
- Shipment costs
- Established markets and new markets

The traditional solution to the utilization of a smaller amount of fish by-product in the past was installation of a small fish meal plant, often a so-called compact plant, because these plants are built skid-mounted ready to hook up to utility supplies on site.

We are looking into the feasibility of a plant with a capacity to process one metric ton of offal per hour. Plants with larger capacities of two or even up to four or five tons per hour are available, but the one ton per hour plant can be built fairly easily into many of the existing factory trawlers and is small enough for many shore-based plants. If we can find economy in installing this small-capacity plant, we certainly can do so if installing a plant with a bigger capacity, if the raw material exists.

Small plants have the same components as bigger plants. The main components are shown in Figure 1. We can either produce presscake (Figure 2), or we can install an oil recovery system and a stickwater recovery system and produce whole meal (Figure 3). The latter is

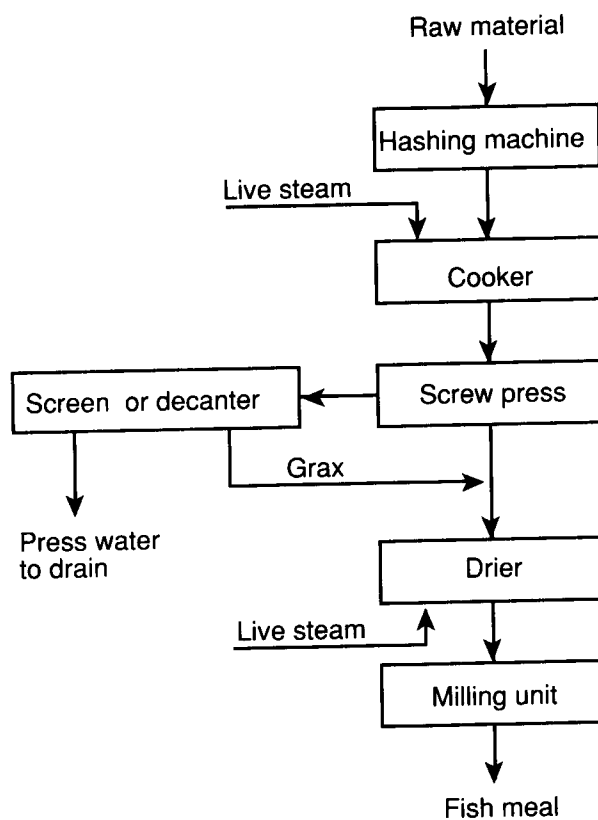


Figure 1. The main components of a simple fish meal plant.

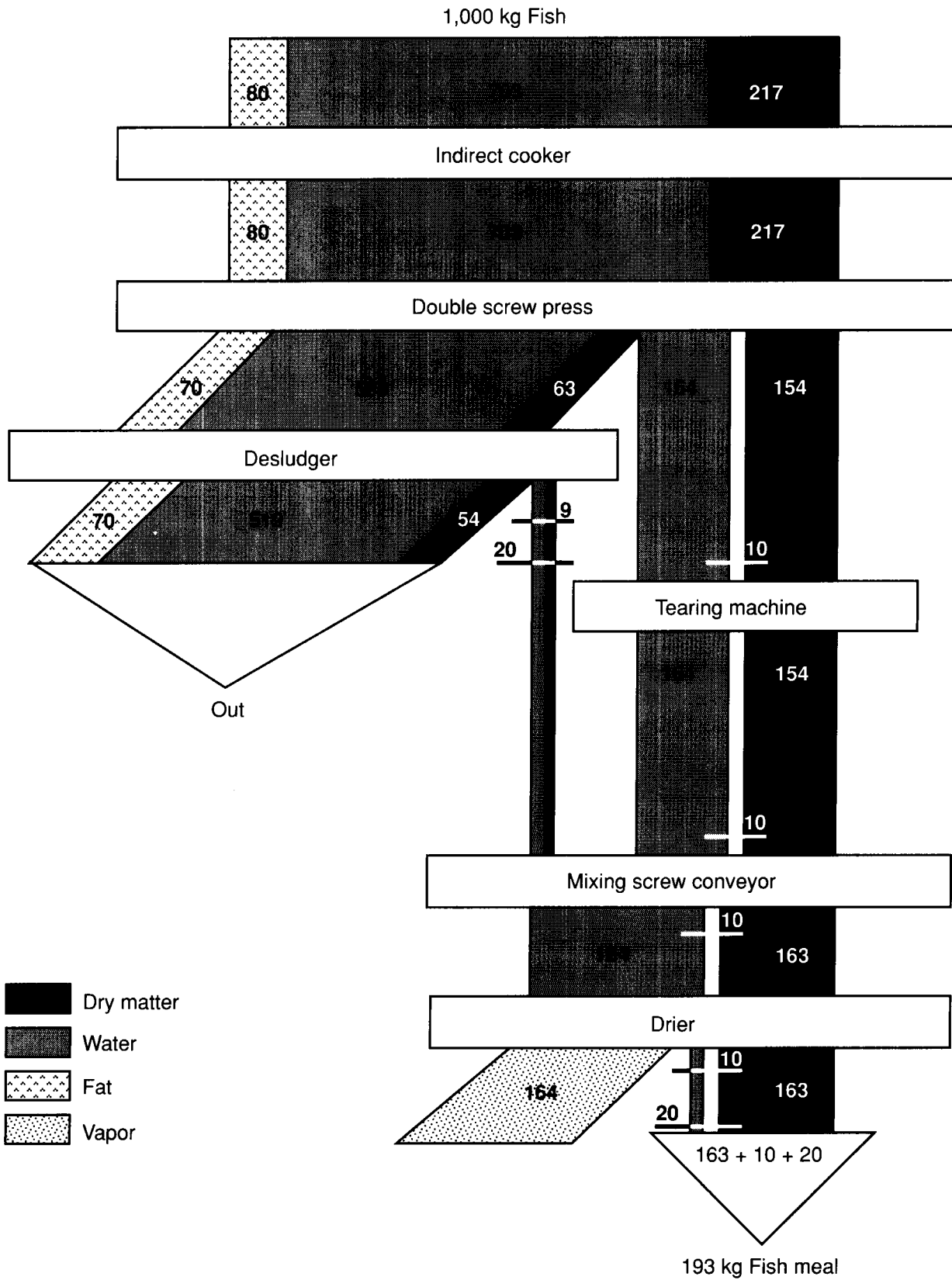


Figure 2. Flow diagram for fish plant producing presscake.

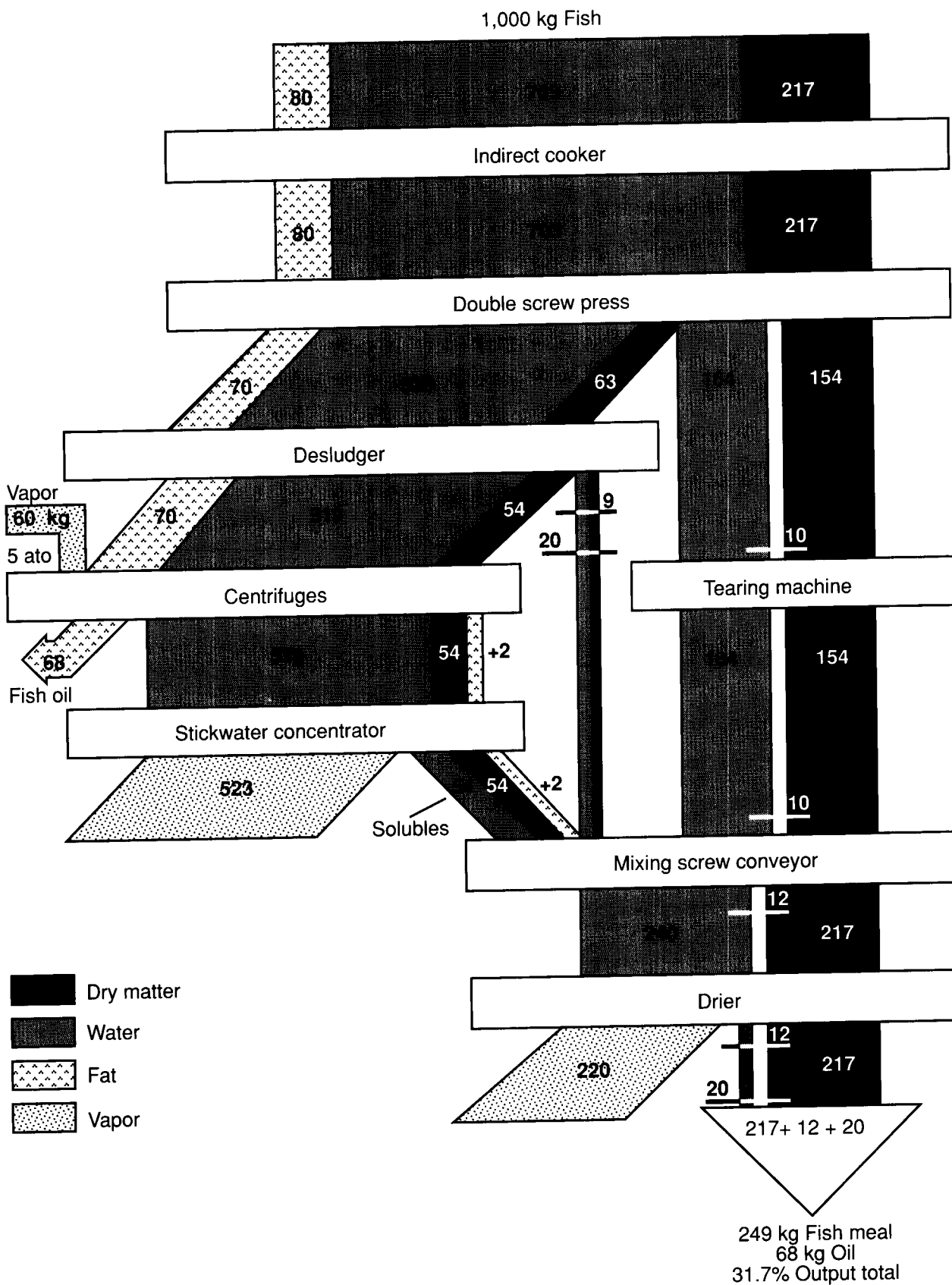


Figure 3. Flow diagram for fish plant with oil and stickwater recovery system, producing whole meal. (ato = atmospheric overpressure.)

Table 1. Budget price sheet for one ton per hour plant.

Compact fish meal plant, ACP 25 capacity 1.0 MT/h	290,000	
Raw material conveyor, with hopper	20,000	
Meal conveyor, bagging station, scale, etc.	15,000	
Mechanical and electrical installation	20,000	
Freight, customs duty	40,000	
Steam generator 25 BHP (estimate)	45,000	
Buildings & foundations (estimate)	20,000	
Subtotal		\$450,000
Fish oil unit	120,000	
Freight, duty, etc.	20,000	
Subtotal		\$140,000
Evaporator	185,000	
Freight, duty, etc.	25,000	
Bigger steam supply (estimate)	10,000	
Installation (estimate)	20,000	
Subtotal		\$240,000
Total		\$830,000

the solution to choose if we are not allowed to discharge the press or stickwater, or if the amount of oil recovered in the raw material or amount of solids in the stickwater justifies installation of the recovery system. The components for the fish meal plant with the oil and stickwater recovery system is shown in Figure 4.

Table 1, a budget price sheet for the one ton per hour plant, gives our estimate for the presscake meal plant and the oil recovery-stickwater recovery plant. No raw material storage or product storage facilities are included in the prices.

Table 2 shows two different production cost calculations:

(1) A 5,000 hour per year operation equally spread over the whole year, and (2) A 90 day (2,160 hour) operation concentrated over a three month period. Calculations are made for a plant producing presscake meal as well as whole meal.

We also made a calculation showing return on investment and operation (Table 3). This calculation is done for the one metric ton per hour plant producing presscake meal, and the same size plant producing whole meal. The latter at the same time recovers a certain amount of oil from the raw material.

With respect to oil recovery it should be mentioned that all the oil in the raw material will be recovered. The oil yield, generally at 5.0%, is dependent on the amount of oil in the raw material. About 7%–9% of the produced meal will be oil, but the remainder of the oil

will be recovered.

With 15% meal recovery of presscake meal and a meal price of \$500 per metric ton, we will earn about 35% return on invested capital in the 5,000 hour per year plant, even based on a five-year depreciation. We are just about at the break-even point after 90 days of operation, however, with a 10-year depreciation of the investment.

A plant producing whole meal can reach the break-even point in about five years on non-oily waste, at 5,000 hours operation per year, but the plant cannot meet expenses in a short 90 day season.

If the raw material is waste from a salmon operation, the situation is quite different: A higher solid content in the salmon waste results in a higher meal production.

Any saving in cost of discharging the waste, if no fish meal plant is available, is to be added to the above calculation as a further improvement.

Still a certain amount of raw material is needed to secure an economical operation of a small fish meal plant.

Several alternatives exist; but because of the established market for fish meal, we made our calculation for the traditional utilization of fish wastes into production of fish meal. Nearly any of the alternative utilizations of fish wastes will produce a semi-produced product or an end-product for which an established market, like the one for fish meal, does not exist.

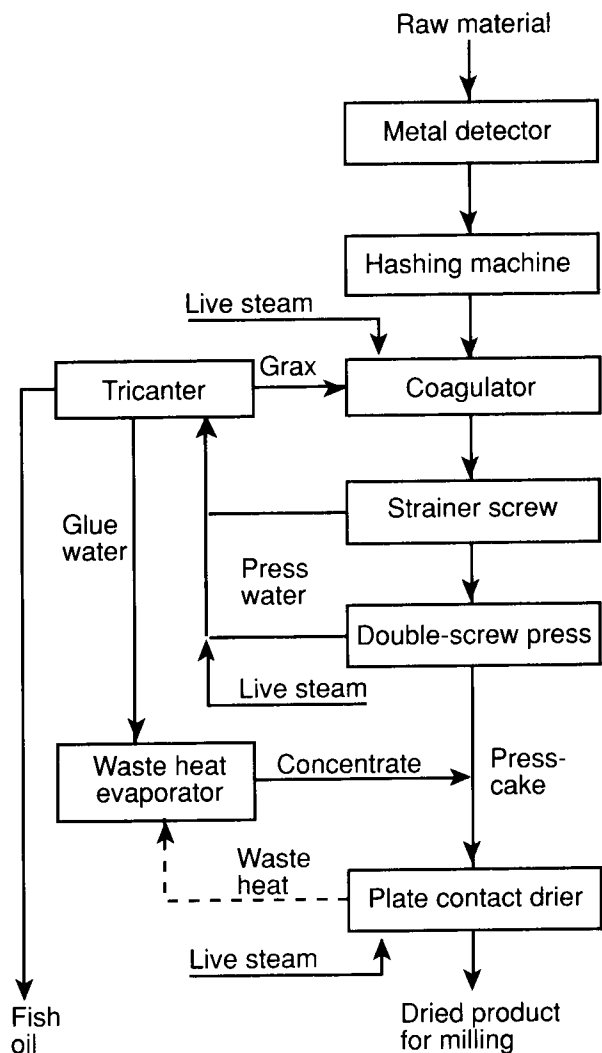


Figure 4. Components for fish meal plant with oil and stickwater recovery system.

An obvious solution would be hydrolysis to produce fish silage. The problem with using this method in Alaska is that the weight of the product will not be decreased; rather it will be increased unless a rather expensive evaporator plant is installed with a corresponding boiler plant.

Two advantages of producing fish silage are the low investment in equipment and the fact that the product is liquid and storable in tanks and can be moved by pumps.

The volume and weight will make it difficult and expensive to move the product from place of production to consumer. Fish silage can be five times as heavy as fish meal from the same amount of raw ma-

terial, and the volume is 2.5–3 times larger.

Further, fish silage cannot be stored forever. According to Norwegian feed experiments, growth of mink and salmon fed silage hydrolyzed with formic acid will start decreasing if the silage is more than five to six months old. Fish silage has for several years been produced in Northern Europe and used for mink and other animal feeds.

A concentrate of fish silage can also be produced without the above-mentioned evaporator by using a combination of acid and salt for hydrolysis of the fish. Tests on this method have been carried out by the Research Laboratory under the Danish Ministry of Fisheries, and the product has been used for mink fodder with good results.

The acid-salt hydrolysate will drain quite freely and can further be pressed to a fish silage concentrate with approximately 42%–45% solid content. The raw material has to be minced, mixed with salt (NaCl), acid, and an anti-oxidant. The processing equipment needed for this process is simple as shown in Figure 5.

The comparison of the analysis for the raw material (herring offal) shows that the protein content is increased twofold and the oil content is reduced by half (Table 4). The salt content is of course increased, but not to the extent expected. Analysis has shown that the salt content is proportionate to the water content and is thus drained off in the press.

About 10%–20% of the raw protein will go out with the liquid phase, as will approximately 50% of the oil in the raw material. This oil can be recovered easily by separation, and the quality will be excellent because the material has not been exposed to temperature treatment.

From the above you will notice that we are reluctant to recommend systems other than those producing fish meal of one or another quality. It is not because we are manufacturers of fish meal equipment; we are ready to start manufacturing any type of equipment for this industry needed to produce the right marketable product. The reason we reluctantly recommend other products is that:

- Markets for such products are limited or uncertain,
- We will experience difficulties with costly transportation of voluminous and heavy goods, but
- We know there is a market for fish meal.

Requests for small and cheaper, more simple fish meal plants and the fact that the Alaska Fisheries Development Foundation has tempted us with a presentation during this symposium has also got our research and development people to consider other principles and cheaper plant combinations for small fish meal

Table 2. Production cost calculation.

	Presscake meal 5,000 h/year	Whole meal 5,000 h/year	90 Days operation presscake meal day-night 2,160 h	90 Days operation whole meal day-night 2,160 h
One operator/shift, three shifts/day, 210 days/year, \$10.00/h + 20%	60,000	60,000	26,000	26,000
Maintenance/cleaning person, one shift \$10.00/h + 20%	20,000	20,000	8,650	8,650
Steam cost \$8.00/1000 lbs x 750 lbs/h 1250 lbs/h	30,000	50,000	13,000	21,600
Electricity 50 KWH x \$0.13/KWH (75 KWH)	32,500	48,000	14,000	20,750
Lubrication	2,000	3,000	1,000	1,000
Maintenance 3.0% of investment	12,500	25,000	2.0% 8,000	2.0% 16,000
Meal bags	25,000	31,000	11,000	13,400
Subtotal	\$152,000	\$237,000	\$81,650	\$107,400
Depreciation over 10 years	45,000	83,000	45,000	83,000
Interest on investment 14.0% p.a. on an average of 50% of investment	31,500	58,100	31,500	58,100
Total cost per year	\$228,500	\$378,100	\$158,150	\$248,500
Alternatively:				
Depreciation over 5 years	90,000	166,000	90,000	166,000
Interest on investment 14.0% p.a. on an average of 50% of investment	31,500	58,100	31,500	58,100
Total cost per year	\$273,500	\$461,100	\$203,150	\$331,500

Table 3. Return on investment and operation. Raw material is waste from dressed head-off catch.

	Presscake meal 5,000 h/year	Whole meal 5,000 h/year	90 Days operation presscake meal day-night 2,160 h	90 Days operation whole meal day-night 2,160 h
A. Cod-pollock:				
17% Fat-free solids				
Expected yield %	15.0	19.0	15.0	19.0
Meal production MT/y	750	950	324	410
Sales price per year at \$500/MT	\$375,000	\$475,000	\$162,000	\$205,000
B. Salmon and other oily fish:				
Expected yield:				
Meal %	17.0	21.0	17.0	21.0
Oil %	5.0	5.0	5.0	5.0
Meal production MT/year	850	1,050	365	450
Oil production MT/year	250	250	250	250
Sales price per year				
Meal at \$500/MT	425,000	525,000	182,500	225,000
Oil at \$240/MT	60,000	60,000	60,000	60,000
Total return per year	\$485,000	\$585,000	\$242,500	\$285,400

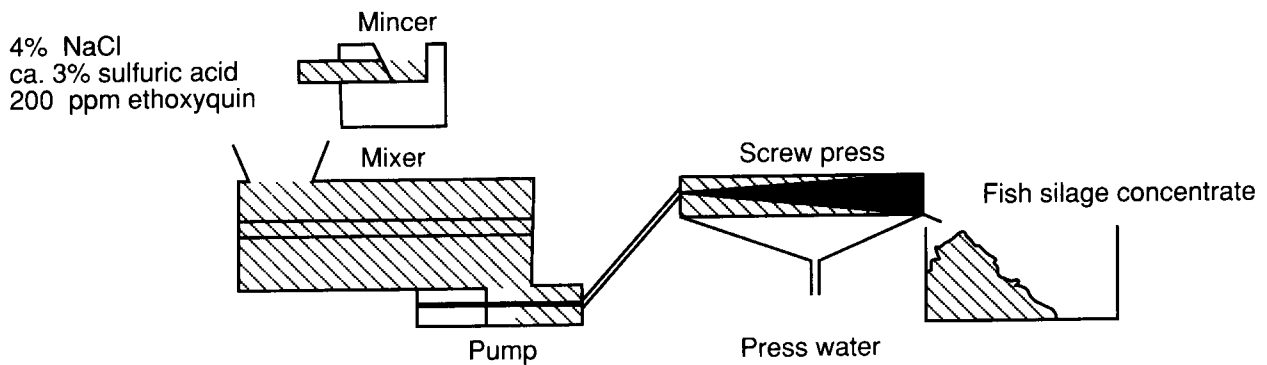


Figure 5. Processing equipment needed to produce fish silage concentrate.

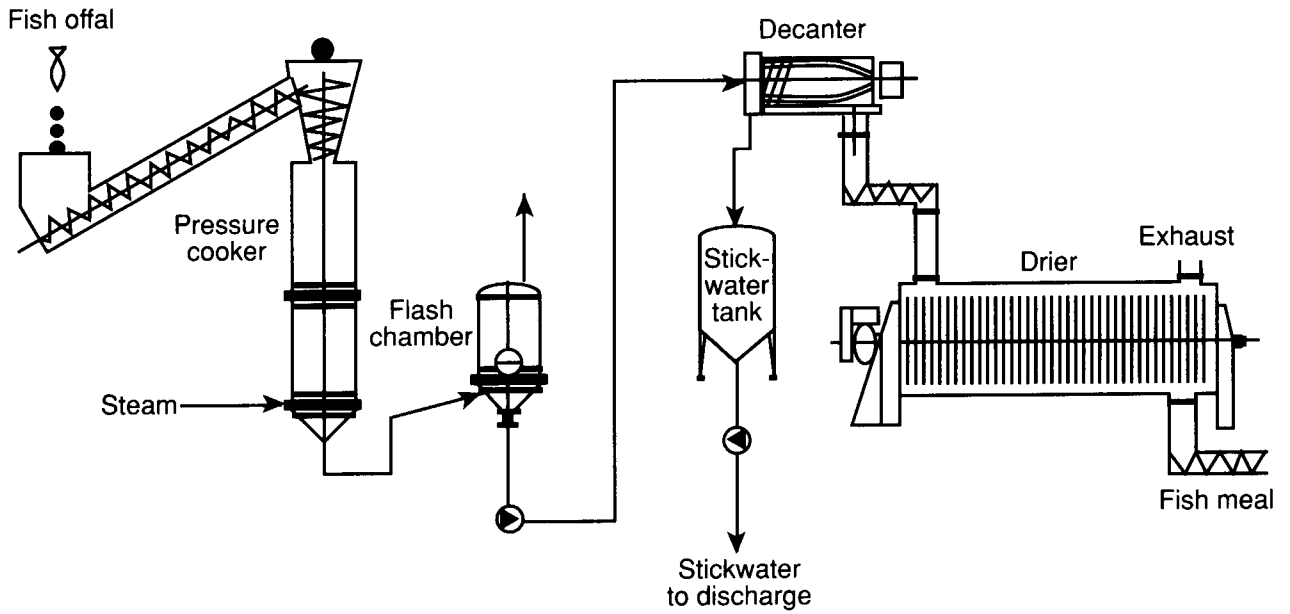


Figure 6. Plant for processing fish offal, with stickwater discharge.

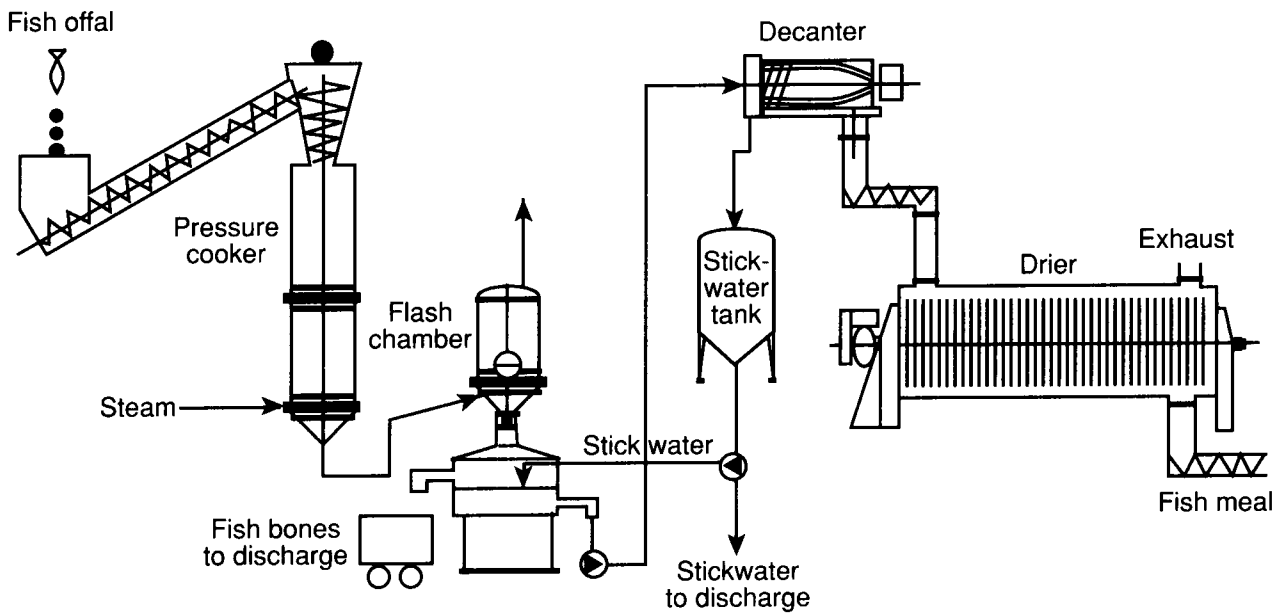


Figure 7. Plant for processing of fish offal, with bone and stickwater discharge.

Table 4. Composition of raw material and presscake (fish silage concentrate).

	Raw material	FSC
Solids %	32.6	43.5
Protein %	13.5	27.1
Oil %	17.0	8.7
FFA %	3	18
Peroxide/kg oil	0.4	3.3
Salt %	0.4	3.3
TVN mgN/100 g	21	22
pH	6.7	3.6

Reference: Research Laboratorium, Danish Ministry of Fisheries, 1985.

FFA = free fatty acids; TVN = total volatile nitrogen.

plants. The result is shown on Figure 6.

Besides aiming for a simple plant, our people have also concentrated on making a plant that can be installed in small and often separated areas on board a ship. The product is moved by steam pressure and pumps, and different equipment can therefore be installed in separate rooms.

The waste is fed to a pressure cooker equipped with a special in-feed screw, and cooked by direct steam injection for three to eight minutes depending on the degree of hydrolysis wanted.

From the cooker, the product is moved by steam pressure to a flash chamber and discharged into a pump taking the fish hydrolysate to a decanter. The decanter separates the liquid and the solid phases, the latter of which can be taken to a drier for meal production.

If working on oily waste, the decanter can for a small additional cost be replaced with a three-phase machine separating the hydrolysate into grax, oil-free stickwater, and fish oil.

If there is no space on board to install a drier, the grax from the hydrolysate can either be stabilized by acid and anti-oxidant or can be frozen, assuming a market for this product can be created.

The system can further be expanded to produce a high-quality meal with reduced ash content by installing a vibration strainer between the flash chamber and the decanter as shown in Figure 7.

If the waste is hydrolyzed properly, the main part of the fish bones can be separated by the strainer before the rest of the hydrolysate is taken by a pump to the decanter for separation into liquid and solid phases.

In test operations, the difference in ash content between the two different plants (Figures 6 and 7) has shown 19% and 13% ash content, respectively, in the final meal, against a reduction in meal yield from

13.8% to 10.9%.

The stickwater from the hydrolysate can in this case, as well as in a traditional plant, be recovered in a stickwater evaporator and the concentrate mixed into the grax for drying or storage.

No specific plant size has been decided upon nor has a budget price been calculated, but it is expected that the total price for a 1.0 metric ton per hour plant will be about the same as the price for a similar size fish meal plant. A slightly bigger plant could be relatively cheaper in investment cost. Electricity consumption will be slightly less than for a traditional fish meal plant. The only drawback will be that for this plant, direct live steam would be consumed, and consequently fresh boiler feed water would have to be provided to replace the steam consumption.

The product quality of fish meal and fish oil produced with the on-board, steam-driven process will be very much like traditional fish meal. Because of the much shorter time the product is exposed to high temperature, the quality should be better than standard. The smaller space requirement and the possibility of a split installation should be an important advantage.

QUESTIONS AND ANSWERS

- Q. I have a question on the price of meal for salmon and other oil fish. I've been told that you can't sell meal made from salmon and other oily fish for the same price as white fish meal.
- A. I think that for white fish meal you should be able to get a little bit better price than the \$500. Salmon is lower for some reason.
- Q. If this were done in stainless steel, what would the increased price be?
- A. It needs to be in stainless steel so there will not be rusting.
- Q. This is stainless?
- A. No. The small units are not made of stainless steel. The oil separator and the evaporator plant are stainless steel, but not the unit itself.
- Q. How much space do you need to operate this plant? Where I come from it's very expensive to make extra square meters. So it would be crucial that the plant is compact.
- A. It is difficult to say exactly how small a space one can squeeze it into. We have several plants of this size on board ships. The space is no more than for the machinery plus a little bit so you can squeeze around it. It's not ideal to have it like that in land installations. But generally I would say that an 8 x

4 meter floor space will be sufficient for a one ton per hour presscake meal plant. An additional 8 x 4 meter space will be needed for additional equipment for a whole meal plant. The height is 5–6 meters.

Q. Could you define the makeup of the waste better than you have on the drawing?

A. No, I have had to generalize. If we knew the specific composition of the waste material, we would have to change the 15%, 17% yields that I had on the former schemes as well as the oils. This is a fair, but in American eyes probably not a very good business to plan, a small fish meal plant with this capacity. I assure that if we made the calculations for a two tons per hour plant, it would be an excellent business under all circumstances, counting depreciation over five years.

Q. (Susan Goldhor) I want to make one clarification which is that there really is a difference between silage and hydrolysate, or at least one of the ways you can make hydrolysate. In making silage, the product is acidified and it's left to continue digesting. And therefore as you correctly pointed out, it is not infinitely storable, and as time goes on it does lose nutritional quality. But one can make a hydrolysate which can be stored for quite a long time and remain stable nutritionally.

I was also very impressed by your ingenious processes, but I want to give one warning: In our experience with hydrolysis, one has to be careful about reducing the water content of the product

prior to the enzyme liquefaction. The enzyme processes need a certain water level, so one must be aware of that.

A. Thank you.

Q. How much moisture do you take off in the flash chamber?

A. The ambient temperature is 10° centigrade, and we cook it up to about 150° centigrade. What will flash off will be the vapor which is in surplus for cooling the product down to 100° again. Some water will be added to the product—that is, the condensate resulting from the direct added steam for heating the product from ambient temperature to boiling point.

Q. What would you have as a percentage of solids coming out of this?

A. You will have to add about 16%, 17% water to it. If you have a product with 15% solids at the intake, you will reduce that to about 12% or 13%.

Q. I'd like to ask a question about the concentration of the solids. If sulfuric acid is in there, and you concentrate, drive off moisture, the sulfuric acid will become concentrated. I got caught once that way by trying to dry some material that had about 0.5% acid. When I dried it, it all turned black because it was concentrated acid. I suppose you would have to neutralize the acid before you tried to concentrate it? Would that put an additional cost on the process?

A. Yes. And it will increase your ash content.

AN INTEGRATED APPROACH TO RECOVERY AND UTILIZATION OF LOUISIANA CRAWFISH PROCESSING WASTES

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ABSTRACT

The Louisiana crawfish culture industry comprises the largest crustacean farming operation in the United States. Processing plants throughout the culture region generate as much as 80 million pounds of peeling waste annually during recovery of the 15% (by weight) edible tail meat. Development of an oil extraction process for carotenoid astaxanthin from the waste has allowed establishment of a commercial industry for by-products. Pigment concentrations as great as 1,500 ppm have been recovered. Currently it is being utilized in Japan as a natural red colorant for red sea bream culture. Remaining protein waste and extracted presscake find application as ingredients in commercial diets and baits in crustacean aquaculture. Chitin-chitosan and carotenoid-chitin-protein complex investigations have demonstrated functional and physiologically active properties of these crawfish-derived products. Recent analytical studies have revealed the presence of important, and potentially recoverable, flavors in fresh waste material. Work in progress is evaluating the feasibility of food-grade meat recovery from the crawfish claws, currently included in the waste fraction. A multi-product recovery schematic is presented with emphasis on applications and opportunities in world markets.

INTRODUCTION

Louisiana has the largest and oldest successful crustacean farming industry in the United States, namely

that of the red swamp crawfish (or crayfish) *Procambarus clarkii*. This aquaculture industry has grown from less than 900 hectares in 1960 to a projected size of nearly 150,000 hectares or more by the end of the present decade. Popularity of ethnic "Cajun" foods and development of several prepared gourmet crawfish consumer products have contributed to the significant growth of the industry. Harvests are from ponds as well as marshes, the latter designated as "wild crop." Increasing effort is directed toward the regulated pond approach, enhancing the predictability of the yearly harvest. It was not until 1984 that local attention focused on processing by-product recovery in an environmentally and economically sound manner. Prior to this, disposal of crawfish waste (head and tail carapace residue) in poorly controlled landfills was costing the state of Louisiana tens of millions of dollars annually, in addition to creating serious local environmental problems. A demonstrated means to convert such waste into commercially valuable products, and increasing federal regulatory pressure, were catalysts that changed traditional thinking in this long-established industry (Anonymous 1989).

The magnitude of crawfish culture is seen in the over 100,000,000 pounds of whole animal harvested. In spite of this volume, tail meat recovery (at 14%–16%) is a manual peeling operation, although several mechanical peeling designs have been tried without commercial success. The "total product" recovery approach reported here may serve as a guide in other crustacean processing operations leading to economically viable by-product recovery and application.

The premise of our investigations over the past two decades generally has been twofold, i.e., minimizing seafood waste disposal, both for crawfish as well as for shrimp, and establishing profitable markets for processing by-products through an active research and development program. The term "integrated" in the title is used to imply establishment of a multi-by-product

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Table 1. Critical factors in economically viable recovery and utilization of crawfish wastes.

Resource availability
Ease of recovery
Processing requirements
Volume and economic value
Competitive products
Applications and markets

base, varying in its economic value and application.

It is necessary to look at some of the constraints and critical factors involved in realistic projection of seafood by-product recovery such as that described in Table 1 for crawfish processing. The same constraints apply equally to other rendering industries where commercial seafood waste utilization facilities are proposed. Foremost, predictable volumes of fresh waste in a logistically feasible area is a critical consideration for establishment of an economically viable operation. In one Louisiana area alone, approximately 50 miles in radius, it is possible to recover in excess of 25 million pounds of fresh waste annually. The freshness of the waste becomes even more significant when potential food applications are being considered. Multi-product use certainly is another major advantage to allow expansion of the economic base.

EXPERIMENTAL DATA

Figure 1 illustrates the utilization concept developed in our laboratory (Meyers 1987; No 1987) and the current and potential by-products focused upon. Information such as this is needed before a realistic economic overview on product application can be developed. Each of these product areas is discussed in this paper; however, major attention is given to the pigmented oil, presently the basis of a commercial industry in Louisiana. The flavor analysis work from our department, and current efforts to recover food-grade meat from the discarded crawfish claws (now a portion of the waste), are also areas of inquiry.

Composition of Crawfish Meal and Shell

The compositions of crawfish whole meal and shell are compared in Table 2. Application of the pigmented shell with its high concentration of astaxanthin (108 ppm), as well as its potential value as a source of chitin, will be discussed. The whole crustacean meal and the

Table 2. Chemical composition of crawfish whole meal and shell.

Composition	Whole meal	Shell
Crude protein (%)	35.8	16.9
Fat (%)	9.9	0.6
Fiber (chitin) (%)	16.5	23.6
Ash (%)	38.1	63.6
Minerals		
Ca (%)	12.3	24.8
P (%)	0.8	1.0
K (%)	1.0	0.1
Mg (%)	0.2	0.3
Mn (ppm)	545	200
Fe (ppm)	1,610	180
Astaxanthin (ppm)	78	108

Table 3. Carotenoid concentrations from four crustacean meals.

Source	Pigment concentration (µg/g)
Shrimp meal (<i>Penaeus</i>)	2-10
Shrimp head meal (<i>Penaeus</i>)	31
Shrimp meal (<i>Pandalus</i>) (Vacuum-dried)	104
Crawfish meal (<i>Procambarus</i>)	137

partially extracted (spent) presscake, the latter still containing considerable residual astaxanthin, has application in many crustacean diets in aquaculture. Frequently, formulations include as much as 15%–20% shrimp or other crustacean meals if available. With significant worldwide increases in marine shrimp culture, the market will continue to utilize large volumes of crustacean meal as a source of marine protein, carotenoids, and chitin. Several nutritionists and feed formulators consider inclusion of a dietary preformed chitinous ingredient highly desirable for optimal shrimp growth and related molting activities. In Louisiana, whole or spent crawfish meal is included as a feeding attractant in crawfish trap baits.

Table 3 compares pigment concentration in crawfish meal with other crustacean meals. While *Pandalus borealis* is relatively rich in astaxanthin, we are not aware of current efforts to extract its pigment on a commercial scale. Also, the vacuum-dried process, while producing a high quality meal, is no longer op-

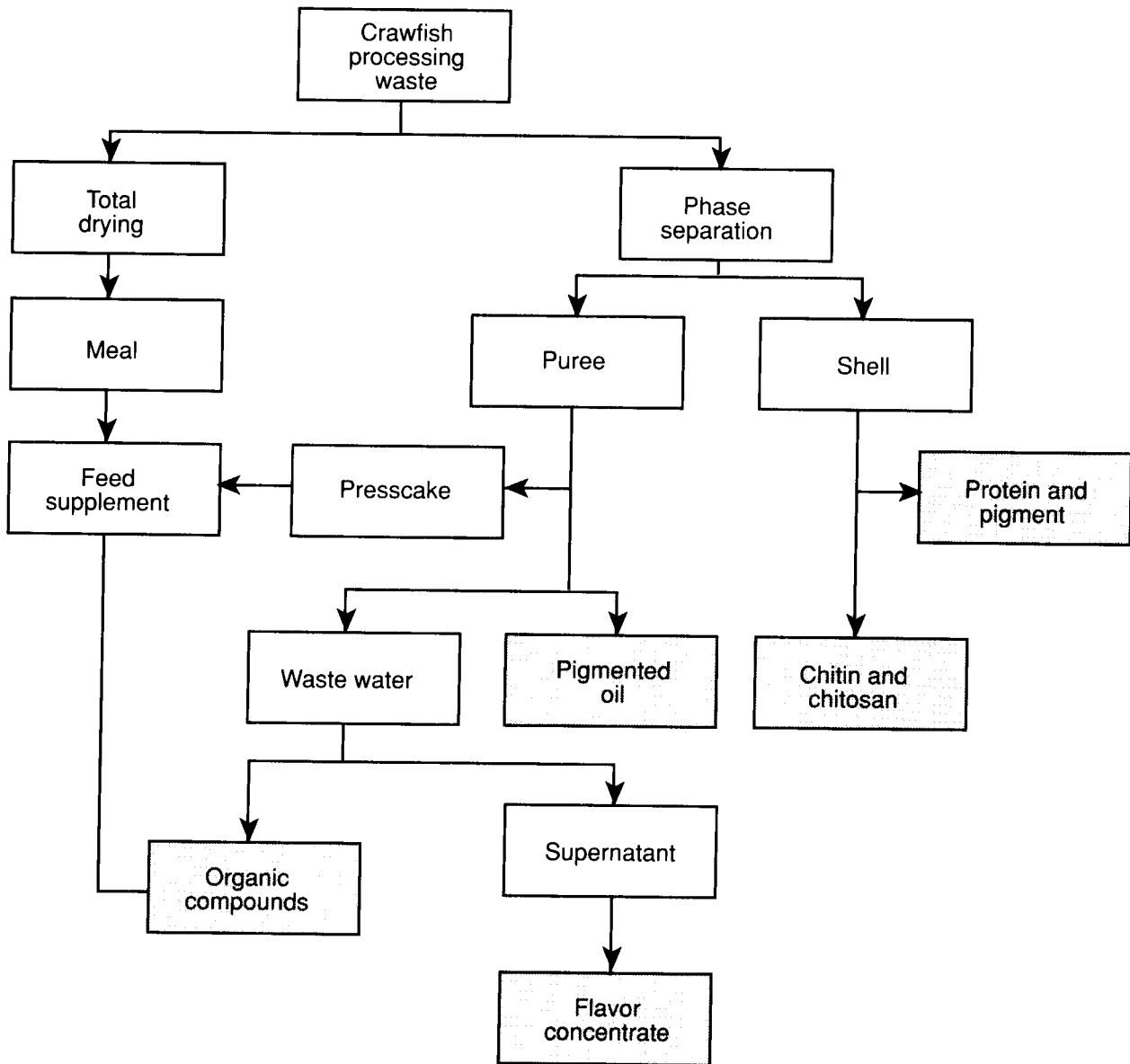


Figure 1. Total utilization of crawfish waste.

Table 4. Acid ensilage of crawfish waste prior to pigment extraction.

Increased concentration of the astaxanthin oil extract by 40–50%
Increased oil recovery by 10%
Twofold increase in free amino acid nitrogen
Reduction (70%) in exoskeleton calcium carbonate
Correlation between CaCO ₃ solubilization and pigment release in relation to silage pH

From Chen and Meyers 1983.

erative. Large volume availability of the resource in a localized area and significant seasonal fluctuations in the wild catch pose additional problems. Nevertheless, innovative approaches to utilization of this and other resources are warranted, especially if small-scale meal rendering units can be developed. This will become of greater relevance when efforts are made to utilize crustacean head waste from shrimp culture operations.

Pigment Research

Acid Ensilage of Crawfish Waste

Results of efforts to enhance pigment recovery through controlled acid pretreatment (Chen and Meyers 1983) are enumerated in Table 4. The increased concentration of astaxanthin in the oil extract is especially noteworthy. Ensilage approaches are now being evaluated on a practical basis to store ground crawfish waste at satellite facilities during the peak season (May-July), with subsequent pigment removal at the extraction plant. Comparable variable processing loads in all likelihood exist at other crustacean facilities and must be considered in projections of efficient by-product recovery. Crawfish waste is extremely reactive due to high concentrations of proteolytic enzymes and must be used fresh or properly preserved to avoid decomposition.

Astaxanthin Extraction

The patented process (Meyers and Chen 1985) for recovery of the valuable astaxanthin pigment is illustrated in Figure 2 and is further discussed by Chen and

Table 5. Crawfish waste and pigment recovery research.

Waste utilization in crustacean feeds and attractant in crawfish baits (Meyers and Thibodeaux 1984)
Pigment characterization of waste (Meyers and Bligh 1981)
Development of soy oil pigment extraction process (Chen and Meyers 1982a)
Ensilage treatment of waste (Chen and Meyers 1983)
Effect of anti-oxidants on astaxanthin stability (Chen and Meyers 1982b)
Color stability in astaxanthin pigmented rainbow trout (Chen et al. 1984)
Analysis of crawfish oil extracts (Omara-Alwala et al. 1985)

Meyers (1982a). In essence this comprises a controlled release of the carotenoid into an oil phase, using either a vegetable (i.e., soy) or a fish oil. The initial grinding through a vertical attrition mill is essential to properly size the puree fraction and to remove up to 10% (by weight) of the shell portion. This ratio can be adjusted according to screen size used, and varies with the crustacean species. The recovered pigmented shell has special applications because of its carotenoid-protein-astaxanthin complex. The efficiency of the process will vary with the oil used and the stages of extraction. While pigment extraction may be somewhat higher in fish (menhaden) oil, soy oil is currently being used as stipulated for the Japanese market. A final terminal polisher has been installed to further enhance stability during storage and shipment overseas.

Carotenoid concentrations from crawfish, red crab, and shrimp meal are noted in Figure 3. Red crab was the focus of considerable studies in the late 1970s (Spinelli and Mahnken 1978); however, the current limited availability of this resource precludes its use as a commercial source of astaxanthin. Single-stage oil extractions of crawfish waste average from 750 to 1,300 ppm. Concentrations in the range of 1,500–1,700 are obtainable with two-stage extraction (Chen 1981). It does not appear to be economically feasible to proceed beyond the second extraction stage. Pigment concentration is a reflection of seasonal development of the crawfish and use of young vs. older animals, the latter with a deep-reddish, highly calcified exoskeleton. Astaxanthin concentrations as high as 2,000 ppm have been obtained at certain periods of the year.

The majority of our composite pigment-related

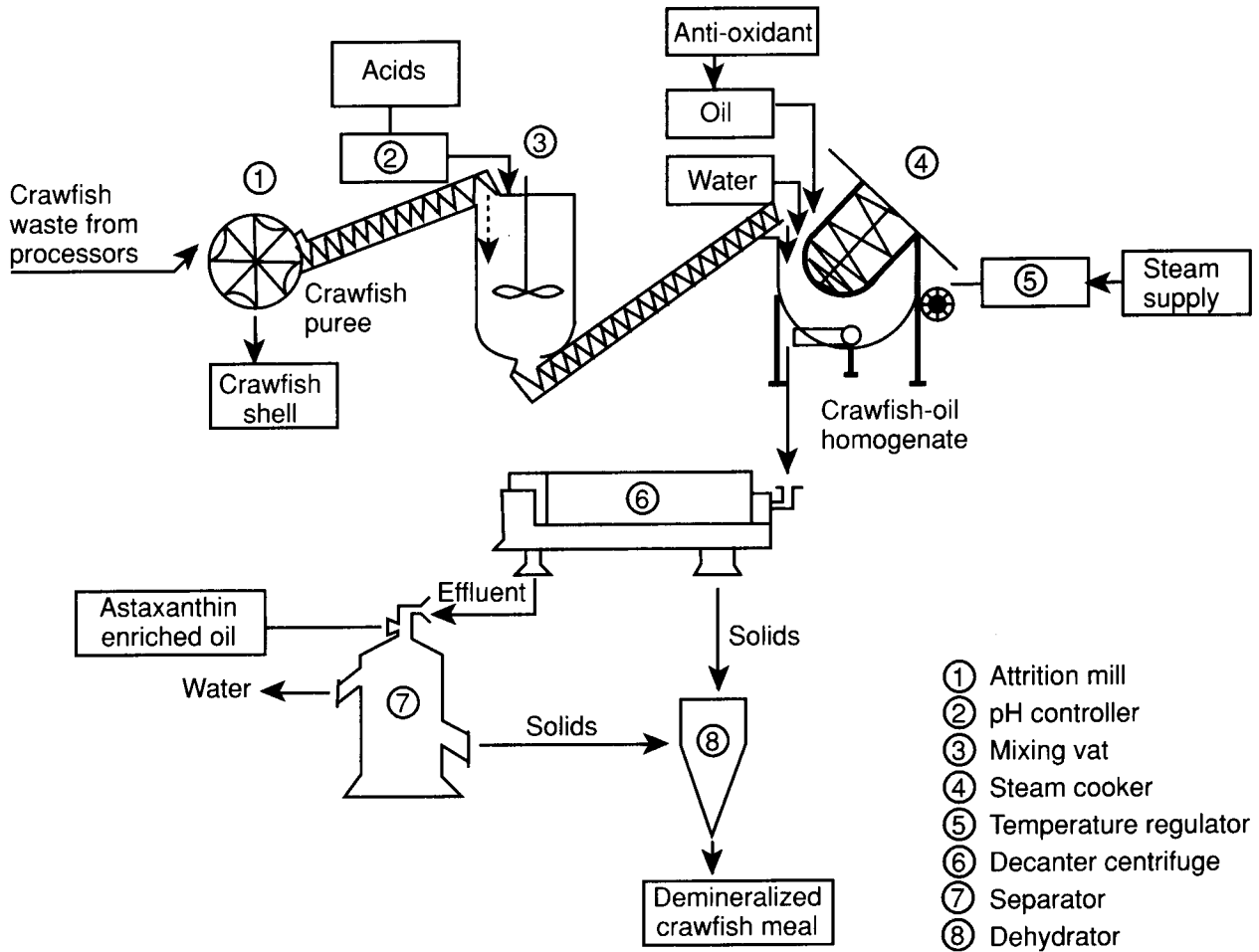


Figure 2. Flow diagram of crawfish astaxanthin extraction process.

investigations, in progress since 1976, have been published and are generally summarized in Table 5. The importance of a sound research and development program cannot be over-emphasized.

The crawfish carotenoid astaxanthin (3,3'-dihydroxy-4,4'-diketo- β -carotene) currently is being utilized in Japan as a natural red intensifier for the large commercial red sea bream farming industry in that country. Astaxanthin has widespread application in aquaculture (Meyers and Chen 1983) and the role of carotenoids in salmonids has been extensively investigated (Torrissen et al. 1989). Natural astaxanthin is especially desired in Japan where the crawfish-derived carotenoid has found a ready market because of regulatory restrictions on use of synthetic colorants in food products. However, serious competition from synthetic astaxanthin and the potential impact of the pigment

derived from the yeast *Phaffia rhodoxyma* (Johnson 1989) in other world aquaculture markets must be considered in this decade.

Analysis of Crawfish Oil Extracts

A few observations on the crawfish pigment are in order, notably the composition of the pigment and the concentrations from the extraction process. The majority of the pigment is in the mono- or di-ester form, with considerable variation in concentrations obtainable (Omara-Alwala et al. (1985). The extraction process results in a pigmented oil rich in omega-3 fatty acids and sterols, in all likelihood enhancing its value as an ingredient in aquaculture diets. Analyses reveal as much as 8% linolenic acid (18:3 omega-3) and a high proportion of other long-chain polyunsaturated fatty acids, i.e.,

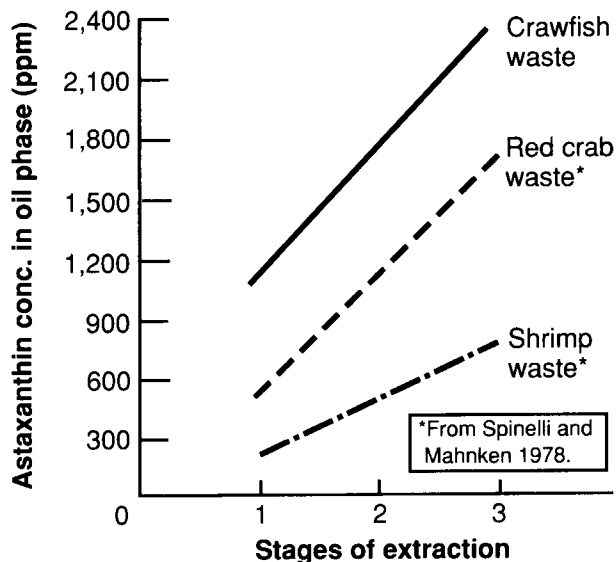


Figure 3. Carotenoid concentrations from oil extraction of different crustacean meals.

20:5 omega-3 (2.3%) and 22:6 omega-3 (1.5%). Sterol levels of 5.9 μg per mg have been obtained. Such enriched, or further fortified, pigmented oil may possess a competitive advantage in specialized markets.

Chitin-Chitosan

As part of our investigation of crawfish waste, we have given considerable attention to isolation and characterization of the chitin component (No 1987; No et al. 1989). Crawfish shell waste is an excellent source of chitin, 23.5% on a dry weight basis (Table 2). Most efforts to isolate chitin from crustacean processing operations have been with shrimp and crab waste shell (Johnson and Peniston 1982). While chitin and chitosan currently are not being produced in the commercial crawfish pigment recovery process, considerable interest has been shown, and the economics may justify a combined cost-efficient integrated approach. In the interim, a good data base on crawfish chitin-chitosan has been established in our laboratory with special emphasis on the nature and biological efficiency of the chitin-carotenoid complex.

The procedure used for isolation of crawfish chitin is shown in Figure 4, and its characterization noted in Table 6. The presence of small residual amino acids in the final product indicates that protein is bound by covalent bonds to chitin, forming a stable complex. The astaxanthin-chitin bond is difficult to break. It may be

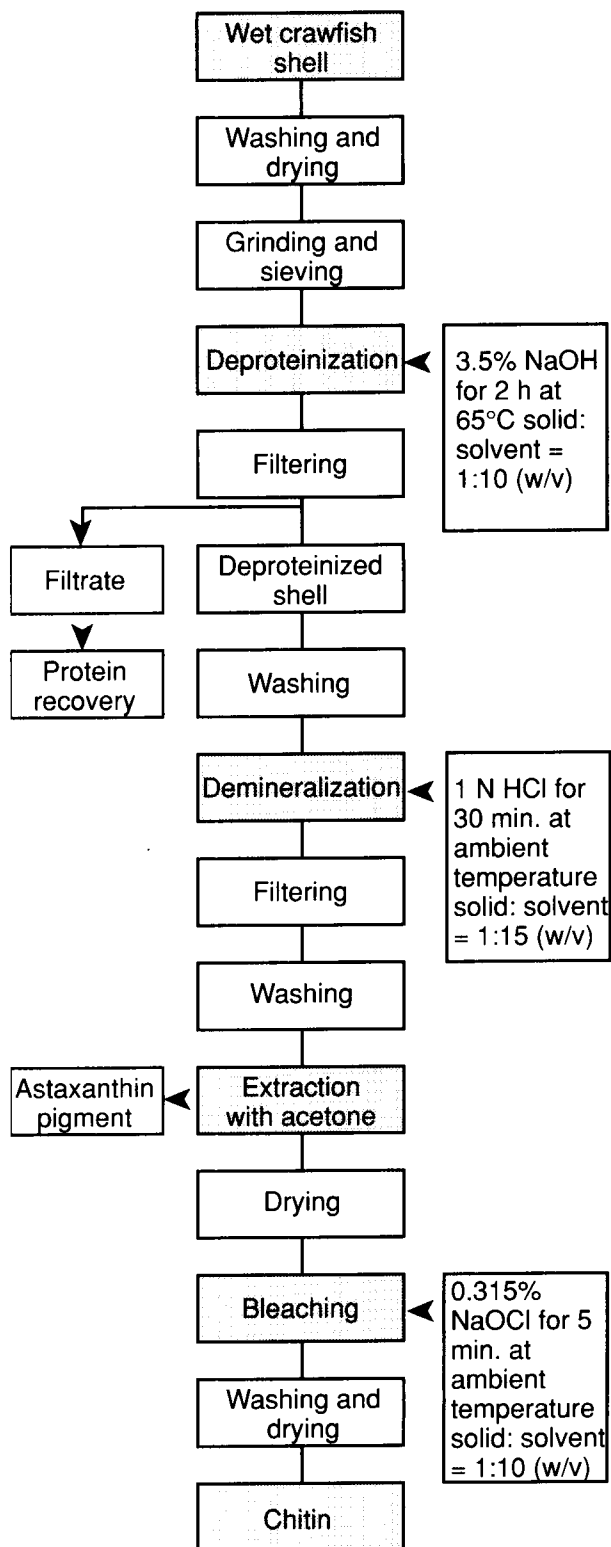


Figure 4. Preparation of crawfish chitin.

Table 6. Characterization of crawfish chitin.

Specification	Description
Nitrogen (%)	7.01
Fat (%)	ND ¹
Ash (%)	0.1
Acetyl (%)	19.6 ²
Deacetylation (%)	7.5
Solubility (%)	26.4 ³
Color	white
Residual amino acids (mg/g)	6.5

¹ND = not detectable.

²Theoretical value = 21.2%.

³N,N-dimethylacetamide containing 5% LiCl.

more economically feasible to produce a pigment-rich chitinous product for specialized markets. Animals with active indigenous or constitutive chitinase enzymatic systems, or with chitinolytic gut bacteria, can readily utilize the astaxanthin at very low concentrations (Lee 1985). Several investigations are being done on use of the astaxanthin-chitin complex as a composite pigmentation source in poultry diets. Application as a biologically active substrate in aquaculture diets is another possibility. In culture of some shrimp species, especially the giant tiger prawn *Penaeus monodon*, workers in the Philippines have reported that astaxanthin supplementation is required to maintain optimal exoskeleton coloration, a factor of importance in some world markets. Furthermore, astaxanthin appears to facilitate prawn physiological processes under low oxygen conditions, possibly serving as a free-radical capture agent comparable to vitamin E.

From a chemical point of view, there are two distinct structural units in the crustacean shell: an acidic polypeptide fraction with a strong affinity for calcium ions (mineralization matrix), and a high molecular weight chitin-protein complex (carrier protein) with no affinity for calcium, arranged in the form of sheets. There are several potential sites in the chitin-polysaccharide polymer where covalent binding can occur, but binding to these sites has not been confirmed. Dissolution of chitin composites is accompanied by degradation of both the protein and chitin components; thus,

Table 7. Percent recovery of amino acids

Amino acid	Am-Cu-chitosan ¹	Am-Cu-chitosan and chitosan
Aspartic acid	85	82
Threonine	93	90
Serine	84	77
Proline	21	9
Glutamic acid	77	79
Glycine	15	71
Alanine	47	89
Valine	51	37
Methionine	79	75
Isoleucine	54	57
Leucine	62	63
Tyrosine	86	84
Phenylalanine	86	86
Lysine	49	36
Histidine	59	63
Arginine	73	72

¹Am-Cu-chitosan = amino-copper-chitosan.

efforts to ascertain the structure of binding sites by solution techniques have not been successful. Astaxanthin is ionically bonded to chitin. There is a well-established stoichiometric relationship between astaxanthin, as a prosthetic group, and protein for carotenoid attachment sites. In order to comprise a prosthetic group, astaxanthin and astaxanthin ester have free carbonyl groups in 4 and 4' positions on the terminal ionone rings. Further studies of these units should shed information on the apparent biological efficiency of the astaxanthin-chitin complex.

Chitosan-Related Investigations

Further chitin-chitosan research has involved development of recovering the organics, especially amino acids, from the oil extraction processing discharge stream (No and Meyers 1989a, 1989b). The percent recovery of amino acids at pH 8 using this analytical approach is given in Table 7. Recovery efficiency is pH-dependent, with lower efficiency yield at higher pH values. The eluate was completely free of copper ions from the initial copper-chitosan column when treated with a second crawfish chitosan column. Once the second column is saturated with copper ions, it can be used effectively as the initial column for primary sorption of amino acids from the supernatant. The amino acids recovered by this treatment have potential product-related applications.

Table 8. Comparison of amino acid composition of coagulated solids from crawfish waste-water with shrimp waste protein.

Amino acid	Content (mg/g)	
	Crawfish	Shrimp ¹
Aspartic acid	61.6	63.4
Threonine	21.1	25.3
Serine	19.1	26.7
Proline	11.5	20.3
Glutamic acid	121.3	91.2
Glycine	17.2	25.3
Alanine	43.0	31.2
Valine	22.7	26.1
Methionine	10.1	16.8
Isoleucine	13.7	19.2
Leucine	48.1	44.6
Tyrosine	16.3	21.4
Phenylalanine	18.8	26.9
Lysine	35.5	36.4
Histidine	8.1	11.2
Arginine	43.5	37.2
Total	511.6	523.2

¹From Toma and Meyers 1975.

Related work (No and Meyers 1989a) has focused on application of isolated crawfish chitosan as a biodegradable coagulant in the waste stream from the pigment extraction plant. The crawfish waste stream is an organically rich source of recoverable products. The proximate composition of the coagulated solids was 27.1% crude protein, 51.7% fat, and 3.3% ash. Table 8 shows amino acid composition compared with shrimp waste protein. The extremely high levels of glutamic and aspartic acid are especially noteworthy. Together with leucine, arginine, and alanine, these five amino acids accounted for 62% of those present in the coagulated solids. A nutrient-rich chitosan coagulate has numerous potential applications as a feed additive, especially since several of the amino acids are known flavor appetite stimulants. Absence of large levels of inorganics, especially iron and aluminum, in the crawfish chitosan-separated solids, and the biodegradable nature of the polymer are worth noting.

The effectiveness of the crawfish chitosan as a polycationic coagulant in turbidity reduction has been examined and demonstrated to be equivalent or superior to the commercial chitosans and synthetic polyelectrolytes (No and Meyers 1989a).

Applications as Pigmenting Sources

Most recent work has involved examination of the crawfish shell as well as attributes of the pigment-shell and pigment-chitin complex. Current research has focused on the pigmented shell itself, recovered in the initial separation process (Figure 2), or from the spent meal. The latter still has a notable concentration of astaxanthin present in its shell.

Research with crawfish by-products has looked at potential applications in the poultry industry, both in laying hens and in broiler diets (Lee 1985). For use of the crawfish pigment in its various forms as an egg yolk pigment, experimental test diets were developed varying the ratio of yellow corn to concentration of astaxanthin (ppm) from three different sources. The concentration of astaxanthin in the crawfish whole meal was 82 ppm, in the pigmented shell 97 ppm, and in the pigmented soy oil 350 ppm. Total concentration of lutein in the yellow corn meal was 15 ppm. The latter is slightly lower than the average concentration (22 ppm) of lutein in yellow corn.

The effect of the crawfish astaxanthin source on the color score of egg yolks is shown in Tables 9 and 10. All three dietary sources, i.e., whole meal, pigmented oil, and pigmented shell, imparted significant egg yolk pigmentation even at astaxanthin concentrations as low as 1 ppm using comparatively low levels of yellow corn. To achieve the optimal target egg yolk color score (a yellow-orange hue most desired by U.S. consumers) of 10–11, produced by 51% yellow corn meal in the diet, levels of this meal as low as 20% can be effectively combined with crawfish astaxanthin at a final 1 ppm concentration. Thus, as much as 30% yellow corn meal can be spared by use of the crawfish pigment.

As shown in Table 10, crawfish astaxanthin is biologically available even at concentrations as low as 1%. The value of the pigmented shell is especially noteworthy. Probably this is due to differences in the biological availability of the shell pigment product (a calcium-chitin-astaxanthin complex) for laying hens with both indigenous and induced active chitinolytic enzymes in their digestive tract. Work with rainbow trout has shown that fish fed carotenoid-protein diets, compared with those containing free pigment, exhibited greater pigmentation rates.

Organics and Flavor Compounds

Most recent research from the Louisiana State University Food Science Department documents yet another facet of potential by-product recovery, namely that of several volatile flavor compounds in crawfish waste and in the tail (Vejaphan et al. 1988; Tanchotikul

Table 9. Fletcher color score of egg yolks.

Yellow corn %	Concentration of astaxanthin (ppm)					
	0	1.0	2.5	5.0	7.5	10.0
0	ND	*	1	1	15	15
10	ND	6	13	14	14	14
20	5	10	11	13	14	15
30	7	10	11	13	14	15
40	7	10	12	14	14	14

ND = not detectable.

*Out of scale.

Table 10. Effect of astaxanthin source on Fletcher color score of egg yolks.

Yellow corn %	Source	Concentration of astaxanthin (ppm)					
		0	1.0	2.5	5.0	7.5	10.0
0	P	2	13*	14*	14	14	15
	S	2	13*	12*	15	15	15
	W	2	13*	13*	13	14	14
10	P	5	10	13	14	14	15
	S	5	10	14	14	14	15
	W	5	11	13	14	15	15
20	P	5	10	11	14	15	15
	S	5	11	12	14	15	14
	W	5	10	11	14	14	15
30	P	9	10	12	13	14	14
	S	9	11	13	14	15	15
	W	9	11	13	14	14	15
40	P	9	11	12	14	14	15
	S	9	12	13	14	14	15
	W	9	10	12	14	14	15

P = pigmented oil, S = pigmented crawfish shell, W = whole crawfish meal.

*Faint color.

and Hsieh 1989). A total of 70 volatile compounds have been characterized in the tail meat and over 117 identified in the processing waste. Some of the more desirable aromas may be contributed by the claw meat component of the waste. Careful selection and recovery of important authentic crawfish flavor components from the abundant waste resource may further enhance its composite economic value.

SUMMARY

Clearly, the designation "waste" is a misnomer when it refers to recoverable and usable by-products

from seafood processing operations. Prudent examination of the composition of the processing material, traditionally discarded or used for composting or minimal cost feed or fertilizer, can reveal profitable alternatives leading to valuable products of commerce. More integrated approaches, such as utilization of Louisiana crawfish processing by-products, are needed to accurately address resource needs of this decade.

ACKNOWLEDGMENTS

The research reported was supported by the Louisiana Sea Grant College Program, NOAA, U.S. Depart-

ment of Commerce, grant number NA85AA-D-SG141, project number R/SST-9.

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QUESTIONS AND ANSWERS

- Q. Recently a natural source of astaxanthin has been discovered, from a yeast *Phaffia rhodoxyma*.
- A. Yes.
- Q. Have you made some comparison about your production and the potential impact of this new technology in the production of astaxanthin?
- A. Yes, I'm familiar with *Phaffia rhodoxyma*, and I think it is a potential competitor in the world market. At this time, I do not believe it is being used commercially. There is pilot production of it. We also must point out that there's a giant out

there, namely Hoffman-LaRoche, that is producing a synthetic astaxanthin. I haven't had a chance to compare it. But as I pointed out at the beginning, part of the homework is to establish your specific market. The people from Japan who are now utilizing astaxanthin pigment worked with this Louisiana company for three years before going into production. We have now established a five-year contract. There is no guarantee that the market we have today will be the same one in five years. But that's one of the reasons we're setting up a multi-product base, and I think it is very foolish if one doesn't do it.

Within five years we may find that the pigmented chitin or that the chitin-chitosan people suddenly say, "Hey, we have an economic base now. We can come into this company, and we can produce chitin-chitosan at half the cost. And why don't we think about a pigmented chitin for a large part of an industry." Yes, I agree with you, there are competitors, but there's an advantage to a natural pigment.

And there's one other point I want to make. I encourage those people, particularly in the Atlantic

salmon industry and the culture industry. I know it doesn't exist in Alaska, but certainly in other states, small producers are going to look for the consumer image of all natural pigment, no additives. And I feel that with the environmental thrust, the image of total recovery of food and feed grade products from natural resources is going to have tremendous appeal.

- Q. What is the concentration actually delivered in the red bream feed?
- A. We can produce pigment with a two stage extraction, depending on the season, as high as 1,900 ppm. We can regularly get 800 ppm with a single stage extraction. We are now running a two stage extraction where we can get about 1,300 to 1,400 ppm. But we have found earlier that with enzyme, a proteolytic enzyme treatment, we can get a greatly enhanced pigment recovery by a mild solvent extraction. This company right now is making money and producing pigment without any of the technological innovations. But as the market tightens we could always shift to those so that there's always that possibility. We're talking about 1,300 to 1,500 ppm.

PRODUCT RECOVERY FROM SURIMI WASH WATER

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OBJECTIVE

The objective of this research project was to test and develop membrane filtration systems suitable for recovery of fish protein currently lost in the wash water and the dehydrator water, and to explore potential uses for the recovered protein fraction.

BACKGROUND

In processing Alaskan pollock into surimi (Figure 1), a substantial amount (approximately 30%–40%) of the protein (fish meal) is lost in the washing and dehydration operations. If this protein could be recovered, a better product utilization would occur, the environmental impact from the disposal of the waste water would be reduced, and the fresh water demand could be reduced through the recycling of the process waters.

With this potential in mind, the National Marine Fisheries Service entered into a cooperative agreement with the National Food Processors Association to investigate the potential of applying membrane technology for recovery of by-products from the process water.

INDUSTRY COOPERATION

To ensure the maximum benefit from this undertaking, an industry advisory committee representing the processors and the membrane system manufacturers was formed. This committee has met throughout the project period for selection of test sites, review of test plans, and evaluation of results, and has provided valuable input to the project.

The initial testing in National Food Processors Association laboratories and pilot plant showed, not unexpectedly, that in order to obtain representative process water for testing, it would be necessary to perform the test at a plant site. Based on the committee's recommendation, tests were carried out at three

different plant sites in Alaska, each having slightly different operations.

If the protein fraction from the dehydrators can be utilized for addition to surimi, the payback becomes very attractive. Initial testing indicates that 5%–10% might be possible, but further developments are needed. Recovery of suspended solids from dehydrators by means of decanter centrifuge produces a fraction with characteristics like surimi; this has a very attractive payback even if no other recovery takes place.

SCOPE OF STUDY

The study had the following objectives.

By means of ultrafiltration membranes:

1. Recover protein from surimi process water.
2. Reduce waste-water impact on the environment.
3. Explore potential for recycling of process water.

Investigate potential for utilizing recovered product:

1. Adding back to surimi.
2. Fish meal.
3. High-grade fish meal.
4. Ingredients and other uses.

Membrane Study

During the course of the study, tubular and plate-and-frame membrane system configurations were tested. After the initial phases of testing, the plate-and-frame configuration was selected as the system most capable of handling the highly viscous product in an economically feasible manner. Even with this system, it was necessary to operate at significantly higher flow rates than normal in order to reduce protein buildup on the membrane surfaces; this will increase electrical cost for pumping. Prefiltration in a decanter centrifuge seemed necessary to reduce or eliminate product buildup in pumps, fittings, and membrane channels.

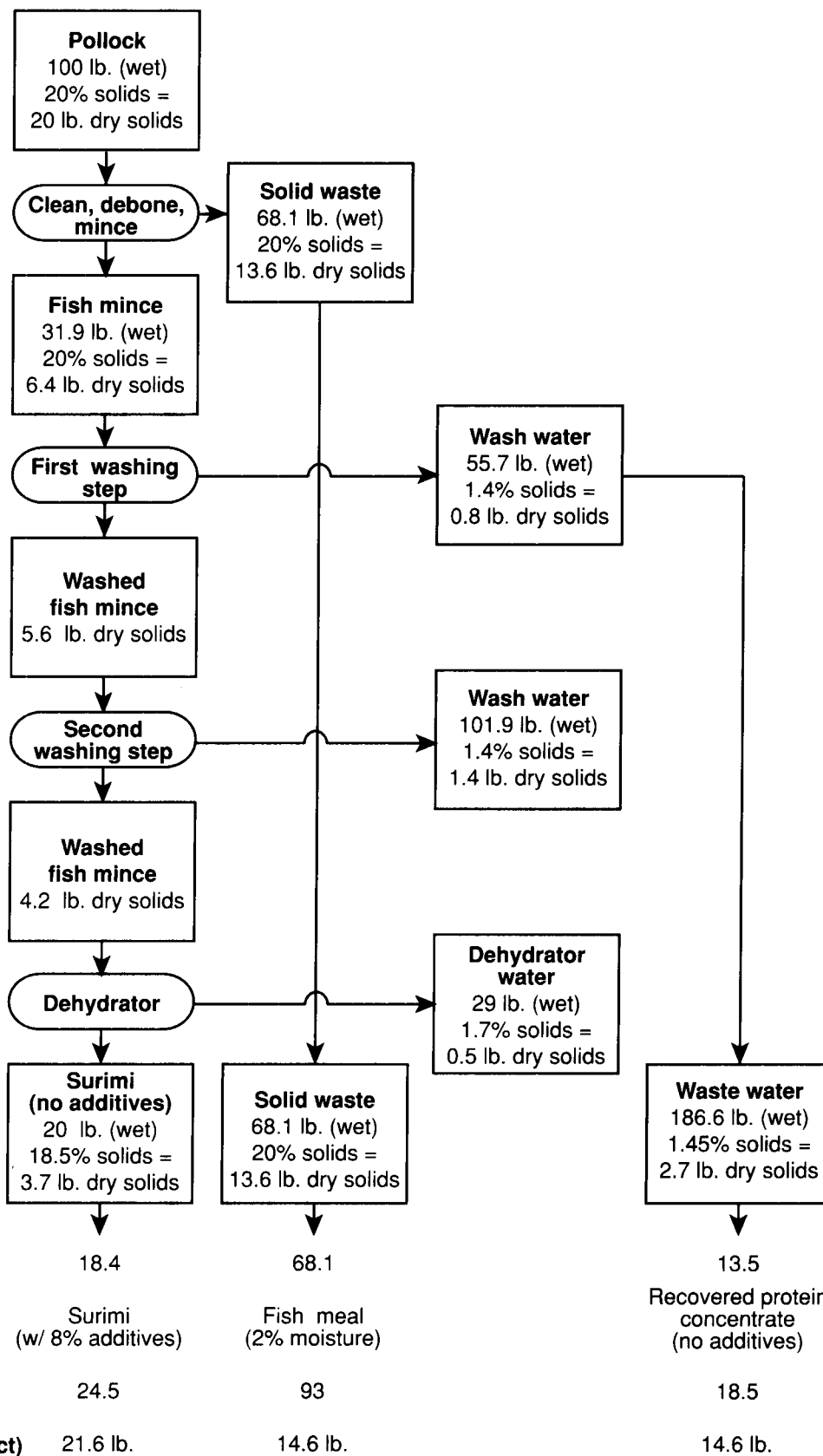


Figure 1. Surimi processing diagram showing mass balance and potential recoveries.

However, the added cost of installing the decanter centrifuge for the removal of suspended solids from dehydrator water would be justified by the additional product recovery when the suspended solids were added back to the surimi line.

Membrane Selection

A total of nineteen membranes of various materials and selectivities were tested under plant conditions. The best performing membrane was a "regenerated cellulose" membrane whose slightly hydrophilic character reduced the tendency of material to adhere to the membrane surface. Other membranes, such as polysulfone, showed a slightly lower performance.

Tests involving different pore sizes (molecular weight cut-off) showed little difference in performance, probably due to development of a product layer on the membrane surface (generation of a dynamic membrane) which acted as the determining membrane for molecules retained. A membrane with molecular weight cut-off of 10,000 was judged to be slightly better than the rest and was used for the long-term testing.

Cleaning

Cleaning with commercial detergent cleaners at pH 11–12 was sufficient to restore fluxes with more dilute fluids and shorter operating periods. However, after extended periods of operation and/or high concentration levels (>16% solids), cleaners with protein-degrading enzymes (proteases) and elevated temperatures (80°–130°F) were necessary to clean the membranes and restore fluxes.

Product Evaluation

Protein content of the recovered protein concentrate was lower than that of whole pollock, but it was about 80% of the solids. (Whole pollock proteins are about 89% of the solids; process water protein before membrane filtration is about 66% of the solids.) Membrane filtration served to remove ash from the process water; in the recovered protein concentrate the ash was only about 3% of the solids, compared to 6% for whole pollock, and 17% for process water before the membrane filtration. Amino acid composition of the recovered protein concentrate was similar to pollock and surimi. (Heating of the concentrate brought the color closer to that of surimi.) Gel strength of recovered protein concentrate with and without added salt were comparable to second grade surimi, but it was more brittle.

Product Utilization

Adding Recovered Protein Concentrate to Surimi

Product recovered from the dehydrators was added to surimi at levels ranging from 5% to 20% product. Initial testing showed that adding up to 10% product resulted in no measurable decrease in gel strength of surimi. Storage at the 10% level showed satisfactory folding tests after two months. After six months of storage, the product had become more brittle and less elastic; however, it would still meet the standards for second grade surimi. The blend developed a fishy odor, which will need to be addressed before commercialization. The product color was stable over time, but slightly more yellow than second grade surimi.

Fish Meal

If the recovered product is added to fish meal, the high protein content in the recovered fraction seems sufficient to increase the overall protein level of the fish meal (including bones) to 65%.

High-Protein Fish Meal

A lobster feeding study was carried out to explore the potential of the recovered product as aquaculture feed. The composition of amino acids and high protein concentration indicate a good potential; however, this feeding study did not give satisfactory growth rates.

Specialty Products

The product was evaluated by some of the major meat processors. The indications are that the recovered fraction might have several potential uses due to its unique gelling properties. However, the lack of availability of the product makes product development less likely in the near term.

Drying of Recovered Protein Concentrate

Drying of the product may open up a variety of potential uses. A few experiments were run. It appears that the recovered protein dries satisfactorily. It is brittle and flaking with a brownish appearance. If dried at temperatures below 50°C, it can be rehydrated, absorbing 80%–90% of the amount of water removed by drying. It retains some of its gelling properties.

Waste Water

The analysis of the permeate (filtrate) from the membrane system indicates that it will meet fish meal plant effluent requirements, which are among the most stringent.

Denaturation

The results indicate potential feasibility of recovering by pH adjustment (to pH 5–5.5) plus heat (about 80°C). These tests were carried out on a very small scale, and it was not possible to test settling or centrifugation as a separation technique. It is difficult to comment on the separation that might be obtainable on a larger scale, but the results may still be quite acceptable considering the high recovery level obtained in these tests.

Economics

Utilizing the recovered fraction for fish meal supplement seems to result in a reasonable payback. If benefits from avoided waste water treatment cost can be incorporated, the payback becomes even more attractive (estimated at less than a year).

QUESTIONS AND ANSWERS

- Q. Did you have a prior treatment to remove the solids from the effluent before going through the membrane, rather than putting all the pressure on the membrane itself?
- A. We use decanter centrifuging which takes out the suspended solids.
- Q. And what then is left? In other words, what I'm really saying is that you may not be able to get all the squeal out, but is it possible that one may have a modified approach to at least recover what would be economically viable?
- A. We take out the suspended solids because if you can take it out in the centrifuge, it's a lot cheaper. It should be done that way. So we are only talking about the soluble solids, and again since we are

working with this 50,000 molecular weight membrane, we are talking about fairly big molecules, molecules that can be coagulated and have certain physical properties. We're not talking about the low end of it.

- Q. What was the price that you were basing the 2.3 return on?
- A. I'm basing it on \$800 a ton of fish meal for a couple of reasons. First, that was the price at the time we did the economical calculation. Second, with 80% protein and 3% ash, if you make the mass balance on the whole thing you should be able to get a protein out that meets the 65% commercial grade, and you won't have to take any bones out. If our numbers are right, it should not be necessary to take any bones out. That's why I used a high fish meal price.
- Q. Two questions. One, have you evaluated the quality of the protein through any type of feeding studies? Is it equivalent to surimi? Is it equal to egg? What is it equivalent to? Have you done any nutritional studies on it?
- And second, have you tried spray drying it?
- A. I'll start with the last one. No, we have not tried to spray dry it. If we could get a hint of what it could be used for, then we could start working on the drying procedure.
- A. (John French) It's a very highly soluble protein. It contains significant amounts of actomyosin and other myofibrillar proteins, and of course contains many insoluble proteins. There appears to be very little protein denaturation occurring during this treatment process. In other words, it appears by all measures I've used so far to be a very high-quality, highly viable available protein.

STRUCTURE FORMATION DURING PRODUCTION OF FOOD ANALOGS

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Gel formation is the basis of a technology for determining the structural properties of analog food products. The gel formation capability of surimi has been extensively studied and depends on many factors (Dudziak et al. 1988, Kim and Lee 1987, Babbitt and Reppond 1988, Hennigar et al. 1988, Lee 1987, Niwa et al. 1988). One of these factors is the preliminary "sol keeping" properties, also called "setting." It is known that setting influences the strength and elasticity of thermoprocessed gel (Nishimoto et al. 1987).

The main objective of our investigations is to study the process of gel formation and variations in structural-mechanical properties of the formulation, which appear at setting (Sawari in Japanese literature).

METHODS

The formulation consisted of: Alaska pollock specified mince, 71.5%; squid fillet, 7.1%; potato starch, 5.0%; egg protein, 5.7%; water, 5.7%; common salt, 2.0%; and other flavor additives, 3.0%.

The formulation was prepared by grinding for 25 minutes. Samples 20 mm thick were packed into plastic film. Setting was carried out in an ILKA temperature chamber in a steam and air medium. Samples were removed after 30 minutes.

Gel formation was assessed by the quantity of water pressed from the samples and by the breaking strength of samples that were thermoprocessed at 90°C for 15 minutes. The quantity of pressed water was expressed in percent of the sample mass. Breaking force was determined by a rheometer "food-checker." The ultrastructure of samples was examined by electron microscopy of EMV-100L-type (Miyake 1965).

RESULTS AND DISCUSSION

Investigations of gel formation during setting of the formulation carried out at 15°, 20°, 30°, and 40°C have shown that gel formation over time is accompanied by a decrease of pressed (weakly bonded) water (Figure 1). Weakly bonded water becomes part of the structure.

As seen from Figure 1, the most water was bound at 20° and 30°C. At 30°C, setting was complete in 120 minutes, whereas at 20°C, setting required 180 minutes. The most rapid binding of water took place at 40°C (complete in 60 minutes), but that temperature was least effective.

As seen in Figure 2, setting (Sawari) depends on time and temperature. The strongest gel formed at 15°C and the weakest at 30°C. When gel strength was plotted against time, the asymptote was approached at about 90 minutes for all temperatures. Nishimoto et al. (1987) found a peak gel strength at 25°C and decreased gel strength with increased temperature.

Our results could be explained by a presence of sarco-plasmatic and other proteins in the formulation that were not influenced by the process of gel formation at lower temperatures. Thus, the presence of proteins, which have different links and serve as the gel matrix, could influence the quality of the initial formulation, and the character and properties of gel formation.

The results of organoleptic investigations during chewing found the most acceptable and similar properties were those samples setting at 15°C for 120 minutes and at 40°C for 30 minutes. The similar organoleptic properties may be explained by the quantities of water retained in the gel structure during setting, very similar for these two sets of samples.

The investigation of ultrastructure of the above samples has shown that the formation of areas with small granular structure is found in samples setting at 40°C within 30 minutes (Figure 3a and 4a) and the formation of areas with dense cell structure is found in samples setting within 120 minutes at 15°C (Figure 3b and 4b) (Sato et al. 1984). The character of gel structure

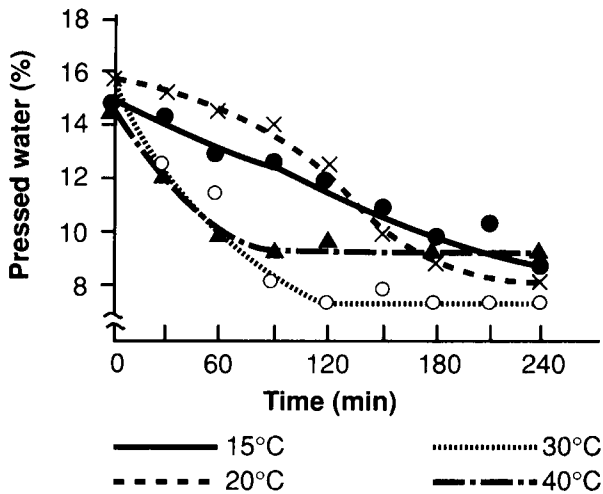


Figure 1. Changes in pressed water extruded as a function of setting regime.

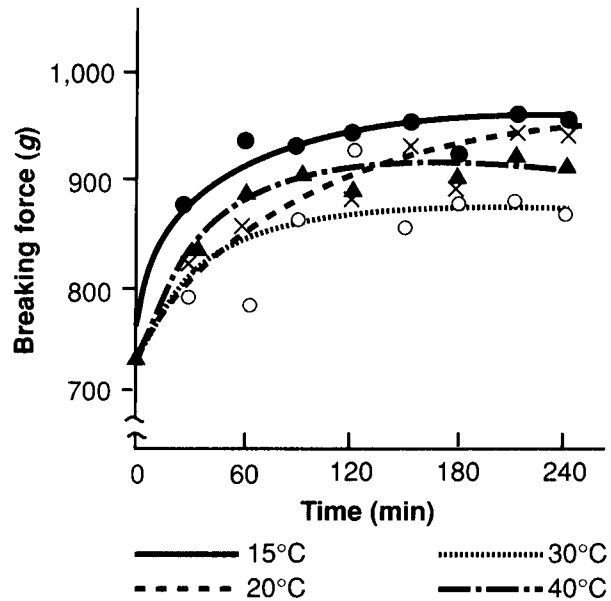


Figure 2. Changes in breaking force of samples as a function of setting regime.

Table 1. Gel structure character and strength after thermoprocessing.

Setting regime		Gel structure	Breaking force (g)			Pressed water(%)		
°C	minutes		\bar{x}	S	S ²	\bar{x}	S	S ²
15°	-	blurred	653.3	43.6	1900	17.4	0.7	0.49
15°	120	cell	716.2	26.3	708.9	12.6	1.1	1.21
40°	30	small-granular	689.0	19.1	365.6	13.5	0.2	0.04

\bar{x} = arithmetical average.

S = standard deviation.

S² = dispersion.

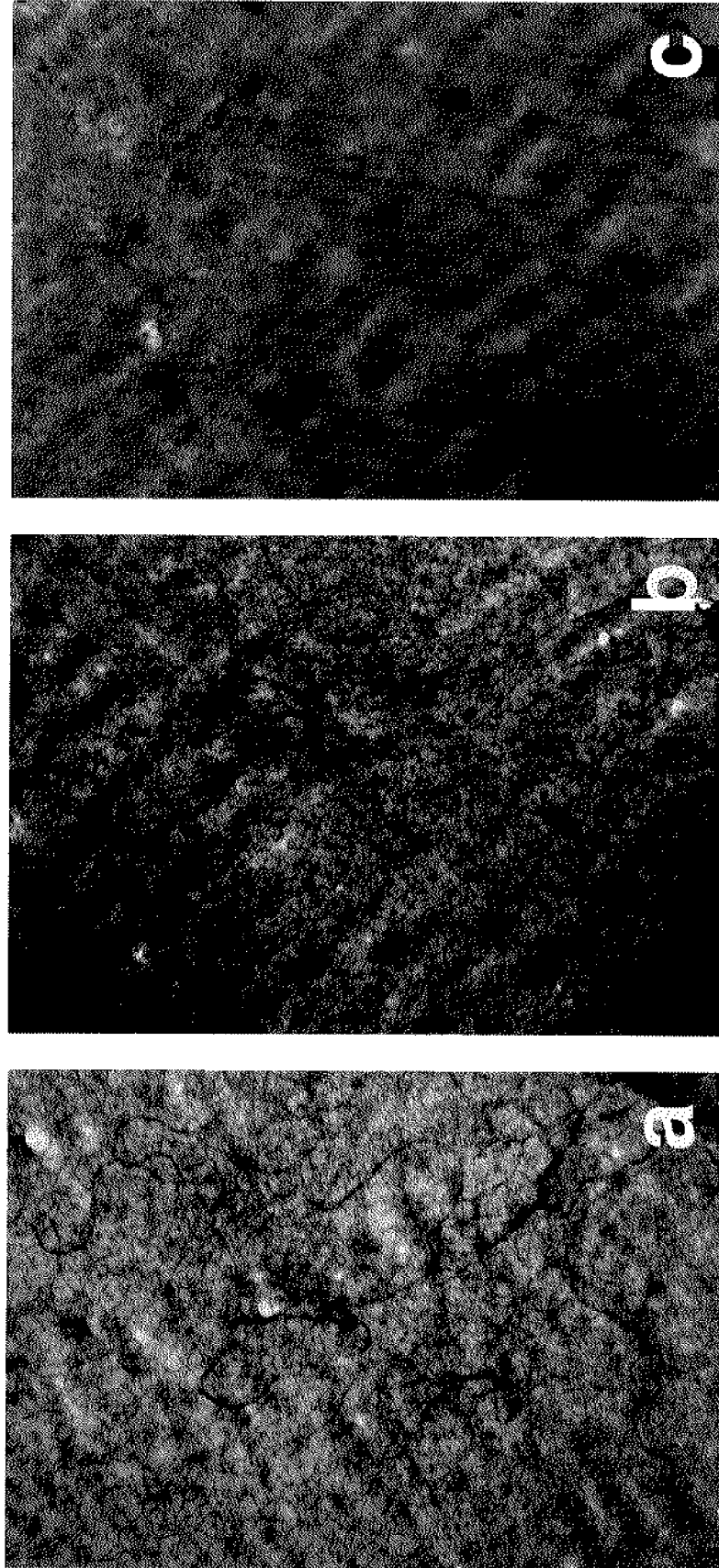


Figure 3. Ultrastructure of formulation samples. (a) Set at 40°C, 30 min. (b) Set at 15°C, 120 min. (c) No setting.

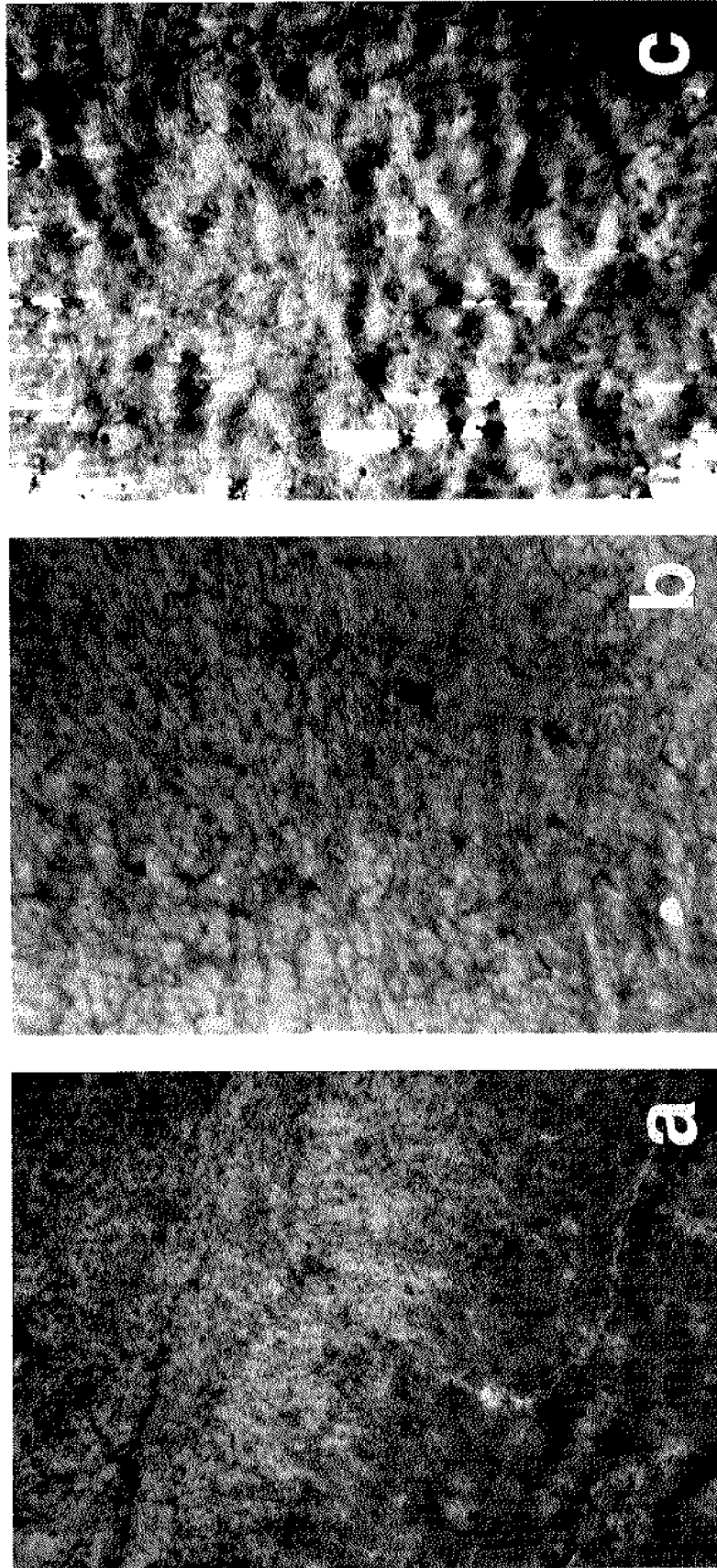


Figure 4. Ultrastructure of thermoprocessed samples. (a) Set at 40°C, 30 min. (b) Set at 15°C, 120 min. (c) No setting.

is correlated with its strength after thermoprocessing (Table 1).

The structure of the formulation prior to setting has a blurred appearance (Figure 3c). Differences can also be noted in the thermoprocessed samples (Figure 4c). Gel tested prior to setting differs by having a lower strength and a lower broken consistency.

Thus, it was shown that through the process of water binding, setting at 15°C is much slower than at 40°C. Gel formation, as it is seen from values and the character of breaking force variations and ultrastructure, is affected by setting temperature. The presence of a low-temperature structure formation is confirmed by other works (Noguchi 1986) that found a vivid zone of variation of dynamic viscous-elastic properties of surimi in the 15°–17°C range.

From the results obtained, it follows that for a given formulation, gel formation is most effective at 15°C; however, from the point of view of economy and technology, setting at 40°C during a 30-minute period could be recommended for production of analog foods.

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COMPOSTING SEAFOOD PROCESSING BY-PRODUCTS: SOLUTIONS FOR THE 90s

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ABSTRACT

Composting processes for rendering fish scraps have been established as a useful and economical alternative to costly and unsafe disposal practices for the fish industry. The process will remove some economic and environmental pressure from the waste producers, while enabling an agriculturally useful material to be generated.

Composting fish scraps is a means of bio-thermal degradation to safely and uniformly reduce fish by-products into a useful soil amendment. It is appropriate where fish waste spoils rapidly and where economics do not favor other forms of rendering wastes.

A composting process begins with an inventory and analysis of fish scrap by-products, followed by identification of complementary "carbonaceous" wastes. It is then necessary to scientifically formulate a compost mix based on ideal moisture, texture, and carbon:nitrogen ratios. Compost piles are set up and subsequently monitored for heating and compositional changes to produce a stable compost product.

INTRODUCTION

In this paper, I present information about composting projects we have recently undertaken at Woods End Research Laboratory. Composting is a form of controlled bio-thermal degradation (Bertoldi et al. 1987). Long considered to be strictly an agricultural process, composting is finding a home in the fishing industry (K. Coons pers. comm.). Not considered meritorious for mention as a viable processing method in 1981 (Otwell 1981) and even as recently as 1986 (New England Fisheries Development Foundation 1986), composting has now been formally endorsed as "an operationally feasible byproduct processing alterna-

tive" by the Maine Governors Fishery Byproduct Task Force (Brennan 1988) as well as by traditional fishing industry representatives (K. Coons pers. comm.). The reason for this acceptance in New England is that we undertook specific research projects with the stated objective of testing the feasibility (Brinton and Seekins).

The utilization and disposal of fish processing by-products is an increasing subject of discussion. On the East Coast of the United States, there are few attractive disposal methods for fish scraps. We have recently pursued composting as a means to produce a safe, nutrient-rich fertilizer from fish scraps.

The fish by-products, or wastes, most typically selected for composting include aquaculture mortalities, hatchery effluent, fish gurry, groundfish racks, whole herring, shellfish scrap such as mussels, clams, and scallops, and crustaceans such as lobsters and crabs. As a general group, these materials are relatively rich in protein and therefore putrefy rapidly after processing. We have developed composting projects for many of the above materials.

Concern for fish by-product utilization is arising chiefly from a perceived environmental crisis in disposal of fish scraps through landfills, land application, or ocean-dumping, all of which have severe limitations. There are forms of rendering wastes into meal and hydrolysates which do not lead to environmental problems, and which we are not addressing.

Large opportunities exist agriculturally for recovery and utilization of nutrients contained in fish wastes. In particular, nitrogen and to a lesser extent phosphorus, plus calcium and magnesium, are plentiful in many by-products. In some cases, these by-products comprise from 30% to 80% of the bulk of processed fish, with crab waste falling in the 30% to 33% range (Otwell 1981).

Traditionally, these agricultural opportunities have centered on rendering into forms of feed additives, such as fish meal, silage, and hydrolyzed protein (New England Fisheries Development Foundation 1986), and to a much lesser extent into fish emulsion used as

a plant foliar spray. But long before these processing techniques were generally known, American Native Indians used fish scrap as fertilizer. Composting is recovering an age-old tradition, but in our approach, implementing it on a massive and economically attractive scale.

We perceive that composting can exist side-by-side with current forms of rendering, since in many cases no single technology can solve the fish scrap problem. For example, despite a thriving fish meal rendering technology, more than 40% of Nova Scotia herring waste is ocean-dumped or put into landfills (D. Fraser pers. comm.). Furthermore, a large quantity of fish by-products, including shellfish and crustacean materials plus fish gurrries and hatchery wastes, simply cannot be rendered easily or economically into marketable supplements. Throughout coastal America, fish scraps are dumped, put into landfills, or discarded in ways that neglect the inherent nutrient value of the material. In the Florida gulf area, there are approximately a dozen blue crab processing plants producing between 1,300 and 3,500 tons per year of wastes, most of which are trucked to the county landfill (Andre 1988). These crab scraps consume more than 17% of the landfill and as much as 25% of the operating costs (Jacobs 1987). A very similar situation exists in Maryland with crab scrap (Hatem 1981, Cathcart et al. 1987). Lack of compliance with environmental guidelines for disposal is forcing us into a crisis situation (Brennan 1988).

COMPOSTING: THE PROCESS

The basis for composting is the oxidative metabolism of carbohydrate by microorganisms—bacteria and fungi—in an environment with adequate nutrients and moisture. Traditionally, the emphasis is on mixing energy-containing matter (carbon) with nutrient-containing matter (nitrogen) in ratios dictated by microbial metabolic requirements. For example, for each 30 parts of cellulose consumed, microorganisms will need approximately one part nitrogen. It is also important for aerobic microorganisms that the compost mass be porous and contain enough water to achieve a 60% to 70% saturation of the water-holding capacity. Understanding the nutritional requirements of microorganisms, therefore, forms a basis for composting recipe development.

As a prelude to composting, we normally conduct an inventory of other agricultural and food by-products disposed of in one form or another in an entire region. Because composting depends on mixing proteinaceous matter with carbonaceous ingredients, it is important to compare the proportions of fishery by-products with

other commonly encountered wastes including those from food, farm, and municipal sectors. The data are collected and provide numbers to compute realistic and economical "mix recipes" of compatible ingredients to induce successful composting (Seekins and Walton 1988).

The inventory process often indicates that a quantity of carbonaceous material exists whereby composting could be accomplished with a minimum of required transport. Sometimes, however, local shortages exist for carbon. Since we are discussing the development of large projects, the need for volume must be appreciated. Of the needed carbon sources, competition may exist for uses other than in composting. Wood chips are routinely purchased for burning in energy-generating boilers, sawdust and shavings for animal bedding material, and bark for horticultural purposes. Another carbon source is peat moss, which is prized both for composting and horticultural uses elsewhere and is available in great quantities in certain regions. The primary focus of composting projects is fishery by-products high in nitrogen including: dogfish gurry, whole herring, groundfish (flounder racks), as well as crab and lobster shells (Brinton and Gregory 1990). Most of these materials contain 6% to 11% nitrogen (dry basis) and require a large amount of carbon to bring about a biological optimum ratio of 30:1 (C:N). The carbon:nitrogen (C:N) ratios of fishery by-products are very low (i.e., 3 to 5). In contrast, carbonaceous ingredients such as sawdust, wood shavings, and peat range in C:N from 50 to 240. The success of composting will depend on the proper blending of such diverse materials.

For every set of compostable materials, a theoretical ideal combination exists that optimizes C:N ratios, moisture, and texture. The determination of mix ratios is performed by a process called a mix-ratio analysis. We have applied a mathematical algorithm to arrive at an exact measure of the proportions of diverse materials to effect a successful composting process (K. Coons pers. comm., Brinton 1988).

Once begun, the composting materials heat up for four to eight weeks. In this time, the proteins are broken down and stabilized by bacteria in the form of cell tissue and humic compounds. Rapid release of ammonia can cause the pH to rise dramatically in the compost at the outset, but a neutral reaction is reached toward the end.

The final compost products are generally rich in organic matter (40% to 70%) and contain between 1% and 4% nitrogen. They may be applied freely to soils for purposes of texture improvement and to provide slow-release nutrients for sustained growth of crops (Brinton 1989, Brinton et al. 1989). With current

concerns of soil degradation, such compost products may fulfill a very useful purpose.

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QUESTIONS AND ANSWERS

Q. I see applications for your low-cost fishery waste. But I don't want the audience here to leave with the impression that crustacean wastes are for landfill operations. I strongly encourage you to read some of the articles that are coming out in the *Journal of Food Science* where they're recovering valuable by-products, flavors, vitamins, and growth-stimulating products from things like scallop viscera.

In areas where a large amount of hand picking, or peeling of crustacean waste is required, the first priority should be to recover economically what can be a valuable food product. The residue I agree can either be dried as meal, or can be used in a landfill operation.

A. I'd like to make an important distinction: Using landfills is not synonymous with composting. In fact it is completely the opposite. With regard to your alternatives, they have been explored. We've done studies, and nobody has followed up. Now disposal is in a crisis situation.

With regard to scallop viscera, it goes from boom to bust every other year. One year we had zero. It went up to 40,000 tons of viscera in 1987. The next year it was back down to 6,000 tons. Because of the wide and violent swings, and the lack of money in the fishing industry itself, nobody's really taken the lead in creating by-products. I agree that if you could create a by-product it would be great, but it's not happening. In New England we've lost our by-product plants because they're not economically viable in the international market.

So we're proposing a solution that works now. Incidentally, some compost producers are getting prices half as good as those for fish meal. And their costs are much lower because of the large market for soil amendments. So I think we have to temper your remarks with the fact that we've got a very broad market. People may end up making as much money composting as anything else. And it can be implemented on almost any scale. It makes

no difference at the compost facility if nothing comes in one day, and 50 tons comes in the next day. They can tolerate that variability. In that sense it's more economically durable. Some of the less well-to-do fish processors are choosing the compost option because it is the only choice they can make right now.

Q. How can the produced heat be utilized?

A. Some researchers in Minnesota have been utilizing the heat produced to heat greenhouses.

Q. Do you have any information on the composition of your leachate, particularly when you are using a lot of liquid?

A. When we launched these projects, everybody said, "Are you going to have a lot of leachate?" The environmental regulators came out in force to observe, but we didn't have any leachate because the material was so dry and porous during the composting. In fact, we have to add water to it. It gets so hot the moisture evaporates. Some facilities are under roofs now, but the problem with going under a roof is that there is no rainfall, and they really have to water their piles. But they do avoid runoff that might occur during a storm.

The surface runoff has a small amount of dissolved nitrogen, but nothing significant enough to severely restrict the implementation of this process.

One of our projects in Maine is being very closely monitored and scrutinized by the environmental department, with monthly monitoring of all the waters coming off the site. After two years, they're going to rewrite their standards based on the results of our project because they feel that if it's not a problem, they shouldn't put so many punitive regulations on this kind of facility. So far, it looks pretty good.

Q. What's the cost and availability of the carbonaceous material? I presume a lot of this is sawdust or shavings.

A. Each area has something different to offer. In Florida we found mountains of cypress sawdust going begging. In Maine a lot of the shavings and chips are recycled, but sawdust is not particularly preferred, and they also don't like to burn it in the energy recovery facilities. So sawdust is available. In Canada they have huge reserves of peat moss. The Department of Agriculture in Ottawa has published a few studies on the feasibility of using peat as a compost amendment. And they're doing that now in New Brunswick. So you have to find the least-cost carbonaceous source in each area. For some composting projects, they're recycling their carbon material. They screen out the chips of wood, and then reuse it, so they get double duty over time.

USE OF MARINE BY-PRODUCTS ON AGRICULTURAL CROPS

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INTRODUCTION

The purposes of this paper are (1) to inform seafood processors and potential agricultural users of the types of marine by-products available, their manufacturing process, and their chemical makeup; (2) to document plant responses to marine by-products; (3) to report on uses of marine by-products; (4) to describe sales and distribution of marine by-products to agricultural users; and (5) to report on studies in progress.

Another reason for writing this paper is to increase our awareness of ecology. Ecology is the study of organisms in relation to their environment. More generally, it's a study of relationships in nature. As Americans, we have been slow to recognize some basic relationships about living on the earth. A good example of our ignorance is the increase of CO₂ we have allowed in our atmosphere. The increase in CO₂ may accelerate global warming, possibly causing droughts and crop failure.

Forestry and agriculture producers are in trouble with environmentalists because resource harvesters are reducing the carrying capacity of the land, while population requirements for food and fiber keep going up. In California soil erosion rapidly fills our bays, estuaries, and rivers with sediment, some of which was once soil sustaining the redwood forests of the north coast and a rich agricultural valley. Among other causes, soil erosion may have killed a run of chinook salmon once native to the San Joaquin River system.

The race of salmon was an indicator of a healthy environment. Through an awareness of nature's relationships, perhaps we could have saved the salmon and maintained the prosperous farms. In the Midwest, farmers contribute to the pollution of their own drinking water through over-fertilization of crops and poor animal waste management.

The environmental movement in agriculture has always been with us, but it began getting a lot of press and public attention during the Vietnam era. Agent orange, the defoliant used to devegetate enemy territory, was probably the largest use of chemical warfare ever unwittingly devised by humans. Cancer caused by the believed-to-be-safe agent orange made us all aware that we were using similar substances in our farming practices. It made us aware that our system of agriculture was headed for deep trouble unless we began to understand the basic agricultural relationships our grandfathers practiced before the boom of petroleum-based fertilizers. One of the lessons we are relearning today as farmers is the use of mulches, cover crops, and compost to increase soil fertility and soil water holding capacity. These nutrient sources, not used much since the 1940s, are again being considered and used as major fertilizers and soil amendments for crops.

Seafood by-products can be a major source of nutrients for composting material mixed with wood waste and other sources of carbon. Since 1987, seafood composting studies and projects have been carried out in Maine, Wisconsin, Massachusetts, Florida, and California. These studies are listed in the bibliography. Fish emulsion is another marine by-product we are learning to use in agriculture. Chemical pesticides, once the main agent in foliar sprays to control pests, are being replaced by mixes of fish emulsion in some areas. One such spray, a mixture of fish emulsion and bacte-

ria, is used to control moths. Mixes of fish and other chemical elements needed by plants are being used by growers of soybeans, corn, cranberries, and other crops during blooming or at other critical times in the life history of the plant. Finally, household plant growers are learning that fish emulsion can be used as a sole source of nutrients for house plants and ornamentals.

MARINE BY-PRODUCTS

Hundreds of different marine species are harvested in the United States and other parts of the world, and the harvest is nearing 100 million metric tons per year worldwide (U.S. Dept. of Commerce 1987). The forms are diverse, varying from whales and fish to the shelled forms such as oysters, crabs, lobsters, and sea urchins. A third to half of this harvest can be used to manufacture by-products. By-products used in agriculture are classified as liquid, dry, and fresh or frozen scraps. The chemical makeup of these by-products is presented in Table 1.

Liquid By-Products

Fish emulsions and oil are primary liquid by-products. Figure 1 presents a simplified model of the fish emulsion manufacturing process. Fish emulsion and fish hydrolysate are names used interchangeably. Nearly all of the liquid products are technically both emulsions and hydrolysates. Hydrolysates are produced when proteins break down to form amino acids during hydrolysis.

Fish Silage

The simplest form of fish emulsion is fish silage. In this process (illustrated in Windsor and Barlow 1981) fish scraps are ground and acid is added in a big vat. The enzymes already present in ground fish digest the slurry in a matter of hours. Bones are screened out and the oil may be left in, decanted, or centrifuged out. The remaining liquid is fish silage, in which proteins continue to break down to amino acids during storage.

Fish Hydrolysate

To make fish hydrolysate, or fish emulsion, fish scraps are ground, digested with the enzyme papain, de-oiled, the bones are screened out, and finally the emulsion can be pasteurized in either a dehydrator or spray-dryer to form spray-dried fish hydrolysate. Liquid fish hydrolysate is made in the same way as powdered fish hydrolysate, except acid is added during or after digestion and the mixture is heated (pasteurized) to stop hydrolysis. Fish soluble nutrients (FSN) are included in

the "family" of emulsions, but it is made as a by-product of fish meal. The meal process is explained in Windsor and Barlow (1981). The simplified FSN manufacturing process consists of cooking the fish, pressing out the liquid, extracting the oil, evaporating some of the liquid, and acidifying (generally with sulfuric acid) to stabilize (pickle) the mass (Figure 1).

Oil By-Products

Bone meal and oil are by-products of the emulsion making process. Bones are dried and ground into a meal. Oil is stored in large tanks for sale in bulk.

Dried Marine By-Products

Fish Meal

Fish meal is the most common form of dried fish. Fish meal is made from either whole fish, such as anchovy or menhaden, or from scraps of fish such as tuna, herring, or white fish. The meal-making process includes cooking, pressing out the liquid, and drying. The pressed-out liquid can either be dried and added back to the meal, or processed further to make FSN (Windsor and Barlow 1981).

Other Meals

Generally crustacean waste and bones are drum dried and ground to form meal; this is one of the easiest by-products to manufacture.

Composted By-Products

Composting is a relatively new method of treating marine by-products. It consists of mixing waste material with a bulking agent (a carbon source) such as sawdust. All kinds of waste, including shark skins, crab shells, and fish frames (bones) decompose to form an enriched soil amendment or compost. The composting process generally requires the addition of some water.

Fresh or Frozen Fish Scraps

Seafood scrap is often considered a separate form of by-product, and it has many uses. Non-agriculture uses include processing for fishing bait and as a pet food additive. In the 1970s and early 1980s much of the scrap material was dumped in landfills because it was the cheapest disposal alternative. As disposal fees increased to around \$50 a ton in areas like New England, finding alternative uses became necessary. Land application on crops was an inexpensive alternative to land filling. In Oregon studies have been completed on agricultural land application of crab and shrimp

Table 1. Chemical composition of fish by-products used on agricultural crops.

Nutrients	Fish soluble nutrients ¹	Fish hydrolysate ⁴	Spray dried fish hydrolysate ⁵	Fish meal (menhaden) ¹	Crab meal ¹	Fish scrap (sole, dover raw offal) ⁶	Sea urchin shells and viscera ⁸	Fish compost ⁹
Nitrogen (%)	5.04	2.38	12	9.79	5.15	1.87	0.11	0.6-1.2
Fat (%)	6.1 ²	2.7 ²	11.5	9.6 ²	2.2 ²	4.4	-	-
Ash (%)	10.1	4.1	6.5	19.1	41.1	3.5	40.1-47.9	-
Moisture (%)	50	74.8	7.5	8	8	81.2	45.6-53.5	-
Phosphorus (%)	0.57	0.09	0.6	2.88	1.58	0.15 ⁷	0.04	0.1-0.5
Potassium (%)	1.64	0.25	1.3	0.7	0.45	0.32 ⁷	0.13-0.16	0.2-0.5
Calcium (%)	0.16	0.31	-	5.19	14.46	0.05 ⁷	13.72-15.99	-
Sodium (%)	2.45	-	1	0.41	0.88	0.09 ⁷	0.488-0.51	-
Iron (ppm)	280	-	45	550	4,350	-	-	-
Zinc (ppm)	43.2	-	15	144	-	-	9-16	-
Copper (ppm)	46.6	-	4	10.3	32.7	-	0.7-1.0	-
Boron (ppm)	3 ³	-	-	-	-	-	0.9	-
Magnesium (ppm)	300	-	100	1,500	9,400	-	5,600-6,700	-
Chromium (ppm)	3 ³	-	-	-	-	-	-	1.9-3.8
Lead (ppm)	-	-	-	-	-	-	-	13-23
Cadmium (ppm)	-	-	-	-	-	0.09 ⁷	<0.05	0.2-1.3
Nickel (ppm)	-	-	-	-	-	-	-	1.1-4.8
Vitamin B ₁₂ (ppm)	506.6	-	140	122	437.6	-	-	-
Vitamin E (ppm)	-	-	700	6.8	-	-	-	-

¹Ensminger et al. 1990.²Ether extract.³Miller 1973.⁴Wyatt and Price 1990.⁵California Spray Dry Co., Mariposa Road, Stockton, CA 95205-0035.⁶Sidwell 1981.⁷Raw muscle.⁸Wyatt 1989.⁹Frederick 1989.

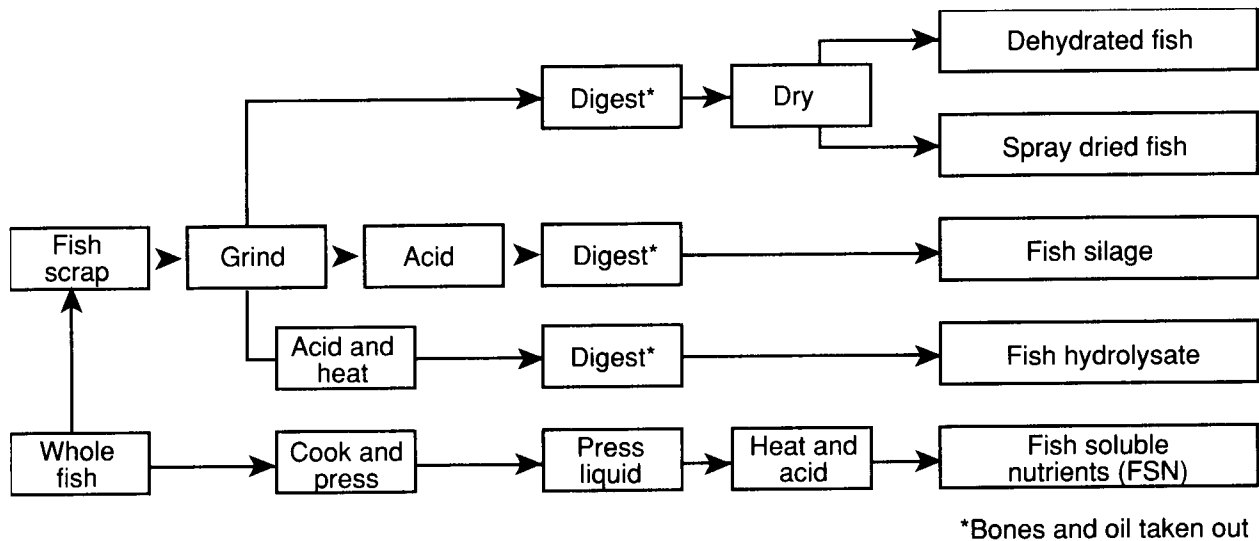


Figure 1. Simplified manufacturing process, "family" of fish emulsions.

waste (Costa and Gardner 1978). Wyatt (1990) is involved in continuing studies with land application of sea urchin waste (see section on Research in Progress).

PLANT RESPONSES TO FISH SOLUBLE NUTRIENTS

L.H. Aung et al. (1984) investigated the use of fish soluble nutrients in the form of fish emulsion application in growing soybeans, corn, peas, radishes, lettuce, rice, sorghum, concord grapes, peaches, and strawberries. The plant responses to FSN are listed below.

Plant response data are generally applicable to the family of fish emulsion products. Some variation in plant response can be expected based on differences in chemical makeup and manufacture procedures. More research is needed to define unique responses in plants.

1. Promotes plant growth. Studies have been completed on peas, radishes, tomatoes, corn, strawberries, lettuce, soybeans, peppers, and others that demonstrate growth producing potential.
2. Retards senescence. Observations indicate retarded aging in lettuce and peas. More work is needed to determine how this property can be used as a management tool.
3. Delays flowering and fruiting. Flowering delay has been observed in tomatoes, but more work is needed to determine responses of other plants. Perhaps this blooming delay could be used in areas where the likelihood of frost in early spring is very

high, or to extend the time a single variety would be available for picking and marketing. The latter might be accomplished by treating part of the crop with fish to delay blooming.

4. Reduces stress at time of transplanting. Fish emulsion has been used as a foliar spray and side dressing at time of transplanting crops such as tomatoes. Vegetable growers questioned at the 1989 Organic Farming Conference in Monterey, California indicated fish emulsion was useful in transplanting vegetable crops to reduce loss and promote quick adjustment.

USING SEAFOOD BY-PRODUCTS ON AGRICULTURAL CROPS

Fish fertilizer has been used on crops since the Roman expansion, and in medieval France along the coast, where shellfish debris was used to raise luxuriant crops (Fryer and Simmons 1978). Ceci (1975) contends that the use of fish in hills of corn was an ancient tradition developed in Europe and not in the New World, as early New England scholars have claimed. Ceci found that Atlantic Coast Indians had to move their gardens each year, because they didn't know how to fertilize the soil.

The average American farmer relies heavily on anhydrous ammonia to provide the major nutrient, nitrogen, to grow high-production crops. Many farmers believe that used alone, anhydrous ammonia produces crops high in water and low in sugar, and generally

high in profit. Dr. Dan Skow, a Minnesota soil consultant, believes that levels of protein and nitrogen of anhydrous raised corn are lower and that anhydrous raised corn is generally less nutritious than non-anhydrous raised corn.

New strategies that farmers and fertilizer suppliers are using could increase the demand for seafood. Singular uses of seafood by-products include (1) a seed soak to enhance sprouting, (2) at transplanting time to enhance survival, (3) to retard blooming time, (4) to retard aging, (5) to control nematodes by encouraging bacteria that feed on them, and (6) fish emulsion is used as a sole source of nutrients by house plant fanciers and probably by some of the nurseries that grow ornamentals.

Fish products are most often used in concert with other nutrients to maximize fruit quality, production, or plant health. Fish products are used to even out the rate of nitrogen release. For example, cranberry growers add fish hydrolysate to nitrogen to reduce the rate of nitrogen release. Explosive nitrogen response is experienced when nitrogen is used alone in its pure inorganic form. Explosive nitrogen response is rapid growth and it gives weeds an unwanted advantage in the cranberry bog. Nursery operators, turf growers, and others could benefit from the increased nitrogen efficiency gained when fish or a similar substance is mixed with the primary nitrogen source.

Fish and kelp are used by table grape growers as a foliar feed to control bunch size and shape, fruit size, and sugar content. Kelp provides the growth hormone, and fish provides at least part of the trace elements and the nitrogen necessary for plant tissue production.

A little fish added to molasses, and a large dose of hydrated ammonia, is the basis for a successful corn and soybean fertilization strategy used by a Minnesota crop production consultant.

Fish oil is used as spreader sticker in tree fruits to maintain the health of bud wood. Fish emulsion is used to increase the vigor of trees. Added vigor when leaves first appear (according to Lanphere 1989) reduces the tendency to overproduce unneeded fruit buds, overproduction which would require hand labor to thin out some of the buds.

Most organic fertilizer suppliers sell a foliar spray formulated with fish and other products including kelp and products like humic acid. The use of foliar sprays to bring about specific plant responses is growing. Plant sugars can be increased by foliar sprays of kelp (Senn 1987). Use of the refractometer to measure plant sugar content is increasing among farmers. The refractometer is an inexpensive tool farmers can use in the field to monitor crop conditions. More information about this process is available from Dr. Dan Skow, Box

233 B, Fairmont, MN 56031.

FSN was the most common source of fish nutrients being used on agricultural crops in the United States in 1987 and 1988. In 1989 farmers began the shift from using FSN to spray-dried fish, either dehydrated or spray-dried fish hydrolysate. Among reasons given by farmers for the shift in product use are: (1) increases in availability, and (2) convenience in using spray-dried product including ease of storage and reduced transportation costs.

Mr. Paul Buxman, president of the California Clean Growers Association, Dinuba, CA 93618, a 100 member, environmentally aware growers association, recently told me that a major spray for codling moth and other moth pests has a fish by-product base. Javelin, the name of the spray, is commonly used in California.

Use of fish scrap in compost or in land application is growing. Seafood waste compost projects recently written up include work in Florida, Oregon, Maine, Massachusetts, Wisconsin, and California (see bibliography). Land application is also an excellent way to utilize by-products.

Getting an agricultural land application project started can be a problem. In Oregon and California some success has been gained by setting up demonstration projects with the university county agent, with input from the county health department. Care must be taken, at all times, to plow or disc by-products into the soil, in order to reduce odor and fly problems.

Fish Fertilization Programs

Two farms were visited that use primarily fish, with compost as the major fertilizer base. The Delmar Ackerland farm in Valley, Nebraska is 700 acres, and the principal crops are corn, soybeans, and alfalfa. Mr. Ackerland switched to organic farming in 1968 because he was unhappy with results of conventional fertilizer practices. Organic matter in the soil had decreased to below 1% on much of his farm. It took three years to begin getting economic yields using organic methods. Ackerland was one of the first farmers to utilize foliar application of liquid fish (FSN). In 1973, Ackerland began purchasing liquid fish in tanker load lots, and over the years he developed the fertilizer program in Table 2.

Lee Shepard of Hemlock, Michigan was visited to obtain information on his fertilization program using FSN (Table 2). Mr. Shepard uses a front-end mounted tank and pump to apply solubles at planting time. A 5/64-inch hole in the sprayer head is used to apply solubles. The fertilizer value of solubles is approximately 3:0:0.5:1.5. Mr. Shepard says fish emulsion solubles give him added plant vigor and growth.

Table 2. Two farm programs using fish fertilizer as a supplement to compost fertilizers.

Crop	Material	Method	Amount per acre
Delmar Ackerland Farm; Valley, Nebraska			
Alfalfa, 1st cutting	Fish solubles & kelp	Foliar spray	3 gal fish 1 lb kelp
Alfalfa, 2nd cutting	Fish solubles & kelp	Foliar spray	2 gal fish 1/2 lb kelp
Alfalfa, when stressed	Fish solubles	Foliar spray	1/2 gal fish
Corn, at pollination	Fish solubles	Top dress	1/2 gal fish
Soybeans, when insects appear	Fish solubles	Foliar spray	2 1/2 gal fish 1/2 lb kelp
Lee Shepard Farm; Hemlock, Michigan			
Wheat, oats, dry beans, corn	Fish solubles	In furrow	5 gal/acre at planting

SALES AND DISTRIBUTION

Fish powder and fish emulsion are the primary by-products sold to farmers. Sales occur in a variety of ways. They include the following:

1. Catalog and newsletter advertised sales
2. Warehouse sales
3. Manufacture sales
4. Sales through consultants
5. Sales by farmers who buy in bulk and sell the excess to other farmers
6. Garden outlet sales
7. Development of brand names

Brand names have been developed by manufacturers who sell to licensed or contracted outlets. The Seagrow line of products from Wenatchee, Washington, is an example. One supplier formulates foliar spray products and sells them through a newsletter or through field representatives, as well as directly from a warehouse where the products are formulated. The trend is for sale of formulated nutrients designed to meet the needs of specific farms and crops. Formulations are a mix of several items often including calcium, molasses (for a carbon source), kelp for growth hormones, and fish as a carrier and source of nutrients.

Major Growers and Suppliers

Major growers and fertilizer suppliers were interviewed who purchase truck load lots of either FSN or hydrolysates. Information from these sources about crops grown and plant nutrient formulations follows.

Nationwide

1. Necessary Trading Company, New Castle, VA 24127. This company is primarily a catalog warehouse company that supplies organic farming products and services. They sell foliar fish (dehydrated fish hydrolysate) primarily "to provide an extra kick for those times and crops demanding nitrogen."
2. Trans National Agronomy Ltd., Grand Rapids, MI 49503. TNA is a fertilizer supplier with field representatives in most midwestern states. Sales are through field representatives, or from the Grand Rapids warehouse. Workshops are being offered throughout the United States, but especially in the Midwest, to attract and educate clients. A monthly newsletter provides growing tips and information to crop and livestock producers about sustainable agricultural methods.
3. New Era, P.O. Box 932, Clinton, CT 06413. New Era sells compost and garden products, and may be a good candidate for increased fish emulsion sales.

Northwest

Integrated Fertility Management (IFM), 333 Ohme Gardens Rd., Wenatchee, WA 98801. IFM relies on warehouse and catalog sale of products and services for field and tree crops. Fish products in their catalog include fish fertilizer (WP Mermaid brand), a dehydrated fish hydrolysate, recommended for fruit trees and field crops. Fish oil is also sold for use as a spreader sticker.

Midwest

1. D.L. Skow Enterprises, Fairmont, MN 56031. Dr. Skow is a soil consultant who puts on workshops for farmers and provides fertilizer recommendations for several thousand acres of corn and soybeans. A typical formulation for the Iowa-Minnesota area is one gallon FSN, three gallons molasses, and 80 to 120 lb hydrated ammonia per acre. Dehydrated or spray-dried fish hydrolysate can be substituted for FSN.
2. Greenworld Inc., P.O. Box 85, Garfield, MN 56332. Greenworld sells fish and seaweed fertilizer.
3. ENP Inc., P.O. Box 218, Mendota, IL 61342. ENP relies on warehouse and catalog sale of product formulations for field crops. Some of their products contain fish and kelp.

New England

North Country Organics, Newberry, Vermont. They rely on warehouse and catalog sales of product formulations for field crops. Some of their products contain fish and kelp.

California

Peaceful Valley Farm Supply, P.O. Box 220, Grass Valley, CA 95945. They sell organic farming supplies.

Manufacturers of Fish By-Products for Crops

1. California Spray Dry Co., P.O. Box 5035, Stockton, CA 95205. Spray-dried fish hydrolysate powder, fish bone meal.
2. Pacific Pearl, 100 E. "D" Street, Petaluma, CA 94952. Ground oyster shell.
3. Seagrow Corp., 3601 10th SE, E. Wenatchee, WA 98801. Dehydrated fish powder.
4. Sea Pal, 32410 North Harbor Drive, P.O. Box 1262, Fort Bragg, CA 95437. Liquid fish.

FURTHER INFORMATION

Research in Progress

Listed below are research projects in progress that could help document agricultural uses of seafood by-products.

1. Salmon bone meal as a fertilizer. Stephen D. Sparrow, University of Alaska Fairbanks, Fairbanks, AK 99775.

2. Several seafood compost projects. William F. Brinton, Woods End Research Lab, Mt. Vernon, ME 04352.
3. Using fish by-products in drip irrigation systems. Glen McGourty, University of California Cooperative Extension, County Court House, Agricultural Center, Ukiah, CA 95482.
4. Fish hydrolysate fertilizer for cranberries. Carolyn De Moranville, University of Massachusetts, East Wareham, MA 02538.
5. Use of fish hydrolysate on agricultural crops. Ron Athanas, University of Massachusetts, Cooperative Extension, Hathorne, MA 01937.
6. Utilization of sea urchin shells and viscera. Sea urchin hydrolysate for house plants, sea urchin shells in compost, sea urchin hydrolysate as a deer repellent, sea urchin shells as a land application. Bruce Wyatt, University of California Cooperative Extension, 2604 Ventura Ave., Rm. 100P, Santa Rosa, CA 95403-2894.

Newsletters

Newsletters and journals that commonly advertise fish or contain articles about utilization of fish by-products, or that contain general information about organic farming are listed below.

1. *Journal of Sustainable Agriculture*, CSA 1, P.O. Box 1300, Colefax, CA 95713, (916) 346-2777. Quarterly newsletter with information on organic farming methods.
2. *American Journal of Alternative Agriculture*, 9200 Edmonston Rd., Suite 117, Greenbelt, MD 20770. Quarterly, \$15.00 per year.
3. *Acres USA*, P.O. Box 9547, Kansas City, MO 64133. Monthly, with information on sustainable agriculture.
4. *Sustainable Agriculture News*, U.C. Sustainable Agriculture Research and Education Program, University of California Davis, Davis, CA 95616. Quarterly, with general information.
5. *Trans-a-Gram*, Trans National Agronomy Ltd., 470 Market S.W., Suite 101, Grand Rapids, MI 49503. Monthly newsletter, free, with information on sustainable agriculture methods.
6. *Fish & Kelp News*, 2604 Ventura Ave., Rm. 100P, Santa Rosa, CA 95403. Quarterly, dedicated to providing information on use of seafood by-products for agricultural crops.

Information on Seafood Processors

Seafood processing companies are major sources of by-products. A list of seafood processors is available in NYNEX Commercial Marine Directories from NYNEX Information Resources Co., Attn. Delivery Supervisor, 201 Edgewater Dr., Wakefield, MA 01880.

ACKNOWLEDGMENTS

This work was made possible in part by grants from the California Sea Grant College Program and the University of California Cooperative Extension. Dan Desmond, director of Sonoma County University of California Cooperative Extension, encouraged me to pursue these studies that bring agriculture and fisheries together in a working relationship. Ed Richardson, coordinator of the University of Rhode Island Sea Grant Marine Advisory Program, provided office space, telephone, and encouragement during investigations on the East Coast. Extension Seafood Technologist Robert Price and Extension Soil Specialist Roland D. Meyer guided me in the technical development of investigations. Laura Sauter typed this manuscript and was patient with the many revisions. Thanks also go to the many farmers, fish processors, and by-product suppliers that gave information and their time. Finally, thanks go to Raedine Lillie who encouraged me to pursue some new creative writing techniques in developing this manuscript.

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QUESTIONS AND ANSWERS

- Q. (Dr. Piggott, Sea Resources Engineering, Bellevue, Washington) A lot of the tests done in Oregon and the northwest that you mentioned came from our plant in Westport. We found out the hard way that the emulsion can't have any solids in it. Any

particles will plug the orifice of the large commercial sprayers on trucks. We had to go to a triple grinding system. It's a lot easier than straining off the bones and you get better results.

For spraying apples in Washington state, we emulsified a certain amount of oil into the product. A lot of the farmers are actually eliminating some of their insecticide sprays now—in particular the lime sulfur spray—because the oil is effective.

Most of the major cranberry growers in Washington state are using our product now. One of the gains is that they get a much longer shelf life for cranberries after they're picked.

Q. With the application of fish fertilizers, have you noticed any traces of fish flavors in the product?

A. (Mr. Wyatt) No, I haven't heard any complaints.

A. (Dr. Piggot) We've never had any complaints on taste. It is interesting that deer won't come near it. Many farmers are putting a spray in the periphery of their orchards, and it keeps the deer from coming in and eating the leaves off the trees.

A. (Mr. Wyatt) One possibility for a side market is a product that results from putting sea urchin shells through a 3/4 inch hammermill. Cats really like this product, which is the same texture as kitty litter. I think this could develop into a real market.

SEAFOOD FLAVORANTS PRODUCED BY ENZYMATIC HYDROLYSIS

**Thaddée In
Isnard Lyraz
Quéven, France**

Isnard Lyraz has developed an original technology to produce seafood flavoring materials by enzymatic hydrolysis. These products are called Protextrait-Lyraz (Table 1). The market is growing, the margin is quite good, and our work is quite profitable.

The problem often is in finding high-quality by-products. The purpose of this paper is to present an example of valorization of by-products in an existing industrial situation. I will first present the principles of our process and our research with different kinds of raw materials, and I will discuss optimization. That is the main job in our research and development department.

The second part of this report is dedicated to our products. It is necessary to understand our extracts, their benefits, and their limits. The characteristics of our products are described, and some examples of industrial applications are given.

Biotechnology has been applied to fish and shellfish for centuries. We have invented almost nothing. There are hundreds or maybe thousands of products. By looking at traditional products, we got ideas regarding industrial enzymatic or fermentative processes.

Almost all the traditional products are very smelly and very tasty, sometimes too much. That is proof that biotechnology processes are effective in producing flavoring materials from fish and shellfish. The question of balance and intensity of taste and odor is only a question of optimization.

In principle our process is very simple. We can summarize it in only three words: liquefaction, separation, and concentration. The liquefaction allows separation of undesirable materials such as shells and bones. The hydrolysis also allows concentration of the product up to 50% or 60% of dry matter. Concentration, by reducing the water activity, eases the storage and improves the shelf life of the product. Without hydrolysis, surprisingly, you can dry the product but you can-

not concentrate it very much. In the latter case, the water activity remains high and storage is very difficult, even at 4°C.

The process can be simple or more complex depending on the raw material, and depending also on the specification of the final product. Sometimes we don't grind the raw material, especially fresh material such as fish. With frozen material, we are always obliged to grind it.

Centrifugation and filtration are not always required. Most industrial foods don't require soluble flavoring materials. So, very often it is not necessary to centrifuge or filter out the hydrolysate. On the contrary, sometimes we have to add some separation steps. For example, we can use chromatography to remove undesirable components. Also, surimi-based products often require soluble and almost uncolored materials, so physical separation is required.

On the upper floor of our factory, we have three reactors. Our capacity is about 5,000 to 6,000 tons of raw material per batch. We have intermediary tanks, filters, and chromatographic columns. On the lower floor of our factory, we separate bones and shells. We have a centrifuge, and a grinder for the raw material. We have a vacuum evaporator in a separate room in order to prevent microbial contamination of the final product.

Our pilot plant is very useful for scale-up calculations, and also for trials when we have to show samples to the market prior to receiving orders for industrial quantities of new products.

The raw materials we use are numerous. Usually they are by-products, and we are still looking for new species. For cod, salmon, tuna, white fish, lobsters, scampi, spiny lobster, and scallop, we actually use by-products from the canning, freezing, and filleting industries. For shrimp and mackerel, we use the pieces that are too small or too big to be sold on the market. For crab, we use an underutilized species.

When we started using the underutilized crab species, it had almost no value. But since we have created

Table 1. Product specifications for the natural seafood extract Protextrait-Lyraz crab.

Attribute	Details	
Designation	Protextrait crab paste	Protextrait crab powder
Presentation	Brown paste	Beige powder
Description	Extract obtained from crab. Dried glucose syrup. 1 kg of extract = 5 kg of processed raw material.	Extract obtained from crab. 1 kg of extract = 8 kg of processed raw material.
Analytical specifications		
Dry substance	55 ± 5%	95 ± 3%
pH of 10% solution	7.5 ± 0.5%	7.5 ± 0.5%
Protein/DS	56 ± 5%	45 ± 5%
Fat/DS	3 ± 2%	2 ± 1%
Ash/DS	25 ± 5%	25 ± 4%
NaCl/DS	15 ± 3%	15 ± 2%
Total plate count/g	< 10,000	< 10,000
Coliforms/g	Absent	Absent
Pathogenic staphylococci	Absent	Absent
Sulf. red. clostridia	Absent	Absent
Salmonella/g	Absent	Absent
Yeasts and molds	< 100	< 100
Applications and dosage	Soups, sauces, dips, pies, convenience foods, processed cheese, and other food applications. 0.5% to 3%	Soups, sauces, dips, pies, convenience food, processed cheese, and other food applications. 0.5% to 3%
Shelf life	3 months at + 4°C in the original sealed packaging.	12 months at 15° to 25°C in the original sealed packaging, without exposure to humidity.
Packaging	35 kg plastic drum	15 kg cardboard drum
Labelling	According to the legislation of the country.	According to the legislation of the country.
Remarks	Histamine content < 50 ppm.	Histamine content < 50 ppm.

a demand, and as the demand has become important because of the success of our crab extract on the market, the price of this crab has seriously increased. This point has to be taken into account if you create a new valorization. The price of the raw material can increase year after year.

In the case of scallop, we use the red part of the animal that Americans fortunately don't accept to eat. This part of the scallop is actually very expensive because it is much appreciated in a lot of countries. We are still looking for new suppliers of this product.

The quality of the raw material is very important for sensory reasons, of course, but for other reasons also. In the case of mackerel, we can buy it only during three

months of the year because of our factory standard regarding the histamine content.

Some of our raw materials are imported, such as scallop, lobster, shrimp, and salmon. Others come from the Brittany coast of France.

Up to now we have been able to apply our technology to every marine species we tried. Fortunately very often we use a discarded part of the shellfish that is precisely the part in which more flavoring substances are present. The yield we get depends mostly on the cooked, fresh, or frozen state of the raw material. The yield also depends on the nature of the raw material, and on the percentage of bone and shell. For each species, the yield also depends on the season of catch

and the condition of handling and freezing. The purpose of our enzymatic process is not to produce additional flavor, but only to release the maximum amount of naturally occurring flavoring substances.

We have to avoid the formation of off flavors, and to insure standardized quality batch after batch. Our main objective is to balance the yield and sensory quality. Among the off flavors we have to prevent are the burn taste, the bitter taste, ammonia smell, and shell or mineral taste. Very soft conditions during concentration are required to avoid the burn taste. To accomplish this we concentrate our product in a vacuum evaporator at a maximum temperature of 40°C.

The hydrolysis process itself will determine a good or a bad taste. The rate of hydrolysis and the nature of the end products depend mainly on the exogenous enzymes, and also on the endogenous enzymes allowed to work during the process. The substrate to water ratio is very important because it influences agitation and exchange during the process. The pH can be adjusted or regulated. Another parameter is pretreatment of the raw material before hydrolysis. We are currently finding some interesting possibilities for pretreatment of the raw material.

Many studies have been done on the effect of exogenous enzymes, such as vegetable enzymes like bromelain, papain, and ficin, or microbial enzymes such as subtilisin. But it is important to remember the existence and the importance of endogenous enzymes. Even when you want to apply exogenous enzymes, you have to take into account the action of the endogenous enzymes. If you do not, you may have some surprises.

Very often properties such as the optimal pH, the optimal temperature, and the inactivation temperature of these enzymes differ from those of the same enzyme found in mammals. The optimal temperature is often lower for marine animals as an adaptation to sea temperatures. Some marine enzymes also show two optimal temperatures for maximum activity.

Among the off flavors that can be created by hydrolysis, bitterness is an important one. Bitterness appears after a certain degree of hydrolysis, then it increases to a maximum, and then it decreases. We have also noticed that limited hydrolysis can prevent bitterness. Unfortunately, that is never convenient. For example, if you want to remove the fat by centrifuge you will have to reach a high degree of hydrolysis first. Similarly, if you want a high percentage of dipeptides or tripeptides, you will also have to reach a critical degree of hydrolysis.

The cause of bitterness is well known. The sensation of bitterness occurs when the hydrophobic side chains of an amino acid are exposed to our taste receptors. In protein, the hydrophobic side chains are masked

because of the third and fourth level of protein structure. But with the breakdown of protein during hydrolysis, the hydrophobic side chains become accessible to our taste receptors.

Also the dipeptide lysine-lysine is much more bitter than lysine itself. That explains the relative decrease in bitterness when hydrolysis is pursued to the production of a high content of free amino acids.

Among the different ways to remove bitterness are solvent extraction, plastein reaction, and the use of exopeptidases. Solvent extraction is not very convenient. It is very expensive, and difficult to do on an industrial scale in the food industry. In addition, solvent extraction removes some amino acids and some peptides, and alters the balance of amino acids.

The plastein reaction is not permitted in the United States, and is not very practical on an industrial scale. We are working on the third solution, which works quite well. The debittering effect is due to the conversion of the terminal hydrophobic amino acid peptide into free amino acids.

Amino acid composition is one of the keys to a typical good taste for any seafood extract. Amino acid compositions in enzymatic extracts of seafood can differ greatly in amounts of hydrophobic amino acid, and in glycine amounts. Glycine is very important in shrimp and crab taste. We can control our process to produce high amounts of glycine by optimizing the enzyme action; by adjusting ratios between substrate, enzyme, and water; and regulating temperature, pH, and so on.

Our products, Protextrait-Lyraz, are pure extracts with flavoring properties. A flavor is quite different. A flavor is always a blend of several components: extracts, taste enhancers, volatile chemical components, etc. The raw material prices range from \$.10 to \$5 U.S., and the prices of the industrial product range from \$8 to \$50 per kilo for industrial quantities.

For each product we have chemical specifications. But more important are the taste, color, viscosity, and shelf life. Our products have a shelf life of three months at 4°C, and about two years at -18°C.

Our microbiological standards are very important. The food industry very much appreciates our high standards. In addition to microbiological quality, we control the histamine content. Anybody can pasteurize or sterilize a product, but if you have a high content of biogenic amine because of a bad quality of raw material, the toxin will remain in the final product. Our standards regarding raw materials allow us to guarantee a histamine content lower than 50 ppm.

Our products have many benefits. For the food industry, the Protextrait-Lyraz products are more convenient than the raw material itself. Weight and vol-

ume are lower. With our products, the food industry has not had a problem with bones and shell. And the Protextrait-Lyraz products are truly natural. Our customers have confidence in what we produce.

We guarantee our yield; we have the same yield batch after batch. Our French counterpart to the U.S. Food and Drug Administration has often visited our factory. They can check our batch record, how many tons of crab we have used, and how many tons of final product we get. We can tell our customer, for example, that we make one kilo of crab extract from five kilos of processed raw material. In several countries, it is possible to put on labels that say you have used 5% crab if you have used 1% of our extract. From a marketing point of view, that is important.

The Protextrait-Lyraz products are not flavors, but can be the main component of flavor. At the beginning of our production we sold our product only to the flavor industry. And they have made a good profit with it. Then we decided to produce flavors with our extract. Usually a pound of flavor is more expensive than a pound of extract. But when you have to use 1% extract in your final product, you have to use only 0.1%, 0.3%, or 0.4% flavor. The flavoring cost in the final product is usually lower when you use flavor than when you use extract.

We now have two ranges of product. We have our extract, and we have our flavors. In some applications, for example in crab analogs, the combination of pure extract and other flavoring materials has a good impact. If you use only crab flavor, you will have a very strong taste at the beginning but it does not last. If you combine both of them, you will have a synergistic effect. You will have quite a good first taste, and you will have a nice lasting effect.

The food industry in France is very well developed. We have a wide range of final products: frozen product, serving product, and so on. We help our customers by suggesting how they can use our product, and that is an important part of our job.

Although the principles of our process are quite simple, the daily implementation of the process is not so easy. Marine raw materials are highly variable and very degradable. Also, some suppliers have not yet realized the difference between waste and by-product. We can accept only by-products that answer all the requirements of food grade production. And we have to produce very standardized quality.

We are developing a new generation of products to meet future market requirements. For example, early on we had a highly colored crab extract. Then the crab analog industry requested an extract without any color, so we produced an extract without any color.

Since the Protextrait-Lyraz products were born,

industrial applications have increased. New applications are developed almost daily. We are confident that the technical and commercial possibilities for these products have not yet been exhausted.

QUESTIONS AND ANSWERS

Q. How do your extracts hold up in retort or canning processing?

A. Each case is different from another. For example, we had good success with lobster extract in a bisque soup. We have sold tons of this extract to a major soup company in France. A second company in France involved in the soup industry asked for our lobster extract. We sent them a sample of the extract. Their answer was, "Oh, your extract cannot work in canned product." But in fact it worked.

We have organized an application laboratory, and we work with our customer's product, with their recipe. We share this observation with almost all the flavor companies: Almost 90% of bad results concerning flavor are caused by the percentage used, the way it is used, what you combine with it, and so on. You have to work with the customer to find out how to use the extract. That is true for extracts and it is true for flavors.

Q. How are you able to control the quality of your raw product, particularly when it's coming from countries or areas outside of France?

A. That is a very important point, even if it comes from France. With a mackerel, you have to look in his eyes, and ask him, "Are you a bad mackerel, or are you a good mackerel?" And if you hear something, then you decide. More seriously, when you work with fresh raw materials (i.e. fish frames), a very rapid determination of quality is required. Very often a serious visual control based on checklists of criteria remains the most efficient procedure. The question of raw material quality is very important because we want a very high-quality product. When producing flavor, if you have something bad in the raw material, you will concentrate it in the final product.

Q. Have you set up specifications? For people who have a supply of raw material that might be usable in your operation, do you have specifications for that raw material?

A. Yes we do. We discuss the specifications with our suppliers. We visit them to check how they work. We do that when we will produce a large amount of product. When we are starting in on a product,

there is difficulty. Some products that we start in our laboratory, we sell on an industrial scale as much as 1-1/2 years later, because we have to ensure the supply of raw material.

- Q. Would you consider buying the raw material in dehydrated form?
- A. The question is cost. The food industry doesn't want to put out a lot of money. The more you process the raw material, the more it will cost, and then your final product will cost a lot. For example, we haven't considered dried raw material, but we have considered mince. Some people have offered us lobster heads, and lobster mince. They have already separated the shells. But unfortunately the price was high, and the microbiological quality was poor. So we did not accept them. We

prefer to use the head with the shell.

- Q. It seems that because of the production areas being so distant, such as Alaska, to mince it, freeze it, and ship it would be very expensive because of refrigeration costs.
- A. It depends on the product. It would not be a good idea to do something with cod frames, for example, because the final product would have a low price. But lobster from Canada is successful because they have a large amount of lobster heads. The few companies in Canada handle these heads very carefully, pack them very carefully, and they make a lot of money in France and Europe. Hundreds, maybe thousands, of tons of lobster heads go from Canada to Europe. So it depends on the species. I think crab would be a good challenge.

HYDROLYSIS AND FERMENTATION OF FISHERY BY-PRODUCTS: COSTS AND BENEFITS OF SOME PROCESSING VARIABLES

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Fish protein hydrolysis (FPH) refers to a process in which fish are treated with protein digesting enzymes. The enzymes are from the viscera of the fish itself, or they are commercially purchased. In either case, the fish flesh is turned to liquid. Under ideal conditions, which would include heating and stirring, liquefaction can occur in as little as 10 to 15 minutes.

FPH evolved from the Norwegian work on fish silage. It represents a controlled and elaborate process that is well suited to large-scale industrialization and can produce a higher quality and more consistent product than silage. The first and still major practitioner of this technology is the French company, Soprapeche.

There are two markets into which fish protein hydrolysate (fph) has been accepted and in which it has earned a reputation as a high value product. In the

United States, the major market is in early weaned pig feeds. This market prefers a spray-dried product and pays \$.75 to \$1.30 per pound. The second market, which is rapidly increasing, is the aquaculture feed market. The aquaculture market can accept wet or concentrated product. Prices are varied, but are frequently higher than fish meal of a comparable protein level.

Much of our interest in this technology stems from its extraordinary flexibility. The flexibility operates at every level: volume of raw material required, capital costs, potential markets, types of end products, process design, and engineering. Over the last five years, we have worked at exploiting the immense flexibility of hydrolysis technology in order to increase its usefulness for fishery by-product utilization. Each variable has costs and benefits. All the costs and benefits cannot be covered in this paper, but we will discuss here two aspects of the flexibility and how these lead to processes that may be useful in Alaska, both at sea and on land.

Two problems that seem to affect the utilization of fishery wastes in Alaska are the high ash content of many of the waste streams, and the sensitivity of fish proteins to overheating and over-drying. Both of these problems lower the value of fishery products in the

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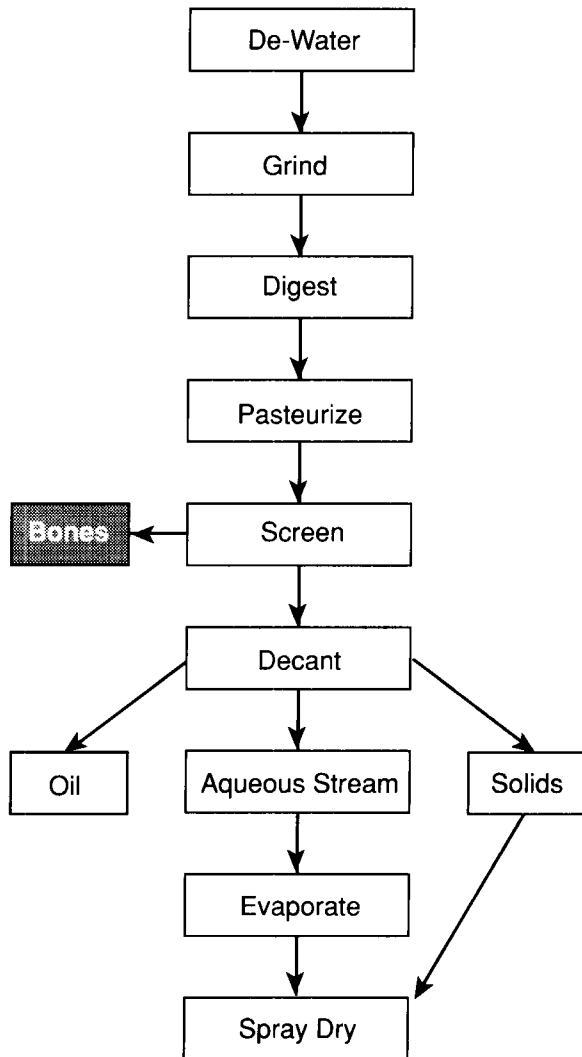


Figure 1. Standard fish protein hydrolysis process for producing a spray-dried fph.

burgeoning aquaculture feed markets. However, these markets are particularly attractive for Pacific Northwest marine by-products.

Ash Content

Because of the large amount of heads, racks, and frames in fish processing wastes, the ash content of waste-derived fish meals can be as high as 20% or even greater. This lowers the feed value of the meal. The high ash content probably will place the meal at more of a disadvantage in future aquaculture markets, as fish farmers become more aware of (and as they face legislation to combat) the pollution caused by excess

Table 1. Composition of spray-dried cod hydrolysate.

Assay	Initial (%)	Dried (%)
Moisture	78.9	8.1
Fat	0.2	0.7
Protein	14.1	84.5
Ash	5.1	5.9
Crude protein digested by pepsin	–	97.0

phosphorus in feed.

FPH offers the possibility for removing most of the bone during processing. Figure 1 shows a standard process for producing a spray-dried fph. Once the flesh is liquefied off the bones, the larger bone fragments can be screened out. Table 1 shows the composition of a dried cod hydrolysate, which we produced, compared to the composition of the wastes from which it was derived. Although the raw material was over 20% ash on a dry weight basis, the final product is only 6% ash (and 85% protein).

Concentration and Drying

The main advantage of hydrolysis is that hydrolysates can be stored for long periods as acidified wet or condensed products and, if properly treated, will remain stable in wet condition. Acidification can be carried out by adding acid, or by adding sugar and a microbial culture so the microbes will produce lactic acid through fermentation.

The process shown in Figure 1 could be installed on board a vessel, but it would require an immense commitment of capital and space for evaporation and drying and for fuel required for those steps. A skilled worker would be needed to run the dryer, preferably one for each shift. Retrofitting this process onto a vessel with a primary commitment to fillet or surimi production would be a massive undertaking.

Condensed On-Board FPH Process

We designed a variant on the process that would emphasize simplicity, minimize risks to the vessel and to the quality of the product, and require less space, less skilled labor, and less capital. The process we designed is illustrated in Figure 2. In this condensed process, the bones and the aqueous stream from the decanter are discarded at sea. The oil may be burned as fuel. Only concentrated solids (the sludge stream from the decanter) are stored.

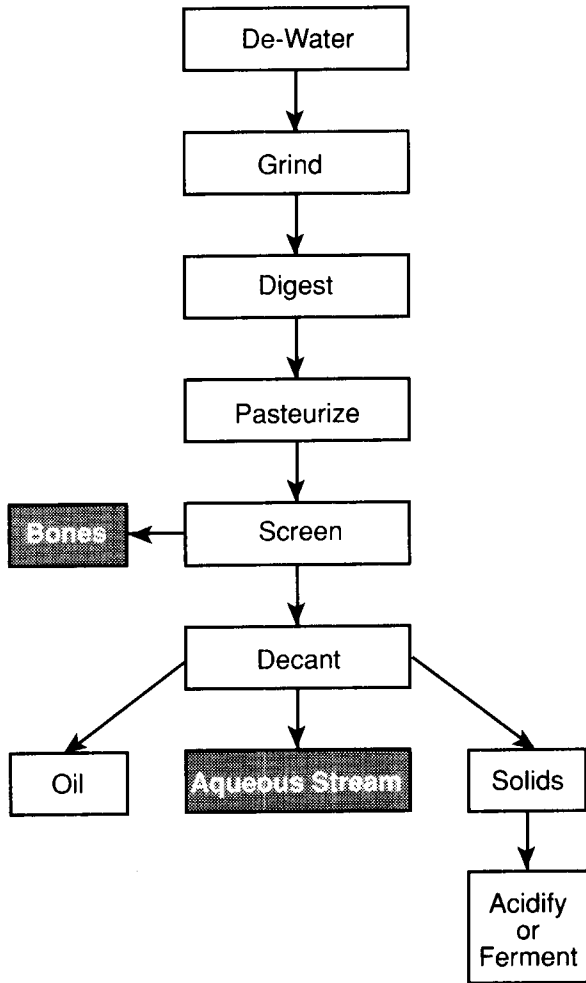


Figure 2. Condensed hydrolysis process designed for use on board the vessel. The bones and aqueous stream from the decanter are discarded at sea.

Because the product is concentrated with a decanter, rather than with an evaporator, and is stored without drying, it is relatively cheap and simple to install on board. It requires very little space and essentially no fuel. However, this process is wasteful. At least half the total protein would be discarded in the aqueous stream from the decanter. The hydrolyzing enzymes chop the protein very rapidly into a variety of sizes of particles and molecules. The smaller sizes are too light to be concentrated by decanting. The smallest particles—free amino acids—are the least valuable in feeds.

In order to make some quantitative extrapolations of what the condensed process will lose and yield, we made a set of assumptions as follows:

Table 2. Change in composition of fish from raw waste to product, condensed process.

	Start (lb)	Finish (lb)
Water	79,000	8,000
Oil	3,500	500
Ash	3,500	500
Protein	14,000	7,000
Total	100,000	16,000

1. 80% of the oil would be decanted off.
2. 80% of the ash would be screened out.
3. 50% of the protein would be in the decanter's aqueous stream and 50% in the solids.
4. The decanter could get as little as 50% water in the solids stream.

The calculations were made assuming that the raw material is flatfish waste. Data on analyses of wastes are taken from the Alaska Fisheries Development Foundation's Final Report on the Characterization of Alaska Seafood Wastes, October 12, 1988.

The proximate composition of flatfish processing waste is reproduced in Figure 3. Using the set of assumptions given above for the condensed process, the final composition of the acidified concentrate produced and stored is 50% water, 3% oil, 3% ash, and 44% protein. Table 2 shows how each component of the fish changes quantitatively as 100,000 pounds of raw waste are converted to product in the condensed process.

Note that at the end of the condensed process, we end up with 16,000 pounds of product to store on board. Table 2 shows we have achieved a threefold concentration of protein, a greater than fivefold reduction in bulk, a sevenfold reduction in ash, a tenfold reduction in water content, and stabilization of the product with minimal processing and capital costs.

If we were making fish meal out of the same material, under the same circumstances, how much product would we end up having to store? If considering retrofitting a vessel whose primary business is human food production, most engineers would choose the condensed process described above and jettison the stickwater to avoid the high costs and space demands of evaporation. This would lose about 20% to 25% of the protein. Thus, starting with the same 14,000 pounds of protein and 3,500 pounds of ash, we would lose between 2,800 and 3,500 pounds of the protein, but relatively little of the ash. Averaging the protein losses, we would end up with the amounts shown in Table 3.

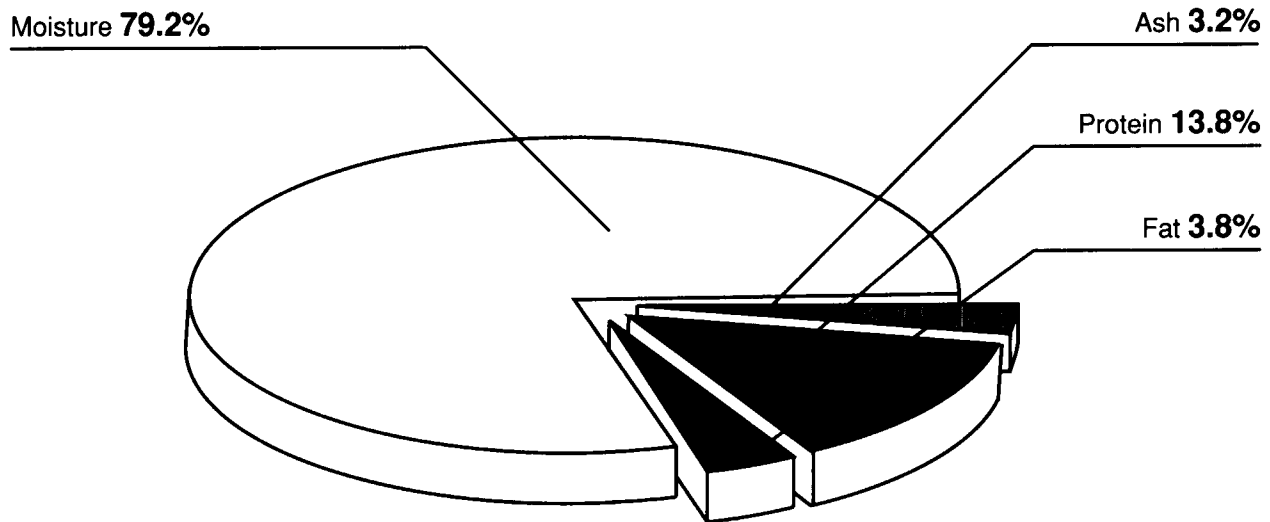


Figure 3. The proximate composition of flatfish processing waste. Taken from the Final Report on the Characterization of Alaska Seafood Wastes, prepared by the University of Alaska for the Alaska Fisheries Development Foundation, October 1988.

Thus, the weights to be stored would be almost identical for the two processes: fish meal and FPH.

Costs and Benefits of Condensed FPH Process

The major costs are that we are carrying a lot of water and that the product we have manufactured is not a commodity; it does not sell itself.

One cost is that we are still throwing an enormous amount of material overboard. However, we would be hard pressed to find storage space for all the potential by-product. The material we are throwing overboard is in a form that can be broken down most rapidly, and it is only half the amount that would be jettisoned with no process in place.

Another cost is that the ash content is higher than if all the protein could be saved. We estimate 6% ash on a dry weight basis; if all protein were utilized, we could get as low as 3% ash content. Still, 6% ash is far less than in any meal made of the same material.

But there are several benefits. First, if we were making fish meal the product would be approximately 65% protein, which is normal for fish meal. But in the marketplace we could be penalized for high ash content and possibly for poor drying. The concentrated fph would be 44% protein. Its ash content would be low and its protein in excellent condition. Given the increasing interest of the northwestern feed industry in the use of wet and condensed products for the manufacture of

Table 3. Composition of fish meal (presscake only).

	Start (lb)	Finish (lb)
Water	79,000	1,500
Oil	3,500	1,000
Ash	3,500	3,500
Protein	14,000	10,000
Total	100,000	16,000

semi-moist aquaculture feeds, we believe this concentrated product's value could be close to that of fish meal, despite the FPH's 50% water content.

In addition, although we might use the same amount of on-board space to store product as needed for fish meal, we would use less space for processing machinery and fuel. Indeed, energy requirements for the condensed process are extremely low; the material must be heated to pasteurization temperature, and a number of motors must be run. The process requires carrying some ingredients; their weight is approximately 60 pounds per ton of manufactured product, either for acidification or fermentation.

The condensed process eliminates the steps most likely to lower product quality. Fire risk is also reduced, as is the number of workers needed. Also,

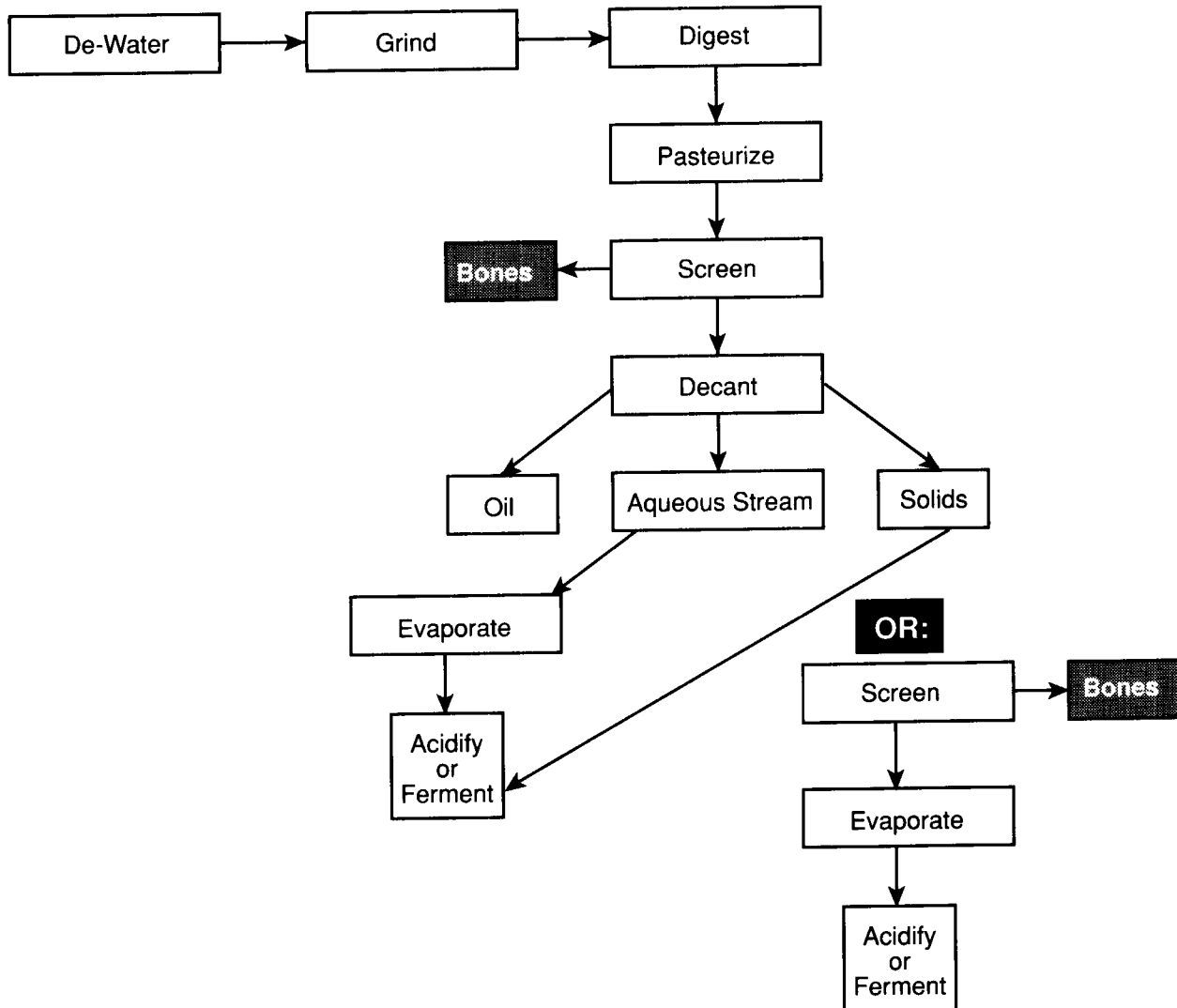


Figure 4. A standardized variant of an FPH process, suited for an on-land plant.

evaporation or drying capacity can always be added, either on board or on land. The process does not cut off any options. It does present the possibility of at-sea manufacturing of a low ash fish by-product of consistent quality, with the lowest possible capital investment and risk.

An On-Land FPH Process

In closing, let us look quickly at a more standardized variant of an FPH process, which also would produce a concentrated acidified product, but which would be better suited for an on-land plant. We assume

this plant processes cod, and that the processing waste has the proximate composition shown in the left column of Table 4. The process is shown in Figure 4, with two alternatives. No part of the waste will be discarded, with the possible exception of the bones, and even these may be dried, milled, and sold as bone meal. An evaporation stage is used to reduce the water content of the aqueous stream. The decision to choose one or the other alternatives shown in Figure 4 depends upon a number of factors, including the fouling tendencies of the evaporator. We assume the final product would have a water content of approximately 50%.

In Table 4 the right column shows that the product's

Table 4. Composition of cod filleting waste: On-land process.

	Start (%)	Finish (%)
Water	80	50
Oil	2	4
Ash	4	2
Protein	14	44

proximate analysis would be quite similar to that of the flatfish concentrate processed on board. The major difference between this and the on-board process is the yield. As shown in Table 5, the on-land process produces 33,300 pounds of concentrated product from 100,000 pounds of raw material, whereas the on-board process produces only half this amount.

It is interesting to note the extremely low ash content of this material: 2% on an as-is basis, and 4% on a dry weight basis. Were this raw material made into fish meal, the ash content could be as high as 20% on a dry weight basis. We suggest profits for a product that is 50% water from the FPH process would be as high as or higher than profits from manufacturing poorly dried or high-ash fish meal from the same raw material, for the following reasons: (1) increasing use of wet and concentrated ingredients for semi-moist aquaculture feeds, (2) high quality of the protein produced in the properly carried out FPH process, and (3) relatively low capital and operating costs of the FPH process compared with the fish meal process.

We wish to emphasize that the FPH process is not necessarily a competitor to the fish meal process. It is a useful alternative; each process has strengths and weaknesses in any situation, and knowing what these are will be useful to the processor in making decisions. Installing both the FPH and the fish meal processes side by side, in the same location, would make sense in many situations. Because FPH offers a way to stabilize wet product, it can be used to handle seasonal gluts without up-scaling the entire plant. It also offers an alternative product, the price of which is not pegged to that of soybean meal. In short, we suggest that FPH offers options of great potential power and utility to the Alaska industry.

Table 5. Cod filleting waste: On-land process.

	Start (lb)	Finish (lb)
Water	80,000	16,700
Oil	1,600	1,600
Ash	4,000	600
Protein	14,400	14,400
Total	100,000	33,300

QUESTIONS AND ANSWERS

- Q. What are your maximum in-feed capacities?
- A. You can engineer the system to accept essentially any in-feed of raw materials.
- Q. The tons per hour, or pounds per hour, is essentially a continual process unlimited?
- A. Right.
- Q. Have you worked up a cost estimate for doing a demonstration on a vessel for this?
- A. No, but we would be happy to do that.
- Q. How far does one have to take this material down, to polypeptides, to peptides? Is there information as to what is the most beneficial from a nutritional point of view?
- A. Our assumption nutritionally is that the minimum digestion is the best. Free amino acids are not well absorbed, and are of the least nutritional value. The least digestion that you can do, getting that product off the bones, is the most desirable.
- Q. Have you thought about the price of soybean meal, which is a comparable level of protein, and of transporting the material?
- A. We have reduced the water content considerably from 80% to 50%. There are major potential buyers who feel it is worth it to cart the remaining water so as not to take any chances with protein quality. One of the interesting things about this FPH product is that in its 15 year history, it has not been linked to soybean in price. For some of the major markets such as salmonid feeds and early-weaned baby pig feeds, soybean meal is not considered a useful high quality ingredient. FPH should not be seen as something linked to soybean meal.

BIOLOGICAL FISH MEAL: BIO-PROTEUS' APPROACH TO FISH-WASTE UTILIZATION

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INTRODUCTION

Bio-Proteus Corporation recently acquired a proprietary proteolytic fermentation method called the Bertullo process. This commercial process, which employs a one-of-a-kind aerobic marine yeast, converts protein-bearing materials into a slurry of principally water-soluble predigested proteins. As fermentation proceeds, the process destroys all common pathogens such as *Salmonella*, *Staphylococcus*, and the avian flu virus. Once the slurry is dried, the resulting high-quality concentrates are ideal for use as dietary supplements. Accordingly, the unique Bertullo process provides the basis not only for manufacturing fish meal, but also for recycling agricultural and food-processing wastes back into the animal food chain.

BACKGROUND

The Bertullo process was originally developed at the University of Uruguay by Prof. Dr. Victor Bertullo as a means of converting protein from underutilized (trash) ocean fish into an inexpensive concentrate suitable for supplementing globally deficient diets. International interest was keen because the concentrate contains predigested protein, which permits it to be fed to severely malnourished infants who are unable to handle intact protein.

In succeeding years, runaway inflation in Uruguay and the unavailability of inexpensive fish, together with loss of political interest in world feeding (which only recently has been renewed), led Bio-Proteus to recommend the transfer of the technology from Uruguay and apply it to the manufacture of fish meal in Canada. Unexpectedly we were introduced to the emerging crises of biological waste disposal. We put

the fish meal project on hold temporarily, and today our priority is working toward recycling agricultural and food-processing (including fish) wastes as a means of biological waste management and conservation.

MANUFACTURING ADVANTAGES

The nature of reduction of protein-bearing substrates with the Bertullo process demonstrates considerable advantages over other typical reduction endeavors.

Satellite Operations

The proteolytic fermentation process is unique in that the slurry from a first-stage digestion can be held safely and inexpensively in fermentation tanks for some time without spoiling. These tanks may be distant from a central location where the slurry is dried. Many such satellite operations can be combined to service a second-stage central drying facility.

Operational Efficiency

By combining and integrating select numbers of the satellite operations into an overall endeavor, material flow to the central, more complex, and costly finishing operation can be controlled so that equipment can be selected to permit continuous operation. In this way, capital equipment costs are reduced and operational efficiencies are realized.

Small Scale Feasibility

Because the digest in a biological process can be held in tanks for long periods without spoiling, even marginal operations with a restricted supply of raw material can become part of any integrated system. Digests in these cases could be held in the storage tanks until enough was available to justify pickup and transport to the drying operation.

Small Scale Economy

In most methods for concentrating proteinaceous material, especially chemical extraction, economies of scale are very important. This is not so with the Bertullo method. A 25 ton per day plant costs only 15% less to set up than a 100 ton per day plant.

Competitive Equipment and Operational Costs

The operational costs as well as capital equipment costs in the Bertullo process are competitive with the wet-reduction (physical) method employed to inexpensively reduce fish and meats into conventional meal.

Production Versatility

The total operation (but primarily the fermentation step) can be as primitive or as sophisticated as desired. For instance, under crude conditions, open cinder-block tanks with no controls or automation would suffice as opposed to jacketed, temperature- and pH-controlled stainless steel tanks. Drying could also be accomplished using primitive means. In effect, the total operation could be carried out under artisan conditions.

It is helpful that when digestion is complete, the watery slurry with protein fragments is free of contaminating microorganisms no matter how primitive the processing conditions. Under a grant from the United Nations, Dr. Enrique Bertullo, son of the inventor and an officer in Bio-Proteus, recently applied the biological technology successfully in South America at a lake fishery in an underdeveloped area without electricity.

Oil Recovery

Because the oil has not been exposed to high heat, market price will be high in relation to competitive oils today.

Protein Sensitivity

Special attention is being given today to developing high-quality feeds for livestock particularly sensitive to the quality of protein in their diets (International Association of Fish Meal Manufacturers Report, 1988, 31 October 1988, p. 8). Livestock such as farmed fish, early-weaned pigs, and high yielding ruminants fall into this category. These upgraded feeds often bring in twice the price of feeds used for broilers.

Environmental Impact

Properly operated, a Bertullo facility will have no adverse impact on its surrounding environment because

no losses are experienced—only water is removed until a moisture level of 5% to 8% is reached.

Market Preeminence

Bertullo products would find preeminence in the reduction industry for a host of reasons:

Product quality. Controlled animal feeding tests backed up by chemical analyses show that the biological value of Bertullo fish meal tested statistically better than that of regular fish meal, including so-called low-temperature fish meal.

Market versatility. Regular fish meal is market-fixed; that is, it is suitable for only poultry feeds. With a Bertullo product, efforts can be directed toward developing upgraded markets for existing products such as pet foods, and tailoring products for higher-priced markets such as fish (trout, salmon) food. These products can sometimes command twice the market price of fish meal—around \$800 or \$900 per ton. Unlike other operations, tailored Bertullo products require only a minimal increase in operating costs.

Raw material advantages. A Bertullo operation realizes a reduction rate of 4:1. The reduction rate for regular fish production is 6:1.

A wet-reduction operation is profitable only on a glut fishery. And seldom is the price structure of low-grade fish meal high enough to make the processing of non-pelagic fish or, in fact, fish wastes profitable.

Feeding Efficiency

Animal feeding tests show an improvement in feed efficiency and rate of gain when Bertullo fish meal is fed in contrast to conventional fish meal.

In experiments with milk cows, when milk production was compared in equivalent studies with prime-quality fish meal, the production increased when an alfalfa-Bertullo product mixture was fed to the animals. In similarly controlled studies, statistically significant increases in weight gain and feed efficiency were noted in chickens that had consumed the Bertullo product in contrast to regular fish meal. In another study, egg production increased considerably. Swine gained up to an additional 40 lb during a three-month feeding period when Bertullo fish meal instead of regular fish meal was added to their diets, as formulated in Uruguay.

The Product

The product from the Bertullo process (mostly from gutted and headed hake) has been tested extensively.

Characteristics

When fish is used as a substrate, the Bertullo product generally has a yeasty-fishy odor, as we'd expect. If chicken is used as a substrate, the finished product has little taste or odor. When slaughterhouse (beef) wastes are used, the product has a slight meaty or nutty taste but little odor. Critical taste testers claim to detect a slightly sharp taste because of the free amino acids and very small amounts of lactic acid. All product is a non-gritty fine powder that is lighter in color if prepared with common sugar. If molasses rather than common sugar is used as an energy source for the yeast, the powder is darker in color.

The Bertullo product is easily adaptable to supplement mixed animal feeds. For human consumption the product is easily incorporated into pasta, bread, gruels, and soups without imparting a gritty texture. The soluble portion can be added to beverages and gravies. If the process is adjusted, fermented fish pastes like the kinds found in the Far East, and fermented fish sauces like the kinds from Southeast Asia can be prepared using select fish as a substrate.

Bertullo products can also be prepared from prime sources such as grains. Prime animal material other than fish could be used. All kinds of by-products such as slaughterhouse residues, chicken wastes, and clam bellies can also be used. Product characteristics vary, of course, with the raw material. Chicken droppings, for instance, result in a light-colored, somewhat nutty tasting product with a high level of protein of good quality.

Chemical Tests

The content of protein, fat, and ash reflect values found in the raw material. In the Bertullo process, no losses are experienced as previously noted—only water is removed until the product reaches a moisture level of 5% to 8%. Lipids may be reduced depending on the market targeted.

Protein content from reference Bertullo product samples prepared from several groundfish species varied from 65% to 72%. Fat ranged from 0.2% to 6%. The pH ranged from 5.4 to 5.8. Ash content varied from 6% to 12%, and the hydrolysate contained essential minerals in good proportion. Vitamins and phospholipids were present in varying amounts. The character of protein from fish and whole chicken is excellent and reflects the composition of the original raw material.

Because of the gentle processing method employed, the protein of the Bertullo product is nearly 100% assimilated by the animal organism. Amino acid balance studies show excellent results. With reference samples prepared from gutted and headed hake,

the hydrolyzed portion of the protein is 70%, in which the ratio of polypeptides to free amino acids is 60:40. The 70% digestion was verified in 1989 with whole chickens at the Memorial University of Newfoundland, St. John's, Newfoundland. The amino acids are all in the "l" form—the only form which is nutritionally available to the body organism.

Toxicity

Toxicity experiments were conducted on groups of Westlar rats over three consecutive years, a longer period than recommended by the World Health Organization or the Food and Agriculture Organization for this type of investigation. The absence of abnormalities in the descendants of the rats after several generations shows that there is no teratogenic or mutagenic potential.

Bacteriology

Microbiological tests show values far below the 6,000 to 8,000 microbes per gram proposed as normal. The periodic analyses have shown *Salmonella* spp., *Shigella* spp., *Staphylococcus aureus*, *Proteus vulgaris*, and *E. coli* to be systematically negative.

Protein Quality

The PER (protein efficiency ratio) of the test product is significantly better than that of casein, a milk protein that is used as a standard reference.

The product excels when subjected to the many other tests related to protein quality: biological value, chemical score, amino acid balance, available lysine (Carpenter's method), net protein utilization, and others. The product also exceeds the model requirements of the World Health Organization and the Food and Agriculture Organization, both of the United Nations, for milligrams of amino acids per gram of protein.

Other Tests

Over 8,000 premature and dystrophic (malnourished) babies thus far have been fed test product with excellent results.

The utilization of hydrolyzed proteins for feeding in cases of chronic diarrhea was a recommendation reached at the Third International Forum of Pediatric Gastroenterology and Nutrition convened in São Paulo, Brazil in 1977. Feeding the Bertullo product, a hydrolyzed (predigested) protein, to children and adults with acute and chronic diarrhea produced excellent results.

Beneficial results were achieved with patients suffering problems of new tissue formation on the surface of various wound-like skin areas (fistulas, lesions, abscesses, perforations, necrotic dermic areas, infected stumps, and bone healing). These favorable results related to tissue regeneration are not unexpected: A report by a U.N. agency states that one of the parameters that evaluates the quality of a given protein is its positive reaction to tissue regeneration (FAO, 1973, Report No. 552).

Lot #10107 of Bertullo product destined for a nursing home program in the United States was purchased and imported by Bio-Proteus from Uruguay to Philadelphia, where it was sampled, tested, and released by the FDA as safe and in compliance with the regulations. Other lots were similarly released. A lot of Bertullo product in tablet form was also rated in compliance by the FDA.

FINANCIAL PROJECTIONS

In-House Operation

It must be clearly understood that a biological reduction operation is ready to proceed only when (1) a site is selected, (2) raw material supply is identified, priced, and secured, (3) plant size is determined, (4) engineering determinants (capital equipment, direct plant costs) are adjusted to 1, 2, and 3 above and costs are defined (Bio-Proteus has a working relationship with United Engineers and Constructors of Philadelphia), (5) operating costs (labor, utilities) are established, (6) conditions for production of batches of yeast are established, (7) market conditions are updated, (8) government participation is identified, and (9) all startup costs and working capital requirements are known.

Obviously, precommercial analyses to arrive at highly detailed pro forma financial statements and startup activities always precede any production endeavor. However, estimates on certain capital requirements for the commercial operation are available as a guide to anyone considering an investment.

Plant Design and Related Costs

In Uruguay, engineering analysis on the proteolytic fermentation process has progressed in a classic manner astride comprehensive product testing and evaluation for animal and human feeding purposes: bench scale to model pilot plant to small commercial plant. In the United States a large (100 tons per day) plant has been designed according to food grade standards. Depending on the degree of sophistication planned, location, etc.,

capital equipment costs for the 100 ton per day plant should range today between \$500,000 and \$750,000. Total plant costs should range between \$1.5 million and \$2.25 million.

Projections

Operating costs are conservatively judged to run about the same as a wet-reduction (fish meal) operation. Oil credits should be higher than a fish meal operation on an average.

Owing to the superior quality of our Bertullo concentrate, we expect its selling price to provide a premium of about \$50 per ton over regular fish meal in the poultry mixed-feed market. We'd expect a similar price advantage using fish wastes as a raw material. As we enter upgraded markets such as pet foods we'll realize a significantly higher sales price for the meal.

Licensing

Bio-Proteus would license the use of the Bertullo process in new reduction operations. Some provisional discussions have occurred relative to use of the process in Denmark, Germany, India, Argentina, and Mexico.

A 25,000 ton per year operation is soon to be constructed on the Delmarva Peninsula that adjoins the Chesapeake Bay. This peninsula, which encompasses Delaware, Maryland, and Virginia, is the site of the most concentrated poultry production in the nation: 40 million lb per week. The purpose of the plant is mainly to recycle the 100 tons of birds that die normally each working day during the grow-out period, back into the animal food chain. Design determinants for an on-farm fermentation system and bio-secure transfer are currently being made at the Biotechnology Institute of Pennsylvania State University under a grant from Bio-Proteus. Present means of biological disposal by burying is destroying the fragile ecosystem of the bay. The regulatory agencies threaten to close down the poultry operations unless an ecologically approved means of disposing of the wastes is found. The Bertullo process provides this means.

CONCLUSION

Because the competitive Bertullo process is so easily adapted to varying conditions, circumstances, and influences affecting processing; because the competitive Bertullo process possesses considerable economic advantages over conventionally reduced concentrates; and because resultant Bertullo production is so easily modified to respond to changing markets, we believe a Bertullo process approach will

eventually be considered the method of choice world-wide for the reduction of fish (and other biological material) into nutritional concentrates for supplemental feeding purposes. For the same reason, the Bertullo process will find use in biological waste management and conservation. Agricultural and food-processing wastes can be processed into animal feed supplements for recycling back into the animal food chain. In this way, not only do we protect the environment, but we conserve the biomass at the same time.

QUESTIONS AND ANSWERS

- Q. Did I hear you say that your process depends on a marine yeast fermentation?
- A. Yes.
- Q. Can you tell us anything about it?
- A. I'm not a microbiologist, but I understand that it's unusual to find a marine yeast. I also understand it's unusual to find a proteolytic yeast. Bertullo found

a marine proteolytic yeast by pure chance 20 or 30 years ago while fishing with his son in a river. The yeast was living in association with the liver of a golden croaker. He brought it home and plated it out, found out it had proteolytic activity, and through successive generations he increased the proteolytic activity by about 70%. The interesting thing is that the quality as measured by the content of methionine and lysine in a slurry of whole ground chickens (no feathers) remained constant after 18, 24, 48, and 72 hours of fermentation; it reflects exactly the same content of these two amino acids as the original raw material.

- Q. Aren't there other proteolytic microorganisms?
- A. Yes, but none of the many microorganisms that we have looked at, at the laboratory, were satisfactory for a host of reasons. *Acidophilus* or something like that might work because the acid produced is holding the product. We found only this yeast to be satisfactory overall. It works.

A SYSTEM TO RECOVER UNDERUTILIZED PORTIONS OF GROUND FISH

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Over several years, fish processing companies have begun to look at ways of increasing the total recoverable yield from their operations. Much of this motivation has come because of a scarcity of the resource, increased harvesting competition, and to supply the increased demand of the marketplace.

Currently most operations remove the fillet only. Some processors recover the roe from cod, and also the tongues, cheeks, livers, hearts, swim bladder membrane, and split and whole heads. In some cases, the skin is utilized in tanning operations.

The market for cod tongues and cheeks is an emerging one, and prices are very healthy for these delicacies. Liver recovery occurs mainly in Europe for the production of cod liver oil. The hearts and swim bladder membranes (known in Newfoundland as "sounds") have small markets, primarily in small coastal communities in Newfoundland. Cod roe is a high-demand product tapped mainly in Europe, where it is mass produced in smoked form and sold in tubes. There is also a high-end market in France, where it is a delicacy. There it is eaten the same day that it is smoked.

After all this potential is taken into account, there remains the skeleton (frame) and the neck (collar) area of the fish, which is laden with valuable flesh. The problem with recovering this meat has been in the removal process. Simple cutting with a knife is not so simple due to the presence of rib and dorsal bones, and on the collar due to the presence of the angular collar bone. The process of deboning these portions leaves the remaining mince contaminated with blood, specks of membrane, and other objectionable matter.

THE MINCE WASHER SYSTEM

Canpolar East of St. John's, Newfoundland, has developed a semi-automated process of removing the

blood and other objectionable matter from this mince, leaving a product that is comparable to regular, deboned V-cut and fillet mince. The increase in product output can be as high as 15%, depending on current filleting yields.

The mince washer process begins with the entry of the whole, or head-on, gutted fish into the plant. The heads are removed by a fish deheading machine. These fall onto a conveyor table where the collars are manually pulled off. The collars fall into an automatic scrubber, where any attached liver or kidney is removed. The collars are then ready for deboning. In the deboning process, the collars drop into a mincing machine supplied with a drum having a 5-mm pore size. This drum pore size is recommended in order that the mince remains fibrous during the washing process. A smaller drum pore size can result in the mince clumping while in the mince washer wash zone.

Recovery of the frames from the filleting process is easiest when using a filleting machine that has a frame trimming device attached to it. This removes the ventral portion of the frame, which contains the swim bladder membrane and other non-water-soluble material. The trimmed frames drop into the bone separator in a similar fashion as the collars. The mince that leaves the bone separator is comparable to hamburger meat in color.

From the separator, the mince is fed into the mince washer at a metered rate of about 540 pounds per hour. The mince is agitated and washed in the wash zone for about four minutes. The mince travels up the trough of the Mince Washer with the use of a perforated auger. The washed mince then travels through the drainage zone, where most of the unbound water is released. The washed, drained mince is then ready for refining. Refining the mince removes any small (over 3 mm) bones, parasites, or other objectionable non-water-soluble particles leaving a near white fibrous mince product ready for freezing.

YIELDS

Yields from a mince washer system process vary. Much depends on species, fillet recovery process, size of fish, and current yield capabilities. If a processor is leaving much of the fillet meat on the frame or collar, it will be recovered as mince in the mince washer process. The higher the fillet recovery currently is, the lower the additional mince recovery will be. With larger fish, a higher proportion of the meat remains on the frame and collar. Machine filleting will also have an effect. Using head-on, gutted Atlantic cod as a base, typical skinless fillet yields (including V-cut) are about 44%–45%. The amount of washed mince will be in the area of 5%–6% of the head-on-gutted state. This gives a total potential recovered flesh yield in the neighborhood of 50%. Another way to look at it would be a 14% increase in the output of frozen product, and a corresponding reduction in the amount of waste.

For the entire Alaskan pollock and cod processing industry, an annual round weight of 2.7 billion pounds and a recovery of 5% of additional saleable product from collars and frames would give an extra 135 million pounds of mince over and above the production that's now being generated. This is significant, especially for the Alaskan industry, where there is greater emphasis on reducing the amount of fish that is put into fish meal or thrown away.

THE MARKET

The market for washed mince is still emerging. We know that the market for minced white fish, mostly cod and pollock, is healthy. A benefit to this new product is that it fits well into an already existing market, primarily as a mixture with regular minced portions. The type of mixture is dependent on the end use. There will be different specifications for breaded portions from blocks than there will be for fish sausage utilizing this mince as stock.

The mince washer system output is about 500 pounds per hour. With this output and with current mince prices, the system has a pay-back of generally less than one operating season.

QUESTIONS AND ANSWERS

- Q. Realizing, of course, you've bled your fish on board—how do you separate the collars from the heads?
- A. After the bleeding process is complete, there remains a thin attachment of meat and skin between the collars and the back of the head. By grasping the collars together in one hand and the head in the other and pulling apart, the two collars separate very easily.
- Q. It is all done by hand?
- A. Yes, currently the removal of the collars is a manual operation. The fish processing machinery company Baader has developed an automated collar cutter that comes with a deheading-filleting machine package that will negate the need to manually pull collars. This will certainly reduce any labor costs associated with collar collection.
- Q. What was the refiner used in the process?
- A. The refiner we used was a Baader 694. The drum pore size was 3 mm. However, 1.5 mm or 2 mm is acceptable for the process. The buyer of the mince product will ultimately determine what will be acceptable. Canpolar East is currently developing a refining unit as an attachment to the mince washer.
- Q. What are the implications for the taste of the product, and the elimination of parasites?
- A. I'll address the parasite question first. There is not a high incidence of parasites in the collar area of the fish. I am referring to Atlantic cod only. This process, however, does not remove them. In the refining operation, using a small drum pore size will have the effect of reducing the size of the visible parasites.
- With regard to the question of taste, it is bland. As the mince is washed, the flavor is as well. We have found that this is not a problem with the processors of secondary products because they are supplying flavor through the addition of spices, breading, and batters.
- Q. What is the moisture content of washed mince?
- A. It depends on raw material quality, but generally around 85%.
- Q. What about the frozen storage characteristics of this mince compared to the regular V-cut mince?
- A. Independent shelf life studies have been carried out in the U.S., and it was determined that there wasn't any significant difference between the two.
- Q. What is your experience with fish close to shelf life, say, eight-day-old caught cod?
- A. Do you mean post mortem age before processing?
- Q. Yes.
- A. With Alaskan on-shore processors, I believe the post mortem age might be three to four days when processed. In Newfoundland, trawler trips can

last up to 10 days. The differences go far beyond that, however. In Newfoundland the fish are bled and gutted before they are stored on board. Doing this considerably reduces the amount of bacteria and harmful stomach enzymes that can increase the rate of degradation. Also the catch is

well chilled through icing. This also retards degradation. So after a 10-day trawler trip and another day or two in holding at the plant before processing, we have not experienced any significant characteristic changes that would affect the ability of the mince to be washed successfully.

FUTURE OF THE RESOURCE IN ALASKA'S OFFSHORE WATERS

Brian Bigler
Wards Cove Packing Company
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ABSTRACT

Since implementation of the Magnuson Fishery Conservation and Management Act of 1976, the fisheries of the North Pacific Ocean have reversed from dominance by foreign interests to 100% American in 1989. Though the commercial fishing industry in Alaska is typically associated with salmon, the groundfish resources of the Bering Sea and Gulf of Alaska have supported an annual harvest of about two million metric tons for the past several years.

There are 10 commercially viable species of groundfish including: pollock, cod, atka mackerel, soles and flounders, sablefish, rockfish, and perch. Pollock forms the primary source of raw material for the manufacture of surimi, a flavorless paste from which a variety of imitation fish and meat products are produced. Cod forms the basis for several other products processed at the Alyeska Seafoods plant in Dutch Harbor. These products include the front portion of the face, the stomach, roe, and milt. As processing methods and markets evolve, more and more protein that has been either discarded at sea or ground to meal is being processed to a widening variety of food products.

Some feel there is no end to the plentiful fisheries of the North Pacific Ocean, yet within the next year the fishery is in jeopardy of overcapitalization, which has led to the collapse of virtually every other commercial fishery in U.S. history. None have been singled out as declining, but wasteful harvest techniques may be creating a bust cycle for some species. Fishermen have to discard whatever portion of their harvest is illegal or unprofitable to keep. The harvest by bottom trawlers during 1989 was 330 million pounds, with the incidental harvest estimated at 160 million pounds.

Roe-stripping of pollock has been an accepted

practice until 1990. This activity consists of separating the female pollock from all other fish, removing the mature roe, and discarding everything else. This wasteful practice was responsible for the premature closure of the pollock fishery in the Gulf of Alaska during March 1989. Resolution of the issue of waste will require the efforts of both government and industry. We all have a responsibility to assure that the groundfish resources of the North Pacific are managed in a manner to make them available for future generations.

GROUNDFISH HARVEST

Commercial fishing in Alaska has typically been associated with the harvest of salmon, yet annual groundfish harvests in the Gulf of Alaska and the Bering Sea have approximated two million metric tons in the past several years. If it were considered a separate country, this volume of harvest would rank Alaska eighth in the world as a source of fish protein. The groundfish resource in these waters includes 10 commercially viable species: pollock, cod, atka mackerel, soles and flounders, sablefish, rockfish, and perch. The Alaska groundfish industry has provided opportunities for developing products that would not be practical in other fisheries. One such product is surimi, a flavorless paste that can be molded into a wide variety of imitation fish and meat products.

Pollock forms the primary source for all surimi producers in the North Pacific (Figure 1). In recent years, the annual harvests of pollock have been regulated at just over one million metric tons. The lucrative harvests during the early 1970s were followed by what appeared to be a precipitous decline. Without implementation of the Magnuson Fishery Conservation and Management Act of 1976, the pollock and other resources might well have declined beyond the possibility of recovery.

The Magnuson Act gave the Secretary of Commerce regulatory authority over fishing from within three to 200 miles off American shores. The vehicle of

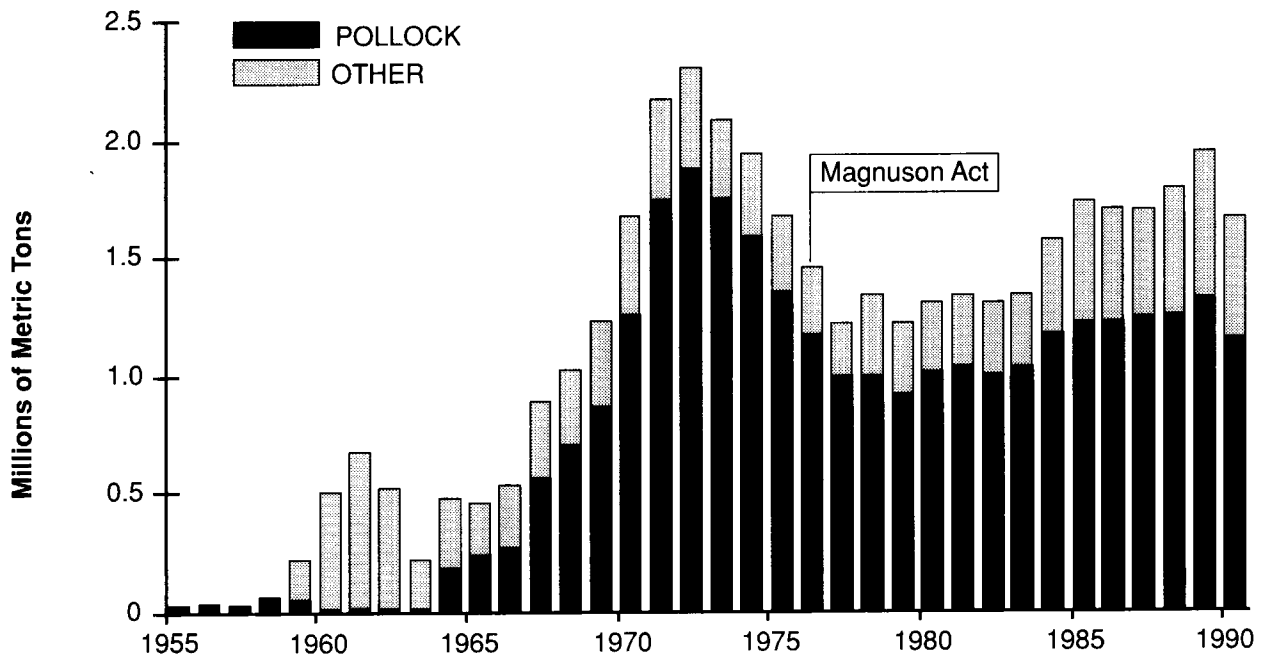


Figure 1. Pollock and all other groundfish harvests in the Bering Sea-Aleutian Islands, 1955–1990. (1990 = allocated.)

this authority in waters off Alaska is the North Pacific Fishery Management Council. When it became law in 1976, there were few American fishermen harvesting bottomfish in the North Pacific. At that time, trawlers and processors from Japan, Taiwan, Korea, the Soviet Union, and Poland comprised the bulk of the fishing fleet and the pollock resources were considered inexhaustible. Since enactment, the fleet composition converted to 100% American fishermen in 1989, and under guidance from the council, the harvests of groundfish from the North Pacific Ocean have sustained a rapidly expanding fleet of fishing boats and processor vessels.

Although pollock constitutes the bulk of the groundfish harvest, the ex-vessel value of other, less abundant species is higher and accounts for a larger portion of the overall revenues generated. For the past two years, the combined revenues for groundfish in the North Pacific have approached \$250 million (Figure 2). It is hoped that as the markets for fish by-products evolve, more and more of the protein that has been ground to fish meal, and in particular that which is being discarded at sea, will instead be processed into a widening variety of food products.

As has been established by the North Pacific Fishery Management Council, the harvest of pollock this year will be more than 2.7 billion pounds. Alyeska

Seafoods purchased more than 175 million pounds of pollock in 1989 and produced 30 million pounds of surimi, 5 million pounds of meal, and 200 thousand gallons of fish oil (Figure 3). The fish meal was produced from unusable skin, bones, viscera, and flesh that auto-matic filleting machinery cannot remove.

One immediately useful by-product of pollock is the oil removed from the flesh during processing. A gallon of diesel fuel in Dutch Harbor currently costs more than a gallon of fish oil. Fish oil is burned in boilers at Alyeska Seafoods and constitutes an immediate benefit from processing. Roe production amounted to less than one half of a percent in terms of weight, and occurs over a limited period in the spring when the female pollock are sexually mature.

Alaskan surimi production during 1989 is estimated at 100,000 tons, twice the level of production in 1988 (Figure 4). Two land-based plants operating year round in Dutch Harbor, one in Akutan and two in Kodiak, produced approximately 30,000 tons of the total. The remaining production was divided unequally among 13 at-sea surimi processors, six of which are at sea year round. Twenty and fifty percent, respectively, were exported to Korea and Japan, and the remaining 30 percent was transferred to imitation crab producers in the United States.

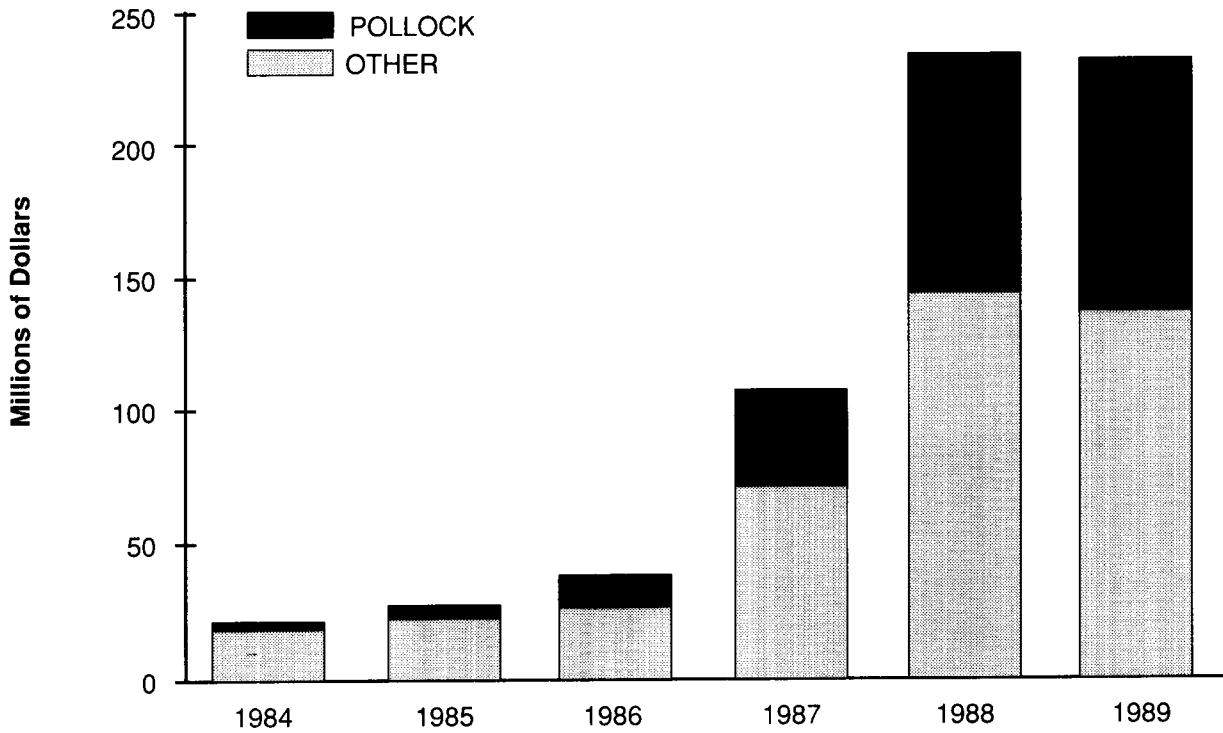


Figure 2. Ex-vessel value of pollock and other groundfish, 1984–1989.

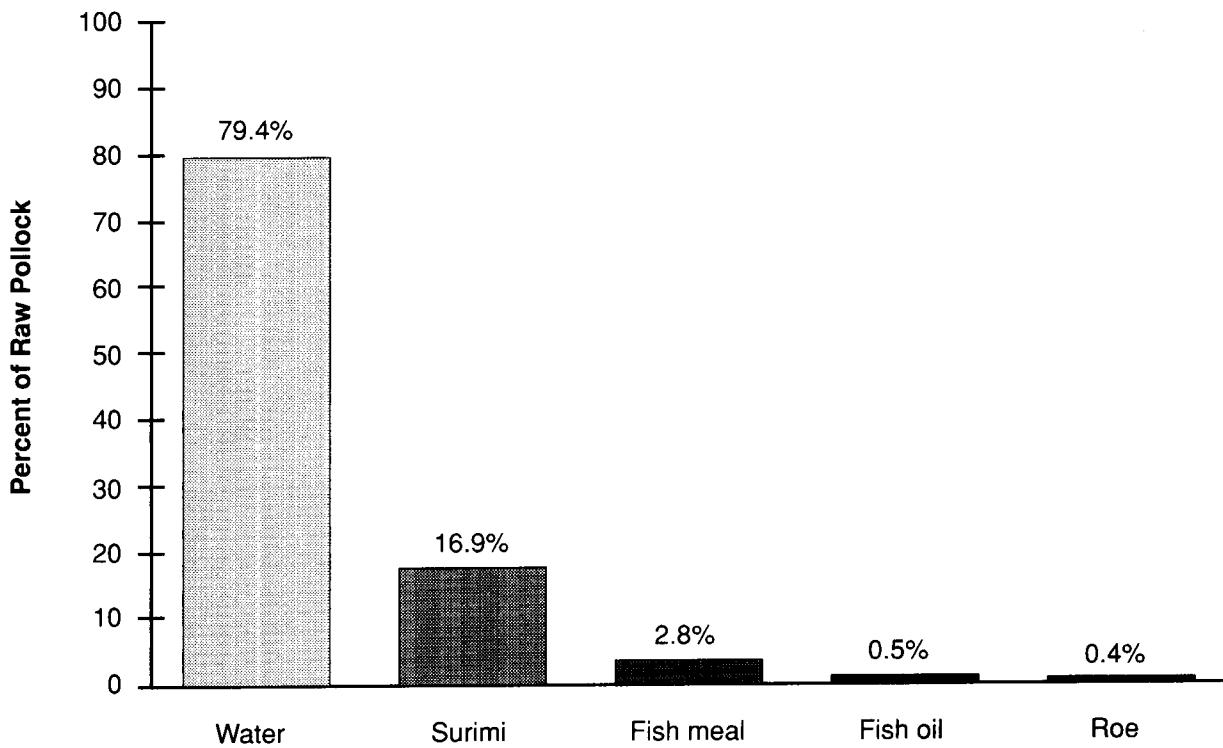


Figure 3. Products derived from raw pollock in 1989, Alyeska Seafoods. Total raw pollock was over 175 million pounds.

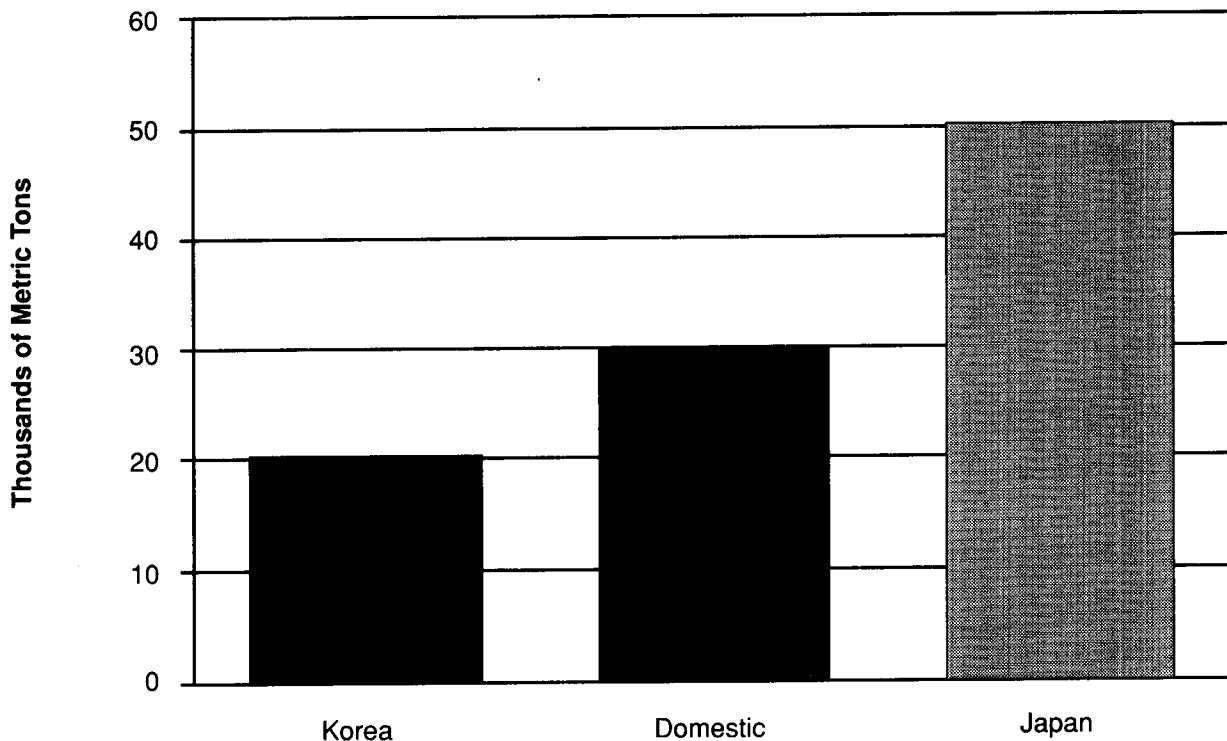


Figure 4. Disposition of 1989 Alaska surimi production, 100,000 tons.

Pacific cod is another important fish that we've been able to market in various forms (Figure 5). The bulk of salt cod we produced from the more than one million pounds of fish purchased was exported to Korea. Special markets for the front portion of the face, the stomach, and milt, as well as roe, exist in Japan, Korea, and Portugal. Any remaining body fragments were processed into fish meal.

Last year, Alyeska Seafoods processed more than 200 million pounds of seafood including salmon, scallops, herring, and various species of crab, in addition to pollock and Pacific cod (Figure 6).

The high seas fisheries of the North Pacific have been operating at an increasingly frenzied pace since the late 1950s. To some there is no end to the plentiful fish resources. However, we have seen a decline in the Shelikof Strait pollock biomass and there is concern in many areas over the impact of unregulated fisheries in the Exclusive Economic Zone on the health of the stocks in the Bering Sea. In the course of human history, periods of seemingly endless resources have always spawned a decline. I need only mention the Alaska king crab, Kodiak shrimp, and the California herring. We hope there will be no more harvest-accelerated collapses in Alaska.

FISH WASTE

An area of concern to all in the groundfish fishery is the non-utilization of fish and fish waste in the present fishery. Different gear types account for varying degrees of mortality in fish caught, and despite the high mortality inflicted by some gear types, regulations and economic pressures forbid the retention of several species even if the fish is dead.

Wasteful harvest techniques brought upon by overcapitalization and the struggle by fishermen to catch a larger percentage of a finite harvest allocation may lead to a bust cycle for several fish species. The amount of fish caught and discarded is difficult to estimate because little reliable information is currently available. Trawl nets account for a great deal of discarded fish each year because they scoop up anything that will not pass through the webbing. Groundfish typically dwell at great depth, and the rapid ascent in fishing gear causes shock and usually death. In spite of efforts to avoid over-filling their gear, trawl fishermen occasionally bring in too much fish and the gear physically cannot be brought on board. In this instance fishermen have to release the excess fish, which may all be dead.

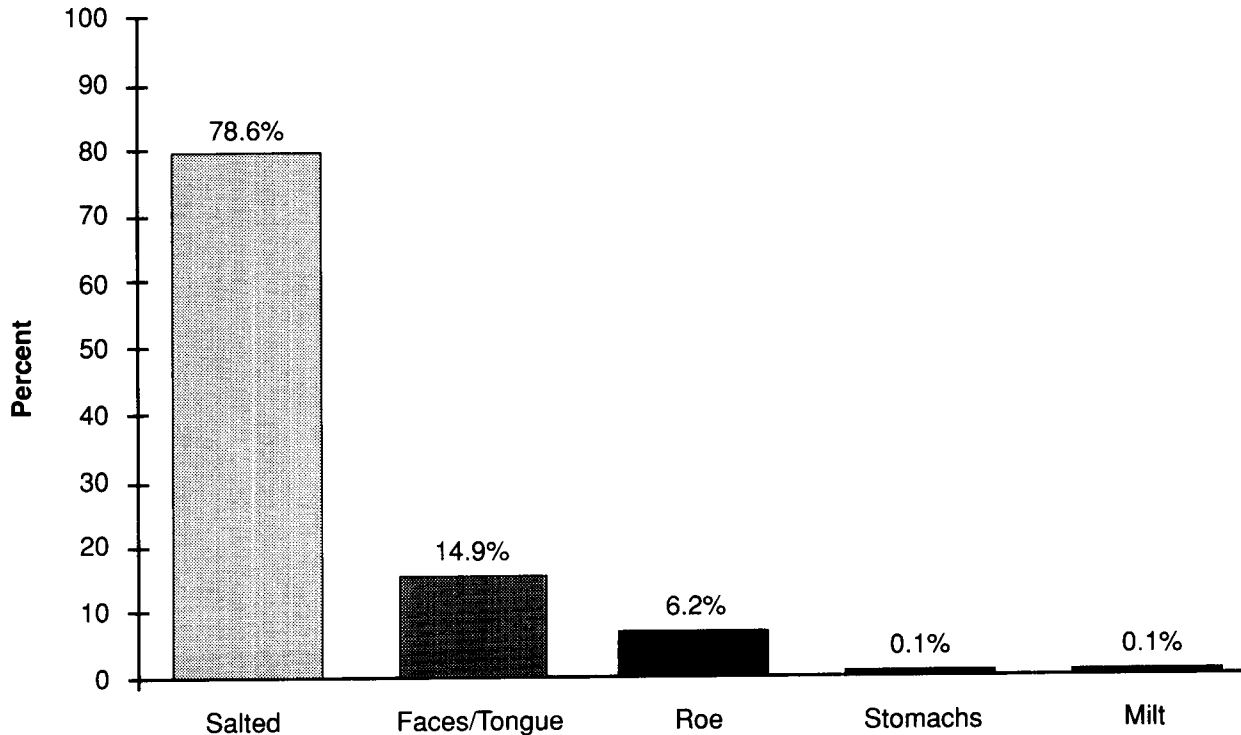


Figure 5. Products derived from Pacific cod, Alyeska Seafoods. Based on a total production of one million pounds.

The harvest of groundfish species by bottom trawl off Alaska in 1989 was 330 million pounds. One recent estimate states that up to 160 million pounds of other fish were incidentally harvested and discarded that season. In addition, depending upon the time of season, some fish have poor flesh quality, as in post-spawn pollock or sablefish which are found with jellied flesh. Fishermen have to dump hundreds of millions of pounds of fish each year because it's illegal or unprofitable to keep everything.

Wastage includes not only the discard of excess, unusable, or prohibited species catch, but also the discard of undersized fish and body parts after processing. Until it was made illegal this season, roe-stripping of pollock has been a legitimate practice in the North Pacific. During the pollock spawning season in March and April, it became more economical to harvest pollock, separate the females, and remove only the mature roe. All other fish, including the carcasses of the females, were then discarded at sea without further processing.

An example of this practice occurred during March of 1989 near Kodiak Island. A fleet of 17 vessels, some up to 340 feet long and costing about 35 million

dollars, harvested more than 37,000 metric tons of pollock in just 11 days, saving only the roe as product. Approximately 35,000 metric tons, or over 77 million pounds, of pollock was discarded over the side. No estimates are available for incidentally harvested species.

There are five land-based surimi plants in Alaska, and two of those plants are in Kodiak. These two plants were forced to stop production and lay off workers when the pollock allocation in the Gulf of Alaska was reached and the season closed. By the beginning of 1991, the seafood industry's ability to harvest and process the fisheries resources of the Bering Sea will exceed the available resource. This overcapitalization will cause reduced fishing seasons as the allowable catch is taken before the year is over. Each individual operator will therefore have increasingly smaller amounts of product to process and market. As competition for the finite fisheries allocations increases, the owners of the modern fishing vessels will look for innovative ways to increase their share of an allocated resource. One such innovation was the capability to catch and subsequently process surimi at sea, an innovation that is expensive, and necessitates a bountiful

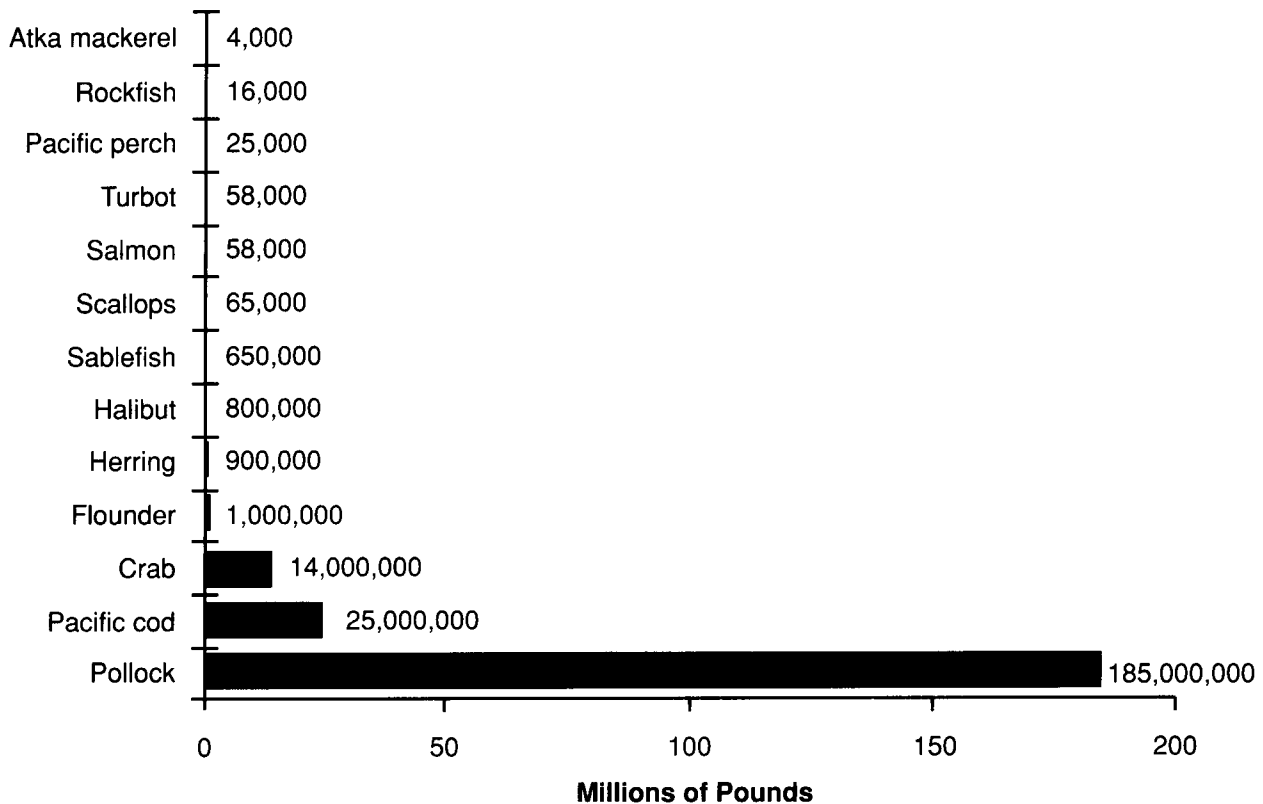


Figure 6. Pounds of fish and shellfish processed in 1989, Alyeska Seafoods.

catch to prove profitable. A more recent innovation is a “mega trawl” net. This type of net will be deployed in the North Pacific Ocean this year and is of sufficient size to engulf the entire Egan Civic and Convention Center in Anchorage.

By now it should be clear that under present regulatory regimes and harvesting and processing methods, enormous amounts of protein are either wasted or are being returned to the ecosystem. The requirement that perfectly good fish be discarded as prohibited species is seen by some as being morally offensive and by others as a necessary management tool. The discarding of unwanted species is a long standing practice, but as we are starting to see in the Gulf of Mexico shrimp fishery, discarding “scrap” fish can raise both environmental concerns and concern for the health of the stocks that are being discarded.

MANAGEMENT OF THE RESOURCE

It will take cooperation by the regulatory agencies and industry to find uses for fish presently being discarded, and economic pressure to maximize returns

from harvested fish will very likely lead to increased attempts to make better use of protein that is now being discarded.

In the meantime, resolution of the issue of discarded fish or processing waste will require balancing of fishery management and economic operating considerations. It will be the task of the North Pacific Fishery Management Council and the National Marine Fisheries Service to try and strike a balance. In the face of all these concerns, however, we must never lose sight of our most important objective—the maintenance of a vital biological resource. Those of us who have been engaged in Alaska fisheries over the past 25 years have seen a number of boom and bust cycles. We are at a stage where the Alaska salmon resource appears to be in a healthy condition following a number of years of reduced returns. We are still living with the results of the shrimp and king crab collapse, and we saw the scallop industry in the Gulf of Alaska disappear virtually overnight. Alaska's groundfish resource is our last chance. We all have a responsibility to see that it's managed in a manner to make it available for generations to come.

TRENDS FOR THE FUTURE

John S. Kilpatrick
TROUW International BV
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In being asked to discuss trends for the future, I was given a very broad scope—trends in what? And how far into the future? I think 10 years ahead is ambitious enough; and I will concentrate on fish meal—production, uses, and quality.

“Trends” is an appropriate term, as changes in fish meal quality and use have been gradual, and are continuing. To review them, one needs to look back for about 10 years, in some cases 20 years.

World production of fish meal at present is about 6.5 million metric tons. Figure 1 shows the proportion of world fish landings, which total about 92 million metric tons, converted to fish meal and oil. You will note that about 30% of this still represents the largest single use of fish.

Figure 2 shows production with exports. Chile, Japan, and Peru produce around one million tons each. The 1986 world production of fish meal was 6.7 million metric tons, the highest production yet attained. The last official total available is for 1987, at 6.4 million metric tons.

There is always a considerable delay in obtaining the world total. Although some countries report their total production promptly and accurately, others, such as the USSR, are notoriously slow in producing statistics.

My own estimates for 1988 and 1989 respectively are 6.4 and 6.5 million metric tons. 1986 was the year of the maximum production to date, 6.7 million metric tons. To put this in perspective, production in 1970 was about five million metric tons, and the first six million metric ton year was 1984, with 6.08 million metric tons. Last year, Chile produced 1.33 million metric tons, Peru produced 1.10 million, Denmark 324,000. These figures I obtained from the International Association of Fish Meal Manufacturers.

You will note that Japan is not a major exporter.

Actually with its import-export trade, it is a net importer. The great preponderance of exports comes from Chile and Peru. Iceland exported more than it produced, due to carryover of stocks. Iceland normally exports a high proportion of its production. World exports are about half of total world production. The USSR, while a significant producer, is not an exporter at all.

Figure 3 shows fish meal relative to other world protein meals. Fish meal is only 7% of the world production of over 90 million metric tons, dominated by soybean meal.

As to the uses and changes in use, as shown in Figure 4, world poultry meat production is about 30 million metric tons. About 3.5 million metric tons of fish meal goes into poultry diets, or 55% to 60% of all world fish meal production. What develops here is obviously critical to the future of the fish meal industry. Present indications suggest strongly this use will decline. Substitute proteins and synthetic amino acids will be formulated in by the computer. One poultry feed producer has already described fish meal as “an expensive luxury.”

This brings us to the growing worldwide aquaculture industry. Where is the fish meal used? And where will it be used? There are wide variations between species, with the maximum use in such species as salmon and low levels in such species as catfish. The price and availability of fish meal could affect the future species mix.

Figure 5 shows fish meal use in aquaculture in 1987 and 1992. At present, about 10% of world fish meal is used in aquaculture feeds. This is projected to increase to 14% in 1992 and to around 20% to 22% in the year 2000.

To see trends in the characteristics and quality of fish meals, we can start by looking back about 20 years. There were some false starts, but better quality meals started to be produced in Scandinavia, especially Norway. Considerable work was done on fish protein concentrate for human consumption. Special fish meals were developed for fur bearing animals.

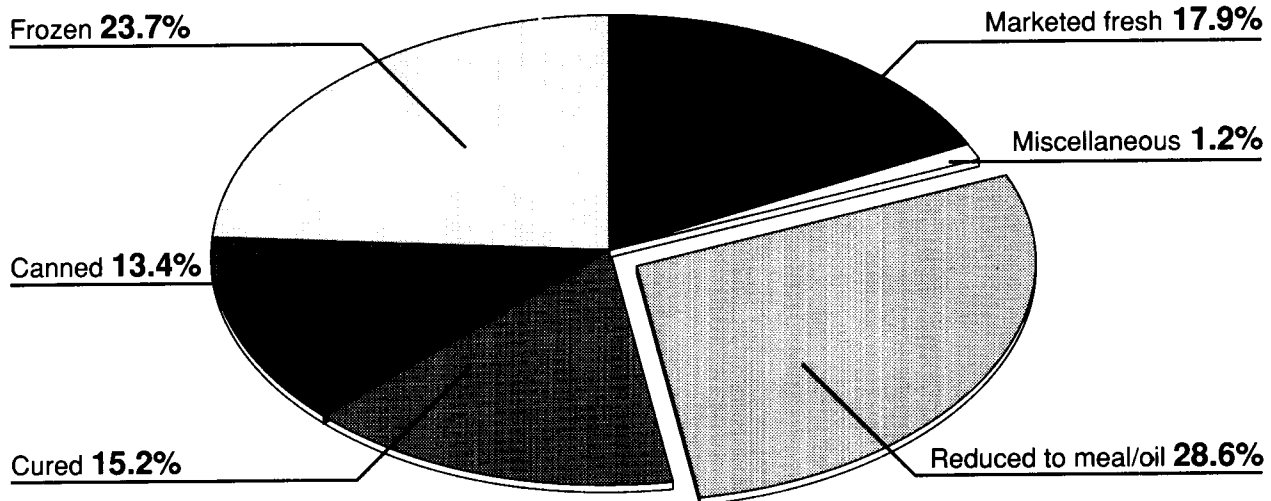


Figure 1. Disposition of world fishery landings. Total for 1986 was 92.153 million metric tons.

particularly mink. Hence, the introduction of NorSeaMink.

About that time, salmon farming was developing in Norway, and the positive effects of high-quality fish meal on fish health and growth were soon recognized.

NorSeaMink was used successfully in diets for salmon. An even better quality, Norse LT 94 was introduced in 1979. This still sets the standard for fish meal quality; it has been developed and improved over the last 10 years. Danish Special A and other superior grades have also appeared. In 1988, 68% of Norway's fish meal was of special quality, and this proportion is still increasing.

The special quality meal has required changes in equipment, in the quality control of the raw material, and, I would stress, the method of operation of the plant. A common misconception is that you just buy the equipment and you are in business. This sometimes carries through in the promotional literature. I saw a brochure that asked the question "What is LT meal?" And answered it, "Quite simply it is fish meal dried by a special low temperature drying process." That can be a fatal misconception. It is vital to control the quality of raw material, the processing parameters, and the storage and handling of the meal.

Raw material freshness depends on storage time and storage temperature. This includes all the time until the fish enters the cooker. Particularly in South America, one may see fish delivered in eight hours which then can take 36 hours to run.

Ice is used in Norway but not in South America.

Used ashore ice may cost \$10 to \$14 per ton. To cool the stored fish effectively, this equates to \$10–\$14 per ton of fish meal. That doesn't look bad if you consider going from FAQ (fair average quality) to LT quality meal with the cooled raw material.

One sees other details of process control as important—for example, blood water accumulates in stored fish and spoils much more quickly than the fish. It finishes up in the solubles and hence in whole meal. But blood water can be drained continuously and chilled, or used only in batches of solubles for lower quality meal.

I will summarize here. What do we see over the next ten years?

1. We see the proportion of world fish meal going to aquaculture feeds up to around 20%, or about 1.3 to 1.5 million metric tons.
2. We see a considerable increase in the proportion of LT quality meals.
3. We see an increase in competition for lower quality fish meal by substitutes. This will mean the premium for LT meal over standard quality increases in percentage terms.
4. While fish meal may be an "expensive luxury" for poultry diets, it will be a very necessary ingredient of many aquaculture diets. But quality and consistency will be essential, and will be measured more critically than they are now.

There are some other concerns to address: *Salmonella* contamination of fish meal has been a recent

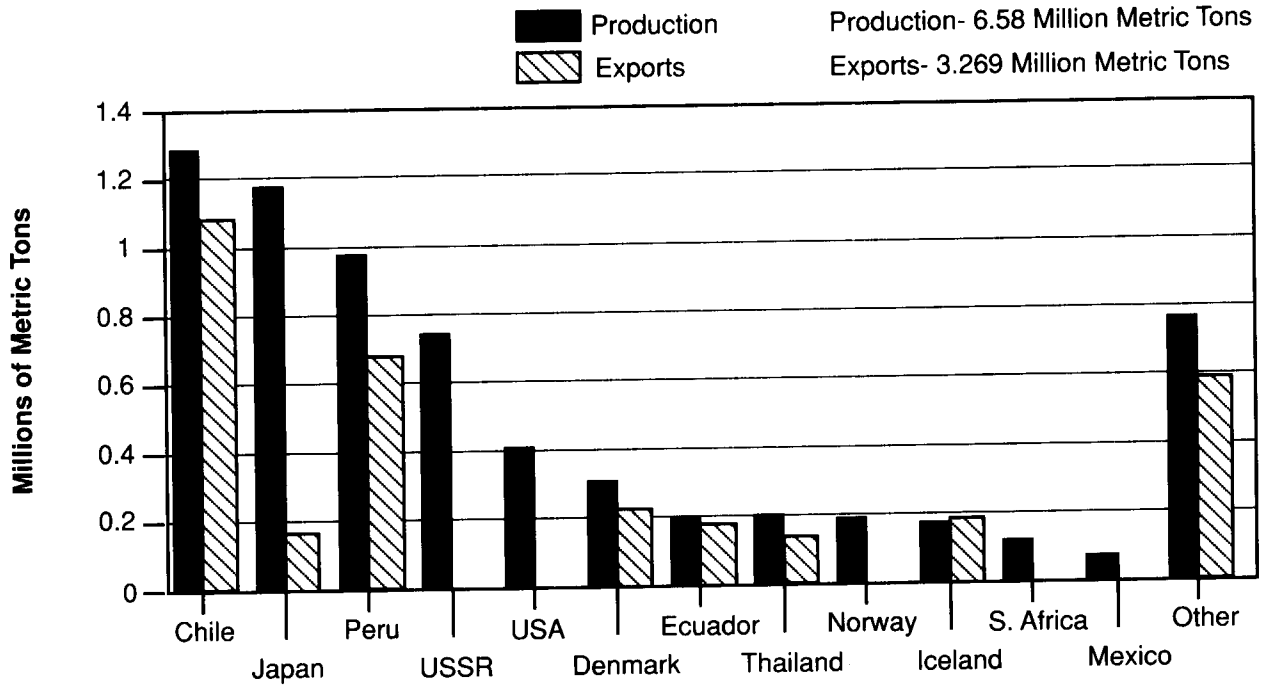


Figure 2. World fish meal production and exports, 1986.

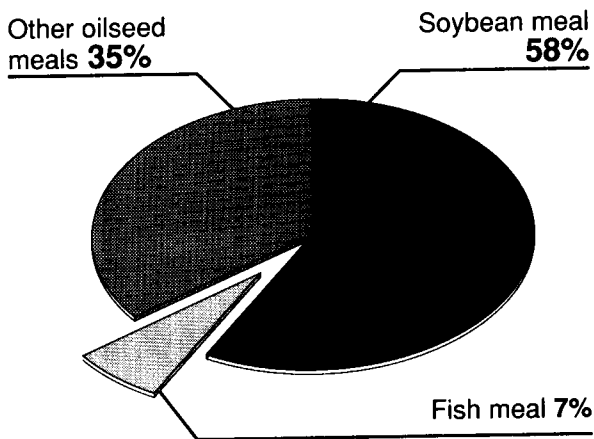


Figure 3. Major protein meals, 1986.

major focus in the United Kingdom. We must ensure *Salmonella*-free fish meal. This requires attention to detail in both plant design and operation. Plants need to be designed to be sanitary, with proper cleaning systems and sanitation programs.

These problems are being addressed, with clean in-place, sealed systems, and superior design going into many new plants. At one new plant in southern Chile, I was shown how they have even eliminated "I" beams where dust can collect, and the whole plant has smooth, closed-box-section structural steel. Infected dust can be a source of *Salmonella* contamination.

In storage of meal, we see much more use of silos, both for sanitary purposes and to enable blending for better consistency. Variations in analysis within lots will not be acceptable.

Environmental concerns will increase the demand for low-ash fish meals. Already Denmark has regulations limiting phosphorus discharge from farms and phosphorus content of the feed, and requiring—already—a 1.2:1 conversion ratio, shortly to be 1.0:1. This can only be achieved by special quality, high protein-low ash fish meals.

This sort of regulation can be expected to be copied elsewhere. After 1992, when many economic barriers in Europe are removed, regulations such as the Danish one probably will be adopted in other European Eco-

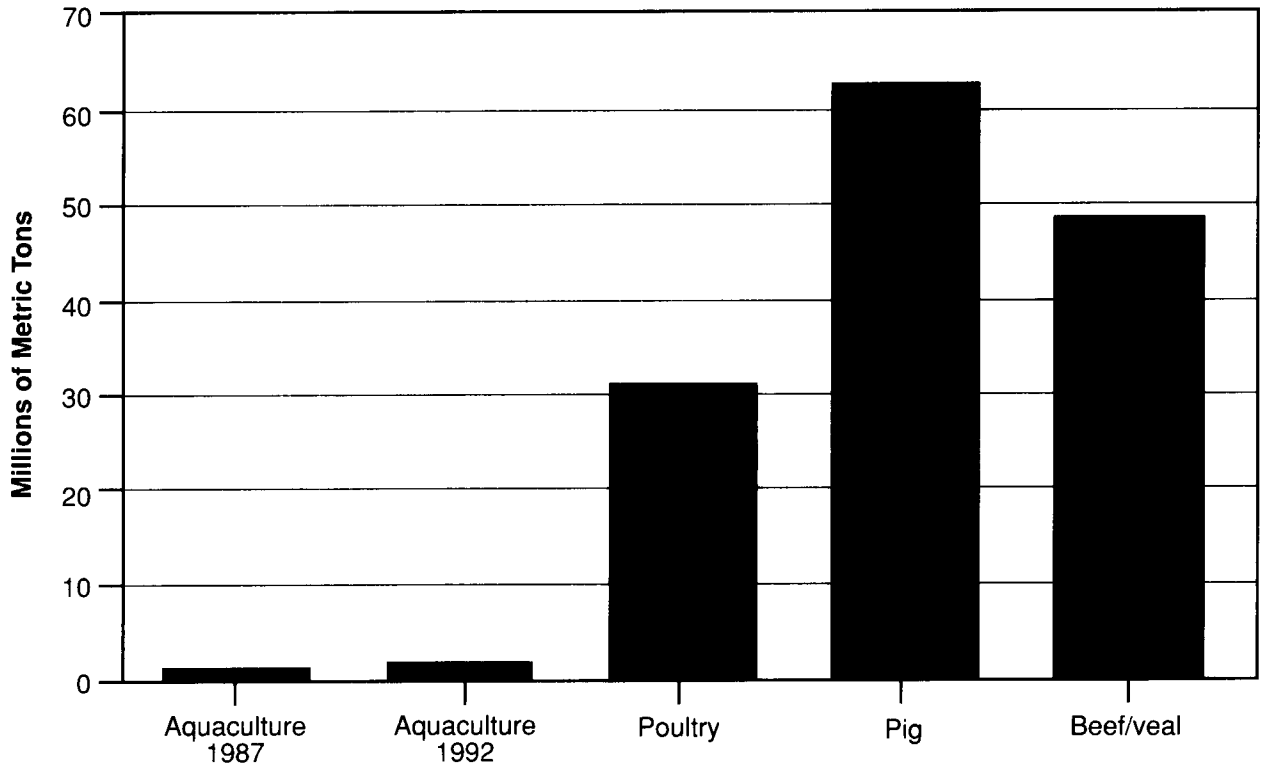


Figure 4. World animal meat production in 1987, dressed weight. Aquaculture production is projected for 1992.

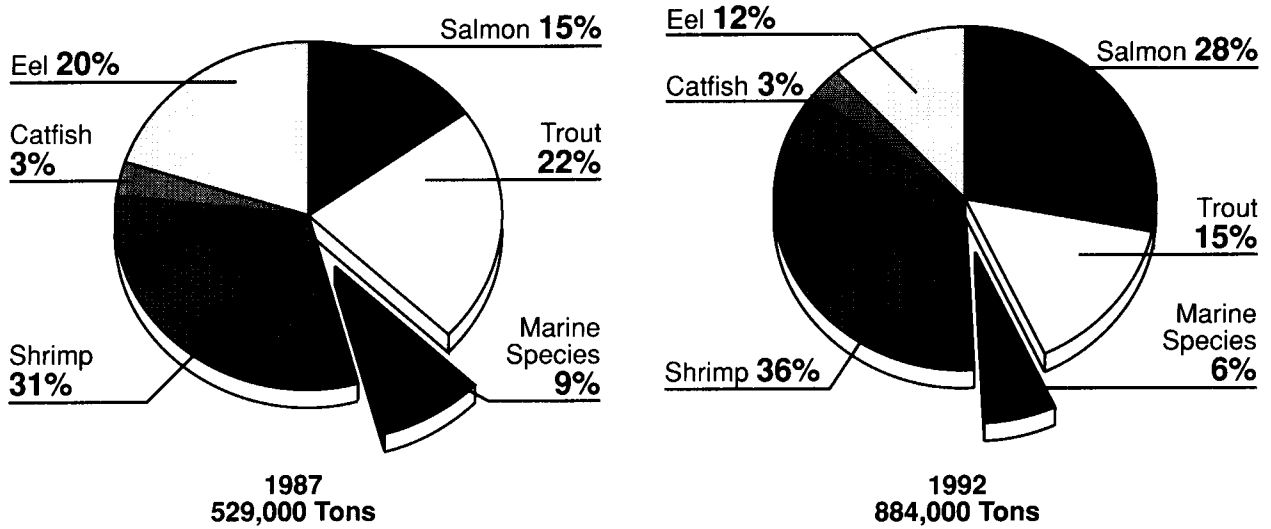


Figure 5. Fish meal use in commercial aquaculture.

conomic Community countries. Incidentally, this also means that dry feeds will further displace wet feeds. Wet feeds are already prohibited in Denmark. To illustrate what is possible, in 1974 Denmark's trout production was 12,000 metric tons, and feed used was 60,000 metric tons wet, 4,000 metric tons dry. By 1987-88, production had almost doubled to 22,500 metric tons, and this was produced on 36,000 metric tons of feed, all dry.

Finally, to look beyond 2000, I am sure aquaculture production of fish will continue to grow, as demand for seafood continues to increase and the human consumption of wild fish remains static or declines. I expect the use of fish meal by aquaculture to continue to increase, until over half of all world fish meal is used to feed fish and shrimp. The quantity now used for poultry will be used for fish and shrimp—the necessary quality standards, especially raw material quality, being met.

QUESTIONS AND ANSWERS

- Q. What is TROUW?
- A. TROUW International is owned by British Petroleum, and it's the parent company of many fish feed companies. It's the specialty feed arm of British Petroleum. BP Nutrition's sales are about \$4 billion. They are active in aquaculture feeds in most parts of the world, most recently in Chile and Thailand, but earlier in Norway, Canada, and the U.S.
- Q. In working toward an ideal ash level, what do you consider an optimum or desirable phosphorus requirement in a salmon ordered ration? How low should the ash be to have the phosphorus make a maximum contribution?
- A. Phosphorus content in the feed should be about 1%. That would mean in very round figures 2% phosphorus in the fish meal, and that relates to something on the order of 11% or 12% ash. Of course, you can blend meals, and if you have a very low-ash meal on the order of 7% or 8%, then that enables you to use some higher ash meal with it. But, it doesn't mean that all the fish meal used in the feed would have to be on the order of 7% or 8%.
- Q. As in herring meal, 11% or 12% would be desirable?
- A. Yes.
- Q. You have indicated that aquaculture will consume up to 20% of the fish meal output. You also kept at level the total fish meal production. Is that going to change from the 6.5 or 7 million tons you expect?
- A. There's a suggestion that it might decrease by about 5%. But how often have biologists been wrong? How often have they said, "We have a huge resource," and it disappeared the next year? But the catches have been holding up well, and the key people, the Peruvians and the Chileans, are reasonably confident that they are managing the resource well. And they are becoming tighter in management.
- Maybe this possible slight decrease will be replaced to some extent by much better utilization as for by-catch, and offal that is at present dumped. This is where you're going to see small plants, or specialized production of some sort of protein meal such as presscake meal, or a special hydrolysate replacing other parts of fish meal.
- Q. Do you have any numbers for the amount of fish heads or frames that would become available from aquaculture that would add to the production of fish meal?
- A. That depends to some extent on the way aquaculture develops. One thing that's been rather noticeable with salmon farming in Norway, for instance, has been just how much of the fish was shipped to restaurants in France. Quite often even the gills were shipped to France. That's what they wanted.
- People are going to start producing skinless, boneless fillets. And then offal will be developed, and it won't be just heads, but it will be the sort of offal you get from a typical filleting plant, and it will be available for fish meal.
- Q. What would help the situation?
- A. Already this has happened with catfish. There is now meal that goes right back into catfish feeds. And catfish oil is also being put back into the diet.

CLOSING REMARKS

Peter J. Moore
Alaska Fisheries Development Foundation
Anchorage, Alaska

Based on comments you have made to me and other members of the conference planning committee, the first international conference on seafood by-product opportunities has been a great success. The connections made between members of the international seafood industry are exciting to me and others from the Alaskan processing sector, which was well represented here.

We realize we have a long way to go in utilizing our harvested marine resources more fully, and we are thankful for the economically viable options that have been delivered to our doorstep from all over the world these past three days. On that note, I would like to recognize and thank the speakers and participants from foreign countries who made the effort to prepare for and travel to this conference in Alaska. Their willingness to share their ideas for solutions to our "waste" opportunity in English, their second or perhaps third language, is much appreciated by all of us. I was most impressed by those of you who not only wrote and delivered your papers in English, but who also answered questions in your second or third tongue.

For the record, there were 189 participants from 10 countries and 21 states of the United States. As several of you have said, this exchange of ideas should

become an annual event. Already I have heard of some rewarding connections made between participants—Rae McFarland of Diamond Stainless and AFDF will provide Elsen Karstad of Kenya with some technical assistance to upgrade equipment in Elsen's processing plant in Nairobi, allowing for more utilization of his raw material. Baldur Hjaltason of Lýsi in Reykjavik will work with plants in both Cordova and Kodiak to analyze the viability of salmon and groundfish oil production. Svanur Vilhjalmsson of Kvikk in Reykjavik has found great interest among Alaskan salmon processors in his latest invention, a machine that removes the usable flesh from salmon heads, thereby increasing recovery of the round fish weight by 5% to 12%.

The true test of the success of this conference, however, will be in the coming year and years when we hope that some of the ideas discussed during the last three days will be applied to our by-products opportunities. In your efforts to do this, I encourage you to work with the Alaska Fisheries Development Foundation to demonstrate, on- and offshore, some of these innovative solutions to the by-products utilization riddle. Direct your proposals to the foundation c/o Mel Monsen, or to Rae McFarland, of AFDF's Program Development Committee. Thanks for coming.

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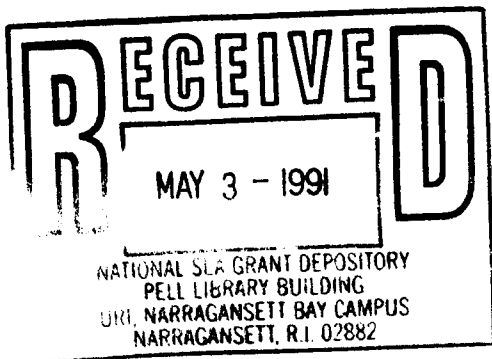
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