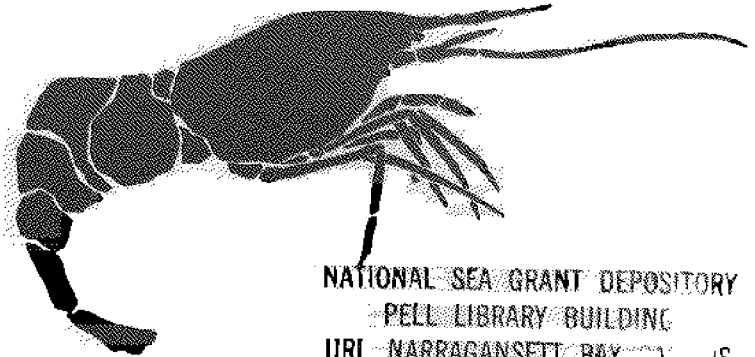


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UTILIZATION AND DISPOSAL  
OF  
CRAB AND SHRIMP  
WASTES



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Utilization and Disposal  
of  
Crab and Shrimp Wastes

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University of Alaska Sea Grant  
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## PREFACE

In this publication we present a comprehensive survey of the use and disposal of crab and shrimp wastes which is based on an intensive review of both literature and ongoing research. Focus is on by-product development and waste treatment, and the intent is to provide a ready reference to literature which reports work on shellfish so that new ways of attacking waste disposal problems may be defined.

The project was initiated in response to a need expressed by the Alaska King Crab Marketing and Quality Control Board, and was sponsored by the University of Alaska Cooperative Extension Service and the Fisheries Extension program. The project represents one of the many facets of the University of Alaska's continuing interest in development of Alaska's important natural resources.

New research on chitin and chitosan is reported in an addendum following the "Literature Cited".

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## Introduction

The Alaskan shrimp and crab industries are faced with a perplexing problem. The wastes which are left after the extraction of meat for canning and freezing, the majority of the animal, have always been dumped into the ocean bays or channels beside the processing plants. This practice has gradually created serious pollution problems where several processors are concentrated, notably in the Kodiak area, or where currents carry the wastes onshore. At the same time, public awareness of water quality has increased, and Federal and State water quality standards have become more strict. Consequently the disposal of processing wastes in natural bodies of water has been declared illegal.

Shellfish processors are placed in the position of finding other means of handling their wastes. The expense of handling wastes is of concern wherever it is practiced, and the search has begun for means to reduce costs. The problems are magnified by several peculiarities of the Alaskan processing industry. Many plants are extremely isolated, which prevents the sharing of treatment facilities and costs with other processors or with a community. Alaska as a whole is isolated from major supply and market centers, and much of coastal Alaska, moreover, has no land transportation to other areas; these factors raise transportation and labor costs. Furthermore, the supply and market of the crab industry have declined somewhat in the past three years, causing further concern for increased costs.

The waste problem has caused heightened interest in a perennial topic, the search for saleable by-products which might be made from the wastes. By-products have been hailed in some of the literature as promising greatly increased capital return while abolishing the pollution problem; it should be noted here that such a revolutionary solution is highly unlikely. However, by-products deserve thorough evaluation.

At the same time, it has become clear that waste treatment and disposal must also be given attention. No by-product process is capable of removing all traces of waste from discharged water. Processors in isolated plants are not in a position to consider those by-products which can be made economically only in a central plant (this does not rule out all promising products, however). Finally, cost analysis of by-product manufacture gives different results when compared with the cost of a waste treatment process, which is the present alternative, than when compared with the simple dumping of wastes, which has been an option until recently but can no longer be considered.

This paper is designed to aid the search for feasible alternatives in solving the shellfish waste problem in Alaska. By-products are reviewed in the light of all currently available information. Waste treatment processes are given a general discussion, which should suggest the direction for more detailed studies. Sources of further information are given throughout, and the means of contacting these sources are detailed in the "Literature Cited".

The method of compiling this review has been to converse with specialists and researchers when possible. Additional references were obtained from abstract services such as the *FAO World Fisheries Abstracts*, *Commercial Fisheries Abstracts*, *Chemical Abstracts*, and a bibliography on crab wastes compiled here in 1969 by Nancy McRoy. Original articles were located whenever possible.

## The Shellfish Waste Problem in Alaska

**Nature of the Wastes.** -- The wastes from shrimp and crab processing consist of shells, viscera, and scraps of meat that are not removed by picking. Waste constitutes 80 to 85% of the whole crab (Lee, Knoebel, and Dedy, 1963; Soderquist, Williamson, and Blanton, 1970); shrimp yield 65% waste when hand-picked (Wigutoff, 1953) to 82% when machine-picked (Jensen, 1965). In addition to the solid wastes, it is necessary to consider as waste the water from washing and cooking, which contains oil, blood, and dissolved substances such as protein (Vilbrandt and Abernethy, 1931). These decay just as do solid scraps. Machine-peeling of shrimp uses more water than hand-picking, and the water from machines contains more scraps (Anon., 1959).

The chemical components of crustacean waste are protein (30



to 50%), calcium salts (about 50%), chitin (3 to 14%), fat and oil (1 to 15%), and moisture. The shell consists of a complex of chitin and protein, which provides its structure, and calcium salts, which give it hardness. The oil and most of the protein, plus water and minor constituents, comprise the soft tissues. Details of waste composition (as determined on crude meals) are given in Table I.

The quantities of wastes produced by the Alaskan crab and shrimp industries are given in Table II.

**Effects of Wastes on Natural Waters.** -- When any dead organic substance exists in normal water, it decays. This process, of course, occurs constantly wherever organisms are living and dying, and is an essential part of every ecosystem. The chemicals comprising the body of a dead plant or animal are broken down to simpler compounds by a series of bacteria and fungi, aided by larger decomposers such as worms, flies, and fish. The decaying tissue is eventually converted to nutrients which are reused by all plants and animals present, and to inert (or slowly decaying) residue. Even chitin is degraded slowly in both fresh water (McCoy and Sarles, 1969), and seawater (Brison et al., 1964). Minerals accumulate on the bottom and as solutes in the water.

The effect of the decay process on the water depends on the concentration of material there. When oxygen is present in the water, decay is relatively inoffensive; the organisms causing decomposition are types which require oxygen for respiration ("aerobic"), and their major products are water-soluble or odorless (nitrates, carbon dioxide, and sulfates; Imhoff and Fair, 1956). If decomposing material becomes highly concentrated, the population of decomposer organisms may place such a demand on the aquatic oxygen supply that it becomes exhausted. Decay will still proceed, but by means of different bacteria ("anaerobic"), which as it happens produce large amounts of nauseating gases, such as ammonia, hydrogen sulfide, methane, mercaptan, and cadaverin (Imhoff and Fair, 1956). Furthermore, all the ordinary flora and fauna of the water are deprived of oxygen and die out. A concentration of decomposing matter attracts numbers of scavenging animals, including potentially dangerous rats and flies. Finally, floating and suspended solid material may be annoying, especially since waste particles become mixed with a scum from the decay process.

**Pollution.** -- Pollution has been defined as "...altering of waters of the state in a manner which creates a nuisance or makes [them] ...unclean [or] ...harmful to public safety, ... industrial or recreational use, ... or aquatic life." (Alaska Statute 46.05.230(5)).

It has been agreed that a serious pollution problem exists in

Kodiak from fish processing wastes, including crab and shrimp wastes. Bacterial levels and low oxygen in the water are handicapping the crab industry (Jensen, 1965; Peniston et al., 1969), because clean water is needed in live holding tanks. Odors, sludge, rats, and prolific breeding of flies have become very annoying (Dispain, 1965; Luken, 1970). Divers find that in areas of low current, the polluted water supports no fish or animal life. Shrimp wastes have accumulated faster than decay can degrade them, in a putrid layer that is over seven feet deep in places (Tilley, 1970).

Pollution by water-borne wastes is measured as the concentrations of decomposable matter and of solids. Decomposable matter is expressed as the rate at which the decomposer organisms consume oxygen, the "Biological Oxygen Demand" (BOD). BOD is determined by allowing samples of the water or waste to stand for a standard period of time (5 days) at a standard temperature (20° C) and measuring the decrease in dissolved oxygen. Solids are measured by filtration and weighing.

The amount of waste which can be discharged into natural waters without causing a pollution problem varies with the character of the water. Most natural waters can receive some moderate level of waste without offense. Waters into which wastes are discharged (termed "receiving waters") are capable of processing them according to physical, chemical, and biological characteristics.

**Physical characteristics** include the size of the body of water, its rate of movement, prevailing winds, and ice cover; these determine the dilution of the wastes that can be expected, and also the rate at which dissolved oxygen is replenished. Another physical characteristic is temperature, which influences both the rate of decay and the ability of the water to hold dissolved oxygen. **Chemical characteristics** are dissolved substances, such as minerals, salts, acids, and oxygen, minor changes in any of which usually affect marine life and water quality. Physical and chemical characteristics of the waste stream are important as well.

**Biological characteristics** of both receiving waters and wastes must be considered. The receiving water has a natural BOD, which must be supplied by the available oxygen in addition to its support of decay; and the BOD of the wastes determines their impact on oxygen levels. Fish processing wastes may have a BOD similar to that of domestic sewage (Soderquist, Williamson, and Blanton, 1970), but in many cases it is far higher or lower (Alter, 1970). The rate of flow of wastes must also be known, of course.

Finally, the waste load which can be handled by receiving waters depends on the standards of water quality that are required (Imhoff and Fair, 1956). Standards are determined by water use, and are often different for different uses. The 1970 Alaska water standards are outlined in the following section.

The receiving water and the quality desired thus determine the waste load that can be handled. The characteristics of the waste stream determine what treatment must be given to achieve this aim. It is clear that measurements must be made on the wastes and the receiving waters before any waste treatment facility can be properly designed. No such studies have been made in or near Alaskan shellfish processing plants (Soderquist, Williamson, and Blanton, 1970). Some studies are now being instituted in Alaskan salmon canneries (Crosgrave, 1970). Such studies are obviously of the first priority in an approach to the waste problem.

**The Alaska Water Quality Standards.** -- As mentioned in the previous section, the laws that regulate waste disposal in natural waters (ocean, channel, river, etc.) are written to specify the quality of the natural waters which are receiving the wastes. Anyone discharging wastes must, therefore, regulate the wastes according to their effect on the receiving waters. In general, the wastes themselves are not regulated directly by the laws, beyond the requirement of a general type of treatment (see below).

This wording of the law allows the processor of wastes to choose the treatment process that best suits his economic and physical requirements. It does place on the processor the responsibility of attention to the natural waters and the effect his treated wastes are having on them.

The Alaska Administrative Code, as amended in May 1970, states that primary treatment (removal of solids) must be performed on all wastes before discharge into natural waters (in other words, that no solids may be disposed of in state waters). Secondary treatment (removal or reduction of dissolved and colloidal substances) is also required, *unless* the discharger of the wastes presents an engineering study showing that the natural receiving waters are within state standards while he is discharging wastes. (7AAC 70.080-090).

The detailed standards for natural receiving waters specified by the Code (7AAC 70.070) cannot be reproduced here, but a sample of the standards can be mentioned. The standards are written separately for seven categories of water, according to the use of the water (drinking, recreation, industry, etc.). Coastal waters are Class D (used for growing aquatic life) or E (used for growing shellfish) (7AAC 70.050). Standards for these classes include: dissolved oxygen greater than 6 mg/l, a temperature not over 5% greater than the natural temperature, no floating or suspended solids visible or in a level dangerous to organisms, inorganic solutes (salts, acids, etc.) not higher than normal, and absence of offensive sight or smell.

The choice of waste treatment facilities is discussed in 7AAC 2.02. Engineering plans for treatment facilities must be approved by the state prior to construction. The means of choosing facilities are discussed both as requirement and as suggestion. A waste discharge permit is or may be required for any waste discharge to state waters, and by law new pollution is prohibited. An engineer who designs treatment works is required to consider the full range of processes which are available and suitable, and to base his choice of process and his design upon a comparison of costs, ease and flexibility of operation, suitability for the climate, and other concerns, as well as adequate treatment.

Specific waste treatment processes are discussed more fully in a later section.

### By-Products

**Crab and Shrimp Meal.** -- Crude waste meal is the oldest commercial by-product of the shellfish industry, having been used in fertilizer since the mid-19th century (Stevenson, 1902). Since whole fish are used in some meals (such as menhaden and shrimp), waste meal will be specified. Crude waste meal will designate the common product wherein the raw wastes are used without altering the proportions of the components.

The typical process for producing crab or shrimp crude waste meal involves drying the waste material and then grinding it. Crab and handpicked shrimp wastes are cooked, since the animals are cooked prior to peeling (Lee and Sanford, 1964 ; Soderquist et al., 1970); uncooked waste is generally cooked in the drying process (Brody, 1965). The commercial waste dryers used by large meal producers on Chesapeake Bay are heated rotary drums (Wharton, 1947; Lee and Sanford, 1964). These processors then grind the wastes in a hammermill.

A common practice of crude waste meal production is for a large central plant, which is often a separate waste-rendering business, to collect scrap from individual meat processors. This is true in the Blue Crab processing region of Chesapeake Bay and in the Dungeness Crab processing areas of the Pacific Northwest (Conn, 1929; Tressler and Lemon, 1951; Dassow, 1970). The rendering plants in the latter region draw upon wastes not only from shellfish processors, but also from other packing industries, including cattle, fin-fish, and poultry. Shellfish meal is a minor component of their products, usually mixed with meal from other wastes (Dassow, 1970). Crude waste meal production by individual processors is less common, but occurs in Oregon (Soderquist et al., 1970).

Shellfish crude waste meal has been used as fertilizer and as livestock food. Early use as fertilizer was on farms near the packing plants (Stevenson, 1902); fertilizer firms took in crab scrap in the East in the 1920's (Churchill, 1920), and shrimp waste fertilizer was produced on the coast of the Gulf of Mexico and in California (Stevenson, 1902; Tressler, 1923; Vilbrandt and Abernethy, 1930; Manning, 1943). Some fertilizers still contain wastes from crabs (Lee, Knobel, and Deady, 1963 ; Soderquist, 1970) as one component. The value of the meal in fertilizer lies in its protein and calcium content (which are given in Table I). The chitin is also utilized slowly by the soil (Peniston et al., 1969). The market which the fertilizer industry provides for shellfish waste is subject to the same influences that affect the meal market in general (see below).

Crude waste meals of crab and shrimp are included in feeds for cattle, swine, and poultry (Borgstrom, 1952; Morrison, 1956; Dispain, 1965; Law, 1970). Four animal feed plants utilized fish and shellfish wastes in 1968 (Soderquist, Williamson, and Blanton, 1970). The mineral and protein content in the wastes provide the principal benefits. The protein appears to have as high a nutritional value as soya protein, a common component of livestock feed (Peniston et al., 1969; Novak, 1970). Crab and shrimp meals can be used similarly to fin-fish meals in feeds, i.e. as one of several protein sources in the feed. The "biological value" of shellfish meal proteins (the fraction of the assimilated protein which is actually retained and utilized) has been said to be equal (Sure and Easterling, 1952) or superior (Novak, 1970) to fin-fish proteins.

The principal mineral in shellfish wastes, calcium, is needed by all vertebrates, and in highest quantities by laying hens and growing young (Morrison, 1956). It is often provided in feeds by supplements such as powdered bone or oyster shell.

Other nutrients are present in shellfish meal. An "unidentified growth factor" in crab meal (among other meals) seems to increase growth in chicks (Combs, Ascott, and Jones, 1954; Sullivan et al., 1970). The trace mineral and vitamin content of crab meal was analyzed by Lubitz, Fellers, and Parkhurst (1943), and of shrimp meal by Dassow and McKee (1958). No nutritive value has been detected for chitin or its subunits, despite their nitrogen content (Lubitz, Fellers, and Parkhurst, 1943); probably this is due to the absence of chitin-degrading enzymes in the vertebrate digestive system. Although most of the research on the nutritive value of meals has been done with species from the Southeastern United States, King Crab meal gives similar results to Blue Crab meal (Snyder, 1967), and is higher in protein (Table IA).

Crude waste from shellfish cannot provide the major source of protein in livestock feeds, because it would contribute an excessive

proportion of calcium in the diet (Morrison, 1956; Novak, 1970). There has been some disagreement on this. Laying hens are said to do well with crab scrap as 20% of their rations (Manning, 1929), perhaps because of their especially high calcium requirements. Sure and Easterling (1952) were of the opinion that crab meal was inferior because of the digestibility of its protein, rather than its calcium content. However, digestibility depends strongly on non-protein components of the diet, including calcium (Morrison, 1956). A simple and inexpensive method for decalcifying meal has recently been developed: the dried ground wastes are screened at a carefully adjusted mesh size which separates the shell fragments from the finer protein powder. This could produce a meal with 55% protein and only 6% calcium (Novak, 1970). The method is possibly of great potential importance.

A fishy flavor in meat or milk can result from feeding of fish meals, but this can be prevented by discontinuing before slaughter (Brody, 1965) or by avoiding excess in the feed (Morrison, 1956). Strong-flavored feeds may also be unpalatable or dangerous to stock. Excessive flavors (rancidity) result from the oxidation of oils. Meals can be deodorized by controlled oxidation of the oils with nitrates (Arakawa and Tominaga, 1969) or peroxide (Solomon, 1969); or the oils can be removed by distillation (Levin, 1959 and 1961). Antioxidants are commonly added to prevent rancidity, but their use in either animal or human foods requires careful study with the particular chemical dosage and animal intended, if adverse effects are to be avoided. (See Leekley and Cabell, 1961, for a discussion of such studies on mink feeds).

Shrimp wastes have been tried as mink food (Leekley, 1967; Anon., 1967); they are being sold for the purpose in Oregon, but the market is declining (Soderquist, 1970).

A specialized market for shrimp meal exists in the fish food industry. It has been found that the red pigment of shrimp (astaxanthin—Rousseau, 1960) supplies the pink color which is characteristic of wild trout flesh but is absent in farm trout. The flavor is also closer to that of wild trout (Anon., 1968; Steele, 1970). Shrimp meal is 4% of the "Oregon Pellet", a standard commercial trout food (Law, 1970). The pigment is readily lost from the meal with certain types of handling—it is leached out in machine peeling, and is partially destroyed through oxidation under the heat of drying processes or during spoilage (Rousseau, 1960; Anon., 1968). Oxidation losses can be minimized by vacuum-drying at low temperatures (lower than +70° C—Anon., 1968) and by use of preservatives (Rousseau, 1960). Vacuum-dried shrimp waste meal is produced and sold to trout farms in Denmark (Anon., 1968a).

Unfortunately for the shrimp meal market, most consumers of trout in the United States prefer the bland and pallid flesh from farms, rather than the pink flesh of wild or shrimp-fed trout (Law, 1970; Collins, 1970). In any case, the synthetic carotenoid canthaxanthin can replace shrimp pigment more cheaply (Schmidt and Baker, 1969).

One possible use for waste meals which has not been exploited so far is the feeding of farm shrimp. Shrimp wastes may be especially beneficial in providing substances needed for proper moulting (Law, 1970). Shrimp farming is practiced in Hawaii and is increasing in states bordering the Gulf of Mexico. However, wastes from the industry there seem likely to supply local demand for feed.

Shellfish crude waste meal apparently has not been proposed for human food use. Waste meal has been proposed as a flavoring material (Gray, 1966) and such a product is being sold by one rendering firm (Soderquist, 1970). Otherwise, shellfish meals for human food use are made only from whole shrimp. They include fish flours (Burkholder, Burkholder, and Centens, 1966; Salomon, 1969), flavoring materials (Anon., 1948b), and Oriental foods (Anderson, 1953).

Fertilizer and livestock feed thus constitute the only established market for crab and shrimp crude waste meals. This market, moreover, is not large, and crude meal seems to offer little, if any, profit. It might seem that crude meal should be in greater demand. Two major reasons for the prevailing price seem to be the nature of the meal and the irregularity of the supply. The protein in the meal, though it is of excellent quality, is low in quantity compared with that in fin-fish meals; this is especially true for machine-peeled wastes (Anon., 1959; Einset, 1959). Calcium is proportionately high, and is apparently no different from minerals in more available sources (such as cattle bones or oyster shells). Thus crude shellfish meals are inferior for feed purposes to fin-fish meals. The supply of shellfish meals is irregular and small relative to fin-fish meals; this too reduces demand. Shellfish meals seem to fluctuate in price with the fish meal market as a whole (Anon., 1959; Enge, 1970). Shellfish meals are in fact sold by some rendering plants only as part of their general meal mixture, and not as a separate commodity (Dassow, 1970).

The demand for meal is likely to remain low enough that the market would absorb only a fraction of the meal that could be produced from Alaskan wastes (Dassow, 1970; Soderquist, 1970). Furthermore, the price of crude waste meal is generally too low to support production and shipping of an Alaskan product. Even in Seattle, where there are no costs of shipping to market, almost no profit is available to the crab or shrimp packer from the sale of wastes, for meal-rendering plants take the wastes almost without paying (Dassow, 1970).

There is a small animal feed industry in Alaska at present, which offers the possibility of absorbing at least a portion of the shellfish wastes. There is a limited number of cattle and swine in Alaska, mostly cattle. There are two animal-feed plants at present serving this market, and the Palmer Agricultural Experiment Station has done some studies on using fish and bone meals in feeds. Shellfish waste has not been studied, but could be of interest (Brundage, 1970). The demand for shellfish waste in feeds for Alaska would depend upon its price to the farmer. It must of course be competitive with other feed components, i.e. with bone meals and with other waste proteins (even, for ruminants, plant proteins and inorganic nitrogen).

**Whole Shells.** -- Small markets exist for the whole backs of crabs as ashtrays (Anon., 1956) and for serving stuffed crab (Anon., 1963). A market for all waste shells, however, would require a bulk use. Efforts have been made to develop the use of ground crab shells as abrasives. They have been suggested in place of ground walnut shells as a filler for oil-well drilling mud and in winter tires (Dispain, 1965); similar uses of walnut shells are the sanding of runways and the scouring of jet engines (Doyle, 1970). Another use studied was replacement of oyster shells in the scouring of horseradish during its preparation for marketing (Palmateer, 1970). Although the crab shells are hard and dense (Dispain, 1965), they have proved too brittle for such uses (Palmateer, 1970). Crab shells have also been suggested as a substitute for sawdust in pressed-wood panelling (Dispain, 1965), and for giving texture to paints, but no such products are known.

The mineral content of shellfish waste suggests a similar use to that of clam and oyster shells in the neutralization of industrial acids (e.g. Cronan, 1960). However, no research has been done on this, and the high protein content of the shells (even when cleaned) might leave undesirable residues from such a process.

No use has been proposed for shrimp shells, which are probably not amenable to isolation in the same manner as crab shells.

**Chitin.** -- The isolation of chitin from crustacean shells is well known, for the material has been studied since 1811 (Tracey, 1957) and practical applications have been investigated since 1909 (Knecht and Hibbert, 1926).

Chitin is a white, amorphous solid with a flaky, fibrous or leathery nature (Kent and Whitehouse, 1955). It is insoluble in water, alkali, and dilute acid, but it dissolves in concentrated acids and inorganic salt solutions (Tracey, 1957). It is a relatively stable and unreactive substance (Knecht and Hibbert, 1926), except under the conditions necessary to dissolve it (Tracey, 1957).



Chitin may be chemically characterized as  $\beta$ -1,4-N-acetyl-2-amino-2-deoxy-D-glucose (Tracey, 1957). Its "skeleton", a long polymer of glucose, is identical to the structure of cellulose, which is the rigid substance in plant cell walls, and is the major constituent of paper and cotton. Chitin and its derivatives, therefore, have some abilities similar to those of cellulose to form filaments and films and to absorb dyes (Knecht and Hibbert, 1926). However, many properties of chitin differ from those of cellulose because of the acetyl and amino groups attached to the glucose units of chitin.

Chitin is available from many organisms, though always tightly complexed with other compounds (Tracey, 1957). Sources other than shellfish include fungi, insect exoskeletons, and some bacteria (Knecht and Hibbert, 1926).

Since chitin is insoluble in most substances, and is unstable when it can be dissolved, no important use exists for it as such (Peniston et al., 1969). The primary useful form of chitin is chitosan, a degradation product with varying chain lengths and degrees of deacetylation. Chitosan is a white, flaky solid (Meinhold and Thomas, 1958), which is stable and soluble in dilute solvents (Lusena and Rose, 1953). It forms a number of useful insoluble salts (Tracey, 1957). Other derivatives of chitin are glucosamine, the product of complete deacetylation and depolymerization, which is not very stable (Staňek et al., 1963); and N-acetyl glucosamine, the basic subunit of the chitin molecule. Neither of the latter has much apparent use aside from research chemistry.

*The isolation of chitin* generally involves treating the shells with alkali to remove the proteins and with acid to dissolve the minerals, leaving a residue of quite pure chitin. Numerous variations on this theme have been developed, chiefly to minimize degradation of the chitin by the rather drastic steps necessary to remove the associated compounds. Degradation consists of depolymerization and deacetylation. Dilute acids degrade chitin less extensively than strong, and low temperatures less than high (Tracey, 1957; Hackman, 1962; Peniston et al., 1969). Thus degradation is greater if demineralization is carried out in strong acid (5% HCl) than in more dilute acid (pH 3, or less than .01% HCl; Lusena and Rose, 1953). A long demineralization at low temperatures (24 - 48 hours at 25° C) gives a higher yield of chitin than a shorter process at high temperatures (one hour at 100° C; Lovell, Lafleur, and Hoskins, 1968). Long slow demineralization is common in laboratory processes (Whistler, BeMiller, and Wolfram, 1965; Nikolaeva, Sobolev, and Molochaeva, 1967). Procedures intended for industry require a shorter production time, and chitin of maximal polymerization is not necessary. Hence higher temperatures are used

(70 - 100° C), which reduces the time to 1 - 4 hours (Black and Schwartz, 1950; Blumberg et al., 1951; Peniston et al., 1969). Some laboratory procedures substitute ethylene diaminetetraacetic acid (EDTA) for mineral acids in the demineralization step (Foster and Hackman, 1957; Tracey, 1957; Takeda and Abe, 1962; Takeda and Katsuura, 1964). Others decalcify with formamide (Einbrodt and Stöber, 1960).

Protein is extracted either before or after demineralization. The protein is extracted first in the process used by Peniston et al., (1969), where recovery of the protein as well as the chitin is desired. Deproteinization is performed in 5 to 10% sodium hydroxide at 80 - 100° C for 1 to 12 hours (Tracey, 1957; Whistler, BeMiller, and Wolfram, 1965; Nikolaeva, Sobolev, and Molocheva, 1967; Lovell, Lafleur, and Hoskins, 1968). Industrial processes use periods of 1/2 to 5 hours (Black and Schwartz, 1950; Blumberg et al., 1951; Neinhold and Thomas, 1958). Peniston et al. (1969) use dilute alkali (1 - 2%) and lower temperatures (60° C).

Enzymes are sometimes employed for deproteinization in laboratory procedures, which is a much gentler method (Tokeda and Katsuura, 1964).

Chitin can be highly purified by various means, but these are beyond the scope of this paper.

Chitosan is produced by extreme treatment with alkali, generally boiling with 45 - 55% base (Lusena and Rose, 1953; Meinhold and Thomas, 1958).

Glucosamine is produced by treatment with hot concentrated acid. This may be done after isolation of chitin, as outlined above (Kamasastri and Prabhu, 1961; Oeriu, Dmiitriu, and Craescu, 1962; Nikolaeva; Sobolev, and Molocheva, 1967) or the alkali treatment for separate removal of protein may be omitted (Purchase and Braun, 1946; Hoagland and Hiltz, 1953; Ishii, 1954).

N-acetylglucosamine, the fundamental subunit of chitin chains, can be isolated only by treatment with enzymes (Tracey, 1957; Pope and Zilliken, 1959).

*The uses which research has found for chitin*, or more properly, chitosan, are exceedingly varied. The versatility of the substance depends on several different properties: its ability to form structures such as fibers, the manner in which it can be precipitated from solution as an insoluble powder or coating, and its chemical reactions with other substances.

The structural properties of chitin are exploited in making fibers, films and gels. Chitin or chitin xanthate can be precipitated in these forms from concentrated acid or salt solutions (Tracey, 1957; Giles and Agnihotri, 1969). The films can be used as dialyzers (Knecht and Hibbert, 1926), and the gels as photographic emulsions with good durability and versatility (Ryan and Yankowski, 1969).

The fibers can be woven into an artificial fabric which is rayon-like and water repellent (Anon., 1956; Peniston et al., 1969), but Knecht and Hibbert (1926) considered it unsuitable as a commercial fabric. Tracey (1957) felt that films and fabrics were promising but only if the potential supply of chitin (i.e. of shellfish wastes) were *greater* than at that time.

Chitosan, often as a salt or ester, has been proposed for numerous uses as a filler (an insoluble powder or coating that adds bulk to some preparation). In many cases chitosan modifies the chemical properties of the preparation as well. Cardboard manufactured with chitosan as a filler has been suggested, the matrix being scrap materials such as leather shavings (Feldman, 1959), or tobacco particles (Mosky and Geronimo, 1966). Chitosan has been used in Russia as sizing for fabrics for improving their texture, appearance, and durability; unlike cornstarch, a common sizing material, it does not wash out (Sadov and Markova, 1954a and b; Neely, 1964). However, superior sizing materials have now replaced chitosan (Law, 1970).

Chitosan is used to thicken printing inks, and has a mordant (fixing) effect on the ink dye as well (Sadov and Vil'dt, 1958; Delange, 1958; Oxford Paper Company, 1968). Dilute preparations of chitosan have been studied as an aid in the dyeing and printing of synthetic fabrics, from rayon to glass; the preparation also improves dye-holding properties of the fibers (United Merchants and Manufacturers, 1962). The dyeing properties of chitin have been studied extensively (e.g. Krichevskii & Sadov, 1962), and are different from those of cellulose (Knecht and Hibbert, 1926). Chitosan has been used commercially in dyeing in China (Ming, 1960), though not in machine printing. The water absorbancy and launderability of the synthetic fabrics is said to be improved by chitosan coating (Hurd and Haynes, 1960; Owen and Sagar, 1967), but some suggestion has also been made that chitosan has water repellent properties (Seagran, 1959a; Peniston et al., 1969).

Chitosan has been suggested as a component of adhesives (Tracey, 1957; Neeley, 1964), and as an oil well drilling mud additive (Peniston et al., 1969). It can be used for thickening foods (Peniston et al., 1969), and promotes digestion in infants as well (György, Kuhn, and Zilliken, 1967).

Chitosan can be used as a base for cosmetics, both to thicken creams and to modify their pH (Seagran, 1959a; Bernadet, 1969). Glucosamine has been investigated as a filler for antibiotic capsules (Dispain, 1965), and may, in fact, prolong the effective period of the drug in the body (Nikolaeva, Sobolev, and Molochaeva, 1967). Finely dispersed chitosan particles have the property of adsorbing substances, which promotes coagulation and separation of materials

in a solution or suspension. Thus it has uses such as clarifying vegetable juices (Zeile, Hauptmann, and Sommer, 1957); flocculating sewage (Peniston et al., 1969); as an ion-exchange resin in biochemical research (Peniston et al., 1969 ; Nagasawa, Watanabe, and Ogamo, 1970); and in the isolation of hormones, enzymes, and other compounds in medical research (Nozu, 1960; Evans and Kent, 1962; Turner and Doczi, 1968).

Biochemical properties which have been investigated in chitin derivatives include the anticoagulant activity of chitosan sulphates (Tracey, 1957), promotion of plants' resistance to fungal diseases (Mitchell, 1963), and antitumor properties (Hoagland and Hiltz, 1953). Numerous specialized and academic physiological effects of chitosan have been mentioned in the biochemical literature; no attempt is made to review most of them here.

Photographic research has also made use of chitosan, which aside from forming emulsions, can be used to modify the sensitivity of silver grains (e.g. Steigman, 1962). Numerous patents exist for such uses, all apparently of academic interest at this time.

The commercial possibilities of chitin have been elusive. No market exists at present for any by-product of chitin. Tracey (1957) believed that some applications for chitin found no market because the demand would outstrip the supply, and that other applications (such as cementing and sizing) were more feasible in view of the supply. A chemical firm in the East spent several years around 1960 attempting to develop a market for chitin, but without success (Carter, 1970). One research firm has considered developing a commercial chitin-extraction process (Peniston et al., 1969), but at present they consider chitin extraction to be uneconomical in Alaska because of the lack of inexpensive sources of hydrochloric acid. They plan to extract protein and possibly to ship the inert chitin-calcium residue to other areas for further processing (Peniston, 1970b).

**Protein Concentrates.** -- The protein in crustacean waste exists both in meat and tissue adhering to the shell, and as a complex with chitin in the shell structure. Protein is extracted by digesting the whole wastes with alkali (see "Chitin", above, for details), and is precipitated by neutralizing the solution with hydrochloric or acetic acid (Kamasastri and Prabhu, 1963; Peniston et al., 1969). The protein can be dried by spraying or by evaporation (Peniston, 1970b). The protein thus obtained should be of high purity (Peniston et al., 1969), about 90%. This exceeds the purity of fin-fish protein concentrates, with which shellfish protein would be competitive. Shellfish proteins must be fortified with methionine for vertebrate food use if they are to serve as a major source of protein,

but this is inexpensive (Peniston, 1970a). The concentrate does not contain the troublesome fluorides found in some fish protein concentrates (Peniston et al., 1969). Shrimp protein has a heavy fishy odor (Peniston, 1970a), but defatting or oxidizing can remove this (see "Meal" above; also Bressain et al., 1966).

A commercial plant for extraction of protein from shellfish wastes is entering the pilot stage at Kodiak.

Fish protein concentrates have a strong market at present in the pet food industry (Peniston, 1970b). They should be important for upgrading substandard human diets, but this application has received limited acceptance in practical use to date because of custom and institutional barriers (Small, 1968). Without doubt this market will become important at some future date.

Another type of protein recovery is possible, using the water from cooking, as is commonly done with the "stickwater" from fin-fish processing. For shrimp the yield might be 4.5 pounds of material (with 50% protein) from water in which 640 pounds of shrimp were cooked (Vilbrandt and Abernethy, 1931). Commercial use of concentrated shellfish cooking waters has been made in Japan; the material was fermented and used as a flavoring sauce (Anon., 1948).

**Meat Recovery.** -- A recently developed approach to treatment of shellfish wastes is the recovery of meat scraps which are left by peeling and picking and are normally discarded. The amount of this meat is surprisingly high—its recovery can increase the overall meat yield from shellfish up to 20% (Dassow, 1970).

Two processes have been advocated for scrap meat recovery. A continuous-flow centrifuge can separate shell and tendons from meat quite efficiently (Tretsven, 1970). The wastes are pre-chopped. Refinements of the process have overcome objections such as excessively small fragments and excessively salty meat. The second process utilizes the Yamagiya Flesh Separator, a perforated steel drum which rotates against a belt, squeezing the wastes between the drum and the belt (Soderquist, Williamson, and Blanton, 1970).

Meat recovered by these processes is necessarily in smaller fragments than the quality meat from picking. It nevertheless has market value as minced or deviled meat, and its quantity seems to make recovery worth consideration. Shred lobster meat is widely marketed on the East Coast. The economy-grade shred meat could be marketed under a different label than has been used for the quality products, a common practice in various branches of the food industry. Commercial application of shred meat recovery from crab and shrimp is in the experimental stage, with one Pacific Northwest firm operating a centrifuge.

**Products from Viscera.** -- Crab livers have been sold in Japan as a delicacy and for extraction of vitamins. Their commercial value is negligible (Anon., 1948a).

## Waste Treatment

Waste treatment in Alaskan shellfish processing plants at present consists of discharging wastes into the adjacent seawater. Some plants chop the wastes, which is intended to make them more available to decomposers. But the increase in decay rate improves the situation only if dilution is increased at the same time; otherwise, oxygen depletion is merely intensified, so pollution can be more noxious than without chopping (Alter, 1970). A number of plants pipe the wastes out from shore. In some locales this allows swift currents to disperse the wastes, and prevents bay or shoreline pollution; in quiet bays such as Kodiak, no improvement results.

A rather brief summary will be given of the waste treatment technology that can be applied to the problems of Alaskan shellfish processors. By waste treatment is meant preparation of wastes for disposal, other than sale, to avoid offense or danger to humans or ecosystems. The conditions under which wastes can cause pollution problems when disposed of without adequate treatment have been discussed above ("Effects of Wastes on Natural Waters").

Industrial waste disposal, although industries differ, has certain common problems and solutions. For a wide variety of waste disposal problems extensive research and practical experience can provide the technology for finely tailored solutions. Much research has gone into minimizing costs under each manufacturer's particular conditions. Many special problems of the Alaskan processing industry--irregular production, widely varying waste flows, lack of land space near plants, and subarctic temperatures--have been the subject of some waste disposal research. Consequently, waste disposal methods are available at present to meet the Alaska shellfish industry's problem. Further research can improve technology further.

Treatment of any wastes may include the following steps: (1) separation of coarse and fine solids from water ("primary treatment"), (2) treatment of the solids to reduce their volume and their potential for decay, (3) final disposal of the solids, (4) treatment of the water to remove dissolved decayable material ("secondary treatment"), (5) final disposal of the residue from water treatment, (6) disinfection and further clarification of the cleaned water ("tertiary treatment"), (7) final disposal of the water. Which and how many of these steps are necessary depends on the pollution

problems, site conditions, economic considerations, and applicable laws at the site of disposal.

**Separation of Solids and Water.** -- Primary treatment is started by settling, screening, or otherwise removing coarse materials. Settling is common for soft and finely divided solids (Imhoff and Fair, 1956); it requires ponds large enough to hold all water for the appropriate time, which in turn requires land space. Screening would be feasible for the bulk of shellfish cannery solids, and is used now where wastes are separated for chopping before disposal (Tilley, 1970). The screen is cleaned by means such as a screw conveyor or a jet of water (Soderquist, Williamson, and Blanton, 1970), or the screen is itself a moving belt (Tilley, 1970). Centrifuging has been suggested for separating solids, but would be expensive (Tilley, 1970; Soderquist, Williamson, and Blanton, 1970).

Grease and oil must be removed in a separate step if present in significant quantities (Imhoff and Fair, 1956), but this is probably important only for wastes from oily fish (Soderquist, Williamson, and Blanton, 1970).

**Treatment and Disposal of Solid Wastes.** -- Some methods for disposal of solid wastes require no further treatment, relying on natural decay processes. These include landfill and dumping at sea. However, these apparently simple solutions cannot be accepted without weighing their expense and the problems of site choice and control.

A land disposal site must be chosen which is large enough to accept all foreseeable input. There must be adequate soil covering (at all seasons), to prevent offensive odors, and the location must be such that no products of decay can leach by rain or groundwater into streams or bays. Terrain suitable for dumping—level land with deep soil— is scarce on the southern coast of Alaska.

Marine disposal sites are subject to state water quality standards regulation if they are within state waters. (See section on standards). Concentration of wastes by current or seafloor characteristics must be avoided to insure inoffensive decay, and currents must not carry decay products into public waters.

Dumping of wastes involves equipment for storage, transportation, and handling—conveyors or their equivalent, tanks, trucks or barges, and earthmovers. Containers must be air-tight (and seagull-proof!) to prevent offense from continual decay of the stored wastes. (Preliminary decay can be retarded by chlorination—Imhoff and Fair, 1956). The expense of equipment involves, in addition to the initial investment, its operation, maintenance, and personnel. This expense may become quite large.

The problems of dumping either at land or at sea—finding an acceptable site, preventing offense and continued pollution, and expense—are all capable of exceeding the problems of on-site waste treatment (Alter, 1970).

The simplest proposed method of in-plant treatment for solids is burning. The screen on which the solids are trapped can be a moving cheesecloth belt or other burnable filter, and the filter and wastes together can be passed to incinerators which contribute to the heat production of the plant. Thus fuel value in the wastes is recovered (Alter, 1970). Mineral ash would remain but could be disposed of with relative ease.

A second method of treating solids is biological digestion, which uses natural decay under controlled conditions to convert the wastes to a residue with a smaller volume and greatly reduced potential for decay (Imhoff and Fair, 1956). This stabilized residue is much easier to dispose of by landfill than are the original wastes. However, biological processes require special equipment and precise control, and may not be flexible enough for the irregular waste flows that result from shellfish processing (Alter, 1970).

**Treatment and Disposal of Waste Water.** -- Screening and settling cannot alone remove the large quantities of colloids (fine suspended matter) and dissolved substances in the water. These may constitute over half of the total decayable material in wastes (Soderquist, Williamson, and Blanton, 1970).

Removal of colloidal solids, or "clarification", can follow the primary treatment process. Flocculants are added to the water to coagulate the colloids, either in a holding tank where the material precipitates, or with a continuous bubbling of air which brings the solids to the surface for collection (Soderquist, Williamson, and Blanton, 1970). A great variety of flocculants is available, which differ in mechanism, efficiency, and secondary actions (Imhoff and Fair, 1956; Anon., 1969; Soderquist, Williamson, and Blanton, 1970; Alter, 1970). The colloids are disposed of similarly to solid wastes.

Solubles in water (protein, blood, small amounts of oil, etc.) may be removed biologically or by physical-chemical means. Biological processing is the normal treatment for municipal (domestic) waste water; the solutes are converted to a relatively inert sludge. The process has been considered suitable for processing wastes (Soderquist, Williamson, and Blanton, 1970), but may be inadequate for Alaskan plants because of discontinuous waste flows and low environmental temperatures (Alter, 1970). The physical-chemical treatment of water removes some of the solutes in the clarification step, by use of flocculants that alter and precipitate these solutes as well as colloids. Disinfection occurs at the same time. Completion of solute removal is achieved by adsorption onto



activated carbon. The usefulness of carbon for various solutes can be greatly increased by pretreatment of the water with alkali to hydrolyze large molecules (Anon., 1969).

Tertiary treatment includes various methods for refining the treated water, such as further disinfection if previous steps have not sufficiently stabilized the water, or further clarification if necessary. Many recently developed methods, including removal of ammonia (due to decay) by bubbling of air, have been tested and reviewed by the Federal Water Pollution Control Administration (Anon., 1968b).

**Wastes Associated with By-product Processing.** -- If by-products are made, the waste treatment problem will be reduced. However, none of the by-products reviewed can abolish all waste treatment. Two kinds of waste will still exist: first, there will be the unprocessed raw shellfish waste, which at least will include all the solute-laden water; and secondly, most by-product processes will add new waste substances.

Any raw wastes remaining for disposal can be treated by the methods discussed above. Waste water from washing and cooking would not be changed by any recovery process studied, except for soluble protein recovery; thus this water would probably remain for treatment. Solid wastes would in most cases be reduced in quantity if by-products were made, and the remaining problems would depend on the by-product. If shells were utilized but meat remained, the BOD would be unchanged. If meat or protein concentrates were extracted, but shell was discarded, the decay potential of the wastes would be much reduced (Peniston, 1970b), but most of their bulk would remain. All solid wastes would not be rendered for any by-product excepting meal (Soderquist, Williamson, and Blanton, 1970).

Wastes introduced by the by-product process itself should be considered carefully when any process is evaluated, for they can be extremely troublesome (Soderquist, Williamson, and Blanton, 1970). Chitin and protein extraction require concentrated acids and alkalis. Wastes can be minimized by avoiding the use of excesses in the process (Peniston et al., 1969). Residues can be neutralized or removed by electro-dialysis (Anon., 1968). Recovery of the chemicals for re-use would represent a large saving. Corrosive chemicals must be removed before certain other stages in waste treatment can be performed (Imhoff and Fair, 1956).

### **Reducing the Problems of Waste Disposal**

The problems involved in waste disposal are much larger than necessary in many cases. All waste treatment or processing should

start with wastes that are as easy to handle and as small in volume as possible. This should be one goal of all waste treatment design studies, and indeed is common industrial practice (Imhoff and Fair, 1956; Alter, 1970). Relatively simple modifications of the meat production process itself may result in greater ease and economy of waste treatment.

One method of modifying wastes before treatment is, of course, the conversion of part of the wastes to a saleable by-product. A second and related approach is to avoid spilling or discarding materials whenever possible. Recovery of shred meat from the shells, as noted above, would not only provide capital return, but it would also reduce the decayable material in the wastes and thus make waste treatment easier and cheaper. If by-products were being produced, it would be vital to keep spillage of chemicals to a minimum, both for economy and to reduce waste treatment problems. Cleaning and sanitizing of work surfaces should be performed with the smallest quantities of chemicals adequate for thorough work, to reduce waste loads (cleaning chemicals are, of course, waste materials and potential pollutants).

A third aspect of waste reduction is to keep the wastes as concentrated as possible to reduce the volume of material that must be treated. Dirty water and solid material should be kept separate from water which is essentially clean, such as that which has been used for retorting and cooling cans. The clean water can be disposed of without further treatment. The total amount of decomposable material is the same; but concentrated wastes are easier to strain, settle, digest, and adsorb, and above all, lower volume means smaller equipment.

Finally, waste water can be recovered and re-used, with a reduction in both waste treatment problems and in demands on the water supply. The latter result is potentially of interest in coastal Alaska, for in spite of the abundant rainfall, the major shellfish processing center of Kodiak has suffered severe water shortage in some summers. In such situations water itself can be considered a valuable by-product.

Large volumes of water are necessarily used in shellfish processing, for washing debris from meat, for cooking, and for periodic cleaning. Nevertheless, savings are probably possible. Processing analysis is necessary before recommendations can be made, but possible areas of water recovery can be suggested. Water from certain processes could be reused easily, such as water from retorting and cooling of cans, which would require no cleaning. Other water, such as cooking water, would need cleaning and/or disinfection before reuse. However, cleaning would probably be necessary even without reuse, because of water quality standards.

Disinfection could be accomplished by addition of chlorine in quantities that would not affect the flavor of meat. A residual chlorine content after disinfection of 2 mg/l is adequate (Imhoff and Fair, 1956); this level is not detectable in any fruits or vegetables (National Canners Association, 1968), and tests would probably show that the same is true for shellfish.

Cleaning often involves the use of high-pressure streams of water for removing deposits of waste or even for general scouring of all surfaces and sweeping of floors. Some of this cleaning would perhaps be performed equally well by scrubbing, using tools appropriate to the surfaces and the speed required, followed by rinsing with smaller though adequate quantities of water.

### Summary and Conclusions

This paper has reviewed the by-products which may be produced from crab and shrimp processing wastes, and has discussed major considerations of waste treatment.

By-products are of interest to the Alaskan shellfish industry for reducing the waste disposal problem and providing some capital return. The products reviewed here differ in these respects. As discussed under the separate by-products, crude waste meal and products from whole shells offer little promise of net capital return at this time. Chitinous products have no present market, but although many are of academic interest only, a few are deserving of further development and sales research. Among these is the proposed sewage flocculent. Protein concentrates and shred meat both have a certain established market at present.

The usefulness of by-products for reducing wastes varies also. Meal is capable of adsorbing all solid wastes (but dirty water still remains). Isolation of both chitin and a protein concentrate would utilize all wastes except for minerals, which are a minor problem; however, these by-products do require the use of corrosive chemicals, whose removal from waste water is necessary. Shred meat and whole-shell products each reduce one part of the waste problem—BOD and solids, respectively.

It is apparent that all by-products leave some waste residues. The by-products which seem at this time to be the most promising economically leave solids and/or chemicals for disposal. Thus some waste treatment remains a necessity.

In considering waste treatment, a third approach to the problem must be included—strategies for reducing the wastes before the stage where they are treated, through processing practices. By-products can contribute to waste reduction, but are not the only means to this end.

Several factors thus interact, and all must be considered. The most economical solution to the waste problem of a shellfish processor is likely to involve two or all three of the above approaches. It must be stressed that acceptance or rejection of any approach without adequate study may result either in higher expense than necessary, or in failure to solve the waste problem. Two points may be mentioned again. Although waste treatment in some degree appears to be necessary, it can be simplified with proper planning. It is also important to note once again that, although a by-product may not promise a net increase in profit, it may offset costs of waste treatment and reduce treatment problems.

**Recommendations.** -- This paper is intended as a base from which definitive study may begin. The major directions which work should take in the near future may be outlined.

(1) By-products can be evaluated further. If expert advice is needed, process consultants can advise on manufacturing design; these include both professional consultants (some already in the industry), and the researchers referred to in the text. Marketing consultants can also be retained.

(2) Waste treatment design should be considered with the help of a sanitary engineer. The engineer should be a member of the American Academy of Environmental Engineers (which is evidence of certification to practice sanitary engineering), and should have experience in the geographic area and the industry involved. Engineers can make preliminary surveys as well as designing final facilities.

(3) Process modifications for reduction of waste loads can be evaluated by process consultants and sanitary engineers. Some preliminary analysis of process details would be necessary.

(4) Certain research is necessary. (a) Information on waste characteristics and receiving waters must be gathered before even a general plan for waste treatment can be suggested. No such analyses have been started in Alaskan shellfish processing plants. It is critical that data be gathered immediately on waste volume, flow patterns, BOD, solids load, etc., and on receiving water currents, BOD, and other properties. (b) By-product research should continue, both to refine the promising processes and to devise possible new products. However, the information on which to act is available at present.

**TABLE 1A. Per Cent Composition of Dry Crude Waste Meals:Crab.**

{Approximate composition of fresh waste would be similar except for the proportion of moisture.}

Notes on methods of measurement: Only representative methods can be mentioned, since in few analyses are methods specified. *Chitin* is isolated as described in the text, and subjected to a Kjehldahl nitrogen determination. *Protein* is also estimated by the Kjehldahl method (in recent work). But chitin is included in the results (*uncorrected protein*), unless it is removed from the protein by special procedures (e.g. Brown, 1959) to give a *corrected protein* figure. *Ash* represents the minerals left after combustion of the organic compounds, generally at 550° C. *Calcium* can be determined separately by flame spectrophotometry. *Calcium salts* are the sum of calcium carbonate and phosphate, when these were determined separately.

The variability in some measurements results both from the methods of analysis, and from the variability in the characteristics of wastes from different processing lines. Different proportions of components are obtained with samples from picking-line wastes alone (which are mainly shell) than with those which also contain butchering scraps. Furthermore, in some picking-lines, leg or tail shells are packed with the meat. There is also some seasonal and individual variation among crabs.

<b>King Crab (<i>Paralithodes camtschatica</i>)</b>			
	<b>Average</b>	<b>Range</b>	<b>No. of Sources</b>
<b>Chitin</b>	35.	--	1
<b>Protein</b>			
corrected	43.	--	1
uncorrected	42.	--	1
<b>Ash</b>	32.	28.-36.	2
<b>Oil</b>	8.5	--	1
<b>Moisture</b>	5.8	--	1

**Sources:** Anonymous, 1966; Snyder, 1967; Peniston, 1970b (chitin only).

**Blue Crab (*Callinectes sapidus*)**

	Average	Range	No. of Sources
Chitin	14.	--	1
Protein			
corrected	27.	--	1
uncorrected	31.	28.-35.	6
Ash	39.	29.-50.	5
Calcium	18.	16.-18.	3
Calcium Salts	52.	52.-53.	2
Oil	1.4	0.8-2.9	2
Moisture	6.3	6.0-7.0	4
Undetermined	13.	--	1

**Sources:** Manning, 1929; Lubitz, Fellers, and Parkhurst, 1943; Tressler and Lemon, 1951; Sure and Easterling, 1952; Morrison, 1956; Lee, Knoebel, & Deady, 1963; Snyder, 1967; Novak, 1970.

**TABLE 1B. Per Cent Composition of Dry Crude Waste Meals: Shrimp.**

**Alaskan Shrimp, picked by hand or by unspecified method.**

	Average	Range	No. of Sources
Chitin	28.	--	1
Protein			
corrected	51.	--	1
uncorrected	53.	50.-56.	2
Ash	18.	15.-21.	3
Oil	14.	12.-15.	3
Moisture	7.2	3.-12.	3

**Sources:** Dassow and McKee, 1958; Einset, 1959; Seagran, 1959b; Peniston, 1970b (chitin only).

Table 1B (Continued)

**Non-Alaskan Shrimp or Shrimp from unspecified sources,  
picked by hand or by unspecified method.**

	Average	Range	No. of Sources
Chitin	--	--	--
Protein			
corrected	44.	--	1
uncorrected	50.	47.-54.	4
Ash	25.	18.-30.	3
Oil	3.4	2.9-4.	2
Moisture	12.	9.0-15.	2
Undetermined	16.	15.-16.	2

**Sources:** Daniel and McCollum, 1931; Tressler and Lemon, 1951; Morrison, 1956; Anonymous, 1959; Khandker, 1962.

**Alaskan Shrimp, machine-picked.**

	Average
Chitin	--
Protein	
uncorrected	38.*
Ash	28.
Oil	4.0
Moisture	8.0

**Source:** Dassow and McKee, 1958.

\* One source gives a protein figure for non-Alaskan machine-picked shrimp; it is also 38% (Anonymous, 1959).

TABLE 1C. Per Cent Composition of Fin-Fish Meals.

Six Fish Waste Meals			Salmon Viscera Meal	
	Average	Range	Average	
Protein	58.	50. - 70.	Protein	74.
Ash	20.	11. - 26.	Ash	5.4
Oil	8.9	3.3 - 15.	Oil	18.
Moisture	5.3	3.3 - 8.4	Moisture	0.97

Source: Sure and Easterling, 1952.

Source: Seagran, 1959b.

TABLE IIA. Landings of Crab and Shrimp in Alaska for 1967, and Calculated Waste Quantities.

Shellfish Species	Landings (lbs. x 10 <sup>6</sup> )	Waste	
		Percent	(lbs. x 10 <sup>6</sup> )
Total Shellfish	181.0		132.0
Total Crabs	139.4		109.0
Dungeness	11.6	73	8.4
King	127.7	80	100.0
Tanner	0.1	80	0.1
Total Shrimp	41.8	80	33.0

TABLE IIB. Summary of Fin-Fish\* Landings in Alaska for 1967, and Calculated Waste Quantity.

Total Landings (lbs. x 10 <sup>6</sup> )	Waste		
	Percent (Average Waste Per Species)	Percent (Range)	Total (lbs. x 10 <sup>6</sup> )
179.2	27	0-40	50.0

\* Halibut, herring, sable fish, and five species of salmon.

Source: Dewberry, 1969.



## Literature Cited

**Notes on obtaining original references:** The Alaska State Library in Juneau can help persons at any location in Alaska with obtaining references. *Books* and copies of *published articles*, including government publications, may be available at the State Library or at a local government laboratory. Otherwise these can be obtained through the national inter-library loan system, by placing a request at the State Library. Information on *patented processes* can be ordered from the government which granted the patent; the journal *Chemical Abstracts* contains information on patent offices. For certain references—patents, sources which might be difficult to obtain, those in foreign languages, and those for which I have read only an abstract—I have given supplementary references to abstracts.

*Persons* with whom I corresponded or spoke directly can be contacted at the addresses given here; all are ready to provide further information. These persons, it should be noted, were among the most valuable sources, and above all can give information and perspectives which are up-to-date.

Possible difficulties in using these references as they are given should be mentioned. Authors and dates should be noted precisely, since in some cases there are several references for which these are very similar. The names of publications and their publishers, especially those connected with the Federal Government, change occasionally; all are given as they stood on the date of publication, and are not necessarily the official titles at present.

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## Addendum

March, 1971

(Courtesy of Dr. G. G. Allan, College of Forest Resources, University of Washington)

Research is now in progress on chitin and chitosan at the College of Forest Resources, University of Washington. Chitin is being chemically combined with pesticides. When the compound is applied to plants, it breaks down slowly, releasing active pesticide at a controlled rate over a long period of time. The new concept is of potential interest in agriculture, because it might allow great reduction in the amounts of pesticide that must be applied, and could also permit use of pesticides ("biodegradable" ones) with far fewer side-effects than are caused by the poisons which are commonly used at present.

Chitosan is under investigation at the University of Washington as a paper additive.

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\* "Tappi" stands for "Technical Association of the Pulp and Paper Industry."