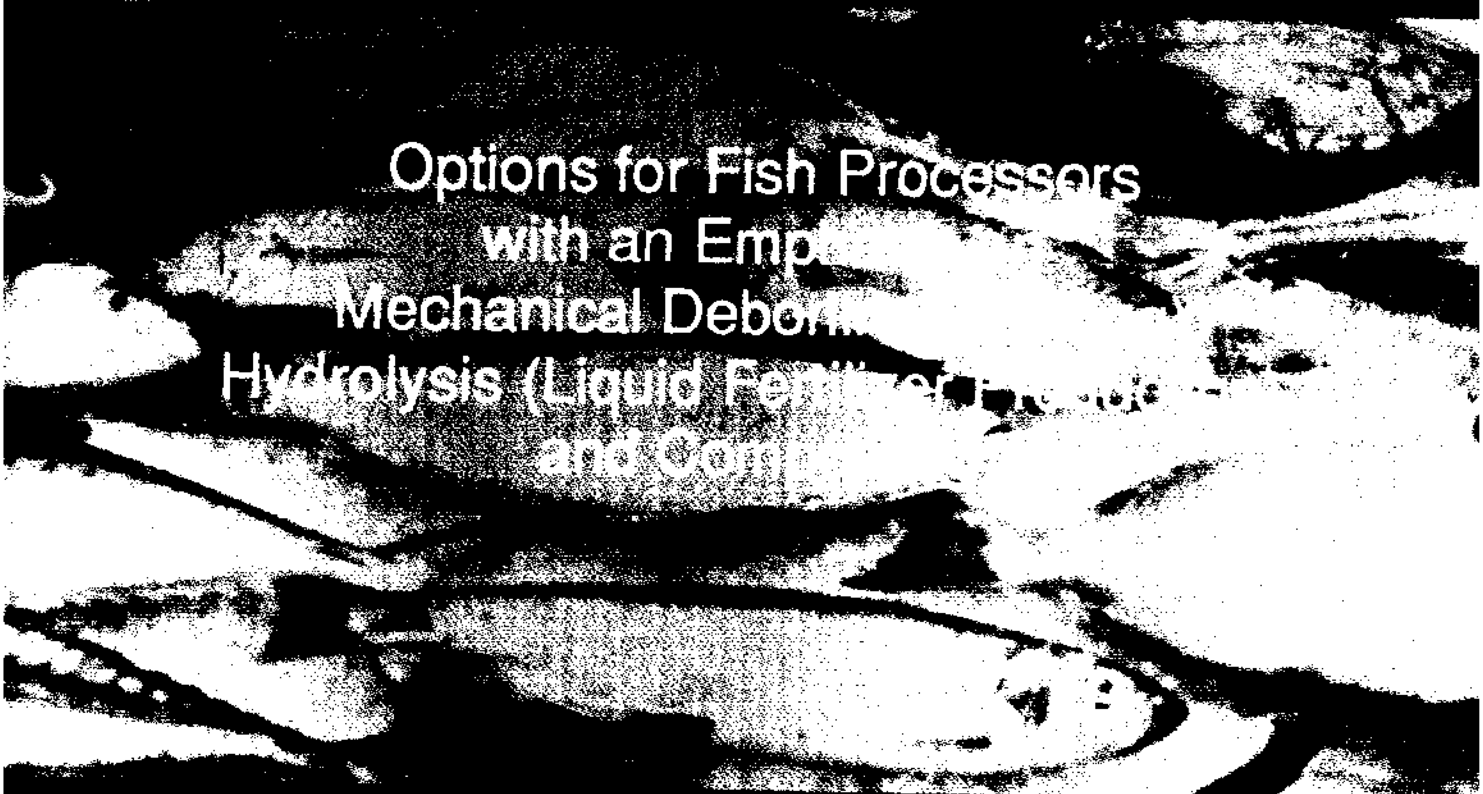
Improving the Profitability of Finfish Processing Waste



Options for Fish Processors with an Emp
Mechanical Debo
Hydrolysis (Liquid Fe
and Com

Susan H. Goldhor
Center for Applied Regional Studies

Joe M. Regenstein
Cornell University

NYSGI-T-91-001

Improving the Profitability of Finfish Processing Waste:

Options for Fish Processors with an Emphasis on Mechanical Deboning (Mincing), Hydrolysis (Liquid Fertilizer Production), and Composting

A Summary of a Study Originally Done for
NORTH ATLANTIC FISHERIES
Rochester, New York

Susan H. Goldhor
Center for Applied Regional Studies
45 B Museum Street
Cambridge, MA 02138-1921

Joe M. Regenstein
Department of Poultry and Avian Sciences
112 Rice Hall
Cornell University
Ithaca, NY 14853-5601

Research Supported by:
New York State Science and Technology Foundation

Published by:

New York Sea Grant Institute
March 1991

Edited by Diana Puglisi
Diagrams on pages 12, 31, and 32 by
Everett Dowling
Typeset by Sharon O'Donovan
Cover by Avery Klauber

March 1991

New York Sea Grant
Dutchess Hall
SUNY at Stony Brook
Stony Brook NY 11794–5001

CONTENTS

ILLUSTRATIONS

ACKNOWLEDGMENTS

Much of the research and all of the writing of this publication were supported by the New York State Science and Technology Foundation in partnership with North Atlantic Fisheries, Rochester, NY.

Funding for the production of this report came from the NOAA Office of Sea Grant, U.S. Department of Commerce, under Grant #NA90AA-D-SG078 to the New York Sea Grant Institute.

Many experts shared their knowledge with us. We would particularly like to thank Phil Averill (Department of Marine Resources, Augusta, ME), Will Brinton (Woods End Laboratory, Mt. Vernon, ME), Joan Brooks (Department of Civil Engineering, University of Maine, Orono, ME), and Sukhdev Mathur (Agriculture Canada, Ottawa, Canada), who contributed generously to our knowledge of composting, and Robert Curren (Robert A. Curren Company, Yarmouth, ME), Robert Levin (Department of Food Science, University of Massachusetts, Amherst, MA), and David Stuiber (Department of Food Science, University of Wisconsin, Madison, WI) who helped us equally generously in our work on hydrolysis.

Both the New England Fisheries Development Association and the Alaska Fisheries Development Foundation supported major projects on byproduct development and utilization which were relevant to this publication.

We would also like to thank the numerous fish processors who invited us into their facilities, and shared their problems and potentials with us. This report is for them.

SHG
JMR

INTRODUCTION

About half of what comes into a fish processing plant leaves it as product. The other half leaves it as waste. The problem of disposing of this waste has become more serious in recent years as communities and legislatures have taken action against air and water pollution. Communities which accepted odor as the inevitable byproduct of industrial jobs a generation ago will no longer do so. Thus, there has come to be far greater pressure on fish processors to dispose of their wastes rapidly and cleanly, at the same time that many of the traditional means of disposal, such as fish meal plants, pig farms, and landfills have been closed or moved further away. The result is that many processors are now paying money to dispose of wastes that would have brought in a small payment in earlier times.

This added hardship for processors comes at a time when other factors are squeezing the industry. Diminishing stocks and smaller catches for the domestic fleet have led to idle plant time, while foreign competition has never been so strong. Amid the general concern about the costs and difficulties of disposing of fish waste, it is easy to lose sight of the fact that this waste is, in fact, an impressive protein resource. Indeed, properly treated, some of this waste is recoverable as human food.

The purpose of this report is to describe current technologies for increasing the value of and/or decreasing the pollution caused by fish processing plant wastes. The report also suggests which of these technologies might be adopted by a processor of finfish, what this might cost, and how such a processor might proceed. Since no two processing operations are alike, these suggestions should be analyzed with an eye to the special requirements of each operation or plant. Our recommendations are primarily targeted at the operators of small- to medium-sized single plants. Since we have chosen to cover in detail those technologies which have been best studied and have the broadest potential applications, we hope that these suggestions will be useful to the maximum number of finfish processors.

CURRENT TECHNOLOGIES FOR BYPRODUCT MANUFACTURE OR WASTE TREATMENT: A SURVEY OF OPTIONS

Significant advances have been made in the past few years in dealing with fish processing plant wastes. These new technologies are designed to increase profits from what is, after all, close to half the output of the average finfish processing plant and/or to decrease the pollution resulting from some of the more common disposal methods currently used.

These technologies yield products that can be divided into three general categories:

1. Human food products.

2. Feed and fertilizer products.

3. Minor products.

Both marketing efforts and product development are of major importance in all categories. We emphasize this at the start because although technology alone may be able to reduce pollution, only the integration of technology with product development and marketing can increase profits for the processor.

In all cases, we strongly suggest that production be started on a small scale and geared up as markets and familiarity with the processes are increased.

The rest of this text consists of summaries of the advances made in handling fish processing plant wastes, grouped under the three categories listed above, along with practical suggestions for implementing these techniques.

1. HUMAN FOOD PRODUCTS

Fish mince, from flesh left on the bone after fillet production, can be used in a variety of marketable food products. In addition, processors may be able to find markets for the meat obtained from cheeks, tongues, and trim waste.

A. Mince

In the meat industry, small scraps and bone scrapings are ground into hamburger and sold at a relatively high price. The advent of deboning machines has made possible a burgeoning supply of minced poultry, which has been developed into a wide variety of products. Deboning equipment, similar in concept to that used for poultry, has been developed for use on fish, and may be used to produce a hamburger-like product called fish mince. Although fillets of whole fish may be used to produce fish mince, there is little economic incentive to do so except possibly in the case of surimi manufacture, where an extremely white product is required for certain applications. The true value of mincing is that it enables the processor to utilize some of the fish flesh trimmed off of the fillet during processing, or left on the frame after filleting, as a human food ingredient of reasonable value, rather than treat it as offal.

Deboning machines are manufactured by a number of companies; the brands most used in this country for fish are Baader (German) and Bibun (Japanese), although the U.S. brands Beehive and Paoli are gaining popularity. The Baader and Bibun machines require the operator to place the fish on a rubber belt which carries the fish to a revolving, perforated, stainless steel drum. The drum's perforations (holes) may be anywhere from 1 mm to 10 mm in diameter. In general, 3 mm to 5 mm seems to be used for fish, with 3 mm being the preferred diameter. The rubber belt is thick and inelastic and forces the fish against the drum. The flesh, fat, and blood, which are the softer components of the fish, pass through the holes and accumulate inside the drum, while the bones, scales, and skin remain on the outside surface. As the drum rotates, one point on its external path is continually in contact with a scraper, which removes the adherent bones, scales, and skin. Figure 1 schematically represents the basic operation of the drum-type machine.

The variability in the diameter of the holes in the drum permits the processor to produce a paste-like material (using small perforations) or a more chewy and chunky material (using large perforations). The tension on the belt is also variable; the greater the tension, the more pressure will be exerted on the fish and the more flesh will be pushed through the drum. In other words, the higher the tension, the higher the yield. At first glance, the highest possible yield might seem desirable; however, this is not always the case, for reasons which will be explained below. (Machines like the Paoli do not have adjustable tensions, but do have the advantage of being far easier to clean.)

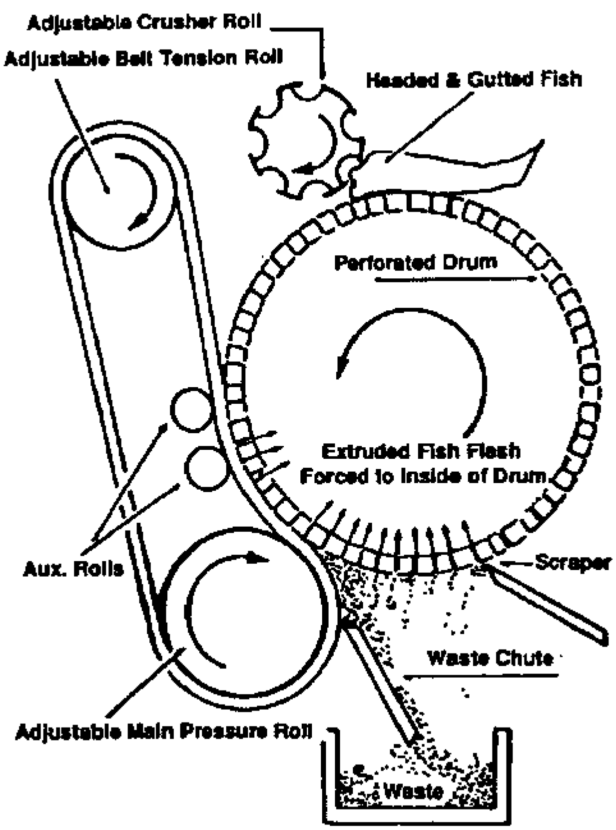


Figure 1. Basic operation of the drum-type deboning machine.

Source: Lanier, T. C. and Thomas, F. B. 1978. *Minced Fish: Its Production and Use*. University of North Carolina Sea Grant College Program Publication UNC-SG-78-08, Raleigh, NC, p. 8.

Mince is classified by the species of fish from which it is taken, and is further divided into various types in order of decreasing quality: fillet mince, "V" and "J" cut mince, whole fish mince, trim mince, frame mince with the backbone removed, frame mince, and rack mince (which includes the head). *Fillet mince* is made of whole fillets. This is generally the economic equivalent of grinding up a steak to make hamburger. The *"V"* and *"J" cut minces* are almost equivalent to fillet minces in quality. Groundfish contain small bones, called "pinbones," in one part of the fillet. In making a boneless fillet, pinbones are sometimes removed (using either a "V" or "J" shaped cut) and these pieces become the starting material for "V" and "J" cut minces. Following filleting, fish are usually trimmed for blood spots, badly gaping pieces, uneven fillet edges, belly flaps with black membranes, etc. The *trim mince* prepared from these materials will be somewhat darker and more strongly flavored than the higher-quality minces since it will contain blood and pigments. *Frame mince* is even stronger in flavor and redder in color than the trim mince since it contains nerve tissue as well as more blood. If the backbone is not removed, frame mince may also contain kidney tissue, the amount depending upon belt tension. Increasing the belt tension will thus increase the color and flavor components of the frame mince. *Rack mince* is similar to frame mince, but would not be acceptable for human food use in this country because of the presence of gill and eye tissue.

The National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration of the Department of Commerce has put out proposed U.S. Standards and Labeling Requirements for Minced Fish Meat (see the Federal Register, Vol. 49, No. 27, Feb. 8, 1984, pages 4804 to 4806). This document attempts to establish standards of identity and recommended methods of handling for such product, with the understanding that participation in the NMFS seafood inspection program is strictly voluntary. These standards are perhaps overly strict with regard to species currently allowed (only four are permitted: Atlantic cod, silver hake [whiting], walleye [Alaska] pollock, and red hake), while at the same time they may not be strict enough with regard to storage temperatures for frozen product. (This will be discussed below.) Since the standards place great emphasis on whiteness of color, it is clear that they are not designed for frame minces but only for trim minces at best.

Almost all mince enters the market frozen. Frozen mince is available in blocks of various sizes, with the 16-pound block being most common. Alternatively, mince may be laminated at a set percentage into fillet blocks, where it may actually improve the appearance and quality of the blocks by filling up any empty spaces between the fillets. The percent of mince acceptable in laminated cod blocks varies according to country of origin. The U.S. market has accepted imported frozen laminated cod blocks but is not producing any at this time. Production of frozen minced blocks or fillet blocks is not yet common in the United States, but at least one New England producer is manufacturing frozen blocks of minced cod, pollock, and haddock. All of this plant's mince production is made from trim; frame mince is not sold in these forms at this time in the United States, presumably because of its unacceptable color and flavor. At least one plant in the United Kingdom is preparing frame mince for human consumption. The end products are fish spreads and pâtés.

While the gadoid species, such as cod and haddock, appear to be the most desirable candidates for mince in terms of availability and name recognition, they exhibit undesirable changes in flavor and especially texture if improperly frozen. These changes are caused by an enzyme which appears to be inactivated when the temperature is sufficiently low. The Torry Research Station (Aberdeen, Scotland) recommendation (J. N. Keay, Minced Fish, Torry Advisory Note No. 79) is that good-quality cod and haddock can be stored for at least six months at -30°C (-22°F), or for three months at -20°C (-4°F). Hake and Alaska pollock have much shorter shelf lives in frozen storage. The U.S. labeling standards mentioned earlier recommend -18°C (0°F) as suitable for six months frozen storage for all species discussed. Research by J. M. Regenstein has shown that undesirable texture changes can be created in about one month if gadoid minces are stored at -14°C (7°F). Therefore, the U.S. recommendations could result in a very poor product. With respect to U.S. production of minces, it is a serious problem that most U.S. cold storage facilities are not designed to go down to -30°C (-22°F), where the reaction causing the gadoid texture changes does not seem to occur.

One possible alternative for frozen storage has been suggested by J. M. Regenstein, whose laboratory has shown that if mince is stored at an extra-cold temperature (around -40°C [-40°F]) for several months, changes appear to occur which stabilize the mince. If mince production were to become a major regional effort in this country, a municipality or even a region could build a suitable freezing facility in which mince could undergo the first few months of frozen storage. Stabilized mince could then be released into the standard U.S. cold store chain with the expectation that the rate of degenerative changes would be much slower. An extra-cold freezing facility might also benefit the storage of regular frozen fish products, and cause a significant improvement in the overall quality of frozen fish in the United States.

Less attention has been paid to flatfish as a source of mince than to the gadoid species. While mince from flatfish does not undergo gross textural changes upon freezing, its initial fresh soft texture is regarded as less desirable in mince than the firmer texture of the gadoids. Nevertheless, at least one New England processor is selling fresh flounder mince, and this product offers a number of options for further processing. This leads into what we believe to be a second and perhaps simpler approach to handling and storing both trim and frame minces. This is to turn them into cooked products destined for immediate consumer sales. Cooking extends the shelf life of fresh (unfrozen) mince and, in the case of gadoid minces, destroys the enzymes responsible for negative texture changes in frozen storage.

The finished products that may be made

from mince are enormously varied, ranging from sausages to salads. Trim mince could be used for traditional fish dishes, such as chowders, seafood Newburgs, and salads, where a white appearance is valued. If the fish is of good quality, no odor or off-flavor will exist. Frame mince can be an excellent red meat substitute in a variety of preparations where the strong color and flavor of the food itself will mask any in the fish. Spaghetti sauce, sloppy joes, taco mix, and sausage have all been tried with success. Products such as these can be sold fresh-cooked, frozen, precooked and frozen, or canned, and can be marketed through a variety of channels.

What kind of yields should be expected from mincing? At least one worker has reported that frozen pollock yielded approximately as many pounds of mince as it did fillets (Babbitt, J. K. et al., Observations on reprocessing frozen Alaska pollack [*Theragra chalcogramma*]. *J. Food Sci.* 49:323, 1984). However, this may be unrealistically high for many operations.

You can determine yields on trim mince in your operation by weighing a given number of fish (for example, twenty) as they enter the processing line, and weighing the trim mince derived from those fish as the trim exits the line. The trim should be broken down by categories, e.g., worms, blood spots, black membranes, gaping pieces, etc., so that it is possible to identify which materials are available for which end uses; unsuitable pieces should be discarded before weighing. The experiment must be done separately for each species, and should be duplicated at least once. Fish of different quality should be studied separately. Often the poorest fish can be found on Monday!

In our experience, trim waste will comprise approximately 4% to 5% of the weight of whole (gutted) haddock in which the pinbones were left in place. About 80% of this 4% to 5% is recoverable as mince. This is far lower than Babbitt's experience with pollock, where a yield of over 20% trim mince was obtained. Whenever "V" or "J" cuts are done, yields presumably will be significantly higher than what we found.

Babbitt's estimate on frame mince from backbones was that almost two-thirds of the weight of the backbones could be recovered as mince, and that the backbones were almost 20% of the weight of the original fish. Thus, about 12% of the original weight of the fish could be recovered as frame mince. In our experience with haddock, the frames were also very close to 20% of the weight of the whole (gutted) fish. However, while a yield as high as 66% mince from frames may be achievable, it is not always desirable. Obtaining a better color, flavor, or texture may be more important. An estimate of 40% to 50% of the weight of the frame for high-quality mince might be more realistic. This would amount to 8% to 10% of the weight of the original fish. Thus, based on work with gutted haddock, our personal experience suggests that 11% to 14% of the weight of the original fish is a realistic estimate for combined trim and frame mince. We would expect the yield for cod to be somewhat higher, because of the "V" or "J" cuts.

If mince were to become a really profitable item, processors might consider looking into a new machine developed in Iceland (the Kwikk 205 Fish Head Splitter), which is said to be able to remove mince from heads, yielding 5% of the landed weight. The U.S. patent for this device was issued in 1986 and has been assigned to Baader (U.S. Patent Number 4,583,265). This machine would be of even greater use to any processor with an ethnic market for cheeks and tongues (see pages 8–9).

Another possibility, if mince were to become popular, would be a two-stage mincing operation. In the first stage, processors would use the traditional fish deboners to produce a good-quality frame mince for use in traditional products. The second stage of deboning would use the higher pressures and smaller hole sizes of the equipment currently being used by the poultry industry, for use in producing products that could accept a lower-quality mince; that is, a mince with more pigment and stronger flavors. These second stage machines operate on

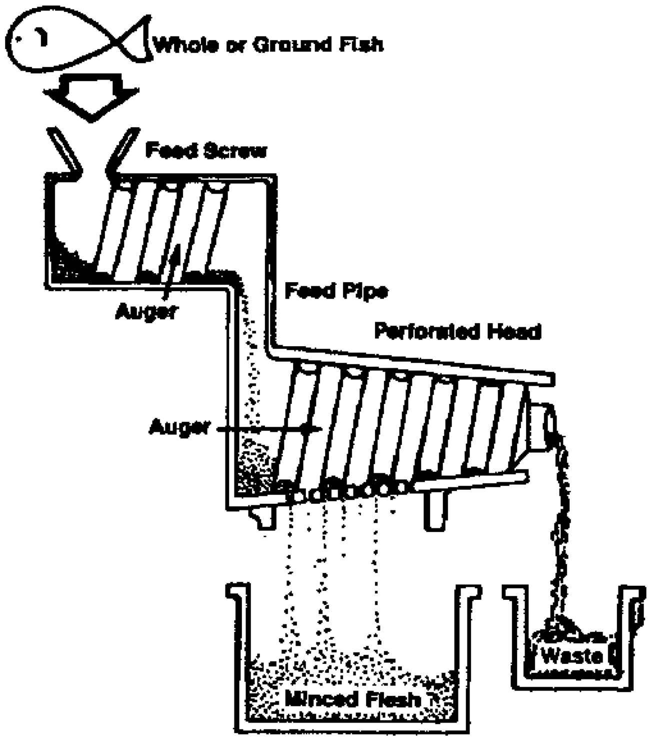


Figure 2. Basic operation of the auger-type deboning machine.

Source: Lanier, T. C. and Thomas, F. B. 1978. *Minced Fish: Its Production and Use.* University of North Carolina Sea Grant College Program Publication UNC-SG-78-08, Raleigh, NC, p. 7.

somewhat different mechanical principles from those designed for fish and described earlier. They work either by augering the meat to the inside of a deboning head from which the meat is expelled through small holes (see Figure 2), or by using a hydraulic ram that forces the meat out through a screen. The hydraulic ram deboners, although using high pressures, have the advantage of subjecting the raw material to only one pressure cycle.

One further word of caution should be added for processors working with cod or other species with heavy parasite loads. Deboning machines are designed for getting rid of bones. Worms pass through most of them intact, and are quite visible in the finished mince, both fresh and frozen. Needless to say, this is unacceptable. Cod destined for mince, like cod fillets, must be candled over a light table and dewormed.

Indeed, for any processor considering moving into mince production, it is important to recognize at the outset that mince is a human food product and must be treated as such at every stage of its production. This may require a reeducation of the work force.

EVALUATING FISH MINCE PRODUCTION

In order to consider making mince, a company would have to invest in a Baader 694 or a similar piece of deboning equipment. The price of such machines is in the range of $15,000 to $20,000, although used equipment is obtainable.

The choice of whether to freeze mince or go directly to fresh product depends on a number of considerations, including freezing facilities, quality, quantity, and expertise.

Freezing Facilities. The production of stable gadoid (e.g., cod, haddock, whiting, hake, cusk, and pollock) mince requires block-freezing facilities (i.e., vertical plate freezers) at -40°C and cold storage facilities at -30°C or lower, capable of storing a significant quantity of material.

Quality. NMFS-proposed standards for mince emphasize whiteness and uniformity of color. Mince prepared under this standard is presumably for use in traditional fish products such as fish sticks and portions, and fish cakes. This means that only the highest quality "V" or "J" cut mince will be acceptable.

Quantity. Only a very large output could justify these capital expenditures for new equipment, including freezers.

Expertise. Processors with no cooking equipment and no experience in the area of prepared foods may wish to stick to very minimal processing and to limit initial sales to fresh or frozen "chowder fish" or "fish nuggets," as a way of utilizing high-quality trim waste and damaged fillets without doing any mincing at all. At the other end of the spectrum are those processors with significant experience in prepared foods (or the desire and funds to hire a person with such experience) and good links to suitable markets. For these people, given the current increase in away-from-home and heat-and-eat seafood consumption, the sky is the limit. Quenelles, sausage-type products, smoked pâtés, and so on are all high-priced products that can utilize minced fish. In between these two extremes are more moderately priced prepared foods, which are discussed on page 8.

The processor wishing to manufacture human food products from mince would also have to select the proper marketing arrangements, i.e., wholesale, retail, or institutional. Generally it is easiest to break into the institutional market.

MAKING HUMAN FOOD PRODUCTS FROM MINCE

There are three major points to be made about mince, whether it is derived from trim or frames.

First, if trim or frame minces are to be utilized, then these streams may no longer be treated as waste. Instead, they must be treated as human food at every step of the way. Indeed, they should be treated with even more care than whole fish or fillets. This is for three reasons:

- Like hamburger, the mince has a high surface-to-volume ratio, providing an enormous growing area for microorganisms.
- No portion is protected from bacterial invasion or oxidation by skin or belly membrane.
- Both trim and frame mince are from the most fragile parts of the fish, which are most prone to spoilage, odor, and off-flavor development. In addition, frame mince is high in blood, pigment, kidney tissue, etc., all of which can develop off-flavors and support microbial growth particularly rapidly.

For these reasons, frames and trim destined for food use should be collected immediately in clean containers and sorted, minced, and cooked as rapidly as possible. If frames and trim must be kept for any length of time at all between steps—even half an hour—they should be put into cold storage. They should not be kept overnight. Raw material should be sorted and chosen early enough in the day to be processed into frozen or cooked food products prior to shutdown. Product should not be held, but should be distributed as quickly as possible.

Second, it is important to remember that not all trim and frames are suitable for human food use. We would recommend against production on Monday from fish which has been stored all weekend. We also would suggest that trim waste be sorted by hand, so that severely discolored or damaged material may be discarded. (Ideally, the trimmers might be trained to separate food-grade from nonfood-grade trim.) Similarly, in making frame mince, material with off-odors should not be used at all, and even with frames in good condition, the mincer should not be set at the highest pressure. High quality should take precedence over high yield.

Third, we suggest using only certain species for mince. In particular, we would warn against cod, because of worms. If cod trim is to be used for mince, it must be put on a light table and dewormed. Cod frames also ought to be candled prior to deboning, although this is more difficult since the bone blocks out some light.

Finally, in selling minced product, the producer will have to decide upon a price and marketing strategy. The price structure will depend partly upon the value assigned to the raw material. We would suggest that values of about $0.40 for frame mince and $0.60 to $0.80 for trim mince would be reasonable at the present time (1991), based on the value of related poultry and fish materials.

If the producer has made the decision to sell processed food products incorporating mince, the question of product choice and development arises.

As a first value-added processed food product, we would recommend something relatively simple such as a fish salad or a chowder. Subsequently, more challenging products could be developed. The producer will wish to consider products on the basis of complexity of preparation, shelf life, potential local markets, and profit margins. The producer may also wish to consider products on the basis of whether they lend themselves to manufacture from white, mild-flavored trim mince or from the redder, more strongly flavored frame mince. The salads and chowders mentioned above will generally require trim mince. So will a variety of other possible recipes, including fish fingers, croquettes, nuggets, etc., which could fit into markets ranging from institutional meal plans to restaurant happy hours.

Frame mince may be successfully utilized in red meat analog products, such as taco fillings, chilies, sloppy joes, or spaghetti sauces. While these are unconventional uses of fish, the end results, when properly formulated, are surprisingly conventional products in appearance, flavor, and texture. The strong flavors and tomato-based sauces cover up any color or flavor in the mince, and the texture of the mince provides a hamburger-like chewiness, provided the proper hole size has been used in the deboner. The red color of frame mince is largely due to blood, and this supplies a meat flavor to these foods, as well as a higher iron content than trim mince or fillets would provide. If these products are properly labeled and marketed, they can offer consumers who do not like fish a way to enjoy the health benefits of fish. They are also appropriate for institutional sales, where they offer an attractive combination of improved nutrition and favorable economics.

Processors interested in producing and selling mince in any form can request a copy of *Minced Fish*, by J. M. Regenstein, from the author. Those interested in formulating either trim or frame mince into processed foods can also request a copy of *Choose Your Title: Kosher Minced Fish Cooking/Fish Cooking with a Food Processor/International Fish Recipes*, from the authors, J. M. and C. E. Regenstein. While the recipes given in this latter pamphlet are small-scale and aimed at home cooks, they are a good introduction to the possibilities of minced fish use, and some are suitable for commercial production and sale.

References

In addition to the sources cited above, those interested in minced fish may want to read the following:

Agnello, R. 1983. Economic potential for utilizing minced fish in cooked sausage products. *Marine Fisheries Review*, 45(7,8,9):21.

Regenstein, J. M. 1981. Minced fish: a critical examination of the Cornell experience. *Seafood America*, 2(1):18.

Regenstein, J. M. 1986. The potential for minced fish. *Food Technology*, 40(3):101.

B. Nuggets, Cheeks, and Tongues

In many processing operations, whether as a result of trimming or damage to a portion of the fillet, a significant amount of material may accumulate daily which cannot be treated as fillet, but which is still high-quality meat. The processor willing to expend the labor necessary to put such pieces through the light table for bone and/or worm removal, may benefit from the current expanding market for "nuggets" or "chunks" or other forms suitable for finger foods or mouthfuls. If sold fresh, these will not have the texture changes or other cold storage problems inherent in frozen mince, and should command a price closer to that of fillets. Such material can also be sold as "chowder" fish.

For certain ethnic groups, cod cheeks and tongues are a traditional food. Cheeks may be saleable as nuggets in a wide variety of locations; tongues, because of their unusual gelatinous texture, are more problematic. Abco of Canada produces a special piece of equipment for tongue removal, and the Icelandic fish head splitter mentioned earlier separates cheeks, tongues, and chins. The challenge is to develop the appropriate markets.

2. FEED AND FERTILIZER PRODUCTS

Fish processing plants have traditionally disposed of waste material by converting it into fish meal, which is used as livestock feed. For several reasons, this technology is no longer a viable option for many processors. The production of liquefied fish (also known as "fish digests," "hydrolysates," or "fish silage") for fertilizer or feed products may be an attractive alternative.

A. Fish Meal

The manufacture of fish meal has been the classic method for stabilizing fish processing plant wastes and industrial fish since the nineteenth century. In fish meal production, fish are ground, cooked, pressed to remove excess oil and water, dried, and reground to a fine texture. There are a number of minor variations on this theme, but this is the basic process. The resulting meal is a highly regarded livestock feed, with an average protein content of 60%, and a well-established global commodities market. However, the reputation and, indeed, the existence, of fish meal plants as a means of disposing of offal in the Northeast have been damaged by two trends.

First, fish meal has lost value in its primary feed market, which is poultry. A decade or so ago, fish meal still offered certain vitamins and minerals that were unavailable from other sources. In some cases, these were unidentified scientifically except by their beneficial effect on growth, hence their original name: unidentified growth factors. Fish meal was also a particularly valuable source of the right amino acids in the proper balance. These properties gave it a strong economic advantage in the poultry feed market. Since then, the vitamins and minerals provided by fish meal have been identified and cheap alternative sources have sprung up. (Only with young turkeys is there still the possibility of an unidentified growth factor.) Additionally, the feed industry has pioneered and adapted the concepts of ration balancing and least-cost formulation, in which each feedstuff's amino acid content is quantitated. The least expensive mix providing the requisite amino acid profile and all other requirements for the best productivity of the animal is determined by a computer program. In the last few years, several of the most important amino acids for livestock feeds have been synthesized in enormous quantities and at low prices.

The net result of all of these advances has been that fish meal is no longer seen as necessary for poultry. Feed manufacturers will use it only if it is economically competitive with soybean meal and other cheap protein sources. In general, this means that fish meal will sell at about 1.6 to 1.8 times the price of soybean meal. Unfortunately, the price of soybean meal dipped very low recently, and the price of fish meal fell accordingly. Some fish meal plant owners and managers have closed their plants down; others have responded by stopping investment in and updating of existing plants. These plants had been based on nineteenth-century technologies to begin with, and many had become eyesores and polluters of both air and water. The result has been the closing of most of the plants in the Northeast. To the best of our knowledge, the Northeast currently has only one small fish meal plant which operates in New York (in Greenport, Long Island) and handles the waste from the filleting plant it is in. Larger, commercial fish meal plants in Gloucester, Massachusetts; South Portland, Maine; and Rockland, Maine have all been closed down over the last few years as a result of pressure from angry neighbors. Attempts to construct a new, modern, minimally polluting plant in either Gloucester or New Bedford, Massachusetts, have run into serious community opposition.

In fact, it is now possible to construct and run a fish meal plant in such a fashion that it can exist in a city without antagonizing its neighbors. A plant of this sort, after a shaky start, now operates in Aberdeen, Scotland, and is run by a processors' cooperative. However, such a plant must not only be engineered so that both air and water are cleaned before emission, but also must be operated in such a way that gurry is delivered in closed, insulated containers or refrigerated trucks, and stored for short periods of time only, in closed, refrigerated pits. The real questions center upon the economics of operating such a plant and the alternatives to it.

The most recent economic analysis suggests that fish meal plant profitability is largely dependent upon economies of scale so that a small plant starts with one strike against it. (*Fish Waste Handling Systems for New England*, 1986. Prepared by American Composite Technology. Available for $25 from the New England Fisheries Development Association, Boston, MA.)

Does a white fish meal made from finfish processing plant wastes have any special economic value that would justify the construction of a small, clean meal plant? In most fish meal markets, such as those for poultry and aquaculture feed, a white fish meal actually has a lower value than the usual oily fish meals made of industrial fish such as menhaden (of U.S. origin) or herring or anchovy (imported). There is only one market we have been able to identify that pays a premium price for white fish meal made to its specifications. The Taiwanese eel feed market purchases large quantities of white fish meal at prices significantly higher than those in the commodities feed market. Whether this market, when costs to deliver product are considered, pays sufficiently well to justify the construction of a small fish meal plant is another matter, particularly when one considers that this market's specifications are stringent but unwritten, and product lots are frequently refused.

No processors should consider a small meal plant without having negotiated with their market ahead of time, in order to establish some economic baseline. Additionally, unless their situation is unusually isolated, they should be certain that their neighbors are not going to litigate them into bankruptcy at the first sign of pollution, since no engineering system performs perfectly all of the time.

(In some countries of the world, a human-grade fish meal is produced, usually from the oilier fish. These operations are often subsidized by the local government and do not seem to offer any market opportunities to the U.S. processor.)

For the reasons cited above, it would appear that fish meal production is no longer a viable technology for economic waste disposal/utilization in the crowded Northeast. The alternatives discussed below may find potential application in this area.

B. Hydrolysis

Hydrolysis really is a family of technologies, rather than a single method of dealing with waste. What all hydrolyzing technologies have in common is that they use protein-digesting enzymes to liquefy the fish flesh. As you will see in the description that follows, hydrolysis technologies are sometimes, but not always, complicated. U.S. markets for fish hydrolysates have only recently started to develop, and very few U.S. fish processors are using this technology for waste disposal at this time. However, this number is increasing.

We believe that there are three reasons why hydrolysis is worth serious consideration:

1. Hydrolytic processes are very clean. They can be carried out on a large scale in a congested urban area, and produce essentially no odor.

2. Hydrolysis can be done on a relatively small scale on a plant-by-plant basis, since capital costs for most hydrolytic processes are relatively low. A major reason for the low capital costs (and the low odor production) is that once the fish is liquefied, it may be preserved wet by the addition of acid. If the product has to be dried, however, the situation changes. Drying will be discussed below.

3. Potential profits are surprisingly high for processors who can fit their products to the needs of one of the developing markets.

HYDROLYTIC PROCESSES

Hydrolytic technologies are often divided into two categories: acid hydrolysis (also known as fish silage) and enzyme hydrolysis (also known as liquefied fish protein). Though these two types of hydrolysis developed at different times and for different reasons, the division between them is currently somewhat artificial. The technologies have become sufficiently sophisticated that aspects of both categories may be combined into a single process. Nevertheless, the two categories are most easily understood in terms of their separate development. Note that both technologies use enzymes to liquefy the fish flesh, and these enzymes may come from the fish itself or may be purchased commercially. Both technologies are shown diagrammatically on page 12. The major difference is that fish silage or acid hydrolysis is preserved immediately by the addition of acid and permitted to digest itself over relatively long periods of time, while enzyme hydrolysis usually refers to a short, highly controlled digestion. When this digestion has gone as far as is desired, it is stopped and the digested liquid may be separated from the bones by screening. Oil may be decanted off, and the resulting wet digest may be stabilized by acidification or drying.

Enzymes are natural molecules found in all living cells. Enzymes carry out all of the chemical reactions necessary for life, but are very specific; that is, one enzyme carries out only one type of reaction. Enzymes are *catalysts*, which means that they speed up reactions without being affected by them. Thus, when the catalyzed reaction is completed, the enzyme is unchanged and can continue working. Since the same molecule of enzyme can carry out the same task so many times (and, if conditions are correct, so rapidly), a relatively small amount of enzyme can digest a very large quantity of fish waste. (For example, it takes about one pound of papain to digest one ton of gurry in about fifteen minutes.) Enzymes are themselves made mostly of protein and have very specific requirements in terms of acidity, temperature, etc. If these requirements are not met, the enzyme will work more slowly. If the environment becomes too hostile (for example, through freezing or boiling), the enzyme may be permanently destroyed. What will kill one enzyme may not affect another, so it is important to know each enzyme's requirements.

In enzyme hydrolysis we are concerned with two sets of temperature requirements; first, that at which the enzyme's activity is greatest, and second, when digestion is complete, that at which the enzyme is inactivated by heating. In our experience, commercial enzymes of vegetable origin, such as papain, are inactivated at higher temperatures than are natural fish visceral enzymes.

Acid Hydrolysis. The fish waste is ground, placed in an acid-proof container, and stirred, while one of a number of commercially avail-

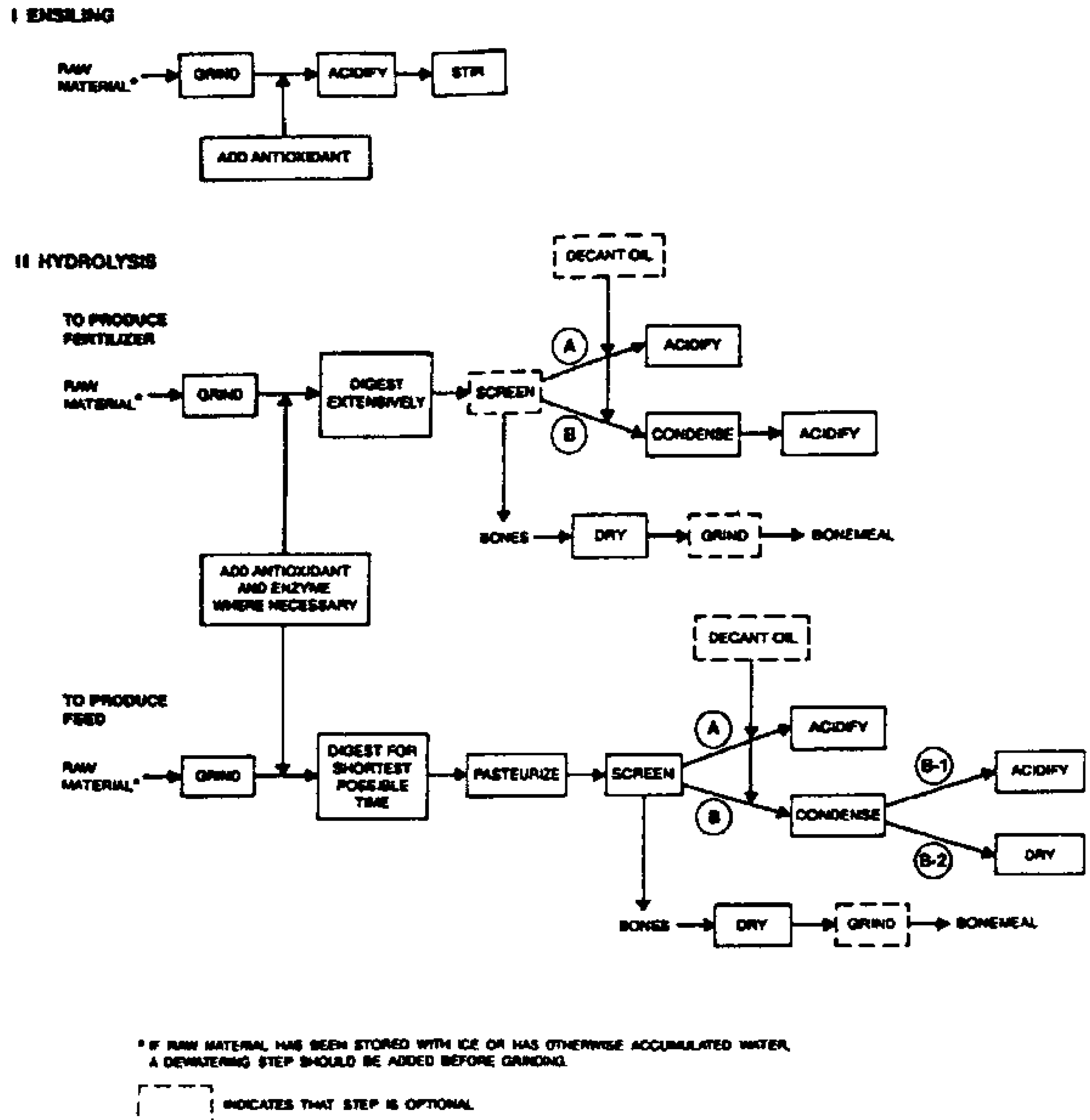


Figure 3. Hydrolysis protocols.

able acids is added in sufficient quantity to prevent the product from spoiling. If the end product is to be used as a feed, an antioxidant should be added to protect the oils present. (Adding acid is the equivalent of pickling; in fact, the flavor and texture changes in pickled herring are the result of a limited hydrolysis.) The amount and kind of acid required and the final pH (acid content) will depend on the product's end use; however, for adequate preservation the pH should always be 4 or below. The acid preserves the waste while the enzymes naturally present in the fish tissue digest it. This digestion will continue as long as the enzymes are alive and there is tissue left to digest. The material is stirred on a regular basis; once or twice a day at first and several times a week later on. The process is usually carried out at ambient temperature. The digestion could be speeded up by heating, but since the product has enough acid to keep it from spoiling, there is not much point in expending energy to speed up the process; presumably, the material is just going to sit around for a while anyway. In fact, one of the great advantages of fish silage is that it can be stored for years, if necessary.

If viscera are present in the waste, the digestion will go more rapidly, since the viscera contain a high concentration of digestive enzymes. If the wastes do not contain viscera, enzymes present in the other fish tissues (particularly the head) will carry out digestion; however, it will occur more slowly and the final product may be more viscous (thick and porridge-like). If the fish have been frozen, hydrolysis may not occur at all, since enzymes may be killed by freezing; however, this appears to vary from species to species. The gadoid fish appear to be most likely to have enzymes that are destroyed by freezing; other types of frozen fish may contain adequate enzyme activities for acid hydrolysis. Test your material. In cooked materials, however, all enzymes will have been destroyed and hydrolysis certainly will not occur unless active enzymes are added. Note that protein-digesting enzymes which will work under acid conditions are available commercially. They are called acid proteases.

The timetable for liquefaction using acid hydrolysis may range from a few days, if viscera are present and the temperature is warm, to weeks if there are no viscera and the material is cold. If the material is not stirred, it will eventually separate, with oil floating to the top and bone fragments and sludge sinking to the bottom. The more viscous the product, the slower the separation rate. For certain products, such as aquaculture feeds, the oil may have value. For other products, it may be preferable or necessary to separate the oil off. In all cases where a hydrolysate will be used as a feed, an antioxidant (usually, ethoxyquin) should be added at the start, and it is probably a good idea to use an antioxidant in any event.

Even when the oil is separated off, and the sludge is left behind when the liquid portion of the hydrolysate is taken off, acid hydrolysate yields are still extremely high, because essentially all of the water from the original wastes is left in the hydrolysate. In fact, in cases where any hydrolysate is kept intact, wet yields can be over 100% because they include all or most of the original material plus the added acid. Although these high yields sound enticing, and mean that the high costs of condensation or drying are eliminated, they also mean that large quantities of water must be stored and shipped. Further, all containers must be acid-resistant. So high yields of wet, acidified product are desirable only if the price is high or if local markets are available.

Provided that the appropriate acids are used, acid hydrolysates can be fed directly to a variety of livestock species, ranging from pigs, poultry, cows, and sheep to trout and salmon. Phosphoric acid is often used for production of fertilizers. Acetic or phosphoric acid may be used for feeds for fish and fur-bearing animals, while formic acid has been used to produce hydrolysates used to feed almost all domestic livestock species. Animals have taste preferences, just as humans do. In deciding which acids to use, ease of handling and economics are important, but animal preferences should also be taken into consideration. The ideal would be to work with an Extension Agent specializing in animal nutrition. If this is not possible, you may be able to work with a local farmer. Keep in mind the following rules: (1) Add the new material to the diet a little at a time. (2) Give the animal at least a week to get used to it. (3) Once the animal is eating it at the level planned for ration inclusion, watch carefully for at least one more week to make sure that no digestive upsets occur.

Enzyme Hydrolysis. The major differences between acid hydrolysis and enzyme hydrolysis are the level of control over the enzyme activity, and the speed of the reaction. Enzyme hydrolyses are carried out in heated reaction vessels, at set temperatures. For example, the ground fish waste plus antioxidant and enzyme (if it were needed) might be heated to 60°C (140°F), and kept at that temperature for fifteen minutes to two hours, depending upon the enzyme activity and the desired degree of digestion. The material would be stirred continuously to ensure even heating and penetration of the enzyme to all parts. Once the desired level of digestion was reached, the material would be further heated to near boiling. This would pasteurize the waste and it would kill the enzymes and stop the digestion. Since all the flesh would now have liquefied, the hydrolysate could be poured through a screen to remove the bone fragments, and it could be put through a decanter to separate out oil. The resulting material could be acidified wet, or it could be condensed to 50% water and acidified, or it could be dried. The costs of drying are high and usually only very large producers have made this investment.

Comparison of Acid Hydrolysis and Enzyme Hydrolysis. The digestion of the fish protein is often more complete with acid hydrolysis than with enzyme hydrolysis. Since nothing is done to inactivate the enzymes present, they go on working for a very long time. However, it is important to remember that a more complete digestion does not necessarily mean a better product. The extent of digestion in enzyme hydrolyses is more controllable, and more consistent from batch to batch. Indeed, because proteins that have been completely digested (down to amino acids) are less palatable and of less value to most animals than those that have been only partly digested, several research groups have worked on ways to limit protein breakdown in acid hydrolysates, such as heating or adding additional acid or inhibitory compounds after a given amount of digestion has occurred.

Historically, these two types of hydrolysis developed at different times and for different reasons. Acid hydrolysis was developed in Northern Europe during World War II as a simple, inexpensive way to stabilize fish wastes for use as livestock feed without using precious fuel for drying. Distances between the fish plants and the farming areas were minimal, so the high water content was not a serious problem. This fish silage was not a high-quality livestock feed, since the protein was usually over-digested and the oil content was often oxidized (which led to off-flavor meat), but no one was fussy in wartime. The silage kept the animals alive. Possibly because of its reputation as a poor-quality feed, very little work has been done in this country on fish silage for livestock, although several processors have used acid hydrolysis to produce fish fertilizers for home gardens and potted plants.

Enzyme hydrolysis of fish waste was also developed in Europe, but at a later time, when enzymes became commercially available and fuel became more economical. Because of the costs of capital equipment and energy for heating and drying, enzyme hydrolysis was always seen as a technology that would be applied to relatively large-scale commercial ventures. To date, the most successful venture has been that of the French cooperative Soprapeche, which for over twenty years has been manufacturing a spray-dried enzyme hydrolysate from processing wastes that commands a premium price as a soluble, high-protein, partially predigested ingredient in milk replacers for early weaned calves and piglets.

As we mentioned earlier, since the origins of these two technologies, the line between them has been blurred. One can, for example, do an enzyme hydrolysis and, instead of drying after pasteurization, add acid to preserve the digest in liquid form. Acid hydrolysates can be condensed or dried. To give an example of the variations possible, a hydrolyzed product is currently being made in the Northeast, in which sardine waste is ground, heated, and partially de-oiled. A bacterial culture similar to the ones used to make yogurt is then added, together with molasses (as a carbohydrate source to help the bacteria grow); the material is then moved to a fermentation tank. The bacteria use the sugar in the molasses to produce lactic acid, and this acidified digest is subsequently partially dried.

Nevertheless, despite these refinements, which blur the line between acid and enzyme digests, there are still two basic approaches to hydrolysis. One approach is geared to inexpensive, odorless waste disposal. It is kept very simple, has low capital costs, and gives a wet acidified product that may be used as a feed or fertilizer. This is the silage approach, and it is well suited to relatively small amounts of waste.

The second approach is far more controlled, has much higher capital costs, and produces a product (or products), usually in dry or condensed form, which may be sold at relatively high prices to specialized markets.

Either of the two basic approaches will solve a waste and/or a pollution problem. Both use enzymes to liquefy the protein of fish flesh. Apart from this, they have little in common, and require very different attitudes and investments from processors.

The more complex hydrolyses do not make sense unless processors have access to a large quantity of high-quality waste, have capital to spare, can gear their manufacturing process and raw materials to a particular market from the very start, and can work with experts to develop an acceptable and saleable product. The plant must also have the management skills necessary to supervise the technology being undertaken.

What are some U.S. markets for enzyme hydrolysates?

- Highly soluble, partly predigested, protein ingredients for early weaned pig feeds.

- Aquaculture feed ingredients, especially for semi-moist pellets for salmon culture. (Salmon prefer semi-moist to dry feeds, and appear to like some of the hydrolysate flavors.)

- High-quality and consistent organic fertilizers.

It may be useful at this point to discuss the properties that the various enzyme hydrolysates offer the marketplace, and how these properties differ from those of fish meal. One obvious difference between hydrolysates and fish meal is that hydrolysates can be stabilized in either a dry or a wet form. The wet form must be acidic, but some of the markets listed above can accept acidity, providing they can choose which acid is used.

A property that hydrolysates and fish meals share is variable oil contents, ranging from almost none to close to 20%. Both classes of products use the same antioxidant: ethoxyquin or Santoquin (Monsanto), to prevent the oil from becoming rancid.

Hydrolysates can offer a higher protein content than fish meals. Protein contents of fish meal range from around 60% to 70%, while hydrolysates offer protein contents from around 80% to over 90% on a dry-weight basis. The major reason for this difference is that fish meals contain all the bone of the original raw material, while hydrolysates may be screened to remove bone fragments. (In some acid hydrolysates, however, all the bone is dissolved.) Since their ash (mineral) content is lower, the hydrolysates' protein content can be higher. From the viewpoint of the animal feed markets, protein content is what counts, and this raises the value of hydrolysates.

Unlike fish meal, hydrolysates are soluble in water. This allows them to be resuspended which, in turn, permits them to be utilized either as a spray in the fertilizer industry, or in liquid feeding systems, such as calf milk replacers.

Perhaps the most unique feature of hydrolysates is the fact that they have been partly predigested and that the extent of this digestion is variable and (in enzyme hydrolysis) controllable. This feature offers two valuable properties to the marketplace. First, it provides improved digestibility and thus improved feed utilization to very young animals with immature digestive tracts. Second, because the partial digestion of proteins can create strong and complex flavors, hydrolysates may offer enhanced palatability to a number of different species.

Because these products and markets are new and varied, it is difficult to pin down prices. At this time, values placed on fish protein hydrolysates (or "fish digests," as some segments of the feed industry call them) range from about $0.07 to $0.20/lb for wet products, $0.20 to $1.00/lb for products concentrated down to 50% solids, and from about $0.75 to over $1.00/lb for dry ones.

PRODUCING FISH FERTILIZERS

The manufacture of liquid fish, which can be used as a fertilizer, is relatively simple. However, to manufacture and sell a commercial fertilizer is somewhat more difficult.

Any processor interested in producing a fish-based fertilizer should write to the University of Wisconsin Sea Grant Institute, 1800 University Ave., Madison, WI 53705 to request a copy of publication #86-789, *Handling Fishery Wastes and By-Products*. Authored by D. A. Stuiber, R. C. Lindsay, and R. Vilstrup, the Wisconsin report is quite complete and covers essentially every step of the process of making a fish-based fertilizer.

Those wishing to learn more about the technical aspects of hydrolysis and to understand the underlying principles should consider purchasing *Fish Protein Hydrolysis: A User's Guide* by S. Goldhor; it is available from the New England Fisheries Development Association, 280 Northern Ave., Boston, MA 02210.

In this report, we cover a few points regarding the production of fish-based fertilizer not addressed elsewhere in the literature. We will not repeat most of what the Wisconsin report covers. There are, however, a few points that are not covered there and some things it might be appropriate to change; we discuss these items in some detail.

The two major difficulties in producing and selling a commercial fertilizer are the need to condense it and the need to list the N:P:K ratio on the label.

1. *Condensation*. Most commercial fish emulsion fertilizers are condensed. Most fish are 75% to 80% water, and hydrolysates are naturally the same. However, if you buy a fish emulsion fertilizer in the supermarket, it will be about 50% water. This is because water has been evaporated from it. Thus, when you buy a pound of such fertilizer, you are actually buying the protein from 3 to 4 lbs of fish. (This is calculated as follows: a pound of raw fish may be 20% to 25% solids, but only 12% to 16% of this is protein; the rest is bone and oil. In the fertilizer, most of the bone and oil have been removed, so that the 50% solids content is largely protein. This is three to four times the 12% to 16% protein content of the raw fish.)

   Unfortunately, there is no cheap and simple method for condensing relatively small quantities of liquid fish, despite ongoing research in this area. The small producer must either sell uncondensed product locally to farmers and gardeners, or sell it to a larger fertilizer manufacturer who will carry out the condensation and then package the product for retail sale.

2. *N:P:K*. All fertilizers marketed in the United States must show on their labels the percents of nitrogen (N), phosphorus (P), and potassium (K) present. The analysis of N, P, and K is something that can be done by a number of commercial laboratories, as well as by the soil and fertilizer labs run by many state extension services. (The extension service will often do the same tests

more cheaply than a commercial lab will.) Most commercial fish fertilizers have N:P:K ratios of between 5:1:1 and 5:4:4. However, not all of these chemicals come from the fish. Some are added by the manufacturer to achieve the desired ratio. In commercial condensed fish fertilizer all the N might be from the fish protein. However, the product from your fish processing plant will be uncondensed, and its N content will most likely be somewhere between 1 and 2. The percent of P in your product will vary, according to how much bone has been left in, and whether or not you have used phosphoric acid. K will be quite low; below 1. The Wisconsin report tells how to achieve commercially acceptable ratios by the addition of various chemicals to the fertilizer, starting with the use of phosphoric acid for preservation. Apart from the addition of acid, which is reasonably simple, the calculations suggested for figuring out how much of each chemical to add are *not* simple. We recommend getting help with the first three batches that you make. If the second and third batches have the same analysis as the first, and everything went similarly and smoothly for all three batches, then you can just follow the recipe for subsequent batches and may have to analyze only occasionally; say, once every fifth batch. Otherwise you will need to arrange for an analysis on each batch of fertilizer you produce.

Note: Depending upon the route you have chosen for marketing your product, you may not have to add any chemicals, apart from acid for preservation. If you are going to sell your product in bulk to a fertilizer distributor, the distributor may wish to add chemicals to particular specifications. Alternatively, if you make an arrangement to sell to local organic growers, they will have their own set of requirements and prohibitions. They will probably request that chemicals *not* be added, even if this means that the percentages of N, P, and K present are very low.

Since organic growers are often willing to pay more for products that are natural and unadulterated, they represent a very desirable market. However, negotiate in advance as to what kind of acid they will accept; they may refuse phosphoric.

Apart from the analysis and calculation for addition of chemicals, the method for making the fertilizer is fairly straightforward and not overly difficult. The major warning is that a large quantity of phosphoric acid is used. Phosphoric acid is a relatively mild acid compared to strong acids such as hydrochloric, sulfuric, and nitric, but it *is* an acid and it should be treated with respect. Employees using it must be warned about it and must wear protective goggles, gloves, coats, and footwear. (*Note:* gloves or boots with holes in them are worse than no gloves or boots at all; check these daily.) Spills onto the floor should be neutralized with baking soda before being hosed off, and a water hose which can be turned on from either end should be nearby and always connected and ready to wash off any employee who spills acid on his or her skin. In this event, use large quantities of water and do so *immediately*.

As is mentioned in the Wisconsin report, the final fertilizer must be bottled in acid-resistant plastic rather than glass. The reason is that if a mistake is made and insufficient acid is added to prevent growth of microorganisms, the fertilizer could ferment and produce gas. If plastic bottles are used, they will stretch and develop pinhole leaks, but glass could explode and cause great damage and personal injury (and lawsuits). We would suggest opaque bottles for three reasons: first, the material is not an attractive color; second, this color may vary slightly from batch to batch; and third, this will cover up slight variations in fill level if filling is done by hand. (If you sell in bulk to a distributor or to local growers, they will probably want the product packaged in 55 gallon drums or 5 gallon buckets.)

The process suggested by the Wisconsin

workers is really an acid hydrolysis, speeded up by the use of heat, in which the acid preserves the fish from microbial growth and degradation, while enzymes present in the fish tissue break it down into a thick liquid. (For processors using gutted fish, it may be necessary to provide an additional source of enzymes—by purchasing proteolytic [protein-digesting] enzymes, by obtaining fish viscera, or by initially grinding the gurry very fine.) If the material is left for a long enough time, even the bones will be dissolved by the acid, and the processor can skip the step of screening the fertilizer. In this case, the chemicals in the bones will neutralize some of the acid, but we are making the assumption that the amount of acid in the Wisconsin procedure is sufficient to preserve the gurry, even with some neutralization. This neutralization will not lower the P content; in fact, it will be raised slightly by the phosphorus in the bones. If you find that the level of acid used is insufficient to preserve the gurry, screening out the bones may be cheaper than adding more acid. (Very finely ground bones will be impossible to screen out. A quarter-inch hamburger plate in the grinder has worked well for us, making the fragments of flesh small enough to be digested easily while leaving the fragments of bone large enough to remove easily.)

There are some points in the Wisconsin recommendations which we feel may not be appropriate for everyone. For example, the report makes the assumption that the processor will make a batch of fertilizer each day, to get rid of that day's waste, and that each batch will be completely digested within that day. This can only be accomplished by heating the acidified gurry; at room temperature the digestion may take anywhere from a week to more than a month, depending on what the room temperature happens to be and on whether or not viscera are present (and at what percent). (While we keep referring to acid as a preservative, inorganic acids [which are defined as acids that do not contain carbon atoms], such as phosphoric, will not protect against mold. For this reason, it is a good idea to add a mold inhibitor. We use 0.25% [a quarter of one percent] potassium propionate.)

The Wisconsin procedure produces a completely digested product within a twelve-hour processing period by utilizing stainless steel, propeller-equipped, heat-jacketed equipment (they suggest used milk batch pasteurizers) which can maintain the ground, acidified gurry at 60°C (140°F) while stirring continuously. This seems impractical to us for several reasons. First, a processing day is not usually twelve hours long. Second, even used equipment of this sort can be quite expensive. Third, this process would require a fair bit of energy input.

When contacted, the senior author of the Wisconsin report indicated that modifications of the paper may be warranted. Even with stainless steel equipment, they found corrosion of gaskets, joints, etc. They would now recommend staying away from stainless steel and using fiberglass instead. Fiberglass is light, inexpensive, acid-resistant, and easy to mold, join, etc. A fiberglass tank is very easy to make. If you want the capacity to heat the hydrolysate, a water-jacketed fiberglass tank is still reasonably easy to make. Do not forget that if your tank has a spigot or valve so that hydrolysate can be removed from the bottom, then this spigot or valve must be acid-resistant as well. (It also must be protected by screening, or be large enough so that it does not get blocked by bones.)

There is one situation in which you can use metal equipment without difficulty. If you add a commercial proteolytic (protein-digesting) enzyme, or if you have a high ratio of active viscera to fish flesh, you may get extremely rapid liquefaction at 60°C (140°F). We have seen liquefaction occur in less than one half-hour. When liquefaction occurs this rapidly, it is unnecessary to add the acid ahead of time. Thus the neutral material can be digested and the liquid mass acidified after digestion is complete.

In fact, if you make an acid hydrolysate, it is important to recognize that every single piece of equipment you use must be acid-resistant. This includes equipment for storing and shipping the hydrolysate, as well as equipment for manufacturing it. In some cases, you will have to do trials of your own, or check with manufacturers or university chemists. Some plastics, such as polyethylene, are acid-resistant, while others become brittle and crack after long contact with acids. The same is true for different types of rubber. Most metals are dissolved by acids. There are grades of stainless steel that are acid-resistant, but these can be quite expensive. Glass and fiberglass are acid-resistant. In evaluating bottles, check the caps as well; in evaluating metal equipment, check the gaskets carefully. Remember that a substance may not instantly dissolve in acid, but may corrode, harden, or crack over a period of time, so that long-term trials are needed. If you are adding a commercial enzyme to an acid hydrolysate, the enzyme must also be one that can work in an acidic environment. Such enzymes are available and are called acid proteases.

Acid hydrolysates do not have to be heated. However, heating provides several benefits. First, it makes liquefaction occur much more rapidly. Second, it permits a much more consistent and predictable timetable for liquefaction. This is beneficial for the producer who needs to process a given amount of material each day. In some cases, particularly where viscera are not present, or when the temperature is very low, sufficient liquefaction may not occur without some heating. (This is easy to test on a small scale.) Finally, some heat appears to be necessary with high-oil fish, to render out the oil and permit it to be separated off.

What level of heat should be applied? The most important specification is that, with visceral enzymes, the temperature should never be more than 60°C (140°F); above this level, the enzymes carrying out the liquefaction of the fish will be killed. At the other end of the scale, some workers have suggested that 20°C (68°F) is the minimum temperature for achieving a reasonably rapid digestion of cold water fish.

In general, with temperatures of 23°C to 30°C (73°F to 86°F), reasonable liquefaction occurs in about a week. The Wisconsin workers found that liquefaction occurred in their material in 96 hours (4 days) at 38°C (100°F) and in 12 hours at 60°C (140°F). Work on trout, sardine, and herring digested in the presence of viscera has shown liquefaction in about one half-hour at 60°C (140°F).

Thus, the type of fish used can have a major effect on the time required for liquefaction. Indeed the rate of liquefaction may be affected by many factors. The presence or absence of viscera will have a large effect, while the physiological condition of the fish, the pH of the hydrolysate, and the fattiness of the fish will all have smaller effects. Your material is unique; experiment with it. And if at any time your raw material changes, experiment with that. Do not make a giant batch of a new material, assuming that it will behave like what you worked with before.

How should heat be applied to an acid hydrolysate? A heating coil immersed in the hydrolysate is not recommended for two reasons. First, it is likely to corrode. Second, it tends to heat locally, so that the temperature may be too high right next to the coil and too low a foot away. On the other hand, a jacketed hydrolysis tank permits heating by circulating hot water through the jacket. Clearly, money can be saved if your facility is producing hot water anyway, and wasting it. This is often the case in plants with compressors. Stuiber suggests connecting the source of hot water to the hydrolysis tank via a small reservoir with an overflow leading to a drain. We also suggest a control device with a thermostat to pump the hot water through the jacket at a rate that will maintain the desired temperature.

Whether the hydrolysate is heated or not, it needs to be mixed. However, if it is not going to be heated, occasional mixing is sufficient, while if it is going to be heated, constant mixing will probably be necessary to maintain the same temperature throughout the tank. There are two points to be kept in mind when purchasing a mixer. First, it must be acid-resistant. Second, it must be heavy-duty. It should be capable of moving very heavy, viscous material over long periods of time. The hydrolysate will eventually liquefy but, at the start, may be close to the consistency of hamburger. (Some people have found it helpful to add a small portion of the liquefied final product from a previous batch of hydrolysate in order to decrease the mixture's viscosity at the start.) It will take a strong mixer to deal with this material. Stuiber recommends either a peristaltic pump or another positive displacement pump. Alternatively, he suggests a Lightnin mixer coated with plastic or rubber. Make sure that any part of any pump or mixer coming in contact with the hydrolysate is resistant to corrosion by acid. ("Contact" includes splashing.)

If the hydrolysate will not be heated but will simply be left after acidification to liquefy at ambient temperatures, then a plastic or wooden paddle will be sufficient (exception: do not use a wooden paddle in phosphoric acid). It is very important that the initial mixing be thorough. If the acid does not penetrate to every bit of minced offal, pockets of decay will result. After the initial mixing, stirring once a day or once every few days should do the job. Make sure that the paddle reaches down to the bottom of the tank so as to agitate the sludge that will settle there.

The other major piece of equipment needed will be a grinder. The gurry must be ground to approximately the consistency of hamburger before it is acidified. Do not purchase the grinder until preliminary small-scale experiments have been carried out. A finer grind may be one way to deal with the lessened digestion caused by a lack of viscera, but may make it impossible to screen out bones. If your gurry contains fish hooks or other metal objects, these will have to be removed prior to grinding.

Once the fish waste is ground, it should be acidified (and stirred) right away so that spoilage doesn't occur. The acidification procedure described in the Wisconsin report, which we recommend, uses phosphoric acid at a level which provides 4% P (phosphorus) in the final product. Because acids as purchased are almost always less than 100% acid, and because not every atom of phosphoric acid is an atom of phosphorus, this does not mean adding 4 lbs of acid to each 100 lbs of gurry. As the Wisconsin report points out, this means adding 6.96 lbs of phosphoric acid if the label says that it is 85% phosphoric acid, or 7.96 lbs if the label says that it is 75%. If there is ever any doubt, it is better to add a little extra acid rather than being a little under.

We mentioned earlier that commercial fish fertilizers come in a variety of N:P:K percent formulas; these include 5:1:1, 5:2:2, and 5:4:4. Since we follow the Wisconsin report in recommending the addition of phosphoric acid to a final level of 4% phosphorus, we already have a P level of 4. The easiest formulation is therefore 5:4:4, which means that extra N and K must be added, after the batch is digested and analyzed, to bring these elements up to the proper levels. As we said earlier, professional assistance will be required the first few times to help figure out how much of each element is present and whether other appropriate chemicals should be added. USDA's Plant, Soil, and Nutrition Labs or a Land Grant University's Cooperative Extension Specialists in agronomy may be able to either do the work or recommend a laboratory to do it. These people should also be able to give accurate advice on labeling requirements for fertilizers, and to suggest other analytical tests that might be helpful. Again, keep your market in mind. The owners of house plants may wish for a complete fertilizer, but farmers and organic gardeners will probably prefer minimal additions.

Since the standardization of a batch of fertilizer is time-consuming and costly, it pays to make reasonably large batches. This is one reason why we suggest processing and/or storing in large fiberglass tanks. This does not mean that all of the gurry must be ground and added at once. There is no reason why you cannot add gurry and acid to the previous day's (or week's) batch. However, you should probably not add gurry over a period longer than two weeks since the enzymes do get slowly inactivated over time, and eventually a new batch, diluted by being mixed with the older ones, will simply not have enough enzyme present to be digested.

There is, of course, another constraint on how big a batch you should make, and that is how much you can market. While this material stores quite well, there is no point in having it sitting around for years on end. Let us picture a situation where there are two tanks in place, each one holding 1,000 gallons, where temperature in the plant is 10°C (50°F), and no viscera are present in the gurry. A thousand gallons is essentially equal to 8,000 lbs or 4 tons. You wouldn't put in that much fish waste, because room must be left for stirring and for adding quite a lot of acid at the end. In fact, for each ton of gurry, you should assume that about 500 lbs of chemicals will be added to make a 5:4:4 fertilizer. So, let us say that 3 tons of gurry are put into a tank and that about 7,500 lbs of fertilizer are the end product. One tank could hold finished fertilizer, while the other holds digesting material. Let us also assume that digestion without viscera at 10°C (50°F) is so slow that it takes a month to complete. Still, that means that annual production is 7,500 lbs x 12, or 90,000 lbs per year. If the product is sold in eight-ounce bottles (the most popular supermarket size for potted plant use), that means selling 180,000 bottles a year. Working up to this figure would represent an impressive marketing achievement. This kind of calculation is useful in figuring out how large your tanks ought to be.

We would suggest starting commercial production with fairly small containers which could hold about 1,500 lbs, and using a thousand pounds of gurry. And, before that, we would suggest making some very small batches (of perhaps 15 to 20 lbs) in buckets, stirred a couple of times each day by hand, to test the system. These small batches are important to make sure that the grind is fine enough, that the acid is strong enough, and so forth. The buckets will show things such as how long it takes for the bones to dissolve, if they do dissolve. Consumers want a product of even, fine consistency. The bucket experiments will show if such a product is possible without viscera and without screening, and how long it will take to achieve it. The one thing that is difficult to do in a bucket is to test the effect of different temperatures, although you could immerse the bucket in a larger container of hot or cold water and stir, or use an aquarium heater and thermostat to keep the temperature stable in the large container. Make sure that your small-scale batches contain representative samples of waste, and that the proportions of flesh, bone, viscera, etc., are realistic.

Don't order any large-scale equipment until you've made sure that everything works on a bucket level. And, make sure that the buckets are acid-resistant.

At the point when a decision is made to start work on a fish-based fertilizer, it would make sense to explore a number of marketing options, as well as to visit a number of possible outlets and look at what they already offer. For those discouraged by the difficulties of the process and the initial purchases (neither of which are as bad as they appear at first glance), the price tags on fish fertilizers are a pleasant surprise. At the time of this writing (1991), an eight-ounce bottle in a local supermarket costs close to $3.00. However, this material is condensed and contains as much fish protein as a quart (approximately) of single-strength fertilizer such as yours. Still, by the use of chemicals, you can offer a comparable N:P:K.

Total costs will be difficult to work out until you've had a chance to see what the prices of equipment and chemicals are and how much labor and laboratory services are involved. The greatest expenses will be bottles and phosphoric acid. Labor can be high for hand bottling, and attractive labels can also be expensive. The

Wisconsin report gives an estimate of costs to produce a thousand gallons of fertilizer to be bottled in gallon containers. This is quite out of date and omits professional consultations, equipment, and labor. It also assumes that processors will opt for cheap labels. However, it is useful in showing the relative magnitude of costs for the various inputs to the product.

There is one last point that is not covered in the Wisconsin report. Since a high level of phosphoric acid (and therefore a relatively high level of P) is necessary to provide sufficient acidification to preserve the digest, one might wonder how a 5:1:1 or a 5:2:2 fish fertilizer is possible. The answer is that such fertilizers are acidified by other acids, such as hydrochloric or sulfuric, and K (potassium) is added in the form of a different chemical, usually potash. The big advantage of using these other acids is that they are much cheaper than phosphoric. Also, since they are much stronger than phosphoric, smaller amounts of them may be used to achieve the same levels of acidity. We do not recommend them. They have one overwhelming disadvantage: because they are so much stronger, they are much more dangerous to work with and to keep around. An accident with these acids is much more serious than an accident with phosphoric acid. Additionally, strong acids may liberate hydrogen fluoride, which is poisonous, from the fish bones. For these two reasons, we suggest that strong acids have no place in most processing plants and should only be used in automated facilities with specially trained personnel.

References

The literature on hydrolysis is large and much of it is extremely technical and of interest only to specialists. We will cite only a few key references, which are relatively easy to obtain; each of these contains further references for the interested reader.

American Composite Technology. 1986. *Fish Waste Handling Systems for New England.* An analysis of equipment and costs for fish meal production versus one version of hydrolysis. This may be purchased from the New England Fisheries Development Association, 280 Northern Ave., Boston, MA 02210 for $25.

Goldhor, S. 1988. *Fish Protein Hydrolysis: A User's Guide.* A thorough handbook for the beginner learning about hydrolysis. This may be purchased from the New England Fisheries Development Association, 280 Northern Ave., Boston, MA 02210 for $18.

Raa, J. and Gildberg, A. 1982. Fish Silage: A Review. *CRC—Critical Reviews in Food Science and Nutrition* 16(4):383. An excellent review of almost every aspect of fish silages made by adding acid or by bacterial fermentation, where the bacteria produce the acid.

Stuiber, D. A., Lindsay, R. C., and Vilstrup, R. 1986. *Handling Fishery Wastes and By-Products.* An excellent and detailed description of how to go about manufacturing a simple home fertilizer based on fish silage. Available (free) from the Sea Grant Institute, University of Wisconsin, 1800 University Ave., Madison, WI 53705. Publication Number: WISCI-T-86-001 (WIS-SG-86-789).

Torry Memoirs No. 619 (*General Review of Fish Protein Hydrolysates*), No. 620 (*Fish Silage: Preparation, Properties, and Uses*), and No. 621 (*Preparation of Fish Protein Hydrolysates*). These are available (free of charge) from the Torry Research Station, PO Box 31, 135 Abbey Rd. Aberdeen, AB9 8DG, Scotland, U.K.

Windsor, M. and Barlow, S. 1981. *Introduction to Fishery By-Products.* Fishing News Books, Ltd. Farnham, Surrey, England, U.K. (16.50 pounds sterling). Useful summary chapters on

fish silage and fish protein hydrolysates as well as all other major waste handling technologies.

Winter, K. A. and Feltham, L. A. W. 1983. ***Fish Silage: The Protein Solution.*** A good discussion of small-scale, simple silage production for local livestock feeding. Available (free) from K. A. Winter, Agriculture Canada Research Station, PO Box 1210, Charlottetown, P.E.I., C1A 7M8 Canada.

C. Composting

Compost is usually defined as a mixture of decaying or decayed organic matter (plant material, manure, etc.) used as a fertilizer or soil-enhancer. More technically, composting can be defined as the aerobic, thermophilic decomposition of organic materials to a stable, humus-like material. (*Thermophilic* means heat-loving, and refers to the class of microorganisms that carry out the composting process.)

Anyone who has had a garden compost heap knows that it utilizes a very simple technology. If the gardener puts in organic garbage, grass clippings, leaves, and so forth; if the heap is small enough or turned often enough for air to get in; and if the proper microorganisms are present, the population of microorganisms in the decaying matter will increase, and microbial activity will turn all of the smelly, unpleasant garbage into a reasonably odorless, rich organic mulch. In the course of this process, the activities of the composting microorganisms will also generate heat which will essentially sterilize the composting mass, except for the desired microorganisms, which are relatively heat-resistant and will survive to about 65°–70°C.

Composting reduces the bulk of the composted materials by 40% to 80%, reduces moisture by 50% or more, and reduces oxygen demand by 90% or more. If the appropriate temperature is maintained for a sufficient length of time, composting eliminates odor and destroys weed seeds and disease pathogens.

In composting, materials rich in nitrogen are mixed with materials rich in carbon. Animal materials such as manure, fish, and crustacean wastes tend to be rich in nitrogen, while plant materials such as sawdust, peat, wood chips, leaves, stalks, and bark tend to be rich in carbon. In general, if the nitrogen-rich materials and the carbon-rich materials were not mixed and aerated in the presence of the proper composting microorganisms, the former would putrefy and the latter would just sit there. It is only in combination and under the right set of conditions that composting occurs.

While backyard composting is very simple, and mistakes are easy to deal with, large-scale industrial composting is more difficult. Despite this, however, composting is still the cheapest and simplest of the waste-stabilizing technologies available to the processor. The questions that the processor who decides to use composting technology must answer have to do with choosing carbon sources, deciding how to combine the carbon and nitrogen sources, selecting appropriate means of materials handling, aerating the pile, and selling the finished product. These issues are discussed on the following pages.

BASIC PRINCIPLES

Carbon and Nitrogen. To start with the most basic principle of composting, how much carbon and how much nitrogen should be combined in a compost pile? In theory, a carbon to nitrogen ratio of 20:1 is reasonable for composting. However, to avoid odors and problems at the start, a number of experts suggest a 40:1 ratio of carbon to nitrogen. This does not mean that composting requires forty times as much sawdust or peat as it does fish; it means that forty atoms of carbon are needed for every atom of nitrogen. In practice, depending upon the carbon source, this can mean anywhere from three pounds of a carbon source to one pound of fish (when sawdust or wood chips are used) to one pound of a carbon source to one and a half or two pounds of fish (when peat is used). Since the number of atoms in any material is not obvious, you can have an analysis done by a laboratory specializing in this kind of work, or run small-scale trials for each new material or combination of materials. In practice, most people start out new materials by using an excess of the carbon-rich component and slowly adding more nitrogenous material.

In addition to the amount of carbon and nitrogen present, you must consider how much of each is on the surface and available for reaction and how much is hidden. As an illustration, let us take equal weights of sawdust, wood chips, and logs. The same amount of carbon is present in each, but much more of it is on the surface (and therefore available) in the sawdust than in the wood chips, while the logs would take years to break down. Most experts suggest using more than one source of carbon to overcome potential problems. For example, leaves and sawdust have high surface areas, but they may also pack down so tightly with the gurry that air cannot circulate sufficiently. Adding wood chips or bark to the pile can prevent this problem. Again, small-scale trials will pinpoint problems of this sort while they are still solvable or, at least, disposable. Interestingly, because fish decomposes so rapidly, the question of surface area for the nitrogen source is less important. Experiments in turned compost piles, where gurry was ground before being composted, showed no advantages over trials where racks, heads, skins, etc., were left whole. Indeed, in one experiment in the series run by the MidCoast Maine Compost Project, whole herring in actively composting turned piles disappeared in three days. In static piles, however, grinding or chipping the fish or shellfish waste is helpful.

In choosing carbon sources, you must also consider their cost, availability, and effect upon the final product. For example, leaves are inexpensive and abundant in many suburban communities in the fall, but nonexistent the rest of the year. Peat is expensive but may be purchased all year long, and may produce a higher-quality, more saleable, and consistent end product. For the processor who wishes to make a significant marketing effort, and who is willing to bag, label, and distribute compost to retail outlets serving organically minded home gardeners, peat may more than repay its initial cost. This may not be the case for the processor who has little time or interest in marketing a byproduct and who prefers bulk sales at low prices to large customers such as the local Highway Department.

EVALUATING THE PRODUCTION OF COMPOST

Perhaps the greatest advantage of composting is that it can deal with any fish or crustacean processing wastes. Several demonstrations in Maine have shown that dogfish wastes, as well as a variety of cooked and raw shellfish wastes, may be composted without problems. In fact, a large-scale commercial dogfish composting operation is up and running in Maine. Thus, even some of the most intransigent wastes, which cannot be ground up and are unacceptable either for rendering into fish meal or for hydrolysis, may be composted. (This includes rotten material, smoked fish wastes, and so on.)

For those processors in densely populated areas, it is important to note that composting, properly carried out, produces no leachate (liquid runoff), no toxic gases, and few noxious odors. There will be some fishy odors at the start, which will subsequently be replaced by a pleasant earthy odor. Nevertheless, such processors should proceed with great care. A large amount of noxious waste, incorporated into a pile, may cause odor only for a day or two—but if new piles are built each day, the neighbors' perception will be that there is continuous odor. Static piles have some advantages here, since all of the gurry is buried in the pile, while in turned piles some fish waste will always be at the surface.

Since composting is the simplest and most benign of all the technologies we have looked at for disposing of fish waste, and since it is widely practiced by numerous backyard gardeners, it is sobering to have to report that composting operations, with and without fish, have still raised the suspicions of their neighbors and are subject to the scrutiny of regulatory agencies. In general, the suspicions of neighbors have been rapidly dispelled, and many doubters have turned into boosters, a claim that cannot be made for most waste disposal methods. However, the president of one commercial composting operation in suburban New England has stated that a significant fraction of his costs (of $35 to $40 per ton) comes from the need for constant public relations efforts and the satisfaction of regulatory requirements. Even more sobering, two large and well managed composting operations in the Northeast are under fire from their neighbors.

How much space is required for composting? The answer to this question may depend upon your neighbors. Joan L. Brooks of the University of Maine at Orono calculated that a processing plant producing 20 tons of gurry a day, and operating five days a week for six months of the year, could compost all of this material on three and a half acres. William F. Brinton, Jr., of the Woods End Research Laboratory in Mt. Vernon, Maine, has stated that it is physically possible to compost close to 7,500 tons of material (although not all of that material is fish) on one acre, but suggests that it would be unwise to start an operation of this size on less than five acres because of the need for access lanes, storage of incoming carbon sources and outgoing compost, buffer zones, etc.

In short, composting has strong advantages for processors with space to spare. Unlike food production, in which poor-quality raw material is unacceptable, or hydrolysis and rendering, in which the "garbage in, garbage out" rule applies, composting can accept even decomposed material and can handle shrimp, crab, and lobster wastes as well as any species of fish. (Indeed, crustacean wastes have the advantage of higher N values in the final product due to the nitrogen in the chitin of the shells. However, clam, mussel, and scallop shells will not disappear in the composting process.) Capital costs are low, although heavy equipment is needed for large operations, unless labor is plentiful and cheap. Regulatory requirements may be stiff, and they should be explored ahead of time. Compost is easy to store, requiring little more than a tarpaulin, and its shelf life is unlimited. Marketing is flexible and can be as elaborate or simple as you wish. Composting remains the cheapest, simplest waste-stabilizing technology available to the processor. For some processors, composting may be the only possibility. Others will have to weigh the pros and cons of composting against those of their other options.

FURTHER DETAILS FOR THE PRODUCTION OF COMPOST

If there is a single rule of thumb about composting, it is the following: composting is a living process carried out by microorganisms under highly variable conditions. Until you have done it over and over again, and have a "feel" for the process, experiment on a small scale and talk to experts or consider hiring one as a consultant. Experts can do several things for you. They can give you advice on how to build and handle your piles. They can analyze your prospective carbon sources and help you to put together a recipe or a series of recipes to cover variation in sources. And, if something goes wrong with your pile, they can troubleshoot—sometimes even over the telephone. As with all technologies, there is both bad news and good news about composting. The bad news is that compost piles can run into problems, the solutions to which are not obvious to the beginner. If these problems are not caught in time, the pile could putrefy instead of composting, or could even burst into flames. The good news is that composting goes slowly and is reasonably forgiving, so that you generally have time to catch the problem. Most "mistakes" can be added back into the pile to undergo additional composting. In the Appendix, we have listed a few people who can provide assistance. If you are not in the Northeast, you'll probably want to find some experts closer to home.

If some of the above sounds ominous, we don't mean it to. Composting is no more difficult than brewing beer or baking bread, two processes that take advantage of a different kind of microorganism. You don't have to be a scientist to compost; anyone can do it. However, as with brewing or baking, no one should expect a perfect process or a saleable product the first time around.

For the processor considering composting, a series of questions must be answered. The first and most obvious is whether composting is indeed your optimal disposal option. For some processors, who have no other means of disposal, that question has only one answer. However, composting takes space. We mentioned above that several thousand tons of material (although that material is not all fish) can be composted on an acre of land, but that a minimum of five acres has been recommended for storing carbon sources and finished compost and creating access lanes, buffer zones, etc. Since composting provides a reduction in bulk of from 40% to 80%, storage of the finished material is not as space-consuming as you might imagine, but storage requirements for incoming carbon sources can be immense. (The Japanese concept of minimum stockpiling and just-in-time delivery is attractive in some industries but frightening to the processor facing aging gurry and nothing to mix it with. This problem is particularly severe when the processor is using a variety of free wastes, such as leaves, sawdust, etc., where seasonal availability varies, and where there is no reliable commercial distributor.)

One possibility that we are currently exploring is that of indoor composting. The square footage needed indoors may be less than that required for outdoor composting. The walls will form a buffer zone and storage can be placed elsewhere. However, indoor composting presents other problems, which we will deal with briefly on pages 34 to 35.

Another question which processors should consider before making a decision on whether or not to compost is how stringent local and state regulatory requirements are, and how high the costs of complying with them will be. In New York the appropriate agency to contact is the New York State Department of Environmental Conservation, and the pertinent regulations (regarding solid waste management) are 6 NYCRR Part 360.

There is an alternative possibility that should be kept in mind, which is that another person or company might be interested in composting your processing wastes. Organic gardening groups, farmers, vocational schools, companies manufacturing soil amendments and fertilizers, and others are all potential partners. Additionally, whether or not anyone in your area wants to start an actual composting business, extension workers, university researchers, environmental groups, and others may be interested in doing the research needed to help you and others in your area get started. This can save you a significant amount of time and money, and answer many of your initial questions about composting.

Assuming that you do decide to at least try composting, the next question to consider is what carbon source or sources you will use.

Choosing a Carbon Source. Peat, dry leaves, sawdust, bark, wood chips, and shavings are some possible carbon sources.

As mentioned earlier, peat is probably the most expensive carbon source, but it is available through commercial sources year-round, and it produces a consistent and very high-quality end product. If the product is eventually to be sold to a retail market of home gardeners, peat has high recognition and perceived value. A product consisting of enriched peat and, most particularly, peat enriched with fish (which is also recognized as having fertilizer value), could command a high price. Additionally, if storage space is a key issue, peat offers significant advantages. First (as discussed below), the same quantity of fish can be composted with less peat than with any other carbon source. Second, peat is highly compressible and can be delivered and stored baled and compressed. Finally, because peat is a commercial product, it may be ordered on fairly short notice from a variety of sources.

Peat and other carbon sources. While a fair amount of research on composting fish and, particularly, composting fish with peat, has been done in Canada, the most recent trials on composting fish and shellfish with a variety of carbon sources have been carried out in Maine. Interest in commercializing the technologies developed has been high. A list of persons able to give up-to-date information on both research and commercial enterprises is included in the Appendix.

Sukhdev P. Mathur (Senior Research Scientist, Land Resources Research Institute, Agriculture Canada, Ottawa, Ontario K1A 0C6) and his group initially showed that: (1) peat was the ideal carbon source with which to compost fish, and (2) it was possible to eliminate the labor of turning and agitating compost piles by designing a static pile in which aeration occurs passively through pipes set into the pile at intervals. Brooks repeated Mathur's work on a variety of wastes, including dogfish processing wastes. No problems were encountered, and essentially complete disappearance of all dogfish parts was seen, with no noxious odors or leachate (fluid runoff).

Peat is the partially carbonized bodies of a variety of plants found in bogs. While peat often consists of mosses, it can be composed of a number of species of plants and, for this reason, is a variable material. In general, the blacker, more humified peats are best for composting. One reason why peat is so effective for composting is that much of the noncarbon part of the plant has disappeared, so less weight of peat will supply more atoms of carbon than will other plant materials. There are other reasons as well why peat is so effective in composting fish. When air is present, as it is in a compost pile, rotting fish generate ammonia. Peats containing sphagnum moss have the capacity to bind a significant quantity of ammonia (i.e., tie it up so it is not released as a gas into the air). Air-dried peat also has the ability to absorb immense quantities of water—up to 30 times its dry weight—and this is a key point in preventing leaching from the pile. Presumably for this reason, some researchers have used peat as the bottom layer of their piles, even when other carbon sources were used for the bulk of the piles.

Not only is peat the ideal carbon source, but it is also the only carbon source we know of that can be used alone to compost fish or shellfish wastes. All other carbon sources, which depart in various ways from the ideal, must be mixed in order to support the composting of fish.

In deciding whether to use peat alone or whether to use a mixture of carbon sources, the major point to consider is economics. The use of peat may be a strong selling point on your label and, since peat is available year-round, it enables you to offer customers a very consistent product. If your customers are going to be upscale gardeners and potted plant lovers, these are important points. However, if your only customer is the local Department of Transportation, and they tell you that they do not care how the compost looks or if it is consistent, but they do care about getting the lowest possible price, then you should move to carbon sources other than peat.

Factors to consider. From the viewpoint of composting, the major points to consider in choosing carbon sources are: amount of carbon, availability of carbon over time, and air flow.

For example, both dry leaves and sawdust have good available carbon for starting composting because they both have a great deal of surface area compared to volume. On the other hand, both dry leaves and sawdust tend to compact, making it difficult for air to circulate through the pile.

The addition of bark or wood chips to the pile might solve the problem of compacting, but might cause another problem. Fish composts very rapidly (six to ten weeks in summer, as a general rule), while wood chips and bark compost quite slowly. Uncomposted carbon sources will not pose a problem for you, but will cause difficulties for the gardener, as they may pull nitrogen out of the soil while they go on slowly composting in the garden. There are several ways to solve this problem. One might be to screen out large (uncomposted) particles. Another might be to add more fish and sawdust/leaves and continue the composting process through several cycles. A third is simply to age the compost for a sufficiently long time to break down the wood chips or bark. (Turning the pile occasionally will speed this process up.) Work done at the University of Wisconsin, and published recently, on composting fish wastes with wood chips showed that there was significant variation with the type of wood used and the size of the chips, but that 18 to 24 months were needed before the wood was completely broken down and the compost could be used for horticultural purposes as opposed to mulch.

From the viewpoint of processing, a major point to consider is the availability of the carbon source relative to your processing season. Dry leaves are in great supply in late fall, but nonexistent at other seasons. Sawdust and wood chips may be available all year long. Tomato or grape pomaces (a pomace is the dry pulp left after juices have been pressed out) tend to be available only in late summer and early fall. On the other hand, the development of controlled atmosphere storage for apples has led to year-round availability of apple pomace from some cider pressing operations.

If you are seriously considering composting with a variety of carbon sources, we suggest doing a census of how much of what is available when, what (if anything) it will cost, and what the transportation and storage requirements will be. You may need to get analyses done to develop "recipes," since the amount of carbon and nitrogen in materials is not always obvious. Potato wastes, for example, might appear to be ideal carbon sources but, in fact, have a significant amount of nitrogen. If you live in a dairy farming or horse raising area, you may be competing with these farmers for sawdust or shavings, which they use as bedding. On the other hand, they need to get rid of the used bedding material. Manure and urine are both rich in nitrogen but, if the bedding has been changed frequently enough, it may still be useful to you.

Contamination. If the raw materials you use are potentially contaminated with pesticides, heavy metals, or PCBs, you may need to have other analyses carried out in addition to analyzing carbon and nitrogen content. If fruit is sprayed with pesticides, almost all of the residues will stay with the pomaces. However, most of these chemicals will break down over time and with composting. Therefore, if you do analyze for such compounds, do not do so until composting is completed. Heavy metals will not break down, however, and PCBs are unlikely to break down. These are most likely to be in the fish wastes, particularly if your wastes are derived from polluted fresh-water sources. Predatory marine fish, rich in liver and body oils, may be polluted as well. This does not mean that wastes high in toxic components, such as heavy metals, cannot be composted, but it does constrain the markets for that compost. Organic farmers (or any other farmers, for that matter) and home gardeners are not reasonable markets for such material. A Department of Transportation, however, which will use the compost for highway plantings, is an excellent market. Highway verges are never used to produce feed or food, since automobile emissions pollute them with lead in any event. Inedible decorative plants, turf, etc., could also be grown using such composts. The level of contaminant, as defined by analysis, will suggest the usage. Most fish-based composts will have very low levels of contaminants, and will be suitable for growing food or feed.

Constructing and Aerating the Pile. In addition to making decisions about the carbon sources to be used in the pile, you will need to make decisions about how to construct and aerate the pile. The microorganisms that cause composting (as opposed to rotting or putrefaction) need oxygen. That oxygen can be supplied by turning or agitating the pile at regular intervals, or by building a static pile with pipes to let air in. When you are composting large quantities of material, the design and construction of static piles are more demanding and less forgiving than those of turned piles; it takes more thought and experience to get a static pile right. In addition, the composting process usually does not occur with absolute uniformity throughout a static pile, no matter how well constructed and aerated it is. The center of the pile composts best and most rapidly (provided it has adequate air flow), while the edges compost slowly and incompletely. This is not the case in turned piles because the material that is at the edge today will be in the center tomorrow, so that composting will be complete and uniform.

If incompletely composted material is packaged, it will either continue to compost or it will rot, depending upon whether air is present or absent inside the package. If it composts, it will heat up inside the package, causing potential packaging problems at best, and fires at worst. If the material rots, it will smell awful when the package is opened. Thus, for reasons having to do with both safety and quality, a static pile, even when well aerated, may have to be remixed, reconstructed, and left to cure for a short time before it can be sold and, most importantly, before it can be bagged.

Turned piles. Turned piles may be the easiest to construct and manage. However, it is important to keep in mind that in the early stages of composting, turning a pile will expose some fish (and thus some odor) to the air. In a large composting operation, the odor generated can be very strong. As composting proceeds, the pieces of fish will disappear and so will the foul odors. But, if fresh piles are being built every day, odor will be ever-present. Turning a large pile every day or even every other day will take either a great deal of labor or fairly expensive heavy equipment. Commercial compost piles are often built in windrows, 8 to 10 feet wide and 100 or more feet long, with sufficient space between them that a tractor can travel up and down the aisles. A number of commercial turning devices are available, many of which work off of a tractor's power takeoff. This sort of operation requires minimum labor for construction and turning of the piles. A good place to see advertisements for commercial composting equipment is *BioCycle* magazine. (See the references on page 36.)

Small piles can just be made in a heap and turned with a pitchfork. For processors with very small quantities of waste, this can be an inexpensive and simple disposal method. If you make the pile with peat, turn it every day or so until composting is complete, screen it to remove sharp bone fragments, and bag it, you should have a product that will be saleable to a local garden store or supermarket. Keep in mind that a pile may take a month or two (and occasionally even longer) to compost, and will need turning for all of that time. (There are products available, aimed at enthusiastic gardeners, which consist of a perforated, rotating drum with a handle. This equipment makes turning easier, and the manufacturers claim it speeds up composting significantly. However, it can handle only a few hundred pounds of compost per batch.) Since the compost pile consists of significantly more weight than just the fish, and new piles will be built (or new material will be incorporated) for every processing day, one way to think about the labor involved is to ask yourself whether you want to turn 50 times the weight of one day's processing waste every day. However, since compost piles shrink in weight as they compost, and since composting times will vary with climate, size of pile, etc., and since no large investment is required, try it on an experimental basis before making a decision. This is also a good way to dispose of relatively small quantities of waste in an emergency, when the landfill closes or the bait market dries up temporarily. You can even do this in your backyard, in a pinch. Some helpful hints are: keep the carbon to nitrogen ratio high, use peat, and keep an eye (or, even better, a nose) on the pile so that you can add more peat if it starts to smell unpleasant.

All compost piles need to be quite moist (the pile should be 45% to 60% water), and air-dried peat is far below this figure, so you will need to add a fair bit of water to the peat. Ideally, you would do this two or three days before building the pile, so that the peat would have a chance to absorb the water; however, in an emergency, just water the peat as you build the pile, and make sure that the water is penetrating more than the top inch of peat.

The organisms needed for composting are found naturally in many waste materials, but they may not be found in fish, and they may not be present in your carbon sources either. At least initially, it is advisable to add the composting microorganisms, just as bakers and brewers usually add yeast to every batch. You can buy these microbes by the can at garden supply stores. Ask for compost starter or builder. If you are stocking up for a possible emergency, a can of microbes should be part of your stockpile, along with peat and a pitchfork. Once you are composting steadily, you will rarely need to add compost starter, but you should try to add some of the old pile to the new one in order to inoculate it.

Static piles. There are two issues that must be dealt with in static piles that are taken care of automatically in turned piles: air flow and construction methods.

1. *Air Flow.* Air intake pipes must be built into the pile at the proper intervals. The most commonly used are 3" or 4" PVC sewer and drainage pipes with holes; these are easy to find and inexpensive. It is also helpful to build a static pile on a base of gravel or wood chips, which will permit air flow from the bottom. Often, passive air flow through the pipes is insufficient, and fans or blowers of various sorts must be used at a level high enough to keep the pile aerated, but not high enough to dry it out.

2. *Pile Construction.* It is necessary to make certain that each piece of fish is surrounded by the carbon source, with no fish at or close to the surface of the pile to cause odors or attract animals.

The original static piles developed by Mathur and coworkers at Agriculture Canada, and used by Brooks at the University of Maine at Orono, employed distinct layers of peat and fish. The air intake pipes were placed only on the bottom layer of peat at two-foot intervals. Figure 4 shows a sketch of such a pile in cross section.

More recent research in Maine by Phil Averill (Maine Department of Marine Resources) and William F. Brinton, Jr. and coworkers (Maine Time & Tide RC & D Waldeboro Project) suggests several changes, which permit carbon sources other than peat to be used and, in fact, will benefit any static pile, including those made with peat as the only carbon source.

First, these researchers suggest that static piles will benefit from a more intimate mixing of carbon and nitrogen sources; thus the fish should be mixed with the carbon source instead of being placed in thick layers between it. (A diagrammatic cross section of such a pile is shown in Figure 5.)

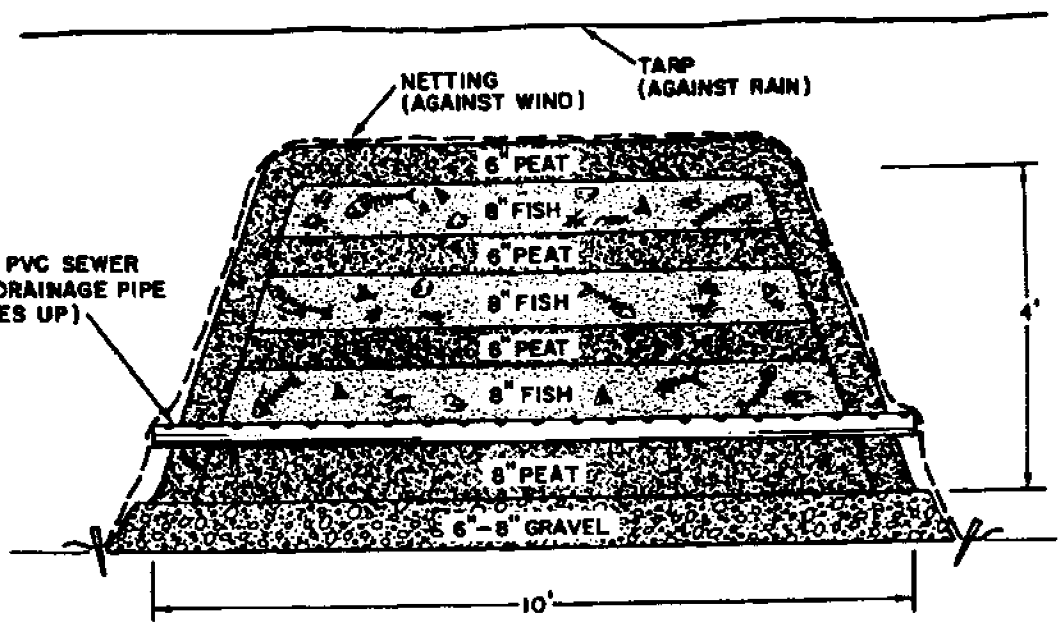


Figure 4. A layered composting pile in cross section.

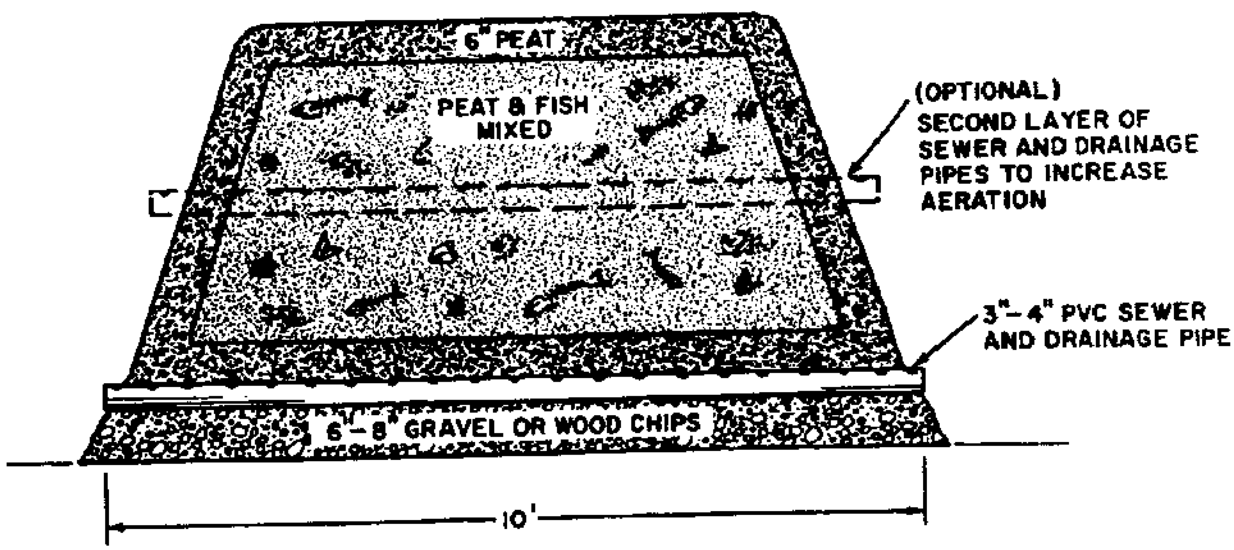


Figure 5. A mixed composting pile in cross section.

Second, they suggest that large frames, heads, lobster shells, etc., will compost more rapidly and completely in a static pile if broken up beforehand. For this task, Averill has used a small wood chipper, which grinds to a good size; a smaller grind would tend to compact in the pile and impede air flow.

Third, Averill has added a long pipe on top of the pile, and down its length, at right angles to the air intake pipes below. (See Figure 6.) This additional pipe, which is only lightly covered with peat, hay, or straw, pulls air from the intake pipes up through the pile and then exhausts it. This improves circulation in the pile, and is particularly important if the top surface of the pile is covered by a tarpaulin, snow, or anything else that would impede the flow of air from the pile's surface.

Finally, these Maine workers, as well as others, have looked at using fans or blowers to increase air movement through the bottom pipes and, hence, through the pile. This increase in oxygen availability leads to more rapid composting but, if not monitored carefully, can also lead to over-drying of the pile. Brinton has suggested leaving fans on for fifteen minutes of every hour for the first three weeks of composting and then increasing the time to half of every hour in order to dry the pile down to a 30% to 35% moisture content, at which level it will be stable.

Others using aerated static piles with sewage sludge found that having the blowers operated by a temperature feedback system was most effective. When the pile reached an upper set point temperature, the blowers turned on and

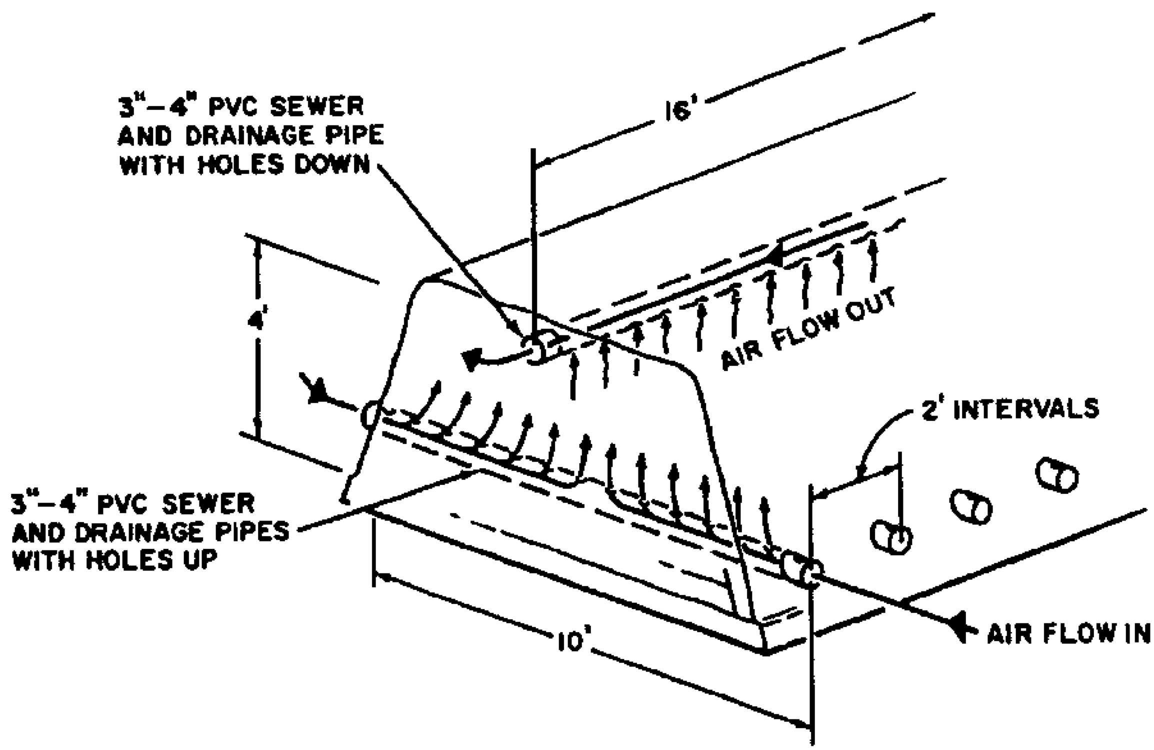


Figure 6. A modified composting pile showing the additional top pipe.

ran until a lower set point temperature was reached. This is known as the Rutgers Strategy, after the work of M. Finstein at Rutgers University.

It is clear that composting technology is becoming more sophisticated very rapidly. If you are going to make a small, turned pile, we advise trial and error. But for large piles, while we certainly advise experimentation and experience, we also advise using a consultant and talking to experts.

The question of how much protection a static pile needs from rain and wind is one on which experts disagree. A static pile on a windy site should probably be netted, simply to keep the wind from exposing any fish waste. A tarpaulin roof, suspended over the pile, might be helpful but will not be necessary in most cases. (In fact, although you may think in terms of protecting a pile from rain, you are more likely to have to add water to it than to have to keep water away. Unless the pile is so small that a bucket can soak it, it should be built within range of a hose.) Putting a tarpaulin directly onto a pile, like a blanket, could hamper air flow. If you do try this technique, which can be useful in winter composting, make sure that there is a top air outflow pipe and that its ends are not covered.

Monitoring the Composting Process. One advantage of a turned pile is that you can see and smell what is happening day by day. The initial odors of fish or garbage turn into earthy, loamy odors. The fish flesh and most of the bones and shells disappear. The color darkens and the pile becomes smaller and more homogeneous. However, with a static pile, there are relatively few odors and nothing is visible. Since you can't see into the pile, how do you know that composting is occurring and how can you tell when composting is complete? There are both low- and high-tech ways to do this. The low-tech (actually, no-tech) way to assure yourself that composting (as opposed to rotting) is occurring is by digging in and using your nose; any initial fish or garbage odors should disappear after a few days. If the pile smells strongly of rot, there is a problem; if it smells pleasantly earthy, things are probably going well. Similarly, you can tell if composting is complete simply by digging into the pile and seeing whether the fish wastes have disappeared. Even after composting is complete, there may be some bone fragments, crab or lobster shell parts, etc., but there will be no meat on them, they will have no fishy odor, and they will crumble easily.

The high-tech way to do the same thing is to monitor the temperature of the pile. Composting produces heat; the rise in temperature tells you that composting is occurring. Most piles will reach from 50°C to 60°C (122°F to 140°F); however, significant variation is possible due to size, water content, air flow, etc. A static pile may reach a higher temperature than a turned one; a large pile may get hotter than a small one, and, like a furnace, a well-aerated pile will generate more heat than one with a sluggish air flow. Air flow is a double-edged sword, however; up to a point, aeration can be used to remove heat and lower the pile temperature. In addition, since the center of a pile near the top is generally hotter than the sides or bottom, the temperature you measure will also depend on where you have inserted the measuring device. Piles that go over 65°C (149°F) should be watched carefully; they may kill off their composting microorganisms or even combust, particularly if the pile is too dry. You can cool a static pile down by placing caps over the ends of the pipes. If that does not work, or if the pile does not have pipes, you can water it. If you add too much water, though, you may spoil the pile. As a last-ditch effort, you can pull it apart.

As the composting process is completed, the temperature will drop to below 50°C (122°F). You may want to wait until it gets somewhat lower, say, 40°C (104°F), before breaking the pile open.

There are several categories of equipment suitable for monitoring temperature in a compost pile, at prices ranging from about forty to several hundred dollars. The major requirements are that the instrument be unbreakable, that the probe be at least three feet long, and that the temperature be read off the end of the instrument (as opposed to a standard thermometer, where the temperature is read off its length—which, in a compost pile, would be buried and invisible). The cheapest suitable instrument is probably a metal dial thermometer. Thermocouple devices are more expensive and more sophisticated tools that provide advantages in certain situations. First, they measure the temperature over a very tiny area at their tip, while a thermometer may measure temperature over several inches of its length. For researchers looking at temperature gradients within a pile, and trying to measure temperature at a precise distance from set points, a thermocouple probe is the instrument of choice. If you have a number of static piles, and want to monitor temperature at a set point in each one by implanting an instrument when you build the pile, you will probably do best by purchasing a number of wire-like thermocouples that can be buried in the piles and plugged into a hand-held thermometer when you want to read the temperature. (Information, as well as instruments of all kinds, is available from Omega Engineering, Inc., Stamford, CT, tel. 800–826–6342.) If you are repeatedly sticking a long metal stem of a thermometer or a thermocouple into a pile for a series of measurements, you are unlikely to put the tip in precisely the same place each time, and the slight averaging effect you get from the thermometer may be all to the good.

INDOOR COMPOSTING

Although indoor composting has received very little attention, we believe that it is worth looking at for some urban and suburban processors. Since our work in this area has just started, we do not know all possible dangers. If you are interested in this option, you should proceed with great caution. The following are potential problems we can envision:

Fire. Although the combustion of a compost pile that overheats is very unlikely, it is possible and is far more dangerous inside most buildings than outside. The pile should be constructed on a concrete slab floor, far from any flammable building parts, and close to a working hose or sprinkler system. You may need to check or consider local fire codes.

Heat. The process of composting produces heat. This might be welcome in winter but could increase energy consumption in summer.

Moisture. During the composting process, the pile loses a tremendous amount of water, all of which has to go somewhere. Any building in which composting is done should have excellent air circulation. This is important for many reasons; the possibility of condensation is just one.

Contamination of Food Products. Current Good Manufacturing Practice Regulations say that food processing areas should not be used to process inedible products unless there is no reasonable possibility of the contamination of human food. Indeed, there is very little possibility of the contamination of human food from an undisturbed, properly composting pile. However, in order to follow the regulations in good faith, and take no chances, we strongly recommend that a partition be constructed between the part of the plant to be used for nonfood products and the food processing portion of the plant. We also suggest that people working in the nonfood section of the plant *not* be permitted to enter the food processing sector without washing their hands and changing their outer aprons/coats and boots.

Most buildings are designed to limit air circulation in order to achieve cost-effective heating and cooling. Composting is dependent upon air circulation to carry off condensation and minor odors and, in static piles, to enhance air intake and outflow from the pipes. The ideal building in which to compost would be a pole shed. The next best would be a barn-type structure with open roof vents. Old warehouse buildings may also be appropriate. In more enclosed buildings, fans will be needed to push or pull air through the compost piles, and dehumidifiers may be necessary. Good exhaust systems are also a necessity, particularly as pile size grows.

MARKETING THE COMPOST

Marketing compost calls for creativity. The material produced by fish/peat composting is a new entity, and is neither fish nor peat. It is a heavier product than peat, with a higher moisture content. It also has a higher nitrogen content. Peat is acidic; this material is closer to neutrality. Because the product is unique and has many attractive features, labeling could be a very important marketing tool. The label could contain wording such as the following: "60% (by volume) fish composted with 40% sphagnum peat to form a highly enriched, neutral, odorless, slow-release soil conditioner with nutrients."

The question of what price such a product could be sold for is not simple to answer. Mathur, who originally developed the technique of composting fish with peat, has estimated that the cost of producing the compost to the processor is about $0.22/kg ($0.10/lb). This assumes all manual labor, small-scale procurement of the peat, etc. He calculated that the N:P:K (Nitrogen:Phosphorus:Potassium) equivalent alone would retail for about $0.30/kg ($0.13/lb) and he suggests that a completely equivalent material might retail at $0.90/kg ($0.40/lb). All of these calculations are on a dry weight basis; thus, if the moisture content of the finished product were 50%, Mathur's calculated retail value would actually be about $0.45/kg ($0.20/lb) on an as-is basis. However, these figures are only to be regarded as the loosest of guides since there is no precise equivalent for such a product and these figures are several years old. In addition, Mathur's costs seem rather low to us. We believe that peat will cost more in most parts of the U.S. than it does on the Canadian coast, and labor costs may also be higher.

If the product were to be targeted at horticultural markets such as greenhouse owners and farmers, a precise value for N:P:K, organic material, etc., would have to be worked out, and tests would need to be run, since this market is extremely cost-conscious and performance is very important. However, we suggest targeting this product to the apartment and home gardener, who may buy only a few pounds per year of such material and is less concerned with price than with perceived value, uniqueness, and "organic" status.

If the home garden products we recommend (i.e., liquid fertilizer from acid hydrolysis, and compost) are produced, the same basic label design could, and probably should, be used for both. In fact, we would suggest having a common brand name, and a common label design and distribution network, so that a small "line" of garden products will be created. The existence of two or more package sizes for each product will further the impression of a line of products. To avoid confusion with the food part of the business, these have to be handled and distributed separately from a company's food-grade fish products. Additionally, marketing experts might suggest that a somewhat different name be used for the nonfood business.

We would suggest that any processor consider the following route: As soon as the decision is made to attempt fish/peat composting and to build an initial pile, contact horticultural experts at nearby universities who might be willing to test the product. (If you are unable to obtain help at your state university, there are commercial laboratories that will do this testing on a fee basis.) The first pile should be dedicated to research and no attempt should be made to sell it. In fact, no investment in label design, printing, bagging, etc., should be made until after the first pile has been successfully produced and the product has undergone at least some testing.

After constructing the first pile, you will have an idea of some of the costs of production. At this point, you could start looking at peat and related product prices in supermarkets, garden supply stores, etc. When the first pile is completely composted, samples will be available. This will be a good time to think about distribution and sales and to talk to people in potential outlets or distributorships about the product, whether they would carry it, what their markup would be, what sort of sales volume they would envision, and what package sizes they would recommend.

Ultimately, decisions will have to be made on package size, bagging material, labels, prices, amount of initial production, and where and how to sell the product. We would assume that sales would start small but might grow steadily, through increased consumer recognition and wider distribution.

References

Relatively little has been written on the composting of fish wastes, although a great deal has been written on general composting. To get a sense of the latter, you might want to read a few copies of *BioCycle*, which may be available in a local library. Subscriptions (about $55 per year) are available from JG Press, Box 351, Emmaus, PA 18049. This magazine's advertisements will also fill you in on commercial composting equipment.

Copies of the unpublished report, *Composting Fish and Shellfish Scrap with Peat*, may be requested from the author, Joan L. Brooks, Department of Civil Engineering, University of Maine, Orono, ME 04469.

Phil Averill of the Maine Department of Marine Resources (State House, Augusta, ME 04333) has written a pamphlet entitled *Composting Seafood Byproducts*. He is also available for questions at 207–529–5349.

The Compost Solution to Dockside Fish Wastes, by L. Frederick et al., has recently been published by the University of Wisconsin Sea Grant Institute (WIS-SG-89-434). Request a free copy from them at 1800 University Ave, Madison, WI 53705.

D. Anaerobic Digestion

Anaerobic digestion is somewhat like composting in that it involves putting together a number of organic materials that will foster the growth of certain microorganisms, and then letting the microorganisms work. One obvious difference between the two is that composting is aerobic, which means that it needs air to work properly, while anaerobic digestion only occurs in the absence of air. The medium for anaerobic digestion is usually a liquid, and this has become a common way of dealing with certain high-bulk, high-water, low-protein wastes, such as manure. The process can be used to generate methane, which has some value as a fuel. Anaerobic digestion is very rarely used with high-protein wastes such as fish. Although there are a few anaerobic digestions that are relatively simple, such as that for manure, the anaerobic treatment of a high-protein material such as fish is not simple at all.

Our recommendation would be for processors to stay away from this technology. The capital costs can be considerable, and the potential dangers are very great. Explosive and/or toxic gases may be generated, and toxic products may be formed in the body of the material as well. The combination of no oxygen and fish is a perfect growth medium for organisms like *Clostridium botulinum*. The end products of such a process are of uncertain utility and safety. Additionally, all anaerobic microbial processes are difficult in that you can lose the desired strain of microorganisms and end up with dangerous or simply unpleasant ones. Having to get rid of thousands of gallons of toxic fish waste is a nightmare, and having to sterilize the facility is difficult and costly.

3. MINOR PRODUCTS

New products that may be manufactured from specific waste fractions include gelatin and leathers from skins, and concentrated soup stocks from heads and frames. In addition, it may be possible to find uses for scales in the treatment of food processing plant waste water. Developing markets for these items may help increase profitability, despite the fact that they involve relatively small amounts of waste.

Processors can also take a look at the possibility of selling waste on an as-is basis to alternative feed markets in their area (e.g., mink farms, pet food manufacturers, and other animal raising facilities). This option is particularly worth exploring before any complex or capital-intensive technologies are undertaken, not only because it will take the processor some time to develop such technologies to the point where they can absorb all or most of the fish processing plant's waste, but also because as-is markets are simple and can sometimes be surprisingly profitable.

A. Skins

Cod skins have been used for two different kinds of products: gelatin and leather. Norland Products, Inc. (695 Joyce Kilmer Ave., New Brunswick, NJ 08902, tel. 201–545–7828) has a factory in Nova Scotia which handles 16,000 lbs/day of cod skins to produce a fish gelatin. This product is manufactured to very tight specifications for industrial uses, largely water-soluble photoresists. Fish gelatin has not been used for food purposes because it has a lower melting point than gelatin made from beef or pork skins, and is liquid at room temperature. Nevertheless, Regenstein feels that fish-based gelatin could be used as a glaze for frozen fish and as a viscosity builder in refrigerated and frozen products such as ice cream and yogurt. Such a product would have the advantage of being kosher. (A kosher gelatin would have to be made solely of the skins of fish with fins and scales and these skins would have to come off of a processing line where only fish with fins and scales were handled.)

When tanned, cod and many other fish skins make surprisingly attractive leathers, similar in appearance to snakeskin. Fish skins have been tanned and made into a variety of products by Alaskins Leather Company, Juneau, AK. Shark skins (from the larger species only) have had value for some time as a particularly tough leather, and eel skins have recently become popular for wallets, purses, and other small accessories. Recently, manufacturers of a number of leather items have started to show interest in fish leather, and we hope to see this product move from novelty to commodity.

The Alaska Fisheries Development Foundation recently looked into fish skin tanning, and interested processors may wish to contact the foundation at 508 W. 2nd St., Suite 212, Anchorage, AK 99501, tel. 907–276–7315, fax 907–271–3450.

B. Heads and Frames

The heads and frames of any white fish, if kept in perfectly fresh condition and handled and stored under conditions suitable for human food manufacture, can be cooked in water to form a fish stock or a concentrated fish base. Either of these can be used by chefs or food processors to form the base for a variety of fish soups and stews or to add flavors to processed foods. An excellent example of such a concentrated fish base is made by the L. J. Minor Corp. (30003 Bainbridge Road, Solon, OH 44139); one pound of their concentrated base is mixed with boiling water to make four gallons of fish stock.

The production of extremely concentrated bases of this sort, while well suited to extended storage and transport over long distances, would require processors to invest in a costly drying apparatus (probably a vacuum dryer or falling film evaporator) which would not be justified without a very large output and a suitable marketing network. However, if arrangements with local restaurants and caterers could be made, smaller scale production of an unconcentrated fish stock might be justified. Additionally, some chefs might wish to purchase fresh, high-quality heads and frames for their own use, were they made aware that such a resource existed nearby. (This would be especially true in regions away from the coast where chefs are just discovering fish and all that they can do with it.) Once the stock was being made, some processors might consider going one step further and producing a finished soup or chowder (trim waste might be usable in such a product if it was white, while darker wastes might be acceptable in tomato-based products). These soups and chowders could be marketed through a number of different channels, including local institutions, and restaurant and supermarket "Soup and Salad Bars." They might be frozen in retail- or institutional-size containers, or even canned or bottled as more widely distributed products. It should be noted that producing a stock, like producing mince, will not reduce the quantity of waste generated by very much, but will increase profit.

C. Scales

Although scales seem like a very minor component of processing wastes, they have no value at all (or even negative value) in enzyme hydrolysates, food products, feeds or bait usage, etc., and they cause clogging and B.O.D. (biological oxygen demand) problems when disposed of into sewage lines or bodies of water. They are also not quite so minor as they seem. In the authors' experience, scales may represent almost 2% of the weight of a processor's incoming fish. If 100,000 lbs of fish are being processed daily, the disposal of almost a ton of scales each day is not trivial.

If scales are mixed in with other wastes, they will compost, although scales added as a separate layer to a compost heap slow down the process by blocking air flow. Scales may also be added to an acid hydrolysate. If scales can easily be kept separate from the other categories of waste, special opportunities for their use exist.

Commercially, scales are a source of pearl essence (guanine) which is used to make artificial pearls and pearlized lacquers for decorating a number of items and for making nail polish. The production of pearl essence requires either specialized and reasonably costly equipment, or chemical treatments, involving organic solvents such as gasoline, benzol, or ether to extract the essence from the scales. (Some processes will produce a fish gelatin as a byproduct.) The small production of the average processing plant would not justify the use of any of these methods. There is at least one company specializing in guanine extraction in the Northeast (The Merle Corporation, Estes Point, Eastport, ME 04631).

Alternatively, the scales of some species of finfish have been found to be useful in food processing plant waste water purification. Work by Robert Zall and his graduate student Frank Welsh at Cornell (Department of Food Science, Cornell University, Ithaca, NY 14853, tel. 607–255–3112) has shown that scales may be used with only minimal processing (washing, drying, and grinding) to precipitate protein out of waste water. The processing input needed to get to this stage is actually much less than that being proposed for the treatment of shrimp or crab processing wastes for the production of chitin and chitosan (chitosan is a feed-grade coagulant which could be used for processing plant waste water treatment, and which is also claimed to be cost-effective for food waste). Of particular interest would be the use of ground scales to precipitate animal feed quality waste from food processing plant effluent. This would combine two wastes to give one potentially useful product. (Whether or not the final precipitate of scales plus wastes would have a value as a livestock feed could be determined only by actual testing.)

A processor could try to locate one or more local food processing plants with serious waste water problems, and either sell them the scales or suggest some sort of venture whereby scales would be used to precipitate particulates (suspended solids), and replace alum and ferric sulfate for this purpose. (The fish processing plant producing the scales may itself have such a waste water problem.) Note that the advantage of using scales to precipitate or flocculate wastes lies in the fact that the precipitated material may be used as a livestock feed, whereas material precipitated with alum or ferric sulfate cannot. However, since not all scales have worked well, tests should be run before processors embark on a major sales campaign.

D. "As-Is"

Despite the allure of new technologies which promise high-ticket products at the end of the line, the most profitable disposal method for many processors will be to spend some time and effort in searching for a good low-value market that will purchase waste as is. For processors with herring, flatfish, or redfish frames to dispose of, the bait market appears to be the simplest and the most profitable without major capital investment. It is, however, a seasonal market, and only works for processors near appropriate fisheries. Other markets, which accept gurry on an as-is basis, operate all year round. Such markets include pet food manufacturers and a variety of animal raising facilities. At this time in the Northeast, a great deal of frozen fish waste is sold (or at any rate disposed of) to mink farms. At best, this appears to be a break-even proposition for the processor. Prices received are about \$0.04 to \$0.06/lb ground and frozen. The advantages of this market are that it absorbs a large quantity of gurry and that the marketing effort required of the individual producer is small—i.e., feed for the mink industry has become a commodity, and sales into commodity markets tend to be simple, although often unprofitable.

Before going into a capital-intensive or complex area like fish meal or hydrolysates, it would be worthwhile to look into alternative feed markets in the area, which would take wastes as-is and pay for them. Pet food companies, companies raising animals for research purposes, aquariums, and zoos are among such potential markets for fish byproducts. In addition, they might require less transport and pay more for the gurry than the mink farms. All of these operate on a year-round basis (which actually makes them better markets than the mink farms, which do have a seasonal dip in the winter). Such markets may be relatively small and selective. They may require that only certain categories of offal be delivered. If they are sufficiently close, they might not require that the gurry be frozen. If you can get \$0.03 to \$0.04/lb for fresh offal, it may be worthwhile to serve this market.

As-is markets require essentially no capital investment, no major changes in operation, no extra employees, and no complex marketing. All that they require is a few days of investigation of what exists within a reasonable trucking radius of the processing plant, a couple of laboratory analyses of the product, and a large number of telephone calls. If the processor does not have the time, this may justify hiring a consultant for a week's worth of work.

SUMMARY OF MAJOR RECOMMENDATIONS AND CLOSING COMMENTS

The most important disadvantage of many forms of current waste disposal, such as fish meal or landfill, seems to be the fact that the future of such disposal is uncertain. Ideally, new disposal methods should be clean and reasonably simple, have relatively low capital costs, and result in saleable products that will at least break even, and, preferably, provide a profit. We believe that at least three methods discussed in this report meet these requirements. These are:

1. The utilization of mince, probably in one or more processed food products.
2. The hydrolysis of fish wastes to produce a liquid fertilizer.
3. The composting of fish wastes with peat.

Based on capital, volume, and other resources, a processor might well make the decision to carry out one of these recommendations or all three. (If the decision is made to carry out all three, we suggest that they be initiated one at a time, in the order given; not all at once.) There are good reasons to at least consider all three processes. If your operation generates sufficient high-quality trim waste to justify new product development and marketing, a human food product will bring in the highest price per pound. However, trim constitutes only about 10% of most plants' total waste. Even if all of it were in excellent condition, and could be used for human food, and even if some frame waste could be utilized, the impact of this on the quantity of waste generated would be minimal.

Thus, it makes sense to look at other technologies as well—ones capable of using a larger proportion of a plant's waste. Hydrolysis and composting are such technologies. Composting, in particular, is very simple and can utilize a wide variety of materials, including all species of fish. It can utilize rotten material and is the only method that can do so. Both composting and hydrolysis are clean technologies, which can be carried out with very little or no pollution of air or water. While hydrolysis is not as simple as composting, or as forgiving, its financial rewards are greater. Among the advantages offered by production of both liquid fertilizer and compost are the following:

First, the methods for producing both compost and liquid fertilizer from fish wastes have been developed and made public by university workers who have published instructions and who may be written to or telephoned if questions arise. (Their names, addresses, and telephone numbers are in the Appendix.)

Second, these products both go to home gardeners. Products aimed at professional markets, whether these are composed of farmers, horticulturists, or feed companies, must meet extremely rigorous standards of field tests, chemical composition, and economic competitiveness. Products aimed at the home gardener, who may purchase only small quantities per year, have far more leeway in all of these areas. A product could be brought out on the market with minimal field testing and at a far higher price than would be justified by the amounts of nitrogen, phosphorus, and potassium that it contains. It would sell because it was "organic," because it was easy to use, because it would not burn plants, because it could be labeled as "slow release," because of the associations of fish with the fertilizer recommended to the Pilgrims by the Indians, because of an appealing label design and name, and because of the generally good reputation of the fish-based fertilizers which have preceded it.

Finally, if the decision is made to produce both the compost and the liquid fertilizer, they could form a "line" of home garden products. Although the compost is bagged and the fertilizer bottled, the same design and brand name could be used for both. Most importantly, both could be sold through the same outlets, thus reducing the marketing effort significantly. One choice would be to go to a supermarket chain, either providing a processor label or offering to use the supermarket's private label.

While we do not believe that the compost and fertilizer markets can absorb all of most processors' waste in the first year or two, these are both technologies where it is possible to start small and build up. We recommend starting on a small scale. If the markets can be enlarged, then eventually all waste can go to these products. If the markets cannot be enlarged, the initial investment will have been minimal and the existing arrangements for waste disposal will not have been disrupted.

Since we would guess that all three of these recommended technologies will not use all of a plant's wastes for several years to come (but will use increasing amounts each year as markets are increased), it would be worthwhile for all processors to try to develop alternative markets for their "as-is" waste right away.

In closing, we would like to emphasize that these recommendations are aimed at the owners and operators of small- to medium-sized single plants. For the very large processor or for groups of processors, additional options are available.

APPENDIX: Human Resources

Experts on the technologies discussed in this report who have indicated a willingness to be called are listed below.

Mincing:

Joe M. Regenstein
Department of Poultry and Avian Sciences
112 Rice Hall
Cornell University
Ithaca, NY 14853–5601
607–255–2109

Composting:

Phil Averill
Maine Department of Marine Resources
State House
Augusta, ME 04333
207–529–5349

William F. Brinton, Jr.
Woods End Research Laboratory
R.D. 2, Box 1850
Old Rome Road
Mt. Vernon, ME 04352
207–293–2457

Analyses and compost recipes:

Joe M. Regenstein
Department of Poultry and Avian Sciences
112 Rice Hall
Cornell University
Ithaca, NY 14853–5601
607–255–2109

Analyses and compost recipes (continued):

Tom Richard
Agricultural and Biological Engineering
Riley-Robb Hall
Cornell University
Ithaca, NY 14853
607–255–2488

Fertilizer (Hydrolysis):

Robert A. Curren
Robert A. Curren Company
71 W. Main Street
Yarmouth, ME 04096
207–846–1554

Susan H. Goldhor
Center for Applied Regional Studies
45 B Museum Street
Cambridge, MA 02138–1921
617–876–7252

David Stuiber
Department of Food Science
University of Wisconsin
Madison, WI 53706
608–263–2087