OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

19678

Distr.
LIMITED

IO.53
19 June 1991

ORIGINAL: ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

ENVIRONMENTAL MANAGEMENT IN FISHERY-BASED INDUSTRIES

Working Papers in Industrial Planning
No.5

INDUSTRIAL PLANNING BRANCH
INDUSTRIAL INSTITUTIONS AND SERVICES DIVISION

V.91 25798

WORKING PAPERS IN INDUSTRIAL PLANNING

The papers presented in this series have been produced by the UNIDO secretariat or by outside experts in the course of the technical co-operation activities carried out by the Industrial Planning Branch. The series contains selected papers that are believed to be of interest to a wider audience. They are often of an explanatory and tentative nature, presenting issues for discussion, and do not necessarily reflect the official views of UNIDO.

Preface

The main objectives of this study are to present technical information and costs related to waste management in the seafood processing industry. Although there is a lack of published data on environmental management in the fish processing industry in developing countries, the focus is on seafood processors in developing countries drawing upon developed countries' experiences as relevant.

Recovery and utilization of seafood wastes, both from wastewater and solid wastes, can be good policy for protecting the environment and for the seafood processing industry. Various options, such as production of fish meal, fish silage, and mince are explored. Fish silage, for example, is generally suggested as an option for waste utilization in small operations, whereas production of fish meal is more suitable for large plants.

The present study is a revision and update of an earlier study entitled "Environmental assessment and management of the fish processing industry", Sectoral Studies Series No. 28, PPD.15. The purpose of the study is to give a basis for incorporating environmental considerations in UNIDO's technical co-operation projects relating to fishery-based industries.

Contents

Contents (cont'd)

Tables | Page

Tables (cont'd) | Page

Figures

Glossary of terms

Amino acids	The nitrogenous organic compounds that serve as the structural units of proteins.
Astaxanthin	A violet crystalline pigment found in combination with protein in the shells of crustaceans ($C_{40}H_{52}O_4$).
BOD_5	The amount of oxygen, expressed as milligrams per liter of water, consumed over a five day period in stabilizing organic material in water of a predetermined temperature and pH.
Bloodwater	The substance oozing out of pits or bins in which fish waste solids and trash fish are accumulated.
Brine	Water containing large amounts of salt.
Carotenoid	Any of several red or yellow pigments related to the red or orange compound carotene ($C_{40}H_{56}$).
Chitin	A polysaccharide (carbohydrates that decompose into more than three simple sugars) that forms part of the hard outer covering of insects, crustaceans and some other invertebrates.
Chitosan	A substance derived from chitin by boiling the chitin in a strong alkaline solution.
Dissolved Air Flotation (DAF)	A wastewater treatment method in which tiny air bubbles are used to remove suspended solids.
Evisceration	The process of removing the inner organs of the body, particularly organs of the thorax and abdomen such as the intestines, heart, lung, liver and kidneys.
Fish meal	Whole fish and/or waste parts which have been cooked, dried and ground.
Fish Protein Concentrate (FPC)	Fish meal which has been ground to a flour-like consistency and which has been manufactured under hygienic conditions appropriate to food for human consumption.
Fish silage	A liquified form of whole fish or fish wastes produced by grinding the fish and then keeping it under acid conditions until the cells and tissues have been broken down.
Flocculate	To collect in bunches; in wastewater treatment it refers to the process of precipitating suspended solids out of the wastewater stream.

Flume	A chute or trough for carrying water.
Mantle	A membranous flap in the body wall of a mollusk.
Minced fish	Fish flesh that has been separated from inedible portions and rendered into small pulverized particles or into a powdered form.
Offal	That part of the fish that remains after the fillets have been removed.
Retort	In the context of food processing, to autoclav, i.e. to heat in air-tight chambers with pressurized steam, or other means which do not entail boiling, to temperatures above 100°C.
Sludge	In wastewater treatment, the solids and/or microorganisms that are precipitated out of wastewater.
Stickwater	Water which has been in close contact with fish, usually as as result of precooking or pressing operations, and consequently contains large amounts of organic material.

EXECUTIVE SUMMARY

This is a technical paper on waste processing in fishery-based industries. It focusses on recycling opportunities of wastes into food products and particularly analyzes the processing methods of seafood currently applied in developing countries.

The paper provides data on the specific features of waste waters and solid wastes, the choice of alternative recycling techniques and the actual processing and discharge methods. It also considers the cost aspect of waste water processing and whatever economic parameters relating to different recycling options.

The primary effects of discharges from the fishery-based industries relate to the BOD of wastes and waste waters. There are important secondary effects relating to nutrients, oil, suspended solids, bacteria, chlorination of waste water and temperature increases in the recipient.

Seafood wastes have a very high nutritional value thanks to their important protein content. They can enter the fabrication of food products for human and animal consumption, or of certain chemical compounds. The production of fish powder calls for large equipments, and is therefore not advisable for small plants. However the production of fish-derived foodstuffs, as well as fish ensilage, ought to be promoted.

The study concludes that there are good possibilities in developing countries to turn by-catch and processing wastes into food-products, additives to animal feed or biogas production. UNIDO could assist member countries to plan the development of fishery-based industries for a sustainable use of the fish resource.

1. GENERAL COMMENTS ON WASTE GENERATION AND WASTE UTILIZATION POSSIBILITIES OF THE FISHING AND FISH PROCESSING INDUSTRY

Up till the late seventies the global fish harvest grew rapidly, but since it has stabilized at level of some 70 million tons annually despite increase in units of effords and sophistication of equipment. In addition to recorded and utilized catch it is estimated that by-catches - trash-fish - amount to 20-30 million tons per year. There seems to be little hope for a radical increase in fish catches in the future. Many of the most valuable species and conveniently located populations of fish are presently exploited at or above sustainable levels. Pollution, daming of rivers and clear-cutting of mangrove-swamps are examples of acts of man that are likely to further reduce reproductive success for many species of fish and shell-fish. New stocks of fish, crustaceans like crill and copholopodes to be exploited may do no more than at the most to prevent total fish catches from dropping. Clearly the prospect for the future is aquaculture. An additional prospect is for better utilization of the hundred million tons or so that are annually cought in mans fishing geans. As the environmental problems from the fish-processing industry is directly linked to the amount of fish being wasted, improved utilization will directly lead to an improved environment. The classical saying that "pollution is a resource at the wrong place" is particularly true for the fish processing industry.

The fish waste can conveniently be grouped into three categories: by-catches, spoilage and waste from fish processing industries. Although the latter is the basic subject of this paper, some comments will be given here to the first two also.

The ratio of desired fish to trash fish varies widely dependent both on the fishing techniques used and the species sought. The ratio is particularly low when trawling for expensive crustaceans like shrimp and crab. E.g. in Indonesia the ratio of shrimp to trash fish ranges from 1:5 during the peak of the shrimp season to as low as 1:20 during off season.1/ The anchouetes fishery off South America is reported to have no more than 10 per cent trash-fish in the catches while hearing fishing in the North Sea results in 20-60 per cent by-catches. An estimated global total is 20-30 million tons per year, constituting 25-30 per cent of the total catches. What can then be done to improve the situation? One step is to use more selective fish techniques or more sophisticated systems to locate the desired species so as to minimize the undesired catch. Another step is to develop processing techniques that can utilize a wider range of species and turn them into products, be it for human consumption or as animal feed. However, as stocks are depleted of high-price species and the prices go even higher, economic factors encourage fishing efforts where only a small proportion of the total catch consists of the desired species such as in the Indonesean shrimp fishery referred to above. Economic factors are also against the handling of many species and/or sizes of fish in rational modern processing plants. Thus no quick or drastic changes should be expected with regard to reduction of by-catches or the utilization of present trash-fish unless market forces are altered. The best chances seem to be to develop processing techniques for e.g. fish with many bones that the customers dislike for that reason and where the fish itself is present in large shoals e.g. dogfish off West Africa.

1/ Kompiang, I. Puta, "Utilization of trash fish and fish wastes in Indonesia (as animal feeds)", in Food and Nutrition Bulletin, United Nations University, Tokyo, 1983, p. 131.

Fish spoil very easily and the higher the temperature the shorter the time must be between catch and processing/consumption. The problem of spoilage is particularly acute in developing countries, since much of the developing world lies in the tropics and since many of the fishing boats in these countries have little or no refrigeration equipment. Spoilage also occurs after the fish arrives at the processing plants. Processing plants in developing countries more often than not suffer from limited refrigeration capacities. If the catch is particularly large it can easily exceed the plants capacity to either process or store the fish quickly enough to prevent spoilage. Failure of electric supply is also an important factor for spoilage of unprocessed as well as processed fish products in developing countries.

Artesian fishery is generally carried out from canoes and other small boats without ice-holding capacities. Catches that are not consumed upon landing can normally only be preserved through smoking which is a slow process mostly with very limited capacity. Shortage of fire-wood is frequently an additional problem e.g. in West Africa leading to "undersmoked" fish or short consumer appeal. It is obviously very difficult to estimate the fish-losses through spoilage at sea, in the processing plants and after the processing but conservative "guestimates" puts the percentage at 10-30 per cent of total catch which could mean about 15 million tons annually.

The third source of the large amount of waste generated in the seafood industry is the processing itself. Waste rates during processing vary tremendously depending on techniques and species. The rates run from almost zero in the case of a large integrated tuna processing plant to almost 90 per cent of the weight of the catch in the case of clams. Crabs and shrimp have wastage rates running up to around 85 per cent. The processing of marine finfish sustain wastage rates of 55-75 per cent.2/ It has been estimated that some two thirds of the fish landed at United Kingdom fish processing plants is lost from the point of view of human consumption. In a developed country like the United Kingdom a high proportion of this "waste" is actually processed into fish meal, a product used primary as an additive in animal feeds.3/ In the developing world, due both to the high spoilage rates and to the inability to process wastes into fish meal, the real wastage rate i.e. the proportion of the catch that find no use but is simply dumped, is much higher. Figures of 70-80 per cent have been suggested. If this figure is representative of the fish processing industry the total amount lost annually and globally would be in the order of approximately 40 million tons.

The wastes generated by the seafood processing industry can be divided into two main categories: wastes from shellfish and wastes form finfish. It is the wastes from finfish that contain the nutrients with the potential to alleviate the problem of human malnutrition on one hand and cause pollution problems on the other. This is because the wastes have nearly as much protein

---

2/ Swanson, G.R., Dudley, E.G., and Williamson, K.J., "The use of fish and shellfish wastes and fertilizers and feedstuffs" in Bewick, Michael, W.M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-283.

3/ Keay, J.N., "Aspects of optimal utilization of the food fish resource through product innovation", in Advances in Fish Science and Technology, Aberdeen, United Kingdom, 1980, p. 275.

as the part processed into food. On a fresh weight basis fish contains typically 17 per cent protein (corresponding to 85 per cent on the dry weight basis) with a composition of amino acids that make it particularly valuable as human food as all the essential amino acids are present in the right proportions.

In the short term, the only process that offers viable means to increase the percentage of fish that can be turned into human food is the use of meat-bone separators. Essentially, in this process various mechanical devices are used to squeeze or tear off scraps of meat that ordinary processing leaves attached to bones or shells. However, even with these devices, large amounts of waste remain from trash fish and from bones, heads, viscera and other fish parts not fit for human consumption. Production of fish meal - as mentioned above in the case of United Kingdom - is the traditional way in which to capture the proteins and other nutrients available in this waste.

Fish meal consists of whole fish and waste parts of fish which have been cooked, dried and ground. In developed countries fish meal is mostly produced in large plants with sophisticated equipment. In developing countries, and in many cases in developed countries as well, many seafood processing plants are too small and too far removed from one another to support a large sophisticated fish meal processing plant. As a result, if attempts are made to produce fish meal it is often of poor quality.

During the last two decades an alternative product - fish silage - has increasingly been produced e.g. in Scandinavia, especially by small, remote fish processors. Fish silage is made of the same ingredients as fish meal and used for the same purpose - as an ingredient in animal feeds. In Norway and Denmark in particular it is used to produce fish feed for the booming aquaculture industry. Production of fish silage is simple and a low-cost operation. The material is chopped and mixed with water. Acids are added and the mixture is allowed to sit until the fish solids have dissolved. Remaining unsolvable parts like viscera and bones fall to the bottom and can be separated off. No sophisticated equipment is needed and a batch of fish silage can be made virtually with any amount of waste that is available, whenever desired. To some extent even fish spoiled from the point of view of human consumption can be utilized. Fish silage stores well even in warm climates and consequently bear great promise as a sollution to seafood waste utilization in developing countries.

In addition to aquacultural uses fish silage has been found to be particularly useful in the feeding of swine. If a seafood processor is located in the vicinity of a swine production unit, the seafood processor, the swine producer and even the country may profit. St. Helena, a small island in the middle of the Atlantic has reaped the benefit of having seafood processors close to hog rearing operations. Prior to production of fish silage by the seafood processors, St. Helenas pig rearing industry was importing fish meal[4/]

4/ United States Environmental Protection Agency, Environmental Assessment of Alternative Seafood Waste Disposal Methods at Akutan Harbor, Alaska, Seattle, Washington, 1984. EPA 910/9-83-114, p. 7.

and seafood processors were dumping the waste in the sea. As locally produced fish silage sells for 20 per cent of the costs of imported fish meal of the same nutritional value, the pig rearing industry benefitted by having a cheaper source of food. The seafood processor benefitted from having a profitable product instead of a waste. St. Helena as a whole benefitted from the better economy and the better environment.

Naturally the seafood processing industry was located near the main fishing grounds. Frequently this was in remote locations, often on islands. Frequently also the fish processing industry works only seasonally during the fishing seasons e.g. spawning period when large scoals are formed and fish are easy to catch. Naturally, both remote locations and seasonal production make waste utilization more problematic. However, over the last two decades the problem is changing. Larger and faster fishing boats with better cooling or freezing equipment allow transportation of catches over longer distances. Economy of scale encourage larger processing units that thanks to lower capital and operation costs can pay a better price for the fish. As an example, the number of fish processors around the North Sea has dropped to less than one third during the last decades while the average production has increased five fold. In developing countries fish processing industries are generally located where harbours and infrastructures are available. Thus the prospects for waste utilization are improving and new techniques as meat-bone separator and fish silage are further enhancing this trend. (See table 1.1.)

A summary of estimated catches and wastes from fishing and fish processing industry is given below:

Global brut catch	100	million of tons annually
Trash fish	- 30	
Registered catch	70	
Spoilage	- 15	
Loss at fish processing plants	- 40	
Products for human consumption	15a/	

a/ This corresponds to 3 kg per human being/year.

Table 1.1 Summary of various types of outputs (products) from the fish processing industry by country and geographical region (metric tons)

Country	Fish, fresh, chilled or frozen	Fish, dried, salted or smoked	Crustaceans and molluscus	Oils and fats	Meals and similar stuff	Fish products and preparations	Crustaceans and molluscus, products and preparations
Africa							
Algeria	-	200	-	-	-	4,000	-
Angola	6,000	22,000	-	1,000	3,000	3,300	-
Benin	-	2,000	152	-	-	-	-
Cameroon	79*	3,900	-	-	-	-	-
Cape Verde	2,300	-	50	-	120	230	-
Chad	-	19,000	-	-	-	-	-
Congo	-	4,000	-	-	-	-	-
Côte d'Ivoire	-	15,000	-	279*	3,717	29,360	-
Egypt	-	-	18	-	-	-	-
Gambia	-	3,982	-	-	-	-	-
Ghana	-	60,000	-	-	-	4,000	-
Kenya	3,872	12,301	-	-	-	-	-
Libya	-	-	-	-	260	1,800	-
Madagascar	-	1,800	6,379	-	-	-	-
Mali	-	2,706	-	-	-	-	-
Mauritania	29,245	581	52,066	-	-	165	-
Mauritius	5,451	944	45	-	1,045	4,540	-
Morocco	119,814	182	-	10,000	30,000	58,000	-
Mozambique	-	3,089	5,113	-	-	338	-
Niger	-	1,000	-	-	-	-	-
Nigeria	-	34,141	-	-	-	-	-
Reunion	700	-	251	-	-	-	-
Sao Tome & Prn.	400	-	-	-	-	-	-
Senegal	46,950	15,890	17,023	10	1,880	19,370	-
Seychelles	700	200	-	-	700	1,300	-
Sierra Leone	-	18,600	-	-	-	-	-
Somalia	-	1,100	-	-	-	14*	-
South Africa	146,718	2,032	3,298	82,900	260,600	11,600	100*
Sudan	-	2,300	-	-	-	-	-
Tanzania	1,041	61,685	-	-	-	-	-
Togo	-	3,600	-	-	-	-	-
Tunisia	-	-	11,648	-	200	4,100	-
Zambia	-	8,000	-	-	-	-	-
Zimbabwe	1,800	5,000	-	-	-	200	-

Table 1.1 Summary of various types of outputs (products) from the fish processing industry by country and geographical region (cont'd)

Country	Fish, fresh, chilled or frozen	Fish, dried, salted or smoked	Crustaceans and molluscus	Oils and fats	Meals and similar stuff	Fish products and preparations	Crustaceans and molluscus, products and preparations
North America							
Bahamas	90	-	1,100	-	-	-	-
Belize	35	4	551	-	-	-	-
Bermuda	-	-	-	-	1,000*	-	-
Canada	299,410	67,676	38,845	10,670	60,240	40,966	690
Costa Rica	-	-	-	-	-	2,000	-
Cuba	106,399	-	13,665	-	6,754	9,745	-
El Salvador	-	-	3,350	-	319*	-	-
Greenland	11,429	1,950	33,740	28*	74	19	8,622
Guatemala	-	42	775	-	-	-	-
Honduras	-	-	3,595	-	-	-	-
Mexico	63,360	657	50,247	14,965	104,280	54,870	940
Nicaragua	-	-	1,108	-	-	-	-
Panama	-	-	1,760	13,782	31,367	-	-
St. Pier Miqu.	3,539	2,319	20*	-	958	-	-
USA	448,029	14,998	285,099	135,397	470,084	393,598	61,787
South America							
Argentina	210,900	7,800	34,770	1,000	20,300	15,200	1,000
Brazil	171,400	21,390	16,510	2,800	26,000	51,500	16*
Chile	58,428	1,345	11,260	172,159	1,081,092	60,362	9,040
Colombia	-	4,627	3,452	-	6*	619	-
Ecuador	35,342	117	50,708	8,818	116,701	33,962	10
French Guyana	496	-	3,085	-	-	-	-
Guyana	-	182	2,713	-	-	-	-
Peru	31,800	22,605	4,538	109,086	821,417	78,535	451
Suriname	-	607	397	-	-	-	-
Uruguay	56,009	25	2,294	552	10,940	8	7
Venezuela	12,931	6,488	892	-	4,945	45,628	1,695

Table 1.1 Summary of various types of outputs (products) from the fish processing industry by country and geographical region (cont'd)

Country	Fish, fresh, chilled or frozen	Fish, dried, salted or smoked	Crustaceans and molluscus	Oils and fats	Meals and similar stuff	Fish products and preparations	Crustaceans and molluscus, products and preparations
<u>Asia</u>							
Bahrain	-	-	95*	-	-	-	-
Bangladesh	2,514	8,800	29,950	-	-	-	-
Burma	4,000	58,000	5,500	-	-	87,500	-
China	428,459	1,390,566	106,181	-	50,000	17,096	14,735
Hong Kong	15,638	3,417	6,685	-	2,020	240	81
India	14,904	150,493	74,502	78	30,000	-	1*
Indonesia	36,160	594,630	43,090	1,310	830	4,170	450
Iran	-	-	-	-	450	6,300	-
Israel	-	-	-	-	-	7,550	-
Japan	3,553,195	867,497	510,356	458,601	1,112,663	1,642,698	43,579
Korea, Dem. Rep.	620,643	138,662	8,278	-	-	3,126	1,761
Korea, Rep.	1,061,373	41,816	40,428	2,733	76,836	129,195	22,293
Kuwait	-	-	1,200	-	-	-	-
Macau	1,465	57	6,277	-	-	-	-
Malaysia	2,426	18,783	11,695	-	55,000	14,517	4,019
Maldives	14,968	5,553	-	24	-	-	-
Pakistan	4,078	12,491	18,589	-	34,017	13*	85
Philippines	13,905	219,463	4,709	-	-	47,805	93,079
Singapore	5,645	-	2,853	-	1,603	2,313	-
Sri Lanka	119	13,777	1,439	-	150*	2*	-
Thailand	220,000	55,050	174,239	44*	217,000	188,741	93,150
Turkey	24,000	4,000	300	9,151	45,000	2,100	2,000
United Arab Em.	-	16,700	-	-	-	-	-
Yemen	3,821	6,378	-	486*	1,926	-	-
Others	-	13,500	7,850	280	4,500	26,600	810

Table 1.1 Summary of various types of outputs (products) from the fish processing industry by country and geographical region (cont'd)

Country	Fish, fresh, chilled or frozen	Fish, dried, salted or smoked	Crustaceans and molluscus	Oils and fats	Meals and similar stuff	Fish products and preparations	Crustaceans and molluscus, products and preparations
Europe							
Austria	-	50	-	-	-	-	-
Belgium	10,003	3,933	5,483	150*	1,150	12,200	827
Bulgaria	76,616	3,905	-	-	7,304	14,489	-
Czechoslovakia	-	7,082	-	-	-	20,592	-
Denmark	205,415	28,712	11,712	85,000	264,459	71,357	20,692
Faero is.	41,144	18,459	4,603	7,191	26,737	1,079	1,334
Finland	11,826	3,800	-	-	1,600	1,900	-
France	112,596	14,350	4,610	3,700	20,300	104,632	1,000
Germany, DR[a/]	26,000	28,000	-	-	-	55,570	-
Germany, FR[a/]	147,364	13,317	444	8,124	26,961	115,723	4,742
Greece	7,987	7,626	7,097	-	-	1,779	1,852
Hungary	4,490	-	-	-	-	1,200	-
Iceland	165,399	95,084	14,368	82,154	159,297	2,343	1,576
Ireland	112,052	1,863	5,734	4,419	3,670	1,291	93
Italy	60,025	3,900	21,368	-	4,500	109,100	4,500
Netherlands	232,032	33,317	150*	-	-	16,899	6,600
Norway	263,750	84,780	23,500	77,750	183,100	35,585	1,410
Poland	170,542	58,451	59,796	1,000	74,399	62,430	-
Portugal	58,203	4,959	881	2,083	7,118	42,395	395
Romania	124,908	39,470	-	594	12,513	20,186	-
Spain	291,360	27,500	166,004	8,520	78,906	117,600	15,680
Sweden	29,200	3,040	-	2,700	10,000	37,360	1,700
Switzerland	146	70	-	-	-	1,502	-
United Kingdom	129,843	21,350	12,323	6,900	51,000	6,405	-
Yugoslavia	900	145	-	430	2,932	30,673	-

a/ Through accession of the German Democratic Republic to the Federal Republic of Germany with effect from 3 October 1990, the two German States have united to form one sovereign State. As from the date of unification, the Federal Republic of Germany acts in the United Nations under the designation of "Germany".

Table 1.1 Summary of various types of outputs (products) from the fish processing industry by country and geographical region (cont'd)

Country	Fish, fresh, chilled or frozen	Fish, dried, salted or smoked	Crustaceans and molluscus	Oils and fats	Meals and similar stuff	Fish products and preparations	Crustaceans and molluscus, products and preparations
Oceania							
Australia	8,858	-	21,355	3,932*	1,300	6,300	2,133
Fiji	256	74	652	44*	1,118	11,079	-
New Zealand	97,687	1,767	40,902	650	1,116	3,800	492
Solomon Islands	26,635	1,734	-	-	-	3,502	-
Tuvalu	296	3*	-	..	-	250*	-
USSR	3,271,980	841,240	-	111,300	766,640	1,348,479	3,255
Total	13,602,394	5,425,679	2,115,715	1,447,381	6,396,114	5,386,995	428,682

*/ Figures are older than 1987.

Source: FAO Fishery Yearbook 1987, Vol. 64 and 65.

2. ENVIRONMENTAL EFFECTS OF DISCHARGES FROM THE FISH PROCESSING INDUSTRY

When discussing environmental aspects of wastes and wastewater from fish processing industries, two fundamentally different philosophies are generally voiced. One says that fish is a natural product that even in the most pristine environment would die and decompose in the sea and that, therefore, it is more of an abuse of the environment to withthold than to discharge wastes and wastewater from fish processing industries.

The other approach focuses on the amount of organic matter (BOD) and nutrients (most important organic nitrogen) that is present in fish. The total brut catch of 100 million tons of the fishing industry contain some 2.7 million tons of nitrogen out of which some 2 million tons are estimated to be discharged to the sea. When compared to NO_x emissions to the atmosphere estimated to 6 million tons (as nitrogen) annually from Europe and some 25 million tons world wide, it is clear that the fish processing industry is not a neglectable source.

When trying to balance the two approaches mentioned above it is clear that it is the concentration of discharges that creates the problem. Following the tendency to further concentration of the industry to larger units, the problem is increasing but so are the possibilities to find economically attractive or acceptable solutions.

The effects observed after discharge of wastes and wastewater from fish processing industries are very much dependent on qualities in relation to the characteristics of the receiving waters. When the waste quantity is small, seabirds, fish and crustaceans will consume a substantial part. Frequently when these animals are attracted and become more aboundant it is seen as a "bioenhancement" - a positive environmental effect.

When the quantities become larger the birds, fish, crabs and other marine species can no longer consume the main part of the wastes. Other organisms like polychactes take care of a larger part and become much more abundant. Selfevidently, bacteria will always be involved in the degradation of the wastes be it as intertestal habitants of the other species or as specialized degraders of dissolved organic matter. When the loading of wastes become larger and larger, bacteria will become responsible for more and more of the degradation and films of bacteria will cover more and more of the surfaces. When exposure is heavy, slimeforming bacteria in treadformed algealike colonies will cover most surfaces.

Bacteria, like the higher organisms which live on wastes from fish processing industries, consume oxygen. A definite break-point with regard to the environmental effects and the ecological charges, come when oxygen consumption exceeds the rate of supply. The early signs are easy visible at most fish processing plants with a marine location. As oxygen depletions start in the sediment, the "normal" bacteria are replaced by a group that utilize sulphate as an electron receptor and form free surphur as a by-product of degradation of organic material. When sediment surface turn white or yellow-white a definite turning point is about to be reached. Examples of this are numerous and can be found in all geographical areas, e.g. Varnemünde at the Baltic coast, Split in the Mediterranean, Callao in the Peruvian coast and Song Khla in the Thai bay.

As oxygen disappear and anaerobic processes take over the degradation of the organic waste material is higher, organisms like fish and crustaceans can no longer survive in the area. Groups of bacteria that reduce sulphate not only to free sulphur but also to foal-smelling sulphide take over. Other anaerobic bacteria reduce iron in the sediment and thereby release sediment stored nutrients like phosphate.

The effects described so far can be termed primary effects of discharges from the fish processing industry. They all have to do with the biological oxygen demand (BOD) of the wastes and wastewaters. The secondary effects relate to the nutrient. The content of organic nitrogen in fish has been mentioned above. Fish contains about 17 per cent protein on fresh weight basis corresponding to 2.7 per cent of organically bound nitrogen mostly as amino acids. It also contains 0.35 per cent phosphorus. The nutrients from the waste and the ones released from anaerobic sediments, accelerate the growth of phytoplankton and therey contribute to entrophication. A part of the phytoplankton species are toxic and contribute after accumulation in fish and shellfish to e.g. paralytic shellfish poisoning. Other are toxic to fish and other members of the marine ecosystem like the red tides in tropical countries or the Crysochromulina plankton bloom in the North Sea 1988. Marine entrophication and planktic blooms also reduce the recreation value of the sea and many have severe effects on tourism as in the Adriatic Sea the summer of 1989.

After the algae-blooms, when the plankton is degraded by bacteria and other organisms oxygen consumption increases with associated increased risks for oxygen deplation especially in stagreant bottom waters. Renewed release of nutrients from anaerobic sediments may further contribute to continued or accelerated entrophication.

In addition to the effects of BOD and nutrients the processing of some fish species generate large quantities of oil. If this oil is not recovered, its discharge into receiving waters can cause a variety of problems. Since oil and greases generally float they are objectionable on aesthetic grounds. Even a very thin film of oil can easily be seen. Grease, both alone and in conjunction with suspended solids can form a surface scum. Fish processing industries along the Pacific border of South America who process anchovetas and other species from the east pacific upwelling zone, offer numerous examples of these types of effects. So does several places along the north west of Africa's Atlantic coast, such as Novadhibou in Mauritania. Films of oil and grease can harm birds which come in contact with them. Recreational beaches which lie in the path of oil or grease discharges can be rendered unfit for use. Similarly, shoreline property, especially residential one, loses both amenity and use values when contaminated with oil and grease residues. Needless to say, oil and grease are also degradeable organic compounds with high BOD values e.g. high oxygen demand for degradation. As they float, though, some of the oxygen comes from air so water dissolved oxygen is not consumed to the same extent as with suspended or dissolved matter with the same BOD values.

Suspended solids are all those particles that can be removed by standard filtration procedures. Suspended solids from fish processing industries may float to the surface, remain suspended in the water or eventually settle out on the bottom. Suspended solids which float on the surface can form a blanket of scum. These blankets are ojectionable on aesthetic grounds. In addition, a scum blanket reduces the amount of oxygen that can enter the water from the air as well as the penetration of sunlight. If a scum blanket is thick enough it provides a breeding ground for flies and other insects, thus constituting a public health hazard. In grave cases, the odeur problems may also be severe. Solids in suspension reduce transparency and change the colour of the water. Solids that settle on the bottom may smothen surfaces and bottom dwelling organisms. Settling organic solids can give rise to anaerobic banks.

Bacteria may be a problem if wastewater is discharged into waters from which shellfish is harvested of where shellfish aquaculture takes place. Wastwater from conventional fish, crab, clam, and oyster processors has been found to contain levels of coliform bacteria exceeding the standards in the United States for safe discharge to shellfish harvesting waters, despite the fact that all plants had separated toilet wastewaters from the process wastewater stream and despite disinfection with relatively large amounts of achlorine.5/

Chlorination of wastewater itself is likely to lead to environmental hazards through formation of organochlorine compounds. This has not been reported for the fish processing industry, but is regarded to be a major problem in connection with other uses of chlorine e.g. bleacking of pulp and disinfection of municipal drinking and wastewater. The basic chemistry is such that mixtures of organic compounds exposed to chlorine are highly likely to lead to the formation of organochlorine compounds.

Fish processing industries frequently release water of high temperature from various cooking and sterilization processes. Care should be taken not to increase the temperature in the receiving water with more than a few degrees C, as higher temperature negatively affect species composition, oxygen levels, fish parasites, and many other factors. This is especially important in tropical areas where the species already live within a narrow margin of their upper temperature tolerance.6/

Environmental effects are often measured in relation to indicator species of two sorts. Those who can not stand pollution e.g. barnacles, and consequently disappear already at an early stage, or those that benefit from it and would normally make up a small percentage of the community but may constitute some 90 per cent of the overall population in a polluted area e.g. polychaetes. Another measurement is species diversity. In an uneffected environment the number of species is generally large but the number of individuals within each species is small, compared to the polluted situation where few species are present but in large numbers.

In summary, discharges from the fish processing industry have very different effects at different levels of loading of the recipient body of water. A definite turning point is when the water turns anoxic. The most long term and large-scale effects in the contribution to constant entrophication.

5/ World Health Organization, Coordinated Mediterranean Pollution Monitoring and Research Programme, First Report on Coastal Quality Monitoring or Recreational and Shellfish Areas (Med VII), Copenhagen, 1978, p. 5.

6/ Gesamp report and studies.

3. WASTEWATER CHARACTERISTICS IN SEAFOOD PROCESSING INDUSTRIES

3.1 Wastewater characteristics of principal types of seafood processors

Fish processing plants can be divided into four categories. These categories are differentiated by types of fish handled. The four categories, together with lists of the main fish species handled in each category, are given below.

Marine finfish

Tuna
Sardines
Cod
Ocean perch (redfish)
Herring
Mackerel
Giant johnfish
Giant grouper
Menhaden

Marine shellfish

Crabs
Shrimp
Clams
Oysters
Lobster

Freshwater fish

Catfish
Salmon
Perch
Smelt
Trout

Fish meal

Waste parts from marine finfish
By-catch fish

Some plants are set up so that they can operate as either marine finfish or marine shellfish processors.

Simplified, the seafood processing operation consists of five operations: pre-processing, precooking, separation of edible meat, inspection, and packaging. Pre-processing may consist of washing of dredged crabs, thawing of frozen fish, or beheading of shrimp. Precooking or blanching is practiced to facilitate the removal of skin, bones, shells, gills or other inedible parts. The separation of the meat from the inedible parts is accomplished by butchering in the case of finfish and by shucking in the case of shellfish. The separation can be done manually, mechanically or by some combination of manual and mechanical steps. After the edible meat has been separated out it is subject to an inspection process. Remaining inedible or undesirable parts are removed and meat in an unacceptable condition discarded. Unless the product is destined for the fresh fish market, packaging will involve freezing, canning and/or pasteurization. More detailed descriptions of the operations involved in the principal types of seafood processing plants, together with information on wastewater characteristics, are given in the following paragraphs.

3.1.1 Marine finfish

Wastewater characteristics in seafood processing industries

Upon arrival at a processing plant marine finfish are placed in holding bins where they are packed with ice to prevent deterioration. In some cases evisceration - the removal of the intestines and other inner organs - has been done on the boats. If not, or if it is necessary to remove the scales, these will constitute the first procedures undertaken at the plant. In most cases the fish will be transported from the bins to the tables where the first processing operations take place by means of flumes - chutes through which a stream of water flows. If the fish are not to be sold fresh, they may be precooked or blanched. In any case, whether it is directly from the holding bins or after an intervening step or two, the fish will be transported by flume to the filleting tables. Here fillets are cut from both sides of the fish. All parts of the fish other than the fillets are called offal and are waste products as far as the marine finfish processor is concerned. The offal, which constitutes some 70 per cent of the weight of the fish, is washed off the working tables and into flumes.7/ The flumes carry the offal into receiving bins from where it will either be discarded or recovered for fish meal or fish silage. The fillets themselves, except for those species which do not need to have their skins removed, are transported by flumes to skinning machines. From the skinning machines the fillets are flumed onward to inspection tables. Here remaining bones are defective meat are removed. If the fillets are to be sold fresh, they are then dipped into a brine or phosphate sollution. If they are to be frozen they may either be frozen as individual fillets or in large blocks.

Large amounts of water is used in a typical marine finfish processing plant. Some 50-65 per cent of the water used is accounted for by the various flumes. Washing of the fish, including the washing necessary to remove the innards and skins, and to separate the fillets from the bones, accounts for some 15-25 per cent of water usage.8/

Estimates of the amount of water that a typical fish processor uses per ton of final product vary tremendously. Water usage seems to depend more on the amount of water available than on the amount of water needed for any particular operation.9/ Although the figure for wastewater given in table 3.1 is 5,240 liters per ton of product for a conventional marine finfish plant, some plants use as much as 204,000 liters per ton of product.10/

7/ United Nations Economic and Social Commission for Asia and the Pacific, Industrial Pollution Control Guidelines, VIII. Fish Processing Industry, Bangkok, 1982, p. 3.

8/ Ibid., p. 9.

9/ Ibid., p. 7.

10/ Ibid., p. 9.

Table 3.1 Marine finfish plant, wastewater characteristics

Parameter	Conventional plant	Mechanized plant
Wastewater	5.240 l/mt	13.500 l/mt
BOD_5	3.32 kg/mt	11.9 kg/mt
SS	1.42 kg/mt	8.92 kg/mt
Oils and grease	0.348 kg/mt	2.48 kg/mt

l = liter
mt = metric ton
kg = kilogram
BOD_5 = five day biochemical oxygen demand
SS = suspended solids

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 227.

Both salt and fresh water are used in marine finfish processing. Salt water is usually used in the flumes running from the holding bins to the tables where evisceration and filleting operations are carried out. Salt water is also used in the flumes used to carry offal from the work tables to the receiving bins. Fresh water is used to transport the fillets to skinning machines, in the skinning machines, and in cooking operations. A list of the various sources of wastewater in a finfish processing plant is given below. Immediately following the list is a table presenting wastewater characteristics for a typical marine finfish plant. All characteristics in this and succeeding tables are given per ton of product.

Marine finfish plant, sources of wastewater

(a) Holding bins for receiving fish
(b) Flumes
(c) Washing of fish, including removal of scales
(d) Precooking
(e) Skinning machines
(f) Washdown at evisceration, filleting and inspection stations
(g) Brine or phosphate dip
(h) Cooking and canning
(i) General clean up including washing of floors

Tuna, plant operation, sources and characteristics of wastewater

In contrast to the majority of seafood operations, tuna plants tend to be large and in operation year round. As a consequence they are in a position to afford sophisticated equipment, both for processing and for wastewater treatment. Almost all of the waste products in a tuna operation, in direct contrast to other seafood plants, are recovered and turned into by-products. Meat that is unsuitable for human consumption is made into pet food. Parts that are unsuitable for either of these uses are recovered in fish meal and oil production operations. Thus a large tuna processor is, in effect, a marine finfish and fish meal plant combined.

Tuna are normally frozen aboard the fishing boats and thawed after arrival at the processing plant. They are butchered, precooked, cooled and cleaned prior to being canned. Wastewater in a tuna plant comes both from the primary operations leading up to the canning of tuna meat for human consumption and pet food, and from the secondary operations involved in the processing of wastes into fish meal, oil and fish solubles. Sources of wastewater from both primary and secondary operations are listed below. Tuna plants normally recover the water from the precooking operation. This water is then used for the production of fish solubles. In addition, the water in which waste parts have been accumulated and transported is recovered It too is utilized in the production of fish solubles. The recovery of these two wastewater streams vastly reduces the organic load of wastewater discharges from integrated tuna/fish meal plants. Table 3.2 shows wastewater characteristics from a tuna processing plant. A general description of the processes involved in the recovery of wastes for the production of fish meal, fish oil and fish solubles can be found in section 3.1.4.

Tuna processing plant, sources of wastewater

Primary operations

(a) Thawing
(b) Precooking
(c) Cooling
(d) Butchering
(e) Cleaning and sorting
(f) Canning
(g) Retorting (steam heating at over 100°C)

Secondary operations

(a) Odor control apparatus
(b) Evaporation procedures

Table 3.2 Tuna processing plant, wastewater characteristics

Parameter	Range	Typical value
Wastewater	5,590 - 45,100 l/mt	22,300 l/mt
BOD_5	6.8 - 20 kg/mt	15 kg/mt
SS	3.8 - 17 kg/mt	11 kg/mt
Oils and grease	1.7 - 13 kg/mt	5.6 kg/mt
Organic nitrogen	0.75 - 3 kg/mt	-
Ammonia nitrogen	0.052 - 0.42 kg/mt	-

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 225.

Sardines, plant operation, sources and characteristics of wastewater

Sardines are transferred by water either to storage tanks or directly to the packing tables. The head and tails are usually removed by hand. They are then packed in cans and precooked to remove undesirable oils. Oils or sauces are then added to the cans. The cans are sealed, retorted, cooled and washed. Wastewater comes from the unloading operation, from holding tanks if these are used, and from packing, cooking, cooling and washing of the cans. Table 3.3 below gives wastewater characteristics from a sardine plant.

Table 3.3 Sardine processing plant, wastewater characteristics

Parameter	Typical value
Wastewater	8,690 l/mt
BOD_5	9.22 kg/mt
SS	5.41 kg/mt
Oils and grease	1.74 kg/mt

Source: Middelebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and sons, New York, 1979, p. 227.

3.1.2 Marine shellfish

No general description of a marine shellfish processing plant can be given as the operations involved depend on the species being handled. In the following paragraphs, process descriptions and wastewater characteristics are given for typical crab, shrimp and clam operations.

Blue crabs

Blue crabs are brought to the processing plant live. They are unloaded onto trolleys for immediate steam cooling at 121°C for 10-20 minutes. The cooked crabs are stored overnight in a cooling locker and then the main claws are removed. The meat from the body of the crab is normally picked by hand. Sometimes the bodies and smaller claws are run through a mechanical picker to separate the meat from the shell. The main claws are hand picked. The meat is packed either into plastic bags or into cans. If it is canned, the cans are pasteurized. Wastewater comes from the containers in which the crabs are brought to the plant, from the cooking and cooling operations, from the stations where the meat is picked, from the claws and bodies, and from canning and retorting. Table 3.4 below gives typical values for wastewater parameters.

Table 3.4 Blue crab plant, wastewater characteristics

Parameter	Range, conventional plant	Range, mechanized plant
Wastewater flow	1,060 - 1,310 l/mt	29,000 - 44,600 l/mt
BOD_5	4.8 - 5.5 kg/mt	22 - 23 kg/mt
SS	0.70 - 0.78 kg/mt	12 kg/mt
Oils and grease	0.21 - 0.3 kg/mt	4.3 - 6.9 kg/mt
Organic nitrogen	0.80 - 1.0 kg/mt	2.7 - 4.4 kg/mt
Ammonia nitrogen	0.06 kg/mt	0.16 - 0.24 kg/mt

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 225.

Dungeness, Tanner and King crabs

With crabs such as Dungeness, Tanner and King, the first step in processing is usually butchering. The legs and shoulders are removed from the main body of the crab which is either flumed or transported dry to a disposal pit. The legs and shoulders are transported in a flume to a continuous cooker. After cooking the legs and shoulders are either cooled and hand picked or sent in a flume to shaking tables where the meat is separated from the shell. This is usually accomplished by pounding. The meat is inspected and sorted and then dipped into a brine solution. It may be sold fresh, frozen, or canned. Wastewater comes from the butchering operation, the cooker, from coolers, flumes, from the tables where the meat is separated from the shell, from the inspection station, and from general plant clean-up operations. Wastewater characteristics for a Dungeness crab plant are shown in table 3.5.

Table 3.5 Dungeness crab plant, wastewater characteristics

Parameter	Range
Wastewater	14,800 - 38,000 l/mt
BOD_5	6.2 - 15 kg/mt
SS	2.1 - 4.4 kg/mt
Organic nitrogen	1.4 - 2.8 kg/mt
Ammonia nitrogen	0.075 - 0.18 kg/mt

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 225.

Shrimp

Shrimp are brought to the processing plant in ice. Upon arrival they are de-iced, separated from debris and weighed. The shrimp are usually blanched. Shells are removed either mechanically or by hand. The exact steps used in preparation of shrimp vary from place to place as well as with the final form in which the shrimp are to be sold. In addition to being sold either frozen or canned, shrimp may be sold either breaded or unbreaded. Wastewater flows come from washing and blanching operations, from peeling, inspection and sorting, and from deveining and retorting where these operations are undertaken. If shrimp are mechanically peeled, the peeling machines are the largest source of wastewater in a shrimp processing plant, accounting for some 45-55 per cent of all water used.[11/] Wastewater characteristics for a shrimp plant are shown in table 3.6.

Table 3.6 Shrimp plant, wastewater characteristics

Parameter	Frozen	Canned	Breaded
Wastewater flow	73.400 l/mt	60,000 l/mt	116,000 l/mt
BOD_5	130 kg/mt	120 kg/mt	84 kg/mt
SS	210 kg/mt	54 kg/mt	93 kg/mt
Oils and grease	17 kg/mt	42 kg/mt	-

Note: In this table loadings are given per ton of raw shrimp delivered to the plant, not per ton of finished product as in other tables.

Source: The World Bank, Office of Environmental Affairs, Environmental Guidelines, Washington, D.C., 1984, p. 92.

Clams

Upon arrival at a processing plant clams are first washed. They are then shucked and the meat is washed. The bellies are removed and the meat is given a second wash. The meat is then sorted and minced and given a final wash after the mincing. This final wash is necessary to remove sand that becomes embedded in the meat during the harvesting (accomplished by dredging). After the final wash the minced clam meat is drained and packaged. Clam meat is sold fresh or frozen or cooked and canned. If the clam meat is canned it is retorted. Wastewater is generated by shucking, by each of the washes, and at the debellying station. If the clams are canned, wastewater also comes from the retorting process. Table 3.7 provides typical wastewater values.

11/ The World Bank, Office of Environmental Affairs, Environmental Guidelines, Washington, D.C., 1984, p. 91.

Table 3.7 Clam processing plant, wastewater characteristics

Parameter	Conventional plant	Mechanized plant
Wastewater flow	4,570 l/mt	19,500 l/mt
BOD_5	5.14 kg/mt	18.7 kg/mt
SS	10.2 kg/mt	6.35 kg/mt
Oils and grease	0.145 kg/mt	0.461 kg/mt

Source Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 227.

3.1.3 Freshwater fish

In general the processing of freshwater fish follows the same pattern as the processing of marine finfish. Two of the more important species are salmon and catfish. Brief descriptions of processing operations along with wastewater characteristics are given in the paragraphs which follow.

Salmon

When salmon arrive at a processing plant they are first sorted into the various species. If the salmon is not to be processed immediately it is iced or put into chilled brine. If the salmon have not been butchered at sea, butchering is the first step in processing. If they have been butchered at sea only the head has to be removed at the plant. During seasons when the salmon catch is particularly good and plant capacity is exceeded, some of the salmon are frozen without being butchered. After butchering salmon are sometimes given a pre-rinse to reduce the amount of slime adhering to the carcasses. The eviscerated fish are then moved to a wash tank. Here remaining blood, tissues lining the body cavity, sea lice, and organ particles are removed. This washing operation, along with the pre-rinse if practiced, accounts for some 90 per cent of the total wastewater flow from a salmon processor.12/ After being washed the salmon meat is cut and packed into cans. The cans are retorted and cooled. As with tuna processors, salmon plants are often set up to process meat unsuitable for humans into pet food. In addition to the pre-rinse and washing operations, sources of wastewater are as follows: mechanisms used to transfer fish from the boats to the plant, holding bins, the packing of the meat into cans, and the retorting, cooling and washing of the cans. Table 3.8 provides typical wastewater values.

12/ Ibid., p. 88.

Tables 3.8 Salmon plant, wastewater characteristics

Parameter	Conventional plant	Mechanized plant
Wastewater flow	3,750 - 5,400 l/mt	18,500 - 19,800 l/mt
BOD_5	2.0 - 3.4 kg/mt	45.5 - 50.8 kg/mt
TSS	0.8 - 2.0 kg/mt	20.3 - 24.5 kg/mt
Oils and grease	0.15 - 7.8 kg/mt	5.2 - 6.5 kg/mt

Sources: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 227. The World Bank, Office of Environmental Affairs, Environmental Guidelines, Washington, D.C., 1984, p. 89.

Catfish

Catfish are generally brought to a processing plant alive. They are electrically stunned and the head and dorsal fins removed. After this they are eviscerated, skinned and given a final cleaning to remove any remaining skin, finds or blood. The fish are then weighed and sorted by size. The larger fish are cut into steaks or fillets. Smaller fish are packaged whole. Catfish are sold either fresh or frozen. Wastewaters come from the tanks used to hold the catfish when they arrive at the plant, from the stations where they are eviscerated, skinned and cleaned, and from the packaging operations. Wastewater characteristics for a catfish plant are shown in table 3.9.

Table 3.9 Catfish plant, wastewater characteristics

Parameter	Range
Wastewater flow	15,800 - 31,500 l/mt
BOD_5	5.5 - 9.2 kg/mt
TSS	6.8 - 12.0 kg/mt
Oils and grease	3.8 - 5.6 kg/mt
Organic nitrogen	0.51 - 0.75 kg/mt
Ammonia nitrogen	0.0045 - 0.045 kg/mt

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 227.

3.1.4 Fish meal processing plants

Fish meal is made from the solid wastes generated in the processing of marine finfish. It can also be made from whole fish harvested for the purpose of rendering into meal. If the wastewater at a finfish plant is screened prior to discharge, the solids from this screening process can also be used by the fish meal plant. The by-catch (trash fish caught during normal fishing operations) can also be utilized. The waste solids, screenings, and/or whole fish are stored as they are, i.e. without drying, in bins or pits. As this material accumulates, the weight of the material causes a viscous substance to ooze from the pits or bins. This substance is referred to as bloodwater. In developing countries where fish meal plants tend to be small, relatively unsophisticated operations, this bloodwater may often be wasted. Bloodwater contains extremely high levels of BOD_5 and suspended solids. The average BOD_5 of blood water is 128,900 milligrams per liter. The average suspended solids load is 15,230 milligrams per liter (mg/l). As a consequence of these extremely high values, there is a substantial risk that the wastewater discharges from a fish meal plant not practicing recovery of bloodwater will have serious negative impacts on the receiving waters In developed countries the fish meal plants tend to be large and well equipped. In these larger plants either the bloodwater is recovered or plant operation precludes bloodwater from being generated. If bloodwater is recovered it is introduced into the continuous cooker, the first step in manufacturing fish meal.

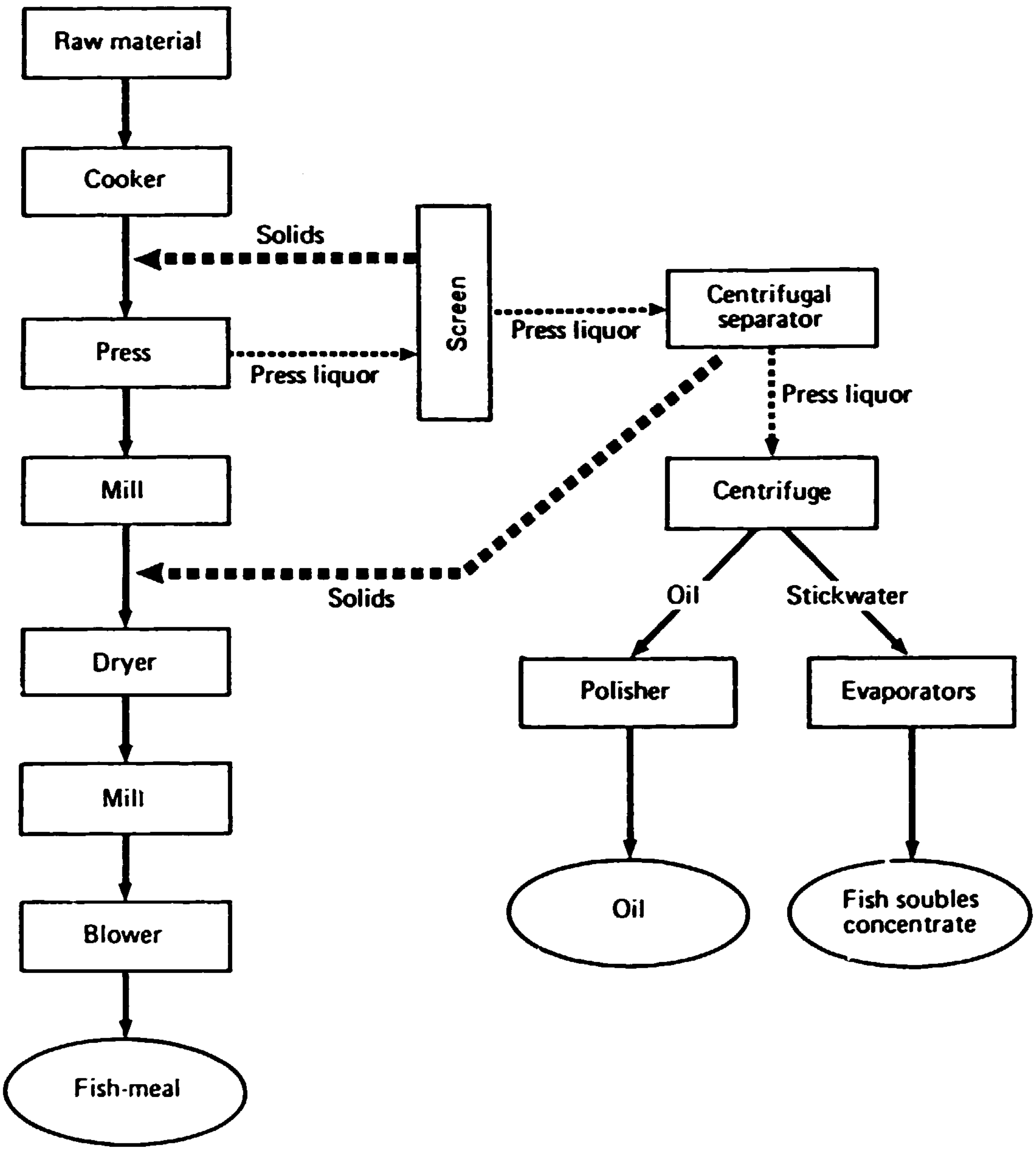
In the production of fish meal the trash fish, waste from marine finfish plants and bloodwater are first put into a continuous cooker. After being cooked the entire mass is transferred to a screw press. This press separates the solid part of the cooked material from the liquid. The solid part is called the press cake. This press cake is dried, ground, and bagged as fish meal. In order to facilitate drying, the press cake is often first milled. Drying is done in forced-draft, gas fired dryers. After drying, the press cake is again milled and then blown to cool it. A schematic drawing of the fish meal production process is given in figure 3.1. The drying of the press cake results in highly objectionable odors. As a consequence many plants have installed salt water scrubbers to reduce these odors. The scrubbers are one of the two sources of wastewater from fish meal processing plants which recover their bloodwater.

The liquid that is generated by the screw press is called press liquid. It consists of oil and water mixed with both dissolved and suspended solids. This press liquid is first screened to remove the solids. These solids are combined with the press cake during the drying process (see figure 3.1). The remaining liquid contains dissolved fish protein, ash, fats and oil. It is pumped to storage tanks, heated, and then goes to a centrifuge where the oil is separated out. This oil is generally washed prior to being sold. The liquid that remains after the oil has been separated out is called stickwater. In general stickwater is any water that has been in close contact with fish and has drawn large amounts of organic compounds into itself. This is most frequently the result of a cooking operation. As with bloodwater, in developing countries this stickwater is most frequently discarded. And as with bloodwater, the stickwater has high levels of BOD_5 and suspended solids. The average BOD_5 is stickwater is 115,990 mg/l. Its average suspended solids load is 9,310 mg/l.[13/] The fact that fish meal plants in developing countries tend to discharge both their bloodwater and their stickwater has been cited as

---

13/ Ibid., p. 10.

Figure 3.1 Fish meal processing by the wet method



Source: Naomi Peña, UNIDO consultant.

one of the reasons for encouraging the production of fish silage rather than fish meal in these countries.[14] In developed countries, or where fish meal plants are larger and can afford sophisticated equipment, the stickwater is recovered. It is heated and then evaporated in triple effect evaporators. The resulting concentrate is either sold separately as fish solubles concentrate or it is combined with the press cake to improve the press cake's nutritional value. The triple effect evaporators are the second source of wastewater from a fish meal plant that practices recovery of bloodwater and stickwater. Wastewater sources from fish meal plants can be summarized as follows:

Plants practicing recovery of bloodwater and stickwater	Plants not practicing recovery of bloodwater and stickwater
Scrubbers	Storage bins (bloodwater)
Evaporators	Pump-out of bins
	Scrubbers
	Centrifuges (stickwater)
	General clean-up

Table 3.10 gives wastewater characteristics for a fish meal plant which practices recovery of bloodwater and stickwater.

Table 3.10 Fish meal plant which practices bloodwater and stickwater recovery, wastewater characteristics

Parameter	Value
Wastewater flow	35.000 l/mt
BOD_5	2.96 kg/mt
SS	0.92 kg/mt
Oils and grease	0.56 kg/mt

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 225.

14/ Ibid., p. 7.

4. SOURCES AND CHARACTERISTICS OF SOLID WASTES

Seafood processing wastes fall into two main classes, those from finfish and those from shellfish. Finfish wastes contain high concentrations of proteins. These are especially valuable from the point of view of human nutrition because they contain a full range of amino acids. Shellfish wastes contain relatively less protein, and the protein which is present does not contain the full range of amino acids necessary for good nutrition. One of the main materials of interest in shellfish wastes is chitin. Chitin serves as a binder in the shells and is primarily of interest as the raw material out of which chitosan is produced. Chitosan can best be described as a gum. Its primary use is as a flocculant in wastewater treatment systems. In spite of the differences in their composition, which are described in more detail in sections 4.1 and 4.2, both finfish and shellfish wastes are difficult to dispose of on land. The difficulty is a result of their high water content and the rapidity with which they spoil. The high water content, ranging from 60-90 per cent of their weight, makes transportation uneconomical except for very short distances.[15/] When the wastes spoil they give off foul odors and rapidly attract insects and vermin. Crab wastes, for example, spoil within five hours in warm climates.[16/] Rain accelerates the spoilage rate. Even when wastes are covered, gases produced by their decomposition can crack the soil and allow odors to spread. These difficulties with land disposal are sufficiently troublesome so that where dumping into a water body is not acceptable, utilization options should be explored.

There are three major sources of solid wastes in the seafood processing industry: spoilage by-catch, and wastes generated during processing. Spoilage rates are particularly high in developing countries where boats and processing plants may lack adequate refrigeration equipment. In addition many developing countries lie in the tropics or sub-tropics where warm climates accelerate spoilage. Little can be done to reduce this source of waste other than increasing access to refrigeration equipment. Wastes from both by-catch and processing, on the other hand, can potentially be converted into either food for humans or animal feeds. In particular, the possibility of converting by-catch fish into minces, from which a number of products can be manufactured, holds promise as an economically attractive way to utilize a major source of waste in the seafood processing industry.

By-catch waste has attracted attention in part because of the sheer volume of material available. It has been estimated that several million tons of by-catch, primarily from tropical and sub-tropical waters, result from shrimp harvesting operations alone.[17/] Table 4.1 below presents estimated annual by-catch from shrimp harvesting operations in selected regions.

15/ Swanson, G.R., E.G. Dudley and K.J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W.M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-327.

16/ Brooks, Clayton, "A Historical Perspective", Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982. Report No. UM-SG-MAP-81-03, pp. 6-10.

17/ United Nations Food and Agriculture Organization, Minced Fish Technology: A Review, Rome, 1981, FIIU/T216, p. 4.

Table 4.1 Estimated shrimp-related by-catch, selected regions

Region	Estimated tonnage
South Atlantic	37,000
Gulf of Mexico	562,000
Gulf of California	160,000
Guyana Coastal Waters	80,000
Indonesia (Java Sea and Arafuru Sea)	227,000

Sources: United States Food and Agriculture Organization, Strategy for Shrimp By-Catch Utilization, Rome, 1982, FIIU/C745, pp. 1-2.
Kompiang, I. Putu, "Utilization of Trash Fish and Fish Wastes in Indonesia (as Animal Feeds), in Food and Nutrition Bulletin, United Nations University, Tokyo, 1983, pp. 131-137.

The characteristics of shrimp-related by-catch vary from region to region. From the point of view of mince production the primary characteristics of interest are size of fish, proportion of fish of commercially valuable species, proportion of fatty fish, whether or not toxic varieties are present, and whether species diversity is low or high. In the Gulf of Mexico and in Guyanan coastal waters, for instance, a good proportion of the by-catch consists of fish of commercial size and species. By-catches with these characteristics lend themselves to being sorted. The commercial species can be retrieved and manufactured into frozen minced fish blocks. In the Gulf of California, on the other hand, by-catches consist of very small fish, very few of which belong to commercially valuable species. However, species diversity is low, with 74 per cent of the fish belonging to one of eight species, and very few fatty fish are present.18/ Both fatty fish and a wide variety of species cause problems in the manufacture of minces. The fact that Gulf of California by-catches are free from these two problems has encouraged investigators to try to solve the problems posed by the one negative characteristic - small size. Efforts of this sort, attempts to adapt mince technologies to the specific characteristics of by-catches in the developing world, are underway in Mexico, Guyana, India, Thailand and Indonesia.

18/ Ibid., p. 4.

The last source of solid waste in the seafood processing industry is the preparation of fish for sale. During processing edible as well as inedible materials are discarded. Scales, tails and fins, viscera, heads, bones and shells, as well as considerable amounts of flesh which remain attached to the bones and shells contribute to the solid waste. Except in the case of large tuna and salmon processing plants, where wastes from preparation of human food are used in producing pet foods and fish meal, the proportion of the raw fish which ends up as waste is high. Table 4.2 below gives the per cent fish which ends up as waste for major seafood categories.

Table 4.2 Solid waste as per cent of raw weight

Finfish - marine and freshwater	55-75
Crabs	50-60
Shrimp	65-85
Clams and oysters	82-90

Source: Swanson, G.R., E.G. Dudley and K.J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W.M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-283.

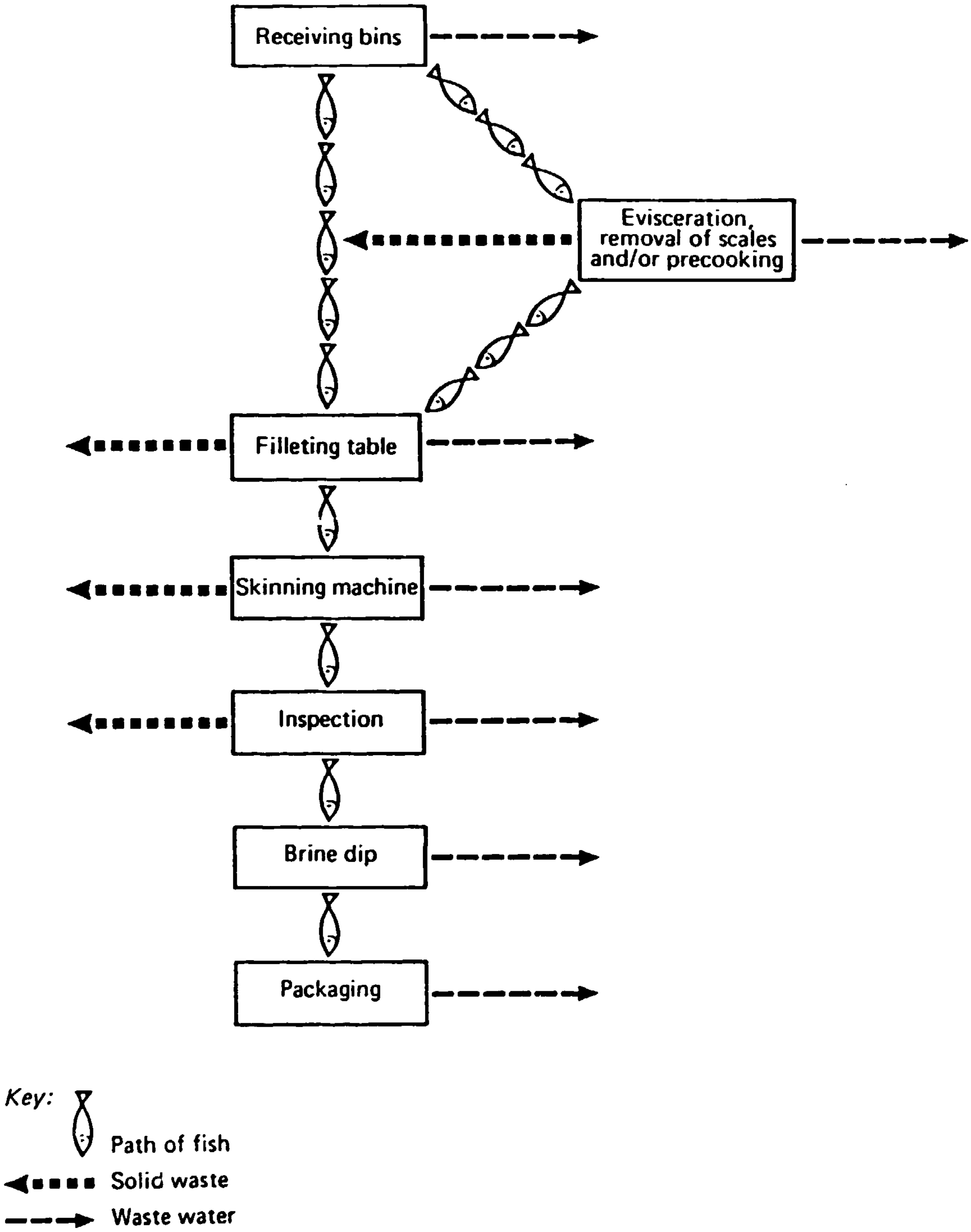
Further details of the sources of waste during processing are given in sections 4.1 and 4.2. These sections also provide diagrams showing typical processing operations for major seafood categories. The diagrams are designed to show at a glance which individual steps contribute to the solid waste load.

4.1 Solid wastes from finfish processing

Figure 4.1 illustrates a typical finfish processing operation. As can be seen, the first sources of solid waste are the preparatory steps: precooking evisceration, and the removal of scales where this is necessary. In some cases fish are eviscerated and/or beheaded at sea rather than at the processing plant. This is generally done, for example, with halibut. After the preparatory steps, if any, the fish are moved to the filleting tables. Here fillets are removed from both sides of the fish. What is left over - bones, head and tail, and considerable amounts of flesh which remain attached to the bones - is referred to as offal and is ordinarily discarded. If a mincing operation is undertaken, somewhere between a quarter and a half of the flesh remaining attached to the bones can be recovered.19/ The other two steps which, in a typical finfish processing plant, generate solid waste are the removal of the skins and final inspection. During inspection remaining bits of undesirable materials, such as bones, viscera, or connective tissues, are removed and flesh which is spoiled or damaged eliminated.

19/ Green, John H. and Joseph F. Mattick, "Possible Methods for the Utilization or Disposal of Fishery Solid Wastes", Journal of Food Quality (USA), 1977, pp. 229-251.

Figure 4.1 Schematic of groundfish processing



Source: Adapted from Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979.

While most finfish operations follow the series of steps shown in figure 4.1, a few variations or exceptions should be noted. The most obvious exceptions are large, integrated tuna or salmon operations. Here virtually all solid wastes generated in the preparation of human food are recovered for use either in the manufacture of pet foods or as inputs into fish meal. An integrated tuna or salmon operation generates, in effect, no solid waste. With fish such as sardines, where the product is canned, the packing of the fish into the cans creates a solid waste stream. Once sardines are packed they are given an initial cook to remove undesirable oils. These oils, plus residues of whatever oils or sauces are used to replace the cooked-out oils, can also be considered a "solid-waste". Finally, in some cases, an initial sorting of fish occurs prior to removal of the fish from the holding tank. Where this is done, as is almost always the case with catfish, the holding tanks themselves are a source of solid waste.

The most important aspects of finfish wastes, from the point of view of both disposal and recycling, are the water content, the fats, the proteins and the minerals present. The water content is primarily a problem where land disposal of wastes is contemplated. The fats pose problems both for disposal, whether in water or on land, and for many recycling options. The fats present in fish are predominantly long chain, polyunsaturated fatty acids. These fats are desirable from the point of view of nutrition but they tend to oxidize rapidly. It is this rapid oxidation, creating spoilage, that causes problems in land disposal. If fat levels are high, as they are in many species, including menhaden, anchovies and sardines, disposal of wastes in water can lead to the formation of films or grease patches. High fat contents are also undesirable in minces, fish silages and fish meals intended for human consumption.

The desirable substances in finfish wastes are the proteins, vitamins, minerals and trace elements present. The protein content of fish wastes is almost as high as the protein content of the portion used for food. With the exception of tuna, which contains 25 per cent protein, a typical fish fillet contains 16-20 per cent protein. Fish wastes contains 10-15 per cent protein. When the water has been removed, i.e. on a dry basis, fish contain 30-65 per cent protein, 6-10 per cent protein-nitrogen, 4 per cent phosphate (P_2O_5) and 1 per cent potash (K_2O). A wide variety of other minerals and trace elements is also present. The protein in fish wastes accounts for the interest in recycling these wastes for use as food for humans and feed for animals. The nitrogen-phosphate-potash combination is the basis for use of fish wastes as fertilizer. Dry fish wastes are equivalent to a 8:4:1 (N:P:K) fertilizer. Raw fish wastes are equivalent to a 2:1:0 fertilizer.[20/]

4.2 Solid wastes from shellfish processing

The bulk of the waste generated by shellfish processing consists of the shells themselves. It is this preponderance of shells in the wastes which accounts for the relatively lower per cent of protein content of shellfish as

---

20/ Swanson, G.R., E.G. Dudley and K.J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W.M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-327.

compared to finfish wastes. Since meals from fish wastes are valued according to the per cent of protein present, meals from shellfish wastes do not command prices as high as those received for finfish-based meals. This, along with the extremely rapid decomposition rates, the difficufties in dewatering, and the fact that shellfish processors are if anything even smaller than finfish processors, explains why shelifish wastes are even less frequently rendered into meal than finfish wastes.

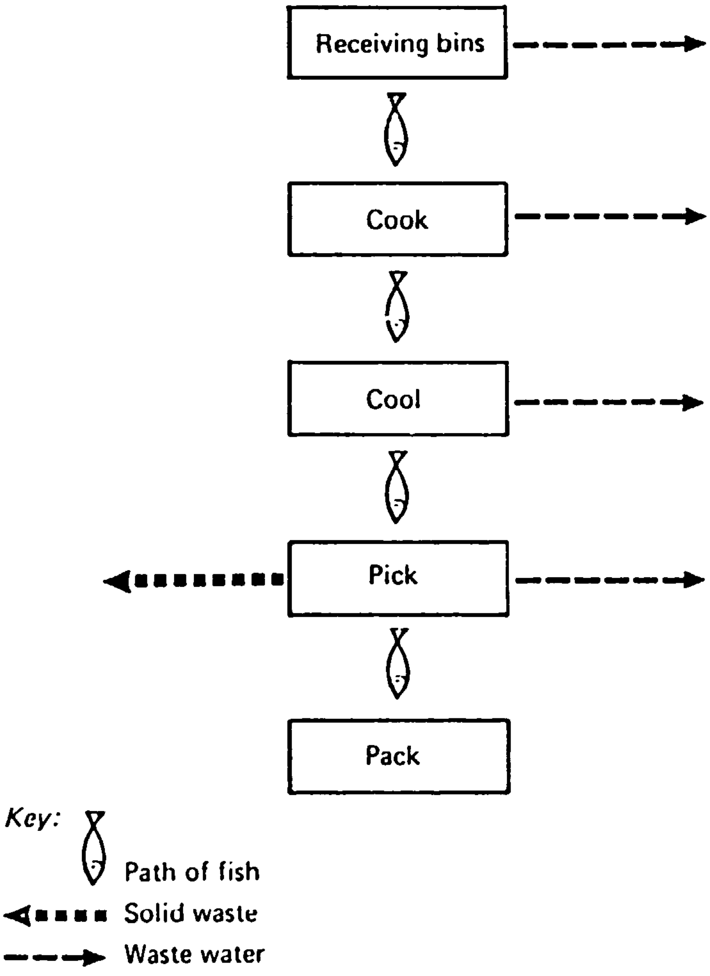
Shellfish wastes fall into two major categories, wastes from crustaceans such as crabs and shrimp, and wastes from mollusks such as oysters and clams. The exoskeletons of crustacea contain 25-45 per cent protein, 15-24 per cent chitin and 40-50 per cent calcium carbonate. It is the chitin content of these wastes that has generated considerable interest in recycling possibilities. The use of chitin-derived chitosan in wastewater treatment has received the most attention, but chitosan's potential uses include many others: to make moisture-proof films and coatings, for sizing paper and textiles, as an additive in oil well drilling mixtures, as a thickening agent, and in pharmaceuticals. At present the chitin content of crustacean shells is exploited only in Japan where it is used extensively in treatment of wastewater, polluted waters and sludges. However, work on extraction and application of chitosan continues and crustacean wastes may prove to be a valuable resource for other countries as well.

4.2.1 Crustacean wastes

Typical plant operations for blue crabs are shown in figure 4.2. As can be seen blue crabs are cooked immediately upon arrival at the plant. The meat is then cooled and removed from the shells. The removal of the meat, called picking in the case of crabs, is the only step in blue crab processing in which solid wastes are generated. The solid waste consists of legs, claws, shells and the attached meat. In the case of other crab species, such as Dungeness, Tanner and King, the process is similar except that the crabs are butchered prior to being cooked. The butchering results in viscera and gills being contributed to the waste stream. Tanner, Dungeness and King crabs are also subject to an inspection after picking where unacceptable meat is discarded. If the crab meat is canned, solid wastes, bits of meat, enter the waste stream at the canning stage.

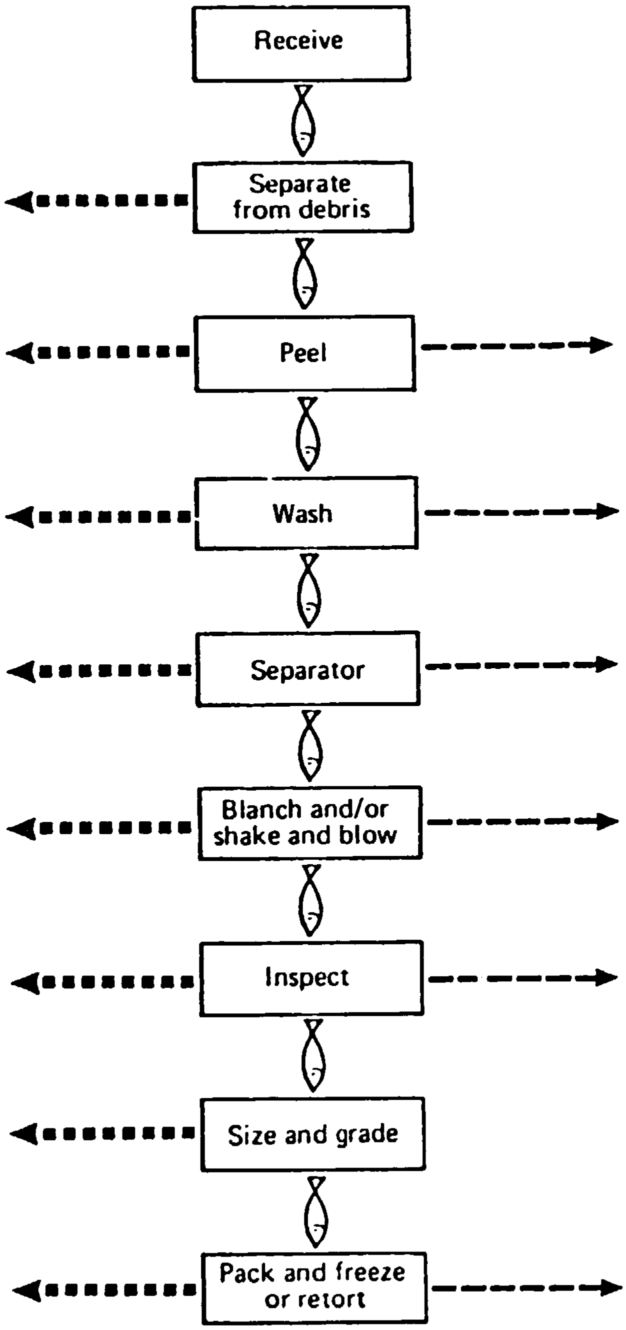
Figure 4.3 presents a general picture of the sequence of steps in a shrimp processing plant. Details vary considerably depending on location, on whether the shrimp is to be frozen or canned, and on whether or not the shrimp is breaded. As can be seen from figure 4.3, solid waste is generated at a large number of points in the process. In the first step the waste consists of trash fish and debris netted along with the shrimp. At the next step - peeling - heads and tails are removed along with the shell. Further pieces of shell are removed in the next series of steps; washing, the separator, shaking and blowing. Blanching may or may not result in pieces of meat entering the waste stream. The final steps - inspection, sizing and grading, and packing - contribute pieces of meat to the waste stream. If the shrimp are frozen rather than canned the packing does not contribute to the solid waste stream. In some cases, in addition to the steps shown in figure 4.3, the shrimp are deveined. If so, deveining generates solid waste. Finally, if the shrimp are breaded, residue from the breading process, i.e. unused batter or batter ingredients, add to the solid waste.

Figure 4.2 Blue crab processing schematic



Source: Adapted from Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979.

Figure 4.3 Shrimp processing schematic



Source: Adapted from Middlebrooks, E. Joe, Industrial Pollution Contrcl, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979.

Table 4.3 summarizes the contents of shrimp and crab wastes. These wastes consist of exoskeletons (shells), meat remaining on shells, heads, tails, and other inedible parts.

Table 4.3 Shrimp and crab wastes, dry basis (percentage)

	Crab	Shrimp
Protein	11-42	11-42
Chitin	9-42	9-42
Calcium cabornate	36-58	36-58
Nitrogen[a/]	4.4-7.3	5.4-7.9
Phosphorous[a/]	0.6-1.8	2.1-2.9
Potassium[a/]	0.4-1.3	1.6
Sulfur	0.5	0.3
Magnesium	0.9	0.8

a/ The fertilizer equivalent of the nitrogen-phosphorous-potassium combination present in the waste is 6:4:1 (N:P:K).

Source: Swanson, G.R., E.G. Dudley and K.J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W.M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-327.

In addition to the substances listed in table 4.3, shrimp wastes contain significant amounts of carotenoid pigments and cholesterol. Carotenoid pigments are red or yellow pigments related to the compound carotene ($C_{40}H_{56}$). These pigments are of interest because, when used as part of the feed, they can enhance the flesh colour of pond raised salmon, trout, shrimp and prawns, as well as the colour of a variety of species raised as pets. Good colour is important because fish with good colour command higher prices. Carotenoid pigments are also found in significant concentrations in red crab and crawfish wastes.

The carotenoid pigments present in shrimp wastes will gain importance as increasing proportions of the world harvest of salmon, trout and shrimp come from aquaculture operations rather than from fishing of oceans or rivers. As of 1975 it was estimated that 80 per cent of the world's aquaculture harvest came from the Indo-Pacific region. At that time the harvest from aquaculture was believed to be some six million tons, with the People's Republic of China being the lead producer.21/

Shrimp culture operations are of particular interest in many developing countries. In addition to the considerable shrimp raising industries in Southeast Asia, a number of Latin American countries are becoming active in the field. For these, and other countries which may be interested in shrimp raising operations, the value of shrimp wastes should be particularly noted. In addition to the carotenoid pigments, shrimp wastes are valuable for shrimp culture because of the cholesterol present and because the wastes act as stimulants for feeding. Cholesterol has been shown to be necessary for some shrimp to molt. Although the specific substances have not been identified, it is known that feeds which do not include shrimp wastes often fail to stimulate feeding behaviour in pond raised shrimp. The inclusion of shrimp wastes in shrimp feeds stimulates feeding, accelerates growth rates and results in larger shrimp.

4.2.2 Mollusk wastes

Clam processing is shown in figure 4.4. The primary wastes in clam processing are the shell and the belly. The belly constitutes 7-10 per cent of the weight of the clam. Since the shell can constitute up to 90 per cent of the weight of the clam, the solid waste in clam processing is many times the weight and volume of the product. In addition to the shell and belly, sand and grit are discharged during processing. Although only three washing steps are shown in figure 4.4, clam processing can include several more washes in an attempt to eliminate all the sand and grit. This sand and grit becomes embedded in the clams when they are dredged, and often becomes embedded in the flesh itself.

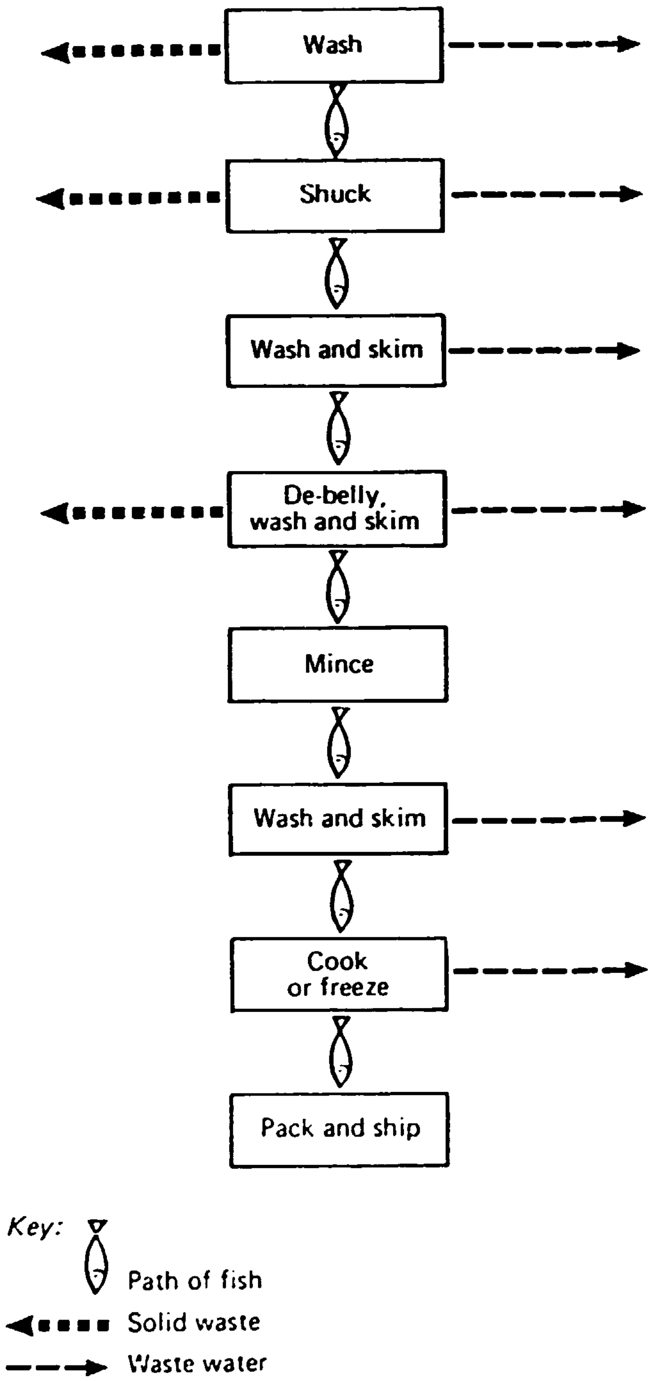
Both clam and oyster wastes are primarily of interest due to the calcium carbonate present in the shells. Oyster shells represent 75 per cent of the total weight of the oyster, and clam shells usually constitute some 65-80 per cent of the clam's weight.22/ Calcium carbonate is the substance from which lime is obtained. Consequently clam and oyster shells can be used in most applications where lime is desired: for soil conditioning, the neutralization of acid wastes, and in the manufacture of cement. The calcium carbonate is also of interest in poultry feeds where it is used for its calcium content. The only other substance of interest in these wastes is laminarinase, an enzyme found in clam wastes which can be used to split polysaccharides.

Unlike other seafood processing wastes, clam and oyster shells can create problems due to their extreme durability. This durability can be taken advantage of in applications such as the use of mollusk shells for landfill or as a roadbed material. If, however, these shells are dumped in one location, over a number of years piles of considerable size will build up. If these piles accumulate in navigible waters they can block channels and create hazards for ships.

21/ Meyers, Samuel P., "Utilization of Shrimp Processing Wastes in Diets for Fish and Crustacea", Florida Sea grant College, Report No. 40, 1981, pp. 261-274.

22/ Ibid., p. 290 and Katsuyama, Allen M., A Guide for Waste Management in the Food Processing Industry, The Food Processors Institute, Washington, D.C., 1979, p. 218.

Figure 4.4 Clam processing schematic



Source: Adapted from Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979.

5. SOLID WASTE REDUCTION: BY-PRODUCT AND RECYCLING POSSIBILITIES

Wastes from seafood processing are inherently valuable. They can be used to produce a wide range of products which may be considered to fall into four general categories: food for human consumption, feeds for animals, fertilizers or soil conditioners, and chemicals. A few specialty uses such as pearl essence, a decorative material, or isinglass, which is used to filter wine, fall outside of these categories, but such uses are not of major significance. The limitations on waste recycling are primarily of an economic nature, although in some cases existing technologies may be too sophisticated for practical application. The only product which has a well established market, a proven technology, and can use virtually all wastes is fish meal. Unfortunately the production of fish meal is impractical for most seafood processors. To be economical, a fish meal processing plant must have a capacity of approximately ten tons per day.23/ Very few seafood processors are large enough, or located in sufficient proximity to other processors to support a facility of this size. Consequently most seafood processors will have to turn to other options if they want to recycle wastes. In most cases the viability of these other options is determined by market conditions. While the products are useful, there may be no local markets for them and shipping costs generally prohibit taking advantge of more distant markets. Alternatively, local markets may exist but competition from other, lower cost products which can fulfill the same purpose may render recycling financially unattractive. The remainder of this chapter discusses the major products in each of the four categories listed above. Emphasis is on applications which are of particular interest to developing countries. Table 5.1 lists the most common recycling options classified by the type of waste from which they are made, rather than according to the major "end product" categories.

5.1 Food for human consumption

The utilization of seafood wastes for food for human consumption is the most valuable of the recycling options. It is the most valuable because the price, per kilogram of waste converted, which food products can command is higher than the price which animal feeds or fertilizers can command. It is also the most valuable option in terms of meeting developing world problems of malnutrition and undernourishment. The two recycling-for-food options which have the potential for absorbing large portions of waste are minces and fish protein concentrate. These, along with some minor waste utilization options, are discussed in the following three subsections.

5.1.1 Minces

The most promising method for waste utilization in the seafood processing industry is the manufacture of minces and mince-based products. Minced fish is fish flesh that has been separated from the inedible portions of the fish. Although the technology involved in making mince is still in need of improvement, and although there is a need for further development of end products, minces must be considered the foremost recycling option for the developing world for a number or reasons.

23/ Carter, P.M., et.al., Recent Developments in the Utilization of Meat and Fish Wastes in the Tropics, Tropical Development and Research Institute, London, p. 3.

Table 5.1 Commonly reported uses for solid wastes

FINFISH	
Whole fish or any part of fish	Fish Protein Concentrate (FPC) Fish meal Fish silage Fish pellets or flakes Bait Fertilizer
Flesh and/or organs	Mince Pet foods Mink feed Insulin Isinglass (used as filter to clarify wine)
Oil	Vitamins Margarine or cooking oil Paints or protective coverings Mushroom culture
Skin	Glue
Scales	Pearl essence Flocculant
SHRIMP AND CRABS	Flavoring Shrimp or crab meal Fertilizers Fish pellets or flakes Carotenoid pigments
CLAMS AND OYSTERS	Lime (soil conditioning, concrete, or neutralization of acid wastes) Roadbed or landfill material Poultry and hog feeds Oyster bed maintenance Bait Chitosan (used for wastewater treatment) Laminarinase (enzyme used to split polysaccharides)

Sources: Green, John H. and Joseph F. Mattick, "Possible Methods for the Utilization or Disposal of Fishery Solid Wastes", Journal of Food Quality (USA), 1977, pp. 229-251. Hood, L.F. and R.R. Zall, "Recovery, Utilization and Treatment of Seafood Processing Wastes", Advances in Fish Science and Technology, Department of Food Science, Cornell University, Ithaca, New York, 1980, pp. 355-361. Katsuyama, Allen M., A Guide for Waste Management in the Food Processing Industry, the Food Processor Institute, Washington, D.C., 1979. Meyers, Samuel P., "Utilization of Shrimp Processing Wastes In Diets for Fish and Crustacea", Florida Sea Grant College, Report No. 40, 1981, pp. 261-274. Swanson, G.R., E.G. Dudley and K.J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W.M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-322. United States Environmental Protection Agency, Environmental Assessment of Alternative Seafood Waste Disposal Methods at Akutan Harbor, Alaska, Seattle, WA, 1984, EPA/910/9-83-115.

(a) No other recycling option holds as great a potential for being able to command high enough prices to make it worthwhile for fishermen to land by-catches in good condition. The possibility of being able to use, for human food, the vast resource which by-catches represent, is almost enough in itself to put mince at the top of the list of options which should be considered by developing countries.

(b) Minces are already being produced and sold both in the west and, primarily in Japan, in the east. Thus there is a proven market for minces and mince products.

(c) Improvements in mince technology and mince product development are being actively pursued in the developed world. This is extremely important since it means that the developing world can take advantage of the research capabilities of the United States, Europe and Japan. Although most of the work in the developed world focuses on flesh obtained from commercial species rather than on by-catch utilization, some of the research results should prove valuable to developing country efforts.

(d) It is too soon to say what the minimum economic plant size for mince production will be. However, the possibility of utilizing by-catch means that many processors which might not otherwise be able to take advantage of any recycling option, may find it possible to recover a sizeable portion of their wastes.

Mince is usually produced by physically screening the flesh from the non-flesh components. Mincing has traditionally been used either on whole fish which have had their heads and guts removed or on the flesh remaining attached to bones after the filleting operation. In the past equipment used in meat and fruit processing was adapted and used in the seafood processing industry. Recently machines especially designed for fish flesh separation have become available. In these machines a belt moves against a perforated drum or cylinder. Two cylinders, one of which rotates, or a screw feed and cylinder can also be used. The flesh is in effect scraped or torn from the bones and forced through the perforations. Depending on speed, pressure, and hole sizes, the resulting mince can range from a powdery consistency to a coarse mince consisting of small flesh particles.

Chemical and biochemical means for separating the flesh are also under development. Of particular interest for the developing world are techniques which can be applied to fish which have not been eviscerated. Such techniques are of interest because, in many cases, by-catch fish are so small that evisceration by hand is difficult. In Norway mince has been prepared from sardines which have not been eviscerated. The sardines are cut into pieces of 1-2 centimeters and mixed with an equal weight of water. They are then washed with acetic or propionic acid. This breaks down the skin, viscera, membranes, and other tissues which contain fats. These substances can then be removed by decanting the mixture. The flesh can be removed from the bones by spraying with pressurized water. Finally the water is removed from the flesh by pressing it through a filter. The yield form this process compares favorably with yields from traditional mechanical methods.[24/]

24/ United Nations Food and Agriculture Organsization, Minced Fish Technology: A Review, Rome, 1981, FIIU/T216, p. 13.

The main difficulty in mince production is achievement of a mince of good quality and desirable characteristics. The precise characteristics desired in a mince depend on the end product or products for which it will be used. In general terms the characteristics of interest are appearance, including colour, texture, the ease with which the mince forms gels, its ability to combine with water, how it reacts when heated, and the extent to which the fats and proteins have decomposed. Problems in manufacturing a mince of the desired qualities are traceable to preprocessing, processing and storage. A brief discussion of some of these problems is presented in the next five paragraphs. Further information on sources of problems is given in table 5.2.

The most pervasive problem stemming from preprocessing conditions is spoilage. Unfortunately spoilage problems are more of an obstacle in the developing world than elsewhere. Spoilage is caused both by the decomposition of the polyunsaturated fats characteristics of all fish and by bacterial contamination. In the developed countries most mince is produced from commercially valuable species which tend to have relatively low levels of fats thereby minimizing problems of fat deterioration. In the developing world mince technology is primarily of interest as a means of utilizing by-catch species. Many by-catch species have very high fat levels and at present there are no really satisfactory solutions to the problems presented for mince production by high initial fat levels.

Spoilage due to bacterial contamination is also more of a problem in the developing world than in developing countries. Prevention of bacterial spoilage depends on keeping the fish cold prior to processing. As mentioned earlier, much of the developing world lies in warm climatic zones and refrigeration equipment is often lacking or inadequate. This problem is fortunately at least in principle soluble. Given sufficient economic justification refrigeration equipment can be purchased and electricity generated.

Bacterial spoilage and high initial fat levels are the primary problems attributable to the preprocessing stage Aside from such preprocessing or initial conditions of the fish, the processing technologies have the greatest impact on final mince characteristics. The processing technologies can be divided into those employed prior to separation of the flesh, the technology used to achieve the separation, and the post separation technologies. It has been discovered that pre-separation procedures have if anything a greater impact on final mince quality than the separation technology itself. As a consequence machines are being developed to control and improve handling of the fish prior to mincing. Examples include machines to cut out the spinal cord and belly membranes and machines to feed the fish into the separator so that the skin is kept away from the screen through which the flesh is pressed. Such devices help eliminate the contaminants which are responsible for decomposition of both proteins and fats.

As far as the separation procedure itself is concerned, the sizes of the perforations, the amount of pressure with which the flesh is pressed against the screen, and the speed with which the fish are moved across the screen are the principal determinants of mince characteristics. Smaller holes and slower speeds result in minces of finer textures. Faster speeds which create greater shear rates can lead to a reduction in the mince's ability to bind water and

Table 5.2 Sources of problems in production of mince

1. Raw materials	Improper storage prior to processing increases bacterial counts. Elevated bacterial levels, aggravated by the dispersal of the bacteria throughout the mince during processing, increases the risk of spoilage occuring.
	Many of the species used for mince contain high levels of parasites. Most of the parasites in marine fish are not harmful. They are, however, aesthetically unacceptable.
	Species which contain trimethylamine oxide (TMAO) - cod, hade, haddock, pollock and croaker - cannot be used in nitrate-cured products.
2. Bones	Fragments of sufficient size to be visible or cause internal injury render the mince unacceptable.
	Bone particles of small size can lead to gritty textures and taste sensations.
3. Proteins	Almost all species are vulnerable to protein breakdown due to the mixing of enzymes from the gut into the flesh. Such mixing and breakdown is most prevalent if fish from which the guts have not been removed are minced. However, if even small amounts of gut materials become incorporated into the mince extensive protein degradation can occur.
	Protein degradation results in a product which is tough and has a grainy consistency. It also results in a decreased ability of the mince to form gels and to bind water.
	The species which contain trimethylamine oxide are subject to protein degradation during frozen storage.
4. Fats	The polyunsaturated fats present in fish of almost all species predisposes minces to problems of spoilage and poor flavours.
	The mincing process disperses enzymes active in the decomposition of fats, increases the amount of surface area exposed to air, and spreads fat-degradation catalysts found in the blood throughout the mince. All of these accelerate the process of fat decomposition.
5. Colour	The mincing process often results in a product of darker colour than the raw material. In many countries a light colour is preferred and is necessary for marketing success.

Source: United Nation Food and Agriculture Organsization, Minced Fish Technology - A Review, Rome 1981, FIIU/T216.

to an increase in the mince's "rubberiness". While these qualities are ordinarily undesirable, in some applications like the manufacture of kamaboko, a Japanese fish sausage, the rubberiness is required in order to give the final product its desired elasticity. In mechanical separation all equipment that comes in contact with the fish must be made of stainless steel or non-metallic materials. Otherwise the mince is subject to ferric ion contamination which greatly accelerates fat decomposition.

Post separation technologies include a wide variety of techniques and additives which have been tried to prevent or rectify problems caused by preprocessing characteristics and separation technologies. Information on some of these is presented in table 5.3. In general, the technologies focus on improving colour and on rectifying or preventing problems caused by the decomposition of fats and proteins. The usefulness of particular procedures depends on the species being processed and on the final products into which the mince will be made.

Problems in the storage of minces are due to the fact that both proteins and fats continue to decompose. Most minces are frozen and some fish species are particularly susceptible to protein decomposition when frozen. For the developing world both canning and drying should be considered as afternatives to frozen storage. Canning is an effective way to reduce fat deterioration. Any other oxygen impermeable packaging will accomplish the same goal, as will glazing of the mince. The most common form of drying mince is with salt. The salt can be incorporated and dispersed through the mince during the separation stage. Minces which contain 20 per cent salt and whose moisture content has been reduced to 15 per cent are safe from microbial spoilage. Antioxidants and/or air and moisture-proof packaging are however still necessary to inhibit deterioration of fats.

Minces can be used to manufacture a wide variety of products. Some of the most important of these are listed in table 5.4. Many of the products listed in table 5.4 are marketed in different forms in different countries. Thus, there are fish balls designed for the Scandinavian market and fish balls of the types eaten in southeast Asia. Further, many of the products can be made either from whole fillets or from minced materials. It is generally believed that products made from whole fillets are preferred to those made from mince. Experiments have shown that this is not always the case. "Prawn" or "scampi" made from finfish mince and then flavored with shellfish extracts cannot be distinguished from the real thing even by experts. Further, although adults, for example, prefer fish fingers made from fillets, children actually prefer fish fingers made from mince.[25]

25/ Key, J.N., "Aspects of Optimal Utilization of the Food Fish Resource through Product Innovation", Advances in Fish Science and Technology, Torry Research Station, Aberdeen, UK, 1980, pp. 275-278.

Table 5.3 Techniques for improving mince characteristics

1. Washing	Once the flesh has been separated from the bone it is often washed. This removes inorganic salts, water-soluble proteins, pigments, visceral contaminants, and bacteria. In some cases it also helps remove fats. Washing improves the texture of products made from fine minces but has little effect on coarse minces or on minces made from high quality raw materials. Since washing can also have undesirable effects it should only be undertaken if necessary. Undesirable effects include losses of proteins, vitamins and minerals. It is also difficult to control the final water content of washed minces.
2. Additives	Shrimp, soy and some cereal products as well as a wide range of chemical antioxidants can be added to inhibit decomposition of fats. Soy protein and polyphosphates can be used to improve the ability of minces to combine with water. A wide variety of substances that preserve foods at low temperatures are utilized to reduce protein deterioration. Proteases, ensymes active in the breakdown of proteins, can be used to reduce toughness.
3. Acid and alkaline treatments	Alkaline treatment in the presence of certain salts stabilizes proteins during freezing. Alkaline treatment is also used to increase the ability of minces to form gels and combine with water. Alkaline washes can improve colour. Acid washes are used to facilitate the removal of blood, skin and visceral pigments.
4. Reformation	The object of reforming is to try to recreate the texture of whole fillets, including their flakiness. Small amounts of soluble alginates are incorporated into the mince. The mixture is then spread in layers of the desired thickness. The layers are gelled by adding calcium ions. They are then washed to remove excess calcium salt, stacked, cut and frozen.
5. Packaging	Poor colour can be masked by incorporating minces into products such as meat sausages or smoked foods where a dark colour is expected.

Sources: United Nations Food and Agriculture Organization, Minced Fish Technology: A Review, Rome, 1981, FIIU/T216. Keay, J.N., "Aspects of Optimal Utilization of the Food Fish Resource through Product Innovation", Advances in Fish Science and Technology, Torry Research Station, Aberdeen, UK, 1980, pp. 275-278.

Table 5.4 Primary mince products

1.	Fish fingers or sticks
2.	Fish cakes or burgers
3.	Fish balls
4.	"Prawns" and "scampi"
5.	Smoked fish
6.	Extender in meat sausages
7.	Surimi[a/]
8.	Kamaboko

a/ Surimi is a semi-processed intermediate product. It has been used for centuries in Japan to make a wide range of products, including kamaboko. In the past it was made almost exclusively from Alaskan pollock. Recently attempts to make it from other fish have met with success.

Sources: Keay, J.N., "Aspects of Optimal Utilization of the Food Fish Resource through Product Innovation", Advances in Fish Science and Technology, Torry Research Station, Aberdeen, UK, 1980, pp. 275-278. United Nations Food and Agriculture Organization, Minced Fish Technology: A Review, Rome, 1981, FIIU/T216.

5.1.2 Fish protein concentrate B (FPC B)

Fish protein concentrates are basically fish meals of a flour-like consistency which are manufactured under strict hygienic standards and are designed for consumption by people. They are classified as either type A or type B. Type A concentrates are light coloured, bland and odorless. In order to achieve these characteristics most of the fat content of the fish must be eliminated. In the United States the maximum fat content of a concentrate designed for human consumption is 0.5 per cent. Since it is presently very expensive to reduce fat levels this far, concentrate of A is rarely manufactured. Type B concentrates have higher fat contents and, consequently, stronger tastes odors. A fat content of up to 10 per cent is acceptable in type B concentrates.

Since fish protein concentrates are manufactured essentially in the same manner as fish meal, as a means of waste utilization they are subject to the same major drawback as fish meal production. In order to be economical a production plant must be fairly large and large quantities of fish must be available virtually on a year round basis. Moreover, since the product is designed for human consumption only fresh fish or fresh offal can be used. The equipment must be made of stainless steel or other materials that can be easily cleaned and sterilized so that the hygienic standards required in food plants can be met. These considerations would eliminate fish protein concentrate as a waste utilization option worthy of serious attention were it not for several counterbalances.

Like mince, fish protein concentrate can be made from by-catch fish. Once again this means that locations which otherwise would not be in a position to support solid waste reduction measures might find a recycling plant attractive. While fish protein concentrate would not command as high a price as mince, a plant manufacturing concentrate might be able to pay fishermen adequately well for them to land by-catches. In 1980, fish protein concentrate B (FPC B) which was 70-75 per cent protein sold for $US 900 a ton.[26/] This makes FPC B one of the cheapest sources of animal protein available for human consumption. This price, the opportunity to take advantage of by-catches plus fish protein concentrate's potential for alleviating problems associated with malnutrition, particularly in children, are the powerful arguments in favour of giving fish protein concentrate a hearing.

The nutritional credentials of fish protein concentrate B are impressive. The protein in FPC B is rated higher or equal to the protein in milk or meat. FPC B is particularly rich in lysine and methionine which are the two amino acids most commonly found in only limited quantities in vegetable proteins. The high lysine content makes FPC B particularly valuable as a supplement in diets based on wheat since these diets are deficient in lysine. FPC B is also useful as a supplement to corn-based diets due to the presence of substantial amounts of niacin and vitamin B_{12}. Vitamin B_{12} is virtually absent from corn and the niacin that is present in corn can only be metabolized to a very limited extent. In addition to these nutrients, FPC B is rich in calcium, phosphorus and iron. Magnesium is also present.

The value of FPC B as a dietary supplement has been proven. It is particularly useful in treating children suffering from malnutrition. Swellings are rapidly reduced, hemoglobin levels increase and weight gain is accelerated. In one study for instance, children who received one teaspoon of FPC B six times a week for three months gained almost two and a half times as much weight as the children who did not receive the FPC B.[27/]

FPC B would no doubt be extensively produced and used as a dietary supplement or food additive were it not for some serious shortcomings. The main difficulties are that many people find the texture unpleasant, it is not soluble in water, and sometimes the "fishy" taste is too strong. FPC B itself is not at all "chewy" and it is often found to impart a feeling of grittiness. Since it is insoluble in water it is difficult to incorporate FPC B in many foods and dishes. In spite of these difficulties, limited testing indicates that FPC B can be accepted by the people of many developing nations. A summary of the acceptability of FPC B in selected developing nations is shown in table 5.5. The countries in which tests were carried out were ones in which dried fish products played an important role in the diet. It was felt that such countries would more easily adapt to FPC B, since dried fish is in many respects similar to FPC B.

26/ United Nations Food and Agriculture Organization, Report on the Marketing Study of Fish Protein Concentrate (FPC B), Rome, 1980, FAO TF/INT 268 (FH), p. 5.

27/ Ibid., p. 5.

Table 5.5 Acceptance of fish protein concentrate B in selected developing countries

Country	Good acceptance	Rejection	Results inconclusive
LATIN AMERICA			
Barbados	X		
Brazil			X
Dominican Republic			X
Haiti	X		
Jamaica	X		
Trinidad	X		
AFRICA			
Egypt		X	
Ghana	X		
Liberia	X		
Malawi			X
Mali	X		
Niger		X	
Senegal	X		
Southern Sudan	X		
Zaire	X		
ASIA			
India	X		
Indonesia		X	
Pakistan		X	
Philippines	X		
Sri Lanka	X		
Thailand	X		

Source: United Nations Food and Agriculture Organization, Report on the Marketing Study of Fish Protein Concentrate (FPC B), Rome, 1980, FAO TF/INT 268 (FH).

It is unlikely that FPC B will become a commercial product on any significant scale in the near future. In order for commercialization to be successful a breakthrough either in product development or in the character of FPC B itself, i.e. in the production technology, will be necessary. However, for any country that is seriously committed to using its by-catch resource to alleviate problems of malnutrition, and is willing to market FPC B through, for example, school nutrition programmes, FPC B represents a viable, worthwhile means of reducing waste.

5.1.3 Use of underutilized parts

To a limited extent solid waste can be reduced by making efforts to recover parts ordinarily discarded. Both with finfish and with shellfish the per cent of the flesh recovered depends on the efficiency of the workers or where the operations are mechanized, the machines. Good filleting and picking practices alone can significantly reduce the amount of solid waste. In the case of clams additional meat can be recovered by boiling whole shells or large shell pieces. The mantle is released from the shell after two minutes of boiling, and the adductor muscles can be removed by minor scraping after being cooked in a pressure cooker at 15 psi for 12 minutes at 121°C.28/ Similarly the mantles of scallops are usually discarded although they can be removed fairly easily. This recovered meat can be most easily used in products such as chowders. Finally, in some cases markets exist for fish eggs (roe), livers, and the male reproductive organs (milt). Recovery of such parts can contribute to plant income as well as help reduce waste.

5.2 Feed for animals

Seafood processing wastes are, with a few important exceptions, used as ingredients in animal feeds because they are a relatively inexpensive source of animal proteins. The exceptions are the use of oyster and clam shells in poultry feeds and the use of shrimp wastes for the carotenoid pigments. The most well established product which serves as an ingredient in animal feeds is fish meal. Fish meal is made either from whole fish caught especially for rendering into meal, primarily menhaden, or from waste fish parts, primarily wastes from tuna and salmon processing plants. In order to produce a fish meal of high quality in an economic manner it is necessary to use expensive equipment. This means that a sizable capital investment is required and the plant must be large and operate throughout the year to bo profitable. Since most seafood processors in developing countries are not in a position to meet these conditions, when they attempt to produce fish meal it is generally of a low and uneven quality. As a consequence it is generally suggested that seafood processors in developing countries produce fish silage instead of fish meal. Fish silage represents a more viable way for developing countries to produce an animal feed from fish wastes. Since it is, in effect, a substitute for fish meal, the two are discussed together in the following subsection. The use of fish wastes in fish feeds and for bait is discussed subsequently.

28/ Hood, L.F. and R.R. Zall, "Recovery, Utilization and Treatment of Seafood Pr cessing Wastes", Advances in Fish Science and Technology, Department of Food Science, Cornell University, Ithaca, New York, 1980, p. 358.

5.2.1 Fish silage and fish meal

When produced in the small cottage industries typical of the developing world, fish meal is made by steaming or boiling the waste fish and then pressing them. These operations are basically analogous to the operations performed in a large fish meal plant. The primary difference emerges in the drying procedures. The small operators do not have drying equipment. Therefore after being pressed the cakes of fish material are left to dry in the sun. During wet seasons or when humidity is high the cakes do not dry properly and their moisture content remains high. The high moisture content leads to the growth of molds and to spoilage.

Table 5.6 shows the content of fish meals made at plants of the type found in developed countries. In contrast to the values shown, samples taken in Indonesia from small cottage industries rarely had moisture contents under 13 per cent. In some cases moisture content was as high as 17 per cent. In addition protein content was rarely over 50 per cent.29/ The low protein content is undesirable since it is primarly for the protein content that fish meals are used in animal farms.

Table 5.6 Fish meal content, standard fish meal plant

Protein	55-70 per cent	Generally 60-65 per cent
Fats	5-10 per cent	8 per cent preferred
Water	6-10 per cent	8 per cent preferred
Ash	12-33 per cent	15-20 per cent preferred
Fiber	Less than 1 per cent	

Source: Swanson, G.R., E.G. Dudley and K.J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W.M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-237.

Fish silage is basically fish wastes that are liquified rather than dried. Properly prepared fish silage will keep without spoiling for at least three months even at warm temperatures (30°C). It may remain in good condition for as long as two years. In preparing fish silage the waste fish or fish parts are minced and mixed with water. The mixture is then either fermented by adding a carbohydrate such as molasses or the solids are liquified through the use of organic acids. The liquification process takes from five to ten days, occurring more quickly at higher temperatures. The only capital investment needed is for the containers in which the silage is prepared and stored. These containers must be acid resistant. Silage can be

29/ Kompiang, I. Putu, "Utilization of Trash Fish and Fish Wastes in Indonesia (as Animal Feeds)", in Food and Nutrition Bulletin, United Nations University, Tokyo, 1983, pp. 131-137.

produced in batches as small as 50 kilograms or in amounts as large as a ton or more a day. If large amounts are to be processed, mincing and mixing devices will also be required. Concrete tanks treated with bitumen can be used to store large quantities of silage.

The acids usually used to make silage are sulfuric, formic or propionic. They can be used either alone or in combination. Most investigators report that formic acid produces the best product. However, investigators in Indonesia found that poultry did better on fermented silage than on silage prepared with acids. In addition they found that it was necessary to use equal amounts of propionic and formic acid in order to prevent growth of molds and spoilage. In Indonesia the acids were used at the rate of 3 per cent (by weight).30/ Although satisfactory results have been reported using as little as 2.2 per cent acid, the United States Environmental Protection Agency recommends using acid at the rate of 3.5 per cent.31/

A fair amount of work has been done testing the use of silage in animal feeding regimes. In practice silage is most often used for feeding hogs. At least in experiments silage has also given good results when used in limited amounts in poultry feeding (up to 8 per cent of the dry matter of the diet), as part of the nitrogen supplement given to sheep (up to 10 per cent of the supplement), as a partial replacement of the milk proteins given to young calves, and in trout and salmon feeds. Silage can only be used in limited amounts primarily because of its fat content. If silage is given in too large amounts growth rates decline and the animals' flesh can acquire unpleasant tastes. In the case of swine, for example, the diet should not contain more than 1 per cent fats of fish origin. Thus if the silage contains 40 per cent fats, as it may if made from very oily fish species, the silage could only be used for 2.5 per cent of the dry matter of the diet (.025 x .40 = .01).32/ If the 1 per cent ceiling on fats is observed, silage can be used for up to 15 per cent of the dry matter of hog feeds with good results. In one test hogs fed silage actually showed better weight gains than the hogs receiving fish meal. Further, food conversion efficiences (kilograms consumed per kilogram of weight gained) improved with increasing per cents of silage in the diet.33/

The fact that fish silage can be used in poultry and swine diets is more significant than may be apparent from the relatively low percentages discussed in the previous paragraph. One of the main problems in raising poultry and hogs in developing countries is the low nutritional value of many of the locally available feedstuffs. Often fish meal and/or soybean meal must

---

30/ Ibid., p. 134.

31/ Austreng, E., "Fish Silage and its Use", Il Pesce (Italy), Vol. 1, No. 4, December 1984, p. 29; and United States Environmental Protection Agency, Environmental Assessment of Alternative Seafood Waste Disposal Methods at Akutan Harbor, Alaska, Seattle, WA, 1984, EPA/910/9-83/114, p. 40.

32/ Macin, D.H., R.H. Young, and K. Crean, "The Use of Formic Acid Prepared Fish Silage Made from Shrimp By-Catch in the Diets of Fattening Pigs", Tropical Animal Production, Vol. 7, 1982, pp. 120-126.

33/ Ibid., pp. 123 and 125.

be imported to supply sufficient protein. As a good source of protein, fish silage can replace such products. Thus the conversion of waste or trash fish into silage can provide an opportunity to substitute local for imported goods. Countries which may be trying to increase hog or poultry production should be particularly alert of the possibilities presented by this option. If advantage is to be taken of fish silage two factors should be kept in mind. Since silage is heavy and bulky transportation costs are high. Poultry and hog rearing operations should thus be encouraged to locate in close proximity to seafood plants. Second, if by-catch fish are to be used attention must be given to their oil content. If oil content is high, an antioxidant should be added to the silage to inhibit decomposition of fats. Animals receiving feeds in which fats have decomposed can develop symptoms indicative to toxicosis.

5.2.2 Fish wastes as fish food

Seafood processing wastes can be used as food for fish either in the form of bait or in the form of meals or pellets in aquaculture operations. The use of wastes for bait is perhaps the oldest of all methods for profitable disposal of processing wastes. Its main use is in lobster and crabfisheries, but locally long-line fishery makes successful use of seafood processing wastes and by-catches. Also sportfishermen may utilize certain wastes.

Clam bellies can be used to produce a bait which can be stored for at least five months. The bait can be used in lobster and crab traps and has an advantage over most conventional baits. With most conventional baits the first animal to enter the trap eats up the bait. The clam belly bait is prepared in such a way that it continues to attract animals after the first victims have been caught. The bellies are treated immediately after the clams are shucked with either formic acid or sodium chloride. This prevents them from spoiling. They can then be stored in sealed glass jars for at least five months. Prior to use as bait the bellies are mixed with a gelling agent and canned. Before being placed in the trap a hole is punched in the can so that the contents ooze slowly out. Although not a major contributor to solving waste disposal problems, such a recycling option may be of interest in selected locations.

Of more significance is the use of fish wastes in aquaculture. Aquaculture is expending rapidly worldwide. Its traditional centre was in Asia where new species such as milkfish, yellowtail, eel and shrimps have been added to the traditional carp species. While milkfish depend on algal growth and primary productivity in shollow pounds, yellowtail, eel and shrimpculture can all utilize fish wastes. As these species are high priced ones, protein and fat of low economic value can be converted to highly valued products.

Also aquaculture in South and North America show rapid expansion of species that can make good use of fish wastes such as shrimp culture in Ecuador and catfish culture in the United States.

In Europe the most expansive success-story in aquaculture is the Norwegian salmon culture which in now rapidly spreading to other countries in Northern Europe and North America. Here fishwaste is generally converted to semi-moist or pelleted feed. Salmon aquaculture is highly competitive for fishbased feed compared to traditional hog and chicken operations and to day fishbased high quality salmon feed sales for $US 1/kg compared to less than half for pelleted chicken food.

For many seafood processors salmon feed or raw material for salmon feed has become an important source of income.

As aquaculture operations, especially the Norwegian penculture type, need clear and protected waters, suitable conditions are frequently food in the same areas where small remote fish processing industries are located. As aquaculture operations utilize and give an economic value to what was previously waste and at the same time produce fish which can be processed in the industries during catch off-season, the combination of aquaculture with utilization of wastes from fish processing industries has proven most successfull. Socially it has been an important factor for economic survival and prospacity of small rural remote communities.

From a water pollution point of view aquaculture in cages in the sea is not a problemfree activity. Only the part of the nutrient that is converted to fish biomass is immobilized. The rest, in the form of local material, excreated ammonia or feed spill effect the marine ecosystem contribute to e.g. entrophication. Shellfish wastes are of particular interest for two reasons. Shellfish wastes are not as valuable as finfish wastes in either mammalian or poultry feeds. Consequently their market price is much lower. In 1982, for example, crab meal sold for $US 110 per ton while finfish meal sold for $US 478 per ton.[34] Secondly as part of the diet for trout, salmon and shrimp shellfish wastes provide carotenoid pigments, particularly the pigment astaxanthin. Although synthetic astaxanthin is available it is thought that the naturally occuring astaxanthin found in crustaceans is more readily absorbed by fish. To the extent this is true, shrimp and some crab wastes can offer a product of unique value to the aquaculture industry.

Although regular shrimp meals contain carotenoid pigments, the levels of these pigments vary tremendously depending on the manner in which the meals are prepared. Drying techniques in particular seem to play an important role. As a consequence of the wide variation - ranging from 2 micrograms per gram to 153 micrograms per gram in one study - in amounts of carotenoid pigments in meals, and as a consequence of the importance of these pigments, investigators have looked for ways to extract and concentrate the pigments.[35] Two such methods are described briefly in the next paragraph.

In order to extract the carotenoid pigments, shrimp or crab wastes are ground and heated. Enzymes which function to breakdown proteins are added. When this process is completed soybean oil is added at a 1:1 ratio. The mixture is agitated and heated to 80-90°C for thirty minutes. It is then cooled and put into a centrifuge in order to separate out the oil. The pigment is contained in the oil. Alternatively, the wastes can be ground and treated with acids, in effect creating a silage. The silage is stirred and heated to 40-45°C for one to four hours. Soybean oil is then added, the pigment is absorbed into the oil and the oil again separated out. It has been estimated that in order to be commercially viable the extraction process must result in 60 milligrams of astaxanthin per 100 grams of oil.

34/ United States Environmental Protection Agency, Environmental Assessment of Alternative Seefood Waste Disposal Methods at Akutan Harbor, Alaska, Seattle, WA, 1984, EPA/910/9-83/114, pp. 36 and 39.

35/ Meyers, Samuel P., "Utilization of Shrimp Processing Wastes in Diets for Fish and Crustacea", Florida Sea Grant College, Report No. 40, 1981, pp. 261-274.

5.3 Fertilizers

In the past fish wastes were used extensively as fertilizers. Today they have largely been replaced by petrochemical fertilizers.36/ However, for countries which have seafood processing industries and which are presently importing fertilizer, the use of fish wastes may offer an opportunity for substituting a local for an imported good. Since wastes from finfish have a higher value when used for animal feeds, most of the present interest in using seafood wastes for fertilizers focuses on shellfish wastes, crab and shrimp wastes in particular.

The primary difficulty with the use of crab and shrimp wastes as fertilizers is that unless they are processed they must be applied and preferably worked into the soil immediately. For most purposes this means that these wastes can only be used either before planting or after the harvest. Consequently, unless the shrimp and crab harvesting seasons coincide with pre or post planting seasons, this is not a viable option. Where the seasons do coincide the use of crab and shrimp wastes can be economically attractive for farmers. In Oregon in the United States, for example, a group of farmers has established a co-operative to collect and distribute unprocessed shellfish wastes. The wastes are given to the farmers at no cost and the shrimp harvesting season coincides with the time of year when the farmers need fertilizers.37/

Crab and shrimp wastes can also be dried and ground prior to being used as fertilizer. The dried and ground products have the advantage that they can be stored for long periods of time and can be easily transported over considerable distances. It is generally assumed that the difficulties of collecting and drying crab or shrimp wastes, along with the costs of operating a processing plant and the limited market for the products rule out this alternative. At least one operator in the coastal United States has found otherwise. He is successfully operating a crab meal production plant which has an annual production of about 800 tons. Further information on costs and revenues of a crab meal production plant are given in chapter 7.

5.4 Chemicals: chitin

While a number of chemicals can be derived from seafood processing wastes, the only ones that have the potential for making a significant contribution to waste reduction are those derived from chitin. The chitin derivative which has received the most attention is chitosan. At present chitosan is primarily of interest as a flocculant which can be used in wastewater treatment. In order to obtain chitosan, chitin must be separated from the protein and minerals which, together with the chitin, are the substances from which the exoskeletons of crustacea are composed. As a

---

36/ Green, John H. and Joseph F. Mattick, "Possible Methods for the Utilization or Disposal of Fishery Solid Wastes", Journal of Food Quality (USA), 1977, p. 243.

37/ Swanson, G.R., E.G. Dudley and K.J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W.M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, p. 299.

consequence a number of other products are produced simultaneously with the chitosan: protein, calcium, chloride and sodium acetate. The fact that protein is recovered along with the chitosan is, of course, of special interest.

At present processes for the commercial production of chitosan require substantial investments and highly trained technicians. There is little experience with the production processes outside of Japan where chitosan is used both in the treatment of polluted water and in sludge recovery. The literature indicates that it is possible to remove either the proteins or the minerals from the wastes as a first step. If the proteins are to be removed first the wastes are washed with dilute caustic soda (sodium hydroxide) and the proteins precipitated out of the solution. The remaining wastes are then treated with an acid to remove the minerals. Once the minerals have been removed, the remaining material, which is essentially chitin, is treated again with caustic soda to remove the acetyl group (CH_3CO). This results in the chitosan product. A diagram of this process is shown in figure 5.1.

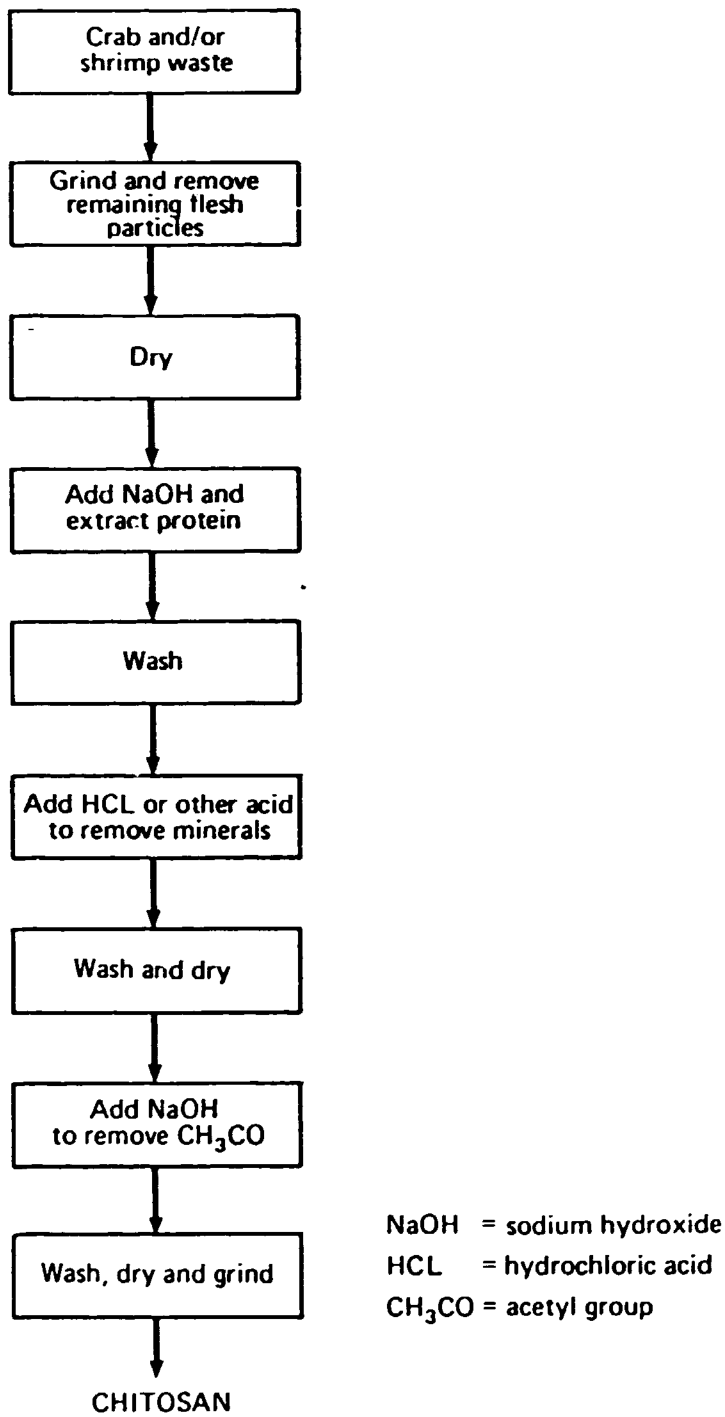
The single commercial producer of chitosan in the United States has found that it takes five to six kilograms of dry crab or shrimp wastes to produce a kilogram of chitin. For each kilogram of chitin produced, a kilogram of protein is also recovered. A kilogram of chitin yields 0.8 kilograms of chitosan.[38/] Of considerable interest is the fact that a pilot plant has succeeded in producing high quality chitosan from dried, coarse-ground crabshell meal. Since the dried meal can be shipped considerable distances, if the process proves effective on a commercial scale it will mean that central recycling plants could be built. Shrimp and crab wastes from many processors could then be amassed in sufficient quantities to justify the capital expenses necessary for chitosan recovery.

Chitosan has been tested for effectiveness. Tests compared chitosan to ten commercially available synthetic flocculants commonly used in wastewater treatment. It was found that chitosan was at least as effective if not superior to the synthetic flocculants.[39/] Petro-chemical based flocculants sell for $US 5.60 - $US 7.50 per kilogram. It is possible to produce chitosan to sell in this price range. Chitosan has the additional advantages that, unlike synthetic flocculants, it is non-toxic and is biodegradable. In order to compete with the synthetic flocculants it may be necessary to market chitosan in a ready-to-use form. To do this it should be put into a solution. For direct use in wastewater treatment the solution should be at a strength of 1 per cent chitosan.

38/ Cantor, Dr. Sydney, "Chitin-Chitosan Production", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 74-83.

39/ Bough, Wayne A, et al, "Utilization of Chitosan for Recovery of Coagulated By-products from Food Processing Wastes and Treatment Systems" in Proceedings of the Sixth National Symposium on Food Processing Wastes, 9-11 April 1975, Madison, WI, EPA-600/2-76-224, p. 31.

Figure 5.1 Schematic of chitosan production process



Source: Adapted from Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979.

6. WASTEWATER TREATMENT PROCESSES AND BY-PRODUCTS

6.1 Wastewater treatment processes

In most cases wastewater treatment is neither practical nor necessary for seafood processors. Most processors, particularly in developing countries, are small, remote, seasonal operations. They are located in coastal areas where they can discharge directly into waters whose assimilative capacities are adequate to prevent serious negative environmental impacts. In those cases where it has been determined that wastewater discharges are having negative impacts on receiving waters, attempts should be made to reduce water usage. Only if receiving waters continue to exhibit undesirable characteristics after reduction of water usage should wastewater treatment as such be undertaken. In addition to expenses incurred in the treatment process, costs will be incurred in disposing of resulting solids or sludges. The problems and costs of disposing of these solids and sludges may outweigh benefits achieved through wastewater treatment.

A determination of the conditions of receiving waters should include a visual inspection, an analysis of water quality, and an analysis of marine organisms. The visual inspection should determine whether oil or grease films can be seen and ascertain whether floating debris is present. Water quality analysis should include tests to determine dissolved oxygen levels, as well as concentrations of nitrogen, phosphorus and ammonia. Ammonia is released when protein decomposes. If it is present in high concentrations it is an indication that seafood wastes are accumulating. If present in sufficient quantities ammonia can be hazardous to marine life. Phosphorus, like nitrogen, is a nutrient for plants. If too great quantities of phosphorus or nitrogen are available plant growth becomes excessive. The analysis of marine organisms should focus on the relative size and distribution or microscopic protozoa, rotifer, crustacean and benthic populations. Finally, if wastewaters are being discharged into shellfish harvesting waters samples should be taken to determine coliform counts.

If an investigation of the type outlined in the previous paragraph indicates undesirable receiving water conditions, attempts should be made to reduce water usage. Studies in Canada showed that biochemical oxygen demand and suspended solids can be reduced by 50 per cent simply be using dry handling techniques rather than flumes to transport whole fish, fillets and offal around the plant.[40/] A reduction of this magnitude should result in significant improvements in receiving water quality. Dry handling techniques for transporting fish include conveyor belts, pneumatic ducts, tote bins and front-end loaders. In addition to the elimination of flumes, water use can be reduced by using hoses with spring-loaded nozzles which shut off automatically when released. Such hoses should be used at evisceration and filleting tables and in general clean-up operations. Water can also be saved by cleaning floors with shovels prior to washing them down. Where fish are packed in ice prior to processing, the ice should be separated by physical barriers from the fish. This prevents organic materials from being absorbed into the melted ice thereby reducing the organic load of the wastewater. Finally, where fish are frozen prior to processing they can be thawed with air, or thawing water can be recirculated.

40/ United Nations Economic and Social Commission for Asia and the Pacific, Industrial Pollution Control Guide-Lines, VIII. Fish Processing Industry, Bangkok, 1982, p. 14.

prior to processing, the ice should be separated by physical barriers from the fish. This prevents organic materials from being absorbed into the melted ice thereby reducing the organic load of the wastewater. Finally, where fish are frozen prior to processing they can be thawed with air, or thawing water can be recirculated.

If water reduction measures do not result in satisfactory receiving water conditions, wastewater treatment can be initiated. The simplest form of treatment is grinding. Grinding is the only treatment technology which does not create a solid waste disposal problem. Grinding aids in the assimilation of seafood processing wastes by facilitating dispersal of solids. When solids are dispersed over a larger area the chances of creating septic conditions or smothering bottom dwelling organisms are reduced. Grinding also accelerates decomposition rates. This may or may not be advantageous. If oxygen levels are depressed for shorter periods of time and recover faster, fish and other organisms are under stress for shorter periods and/or can return to an area more quickly. On the other hand, the accelerated rates may mean the oxygen levels fall low enough to result in fish kills.

If grinding in conjunction with a well placed outfall proves inadequate, more sophisticated treatment methods must be employed. The wastewater treatment methods applicable to seafood processors are screening, biological systems, and dissolved air flotation. Dissolved air flotation is discussed last because, although it is in principle a form of primary treatment, it is the most expensive and difficult of the treatment technologies generally used by seafood processors. All of these technologies - screening, biological systems, and dissolved air flotation - create solid wastes and sludges. Few seafood processors can take advantage of existing landfill operations to dispose of their solid wastes and the costs or operating a private landfill are generally prohibitive. Seafood sludges are difficult to dispose of on land because they are notoriously difficult to dewater. The result is that both solids and sludges must often be barged out to sea.

In American Samoa sludges from seafood processors were originally disposed of on land. The water did not percolate into the ground satisfactorily and evaporation was minimal. As a result the disposal sites became breeding grounds for disease carriers and sources of obnoxious odors. The dikes which should have contained the wastes failed, discharging the sludges into adjacent bays. In addition, drinking water sources were in danger of contamination. As a consequence the processors were forced to apply for permission to barge the sludges out to sea.[41/] In view of histories of this type, serious attention must be given to the costs of disposal of the solid wastes and sludges generated prior to embarking on wastewater treatment systems. Even if land disposal is planned, costs and consequences of barging to sea should be reviewed in case land disposal fails to operate satisfactorily.

41/ United States Federal Register, Vol. 45, No. 166, Monday, August 25, 1980, pp. 56374-56376.

6.1.1 Screens

For most small seafood processors screening will be the most affordable and appropriate wastewater treatment technology, if grinding is inadequate. Screens used in food processing industries are of four types: static, vibrating, rotating and tangential. There is no general agreement as to which type of screen produces the best results. Some processors have good experiences with static screens, whereas others find it necessary to move to more sophisticated types. The criteria that should be considered in choosing among the four types of screens are as follows: the initial cost of the screen, operating and maintenance costs, the hydraulic capacity of the screen,

the hydraulic head which it requires, the speed with which the screen binds or clogs, the percentage of solids captured by the screen, the moisture content of screenings, and the amount of space taken up by the screen. Maximum benefits are obtained from all types of screens when opportunities for proteins and other waste materials to dissolve are minimized. The longer fish solids are in contact with water, the more materials dissolve. As a consequence screens should be located as close as possible to the point where waste materials enter the water stream. Agitation of wastes in water also facilitates the breakdown and dissolving of solids. If pumps, valves or pipes are used in conveyance of the wastewater stream, they should be designed to minimize agitation.

Simple static screens are the type of screen most frequently used by seafood processors. Generally, 20 mesh screens (screens with 20 openings per linear inch) are recommended. The primary limitations of these screens are that they handle only relatively low flows, and in some cases have been found to bind or clog within as little as ten to thirty minutes. Consequently it is often necessary to devise a method for clearing the screen. Backwashing is the most common method although brushes or scrapers can also be used.

A study of small seafood processors on the eastern coast of the United States showed that static screens, if used in conjunction with good housekeeping practices, were sufficient for crab, clam, and oyster processors to meet the effluent limitation guidelines for suspended solids suggested by the World Bank. Blue crab processors were unable to meet the somewhat stricter limitations (2.2 kilograms per metric ton of crabs processed) set forth by the United States Environmental Protection Agency (U.S.E.P.A.). Finfish processors using only static screens were unable to meet either World Bank or U.S.E.P.A. limitations.[42/] Table 6.1 summarizes effluent limitations proposed by the U.S.E.P.A. and the World Bank.

42/ United States Environmental Protection Agency, Waste Treatment and Disposal from Seafood Processing Plants, Robert S. Kerr Environmental Research Laboratory Office of Research and Development, Ada, Oklahoma, 1977, EPA-600/2-77-157.

Table 6.1 Effluent limitations[a/]

	BOD_5		TSS		Oil and grease	
	U.S.[b/]	W.B.	U.S.	W.B.	U.S.	W.B.
Tuna	20.0	2.2	8.3	2.2	2.1	0.27
Salmon	2.7	11.0	2.6	2.8	0.31	2.8
Other finfish	1.2	4.7	3.1-3.6	4.0	1.0-4.3	0.85
Crabs	0.3-10	3.6	2.2-19	3.3	0.6-1.8	1.1
Shrimp	63-155	52.0	110-320	22.0	36-126	4.6
Clams and oysters	none	41.0	24-59	41.0	0.6-2.4	0.62

Note: All U.S.E.P.A. limitations shown are for conventional plants only. U.S.E.P.A. limitations for mechanized plants and for plants engaged in canning operations are considerably higher.

U.S. = United States Environmental Protection Agency

W.B. = The World Bank

a/ Maximum amount to be discharged in any single day. All figures are kilograms per metric ton of raw material processed.

b/ BOD_5 limitations from the U.S.E.P.A. are for new sources only. There are no U.S.E.P.A. limitations on BOD_5 for existing plants.

Sources: United States Environmental Protection Agency, "Effluent Guidelines and Standards, Canned and Preserved Seafood Processing Point Source Categor·" 40 CFR Ch. 1 (7-1-85 Edition), Washington D.C., 1985, pp. 115-180. World Bank, Office of Environmental Affairs, Environmental Guidelines, Wasington, D.C. 1984, p. 93.

Vibrating and rotating screens are able to process larger volumes of wastewater than simple static screens. They are more complicated than static screens but do not clog as easily. Vibrating screens may be either circular or rectangular. In rectangular vibrating screens the solids are discharged at the lower end of the screen. With circular vibrating screens the screened out particles may be discharged either to the center or to the periphery. Rotating screens take the form of a drum. They can be designed so that the flow goes from the inside of the drum, through the screen, and then to the outside, or the reverse. If the flow is from the inside to the outside, the solids collected inside the drum are removed by augers or collected in a trough. If the flow is from the outside to the inside the solids remain on the outside and are removed by a scraper. The literature does not report the effectiveness of either vibrating or rotating screens in the seafood industry. This suggests that these screens are rarely used by seafood processors, particularly by small processors.

Tangential screens are the last type of screen used in food processing industries. These screens are used by seafood processors and their effectiveness has been studied. Removal rates of from 40-75 per cent for suspended solids are reported.43/ Figure 6.1 provides a picture of a tangential screen. In this type of screen thin layers of the wastewater stream are in effect sliced off by the blades that make up the surface of the screen. The solids remain on the surface and are discharged at the screen's lower end. Typically tangential screens are made of 304 stainless steel. They are 1.83 meters high and have openings of 0.7 to 1.0 millimeters. Use of such tangential screens, together with well designed outfalls, has proved adequate to meet discharge in many cases.44/

6.1.2 Biological treatment systems

Biological treatment systems are essentially attempts to duplicate nature's process. In natural water bodies the organic load of a wastewater stream is stabilized by bacteria which consume the organic materials. The object of a biological treatment system is to create an artificial environment in which bacteria or other microorganisms can do the same thing. Once a portion of the organic load has been stabilized in the artificial environment, the wastewater is discharged into a natural water body. Biological systems can be set up to operate under either aerobic (in the presence of oxygen) or anaerobic (in the absence of oxygen) conditions. The basic processes can be indicated as follows:

Aerobic treatment process

Organic matter + bacteria + O_2 + nutrients = more bacteria + CO_2 + H_2O

Anaerobic treatment process

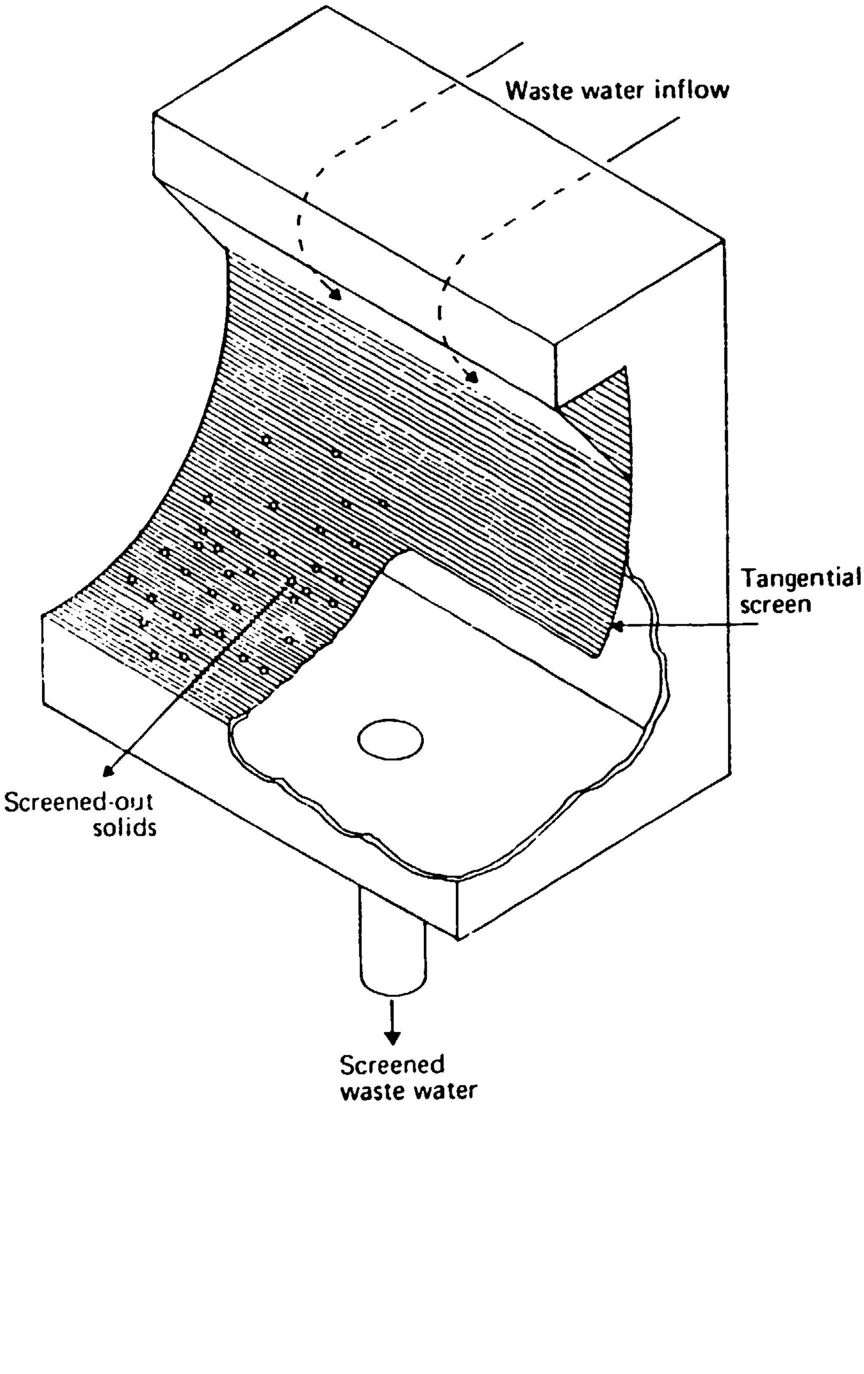
Organic matter + bacteria + nutrients = more bacteria + CO_2 + CH_4
(CH_4 = methane)

Fatty acids in general and unsaturated fatty acids of the type found in fish fat in particular, look at a first glance on the chemical structural formulae a prime substrate for biogas production. Many attempts have also been made to utilize anaerobic treatment systems in fish processing industry. Most of them have failed. As a consequence it has been common knowledge for a long time and up to very recently, that anaerobic treatment and biogas formation does not work for fish wastes. Two explanations for the failures are often cited in the literature:

43/ United Nations Economic and Social Commission for Asia and the Pacific, Industrial Pollution Control Guide-Lines, VIII. Fish Processing Industry, Bangkok, 1982, p. 16.

44/ Ibid., p. 14.

Figure 6.1 Tangential screen



Sources: Katsuyama, Allen M., A Guide for Waste Management in the Food Processing Industry, The Food Processors Institute, Washington, D.C., 1979. United Nations Economic and Social Commission for Asia and the Pacific, Industrial Pollution Control Guide-Lines, VIII, Fish Processing Industry, Bangkok, 1982.

(1) Bacteria normally used in anaerobic systems do not live in salt water.

(2) The protein content in fish wastes is very high. which results in too high concentrations of ammonia after degradation. High pH in the salt water causes NH_4^+ to shift to NH_3 which is highly toxic also to bacteria.

During the last six years anaerobic treatment systems have been in operation in New Zealand at fish processing plants. Economic and environmental success has lead to an increasing number of plants to utilize the system. In particular the biogas (methane) production has been economically interesting. The process applied has been modified to avoid or reduce the problem with salt and ammoniac toxicity to the anaerobic microorganisms. Through managerial means the fish wastes going to anaerobic treatment have been kept separate from salt water. Fish wastes have been rather shoveled than flushed and fresh water streams have been kept separate from salt water ones. In some cases clays with ion-exchange properties have been added to bind ammonia in the anaerobic reactor.

In another case ceramic membranes have been used to separate oxygen and nitrogen in air, and nitrogen has been used to strip off ammonia in the first stage of a multistage anaerobic reactor.

A third method found technically, but in the given situation not economically, feasible is to add acids and keep the pH low so that the equilibrium $NH_4^+ = NH_3 + H^+$ is pushed far to the left.

The successful commercial application has thus accepted the conclusions that salt and ammonia are toxic to anaerobic microorganisms and modified the biogas production process to avoid or reduce the problem. However, experience in other fields of biogas application indicate that anaerobic bacteria can be selected for salt as well as ammoniac tolerance and thus that the problems hitherto encountered can be solved not only by technical means but also by microbiological ones. Independent in both Egypt and Israel, biogas production from cowdung is successfully practiced in deserttype areas where the fecal material collected initially is to dry for an anaerobic reactor and therefore has to be mixed with brackish water.

In the Netherlands biogas production from pig manuer with exceptionally high ammoniac level has met with success after selection and adaptation of the bacteria.

In conclusion: anaerobic treatment, although conventionally regarded as impossible in fish processing industry, today seems to offer an environmentally attractive solution through the energy value in the biogas.

Aerobic treatment can take a variety of forms: ponds or lagoons, activated sludge, biological filters or disks, and trickling filters are the most common. Brief descriptions of the more complicated systems given in table 6.2. However, with the exception of ponds or lagoons - and their artificial equivalent, extended aeration - none of the aerobic treatment systems is suited to small seafood processors. In all aerobic treatment systems other than ponds or lagoons, a colony of bacteria or other microorganisms must be established and maintained. To do this, constant wastewater flow levels must be maintained. Small seafood processors do not generally have a constant wastewater flow, and many have no flow at all during part of the year. Consequently these systems are impractical for small processors. Outside of Japan, complicated biological treatment systems are not generally used even by large processors.

Table 6.2 Aerobic treatment systems

Activated sludge	First suspended solids are allowed to settle out (primary treatment). Wastewater is then aerated together with microorganisms. Following aeration the wastewater goes to another tank or basin (the clarifier) where microorganisms are returned to the aeration tank. The remainder are removed for disposal.
Biological filter	Prior to going to the aeration tank wastewaters are passed through a filter on which microorganisms are encouraged to grow. As in activated sludge, microorganisms from the clarifier are returned to the aeration tank. The clarifier is also the source for the filter microorganisms.
Biological disks	In place of a standard aeration tank, aeration is accomplished by rotating disks. The disks are mounted on a horizontal shaft. Half of the disks are submerged in the wastewater. As a disk rotate, the wastewater is aerated. Microorganisms grow both on the disks and in the tank.
Trickling filter	Wastewater is allowed to flow over beds of rocks. Oxygen is supplied by the air and the rocks provide a surface on which microorganisms can grow.

Source: Katsuyama, Allen M., A Guide for Waste Management in the Food Processing Industry, The Food Processors Institute, Washington, D.C., 1979.

Ponds or lagoons are the simplest form of biological treatment. Since ponds and lagoons can accept intermittent inputs without any problem, they are the most appropriate biological treatment system for small seafood processors. Unfortunately the geology of many coastal areas is not suited for either ponds or lagoons. If the coastline is rocky the cost of creating a pond or lagoon is prohibitive. If the coast consists of wetlands, sandy or other highly permeable soils, and/or has a high water table, ponds or lagoons either cannot be created or, if they are created, will endanger drinking water supplies. However, in regions where land is available, relatively cheap, and soil conditions suitable, ponds or lagoons are good solutions to treatment of seafood processing wastes. If the pond or lagoon is not artificially aerated it should be one to two meters deep. BOD_5 loadings should be kept to 9-18 kilograms per 4,000 square meters and wastewaters should be retained for 60 or more days. If the pond is artificially aerated, the depth can be increased to 4 meters or more, but mixing is necessary. For mixing to be adequate, 8-16 horsepower per 3.8 million liters of water is required. In general 0.2 kilograms of sludge is produced for each kilogram of BOD_5 removed. This sludge accumulates and must eventually be removed.[45/]

In areas where ponds or lagoons cannot be established and where treatment beyond screening is necessary, extended aeration is probably the most suitable technology for small seafood processors. Extended aeration is essentially a system where a tank takes the place of the pond. Such systems can be bought ready made, in which case they are called package plants. In such a system wastewater is typically first screened and then pumped to a first tank, called a roughing tank. The wastewater is aerated for several hours and then solids are discharged to a second tank. Aeration is continued and then solids are allowed to settle out. In tests on wastewater from small seafood processors this type of system achieved 80-90 per cent removal of BOD_5. The system was easy to maintain, only requiring cleaning of screens. At the time the study was done, 1973, the estimated cost for such a system was $US 7,000. This included the cost of equipment and installation.[46/]

6.1.3 Dissolved air flotation

Dissolved air flotation is a sophisticated wastewater treatment system used primarily by tuna and salmon processors. It is a form of primary treatment because, rather than trying to duplicate the natural process in which bacteria consume organic material, the process consists of a means of removing suspended solids from the wastewater stream. In ordinary primary treatment systems the initial removal of suspended solids is accomplished by allowing the suspended solids to settle out. This process is often aided by the addition of chemicals. The chemicals, called flocculants, bind the solids into large clumps, increasing their mass, with the result that a larger percentage of the suspended solids settle out, and do so more quickly. This system is not effective with seafood wastewaters because of the facility with which seafood solids dissolve.

In dissolved air flotation, rather than letting the suspended solids settle to the bottom, an attempt is made to bring them to the surface. The wastewater is first screened, as in normal primary treatment. It is then mixed with a flocculant and fed into the flotation tank. Some of the wastewater is pumped, along with air, into a pressurization tank. When the pressurized mixture of air and wastewater is released into the flotation cell, small air bubbles, 1-100 microns in diameter, form and rise to the surface.

45/ Katsuyama, Allen M., A Guide for Waste Management in the Food Processing Industry, The Food Processors Institute, Washington, D.C., 1979, p. 161-162.

46/ United States Environmental Protection Agency, Waste Treatment and Disposal from Seafood Processing Plants, Robert S. Kerr Environmental Research Laboratory Office of Research and Development, Ada, Oklahoma, 1977, EPA-600/2-77-157, p. 29.

Due both to the action of the flocculants and to the fact that the air bubbles are negatively charged, suspended solids stick to the bubbles and are carried to the surface with them. Chemicals are generally added to the flotation cell both to control the overall acidity level and to foster the negative charge of the bubbles. A skimmer removes the suspended solids from the surface of the water.

If properly designed and operated, dissolved air systems can achieve good removals of suspended solids, BOD_5, and oils and grease. At one plant in California the mean removal rates were: suspended solids, 74.8 per cent; BOD_5, 42.9 per cent; oil and grease, 83.5 per cent. However, at a nearby plant removal rates were much lower: suspended solids, 48.2 per cent; BOD_5, 24.3 per cent; oil and grease, 64.3 per cent.[47/] The main difference was that the concentration of pollutants at the first plant was at least three times as great as at the second plant. The greater concentrations were a result of the fact what the first plant recycled the water used to thaw the tuna.

While the concentration of pollutants in the wastewater is a major factor in performance, it is by no means the only one. Good performance with dissolved air flotation systems depends on alert, trained operators, on maintenance of correct acidity levels in the wastewater, on proper use of coagulants and other chemicals, and on regulation of flow rates. To optimize coagulation of solids as well as to minimize solubility of proteins, the pH of the wastewater should be maintained as close as possible to 4.5-5.0. A plant in American Samoa which was able to maintain the pH in the flotation cell in the 4.2-6.5 range achieved suspended solid removal rates of 95 per cent and oil and grease removal rates of 88 per cent.[48/] As with the California plant which had a good removal record, concentrations of suspended solids and oil and grease in the wastewater prior to treatment were high.

The major drawbacks of dissolved air flotation, aside from the difficulties of correct design and operations, are its cost and the disposal of the resulting sludge. In 1977 initial costs of dissolved air flotation systems were reported at $US 250,000 per plant. Operating costs ran as high as $US 1,000 per day. More than half of the operating cost was attributable to sludge disposal. Since oils and greases are removed along with the suspended solids, the resulting sludge has a high fat content. This high fat content makes it difficult to dewater the sludge. Dewatering with centrifuges has been tried with some success. The high fat content also makes the sludges unsuitable for animal feeds. In the meat and poultry processing industries, sludge from dissolved air flotation systems is often recovered for incorporation into salable products. It is not known whether recovery of sludge from dissolved air flotation systems will be possible in the seafood processing industry.

47/ Ertz, D.B., J.S. Atwell, and E.H. Forsht, "Dissolved Air Flotation Treatment of Seafood Processing Wastes - An Assessment", in Proceedings 8th National Symposium on Food Processing Wastes, Cincinnati, Ohio, 1977, EPA/600/2-77-184, p. 106-108.

48/ Ibid., p. 111.

Dissolved air flotation is the most sophisticated wastewater treatment process used by seafood processors in the west. The Japanese, on the other hand, have experimented with other sophisticated treatment methods. Various activated sludge technologies are reported along with new designs of aeration tanks, and new coagulation methods. The coagulation systems are reported to have achieved BOD_5 removals of 99 per cent.49/

6.2 By-products

As in general in the seafood processing industry, wastewater is of interest primarily due to its high protein content. It was determined, for example, that the wastewater from processing of Alaskan pollock contained 30-60 per cent as much protein as the finished product. That is, about half as much protein was lost as was made info food.50/ Although a number of methods for precipitating proteins from wastewaters are reported, only two products can, at present, be considered of commercial interest. The two commercial products, fish solubles and clam juice, are described below. Brief descriptions of some of the experimental products follow.

6.2.1 Fish solubles

The only truly established product recovered from seafood processing wastewater is fish solubles. Fish solubles are produced by fish meal processing plants. Fish solubles are in effect a concentrated stickwater from which the oil has been removed (see section 3.1.4). If the fish solubles are not returned to the fish meal in order to improve its quality, they are generally sold as a liquid fertilizer. Fish solubles containing 50 per cent solids have been tested on both decorative houseplants and on vegetable crops. Decorative plants grew well, had a good, dark colour with a glossy sheen, and aged more slowly than plants fertilized with inorganic fertilizers. Results on vegetables were also good. The fish solubles were tested on tomatoes, lettuce, radishes, peas, corn, and soybeans. Tomatoes, lettuce, radishes and peas were given from 15 to 30 milliliters of fish solubles per 3.8 liters of water. Soybeans were given up to 60 milliliters of solubles per 3.8 liters of water, and corn up to 90 milliliters. In general vegetables fertilized with fish solubles showed growth comparable to that of plants fertilized with inorganic products. Tomatoes were negatively affected if concentrations were too high but the corn crop was considered excellent and soybeans showed significantly improved yields.51/

49/ Litchfield, John H., "Meat, Fish and Poultry Processing Wastes", Journal of the Water Pollution Control Federation (WPCF), Vol. 53, No. 6, 1981, p. 788.

50/ Litchfield, John H., "Meat, Fish and Poultry Processing Wastes", Journal of the Water Pollution Control Federation (WPCF), Vol. 55, No. 6, 1981, p. 684.

51/ Aung, L.H., et.al., "Fish and Seafood Wastes as Nutrients for Agricultural Crop Fertilization", Florida Sea Grant College, Report No. 40, 1981, pp. 275-279.

6.2.2 Clam juice

The water form the final wash of minced clam meat can be converted into clam juice. The process is relatively simple, the only drawback being the limited market for the product. To produce the clam juice the wash water is put into a steam-jacketed kettle and boiled. This step is necessary in order to prevent the development of undesirable flavors. It also concentrates the liquid. The water is boiled for 10 to 60 minutes depending on the desired concentration of solids in the finished product. After boiling the juice is canned and retorted. Retorting is critical in obtaining a high quality product as it results in a sweeter flavor. Once retorted clam juice remains in good condition for at least six months at room temperature.

6.2.3 Protein extraction and related experimental processes

A number of chemicals have been tried in order to coagulate and precipitate the dissolved proteins from seafood processing wastewaters. Sulfuric acid (H_2SO_4), $FeCl_3$, and calcium chloride ($CaCl_2$), have all been found effective.[52/] It has also been reported that the maximum amount of protein and oil is recovered from bloodwater if the bloodwater is heated to between 65°C and 80°C and the pH is adjusted to between 5.6 and 5.9.[53/] In precipitating proteins from clam wash water sulfuric acid was used. Sufficient 10N H_2SO_4 was used to bring the pH down to 4.0. After a minute of stirring at 100 rpm, the mixture was stirred at 30 rpm for five minutes. It was then allowed to settle for one hour. The resulting precipitate was centrifuged and freeze dried. This method recovered approximately 40 per cent of the protein present in the wash water. The product itself contained 67.9 per cent protein, 1.22 per cent fat, 0.32 per cent fiber and 4.92 per cent ash. Not all amino acids were present in sufficient quantities to meet the standard recommended by the Food and Agricultural Organization (FAO). Valine and Leucine concentrations were particularly low, representing only 80 per cent of the recommended amounts.[54/] Table 6.3 presents the FAO recommended amino acid profile for protein. Given the limitation of proteins obtained from clam wash water, this product would have to be combined with other products to provide Food nutrition.

52/ Hang, Y.D., E.E. Woodams, and G.F. Parsons, "Isolation and Chemical Evaluation of Protein from Clam Wash Water", Journal of Food Science, Vol. 45, 1980, pp. 1040-1041; Litchfield, John H., "Meat, Fish and Poultry Processing Wastes", Journal of the Water Pollution Control Federation (WPCF), Vol. 54, No. 6, p. 690 and Vol. 55, No. 6, p. 684.

53/ Ibid., p. 684.

54/ Hang, Y.D., E.E. Woodams, and G.F. Parsons, "Isolation and Chemical Evaluation of Protein from Clam Wash Water", Journal of Food Science, Vol. 45, 1980, pp. 1040-1041.

Table 6.3 Amino acid profile recommended by FAO (gram amino acid per 100 grams of protein)

Alanine	6.1
Arginine	5.2
Aspartic acid	7.7
Cystine	1.69
Glutamic acid	14.7
Glycine	2.2
Histidine	2.5
Isoleucine	4.0
Leucine	7.0
Lysine	5.4
Phenylalanine	3.05
Proline	10.7
Serine	7.7
Sulfur	3.5
Threonine	4.0
Tyrosine	3.05
Tryptophan	1.0
Valine	5.0

Source: Ooshiro, Zentaro, et.al., "Approaches to the Use of Plastein Reaction in Oily Fish", Memoirs Faculty of Fisheries, Kagoshima University Vol. 30, Japan, December 1982, pp. 369-382.

Other approaches under investigation for recovery or utilization of the protein available in seafood processing wastewater include the precipitation of plastein, a substance resembling protein, and the production of proteases, enzymes active in the digestion of protein. In the precipitation of plastein, proteins that have dissolved into the wastewater are recovered through the use of enzymes. Both the nutritional value of the plastein obtained and the extent to which the plastein is water soluble depend on the enzymes used. In one series of experiments, plasteins derived from the enzymes Molsin and Bioprase were tested. The plasteins contained 78-83 per cent protein, and had amino acid profiles approaching the FAO standard. The Bioprase derived plastein had the better amino acid profile. Only Leucine and Tryptophan failed to meet the standard. Leucine was present in 83 per cent of the recommended amount (5.8 grams per 100 grams of protein). There was no Tryptophan. Molsine derived plastein had only 60 per cent of the recommended amounts of Leucine. In addition only 90 per cent of the recommended amounts of Isoleucine, Phenylalanine and Tyrosine were present. Tryptophan was again absent.[55]

While the above described work has shown that it is possible to precipitate proteins and protein-like substances from seafood processing wastewaters, such precipitation does not result in commercially marketable products. In order to market either precipitated protein or plastein, the precipitate would have to be incorporated into as yet undefined products. An

55/ Ooshiro, Zentaro, et.al., "Approaches to the Use of Plastein Reaction in Oily Fish", Memoirs Faculty of Fisheries, Kagoshima University (Japan), Vol. 30, December 1982, pp. 369-382.

alternative approach, which yields a product that can be directly marketed, is the production of enzymes. Enzymes command high prices, and if the process involved proves feasible at industrial scales this approach could provide an attractive wastewater recycling option.

The basic theory behind enzyme production is that enzymes can be produced by fermenting seafood processing plant effluent. Small scale tests, performed in 4 liter capacity fermentation tanks, have given promising results. In the tests stickwater diluted with tapwater at a ratio of 2 per cent stickwater to 98 per cent tapwater was used. This was considered appropriate as the nutrients in the stickwater were similar to those present in normal seafood plant wastewaters. The best results were obtained when protein concentrations were equivalent to 4 milligrams of bovine serum albumin (BSA) per milliliter of wastewater. Yield was also greatest if the pH of the solution was adjusted to 7 prior to fermentation. However, pH values from 5 to 8 also gave satisfactory yields. Although plain stickwater will produce enzymes, it was found that the addition of some carbohydrates greatly increased yields. If either glucose or mannose ($C_6H_{12}O_6$) were added at the rate of 1 per cent (weight to volume), enzyme yields were tripled. Other carbohydrates tested were not effective in increasing yields. In the experiments various rates of agitation - from 300 rpm to 750 rpm - as well as various aeration rates were tried. If a process of this type is to be scaled up to commercial volumes, it is believed that careful attention will have to be given to aeration rates. Agitator speeds as well as levels of protein concentration will need to be optimized.[56/]

56/ Wah-On, H.C., et.al., "Protease Production by Fermentation of Fish Solubles from Salmon Canning Processes", Canadian Journal of Microbiology, Vol. 26, 1980, pp. 1049-1056.

7. ECONOMICS OF BY-PRODUCT PRODUCTION AND SOLID WASTE RECYCLING

Available literature provides very few details of specific costs involved in manufacturing by-products from seafood processing wastes. What little information is available is from the United States. This cost information can therefore only be used as a general guide for developing countries interested in making initial estimates of feasibility. Actual costs for many of the items, particularly labor costs, costs of construction, and energy costs, will certainly be considerably different in most developing countries.

Table 7.1 shows selling prices for most of the significant products which can be manufactured from seafood processing wastes. Where available selling prices for previous as well as recent years are shown. The literature does not provide any cost or profitability data for the production of either mince or FPC B. In the United States it is generally held that the profitability of a fish meal plant depends on the sale of the fish oil.57/ Fish meal plants produce, in addition to the meal, both fish solubles and fish oil. However, the amount of oil preducted depends greatly on the species of fish processed. For example, on the Atlantic coast of the United States, for every 50 tons of fish processed, one ton of fish meal, 0.7 tons of fish solubles, and 0.2 tons of oil are produced. In the Gulf of Mexico, however, for every 50 tons of fish processed 1.10 tons of oil are produced. The amounts of fish meal and fish solubles are the same as on the Atlantic coast. The additional 0.9 tons of oil produced at the Gulf of Mexico plants represent an additional income of $US 551 to $US 605 per fifty tons of fish processed. Looked at another way, if the sale of fish meal and fish solubles covers the costs of operating a fish meal plant, the Atlantic coast plants have a profitability of $US 122 to $US 135 per fifty tons processed while the Gulf coast plants have a profitability of $US 674 to $US 740 per fifty tons processed. However, the price history of fish meal shows fluctuations of over $US 425 per ton. Thus, if the sale of fish meal and fish solubles covers the costs of operation in average years, when the price of fish meal drops, only plants which produce relatively large amounts of oil will remain profitable. The next subsections provide cost information for the production of crab meal and chitosan.

57/ Dressel, David "Scrap Handling Practices Nationwide", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, Report No. UM-SG-MAP-81-03, pp. 26-30

Table 7.1 Selling prices for products made from seafood wastes

Product	Selling price (US dollars)	Year	Source
Mince (shellfish)	3.75-4.7/kg	1990	1
FPC B	1,530/ton	1990	2
Fish meal	478/ton	1983	3
	573/ton	1990	5
Fish oil	396/ton	1983	3
	200/ton	1990	5
Fish solubles	295/ton	1990	5
Crab meal	187/ton	1990	4
Shrimp meal	121/ton	1990	5
Fish silage	150/ton	1990	4
Chitin (purified)	440/kg	1990	5
Protein from crustacean shells	1,450/ton	1990	5
Glucoseamine	80-105/kg	1990	5
Carotenoid pigments (pur fied)	3,300/kg	1990	5

Sources:

1. Learson, Robert J., "A Look at the Options", in Crab Byproducts and Scrap 1980: A Proceedings", Maryland Univ. College Park MD. Figures recalculated to 1990 $US.

2. United Nations Food and Agriculture Organization, FAO Report on the Marketing Study of Fish Protein Concentrate (FPC) B, Rome, 1980, FAO TF/INT 268 (FH). Figures recalculated to 1990 $US.

3. United States Environmental Protection Agency, Environmental Assessment of Alternative Seafood Waste Disposal Methods at Akutan Harbor, Alaska, Seattle, WA, 1984, EPA/910/9-83/114.

4. Source as above, but recalculated to 1990 $US.

5. World market prices as given May 1990 by Scandinavian fish processing industry/Roche A/S, Copenhagen and Kebo AB, Stockholm.

7.1 Crab meal production

There is a general belief that due to costs of transportation and drying, and to the relatively low prices and limited market for crab meal, its manufacture is not profitable. However, there is reason to believe that the lack or profitability in most crab meal operations is due to use of inefficient plants with old, outdated equipment.58/ Both feasibility analysis of costs and revenues and the experience of a modern plant owner indicate that a crab meal plant producing between 800 and 1,300 tons per year can be profitable.

Table 7.2 shows the initial investment required for a crab meal plant capable of producing up to 1,800 tons of meal annually. No cost for land is included since land costs vary widely from region to region.

Table 7.2 Initial investment for 1,800 ton per year crab meal production plant (1990 US dollars)

Equipment		
Dryer	72,000	
Feeding equipment	33,000	
Mill	7,000	
Air lock and vapor duct	15,000	
Conveyors	16,000	
Heat resistant material	4,000	
Front end loader	16,000	
	163,000	
Installation		60,000
Building		41,000
Concrete slab		8,000
Total initial investment		272,000

Source: Murray, Thomas, "Crab Meal Production: Costs and Returns", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-81-03. pp. 38-45. Recalculated to 1990 US dollars.

58/ Learson, Robert, J, "A Look at the Options", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 109-112.

Table 7.3 shows annual costs and revenues if the plant is operating at a 1,200 tons per year level. The depreciation shown is for equipment only. Both the cost of the equipment itself and the cost of installation are depreciated over 15 years. Straight line depreciation is assumed, with zero value remaining at the end of the 15 years. In calculating the payments for borrowed money, i.e. the amount of principal and interest due, it was assumed that the entire amount needed for the initial investment, plus $US 6,800 to cover taxes and insurance in the first year, would be borrowed. A seven year payback period and a 12 per cent interest rate were used to calculate annual payments.

Table 7.3 Annual costs and revenues for a plant producing 1,200 tons of crab meal per year[a/] (US dollars)

Fixed costs	
Depreciation	15,000
Plant manager	29,000
Principal and interest	61,000
Insurance and taxes	7,000
Miscellaneous	3,000
Total fixed costs	115,000
Variable costs	
Fuel	47,000
Maintenance and repair	2,200
Electricity	4,800
Marketing	6,000
Office supplies	1,000
Telephone	1,000
Labor - salary and benefits	14,000
Total variable costs	76,000
TOTAL ANNUAL COSTS	191,000
ANNUAL REVENUES[b/]	204,000
NET REVENUE	13,000

a/ All prices shown are in 1989-1990 dollars.

b/ Revenues are based on a selling price for the crab meal of $US 170 per ton. This selling price is in turn based on the assumption that the crab meal will be 31 per cent protein. The higher the protein content, the higher the price the meal commands.

Source: Ibid.

As can be seen from table 7.3, the two largest items in the budget are for repayment of the loan and for fuel. As shown, both of these costs are almost certainly higher than they would be in actual practice. In the first place, it is unusual to borrow the entire sum needed for the initial investment. Annual costs can be lowered considerably by reducing the amount borrowed. In the second place, fuel costs are almost certainly overestimated. In calculating fuel costs it was estimated that the plant would be operating at 65 per cent of capacity. At this level it was assumed that the dryer would consume 30 gallons of fuel per hour. The cost of fuel was set at $US 2 per gallon. However, a crab meal plant of this size actually operating at 65 per cent of capacity experienced a fuel consumption rate of only 22 gallons per hour.[59/] Thus the fuel costs shown in table 7.3 may be overestimated by some $US 12,000. This is extremely significant for profitability. As shown in table 7.3, net revenues for a plant producing 1,200 tons of crab meal annually is $US 13,000. Lowering fuel costs by some $US 12,000 would have the effect of almost doubling net revenue. The $US 13,000 net revenue shown represents a 5 per cent return on investment. However, if net revenues are closer to $US 25,000, return on investment would be closer to 10 per cent. A 10 per cent return approaches the level necessary to consider an investment justifiable. This means that a more realistic estimate of fuel costs, particularly if coupled with borrowing less than 100 per cent of the capital needed for the initial investment, would show a crab meal plant producing 1,200 tons annually as a profitable enterprise. That this is almost certainly the case is testified by the fact that an existing plant producing 800 tons annually is doing well.[60/]

7.1.1 Chitosan production

Table 7.4 presents cost data for a plant designed to produce 450 tons of chitosan annually. Such a plant needs to produce 560 tons of chitin (see section 5.4), and will simultaneously produce 560 tons of protein. The authors of the data shown in table 7.4, Johnson and Peniston, assumed that chitin yield would represent 8.33 per cent of the amount of waste processed. That is, in order to produce 560 tons of chitin, some 6,720 tons of waste would have to be processed. Since waste represents approximately half of the live weight of crabs, a plant of this size would have to have a 13,440 ton crab harvest as a source of supply. Since it was considered unlikely that any one location could provide tonnage of this magnitude, it was assumed that a portion of the waste would be shipped from other locations. The raw material cost shown as the first item in table 7.4 reflects costs involved in obtaining crab wastes from distant locations. In order to be shipped, the wastes would first have to be dried. Total cost for drying and shipping was estimated at $US 0.94 per kilogram of chitosan produced. The raw material cist shown, $US 0.38, indicates that roughly 60 per cent of the needed raw materials would be supplied locally at no cost. The other 40 per cent would be obtained from more distant processors.

59/ Conley, Weston, "Running a Crab Meal Plant", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 35-37.

60/ Ibid., page 35.

Table 7.4 Production costs for chitosan (costs shown are per kilogram of chitosan produced) (US dollars)

Raw materials	0.42
Chemicals	
HCl	0.50
NaOH	0.50
Steam	0.45
Water and electricity	0.18
Maintenance	0.07
Amortization of investment	0.20
Total	3.40

Source: Johnson, Edwin Lee and Quintin P. Peniston, "The Production of Chitin and Chitosan", in Proceedings of the First Internatioanl Conference on Chitin/Chitosan, Massachusetts Institute of Technology Sea Grant Report No. MITSG 78-7, Cambridge, MA, 1978, pp. 80-87.

The chemical costs shown in table 7.4 are based on a price of $US 94 per ton of 23 per cent hydrochloric acid solution and $US 270 per ton of sodium hydroxide in a 50 per cent solution. Labor costs are for fifteen men at $US 8.50 per hour, plus salaries for managers totalling $US 85,000 per year. It was assumed that heat would cost $US 6.80 per million BTU (British Thermal Unit). Maintenance was set at 5 per cent of the cost of equipment, cost of equipment being $US 600,000. Overhead was estimated to amount to $US 85,000 annually. The total investment cost, $US 1,020,000, was amortized at 10 per cent annually.

In order to calculate profitability, Johnson and Peniston assumed that the chitosan could be sold for $US 7.50 per kilogram and that the protein could sell for $US 1.30 per kilogram. Using these figures, the net income from a chitosan production plant in 1990 worked out as shown in table 7.5.

Table 7.5 Income and expenditure summary, chitosan production facility

Income			
Chitosan	- 450 tons at $US 7,500 per ton	$US	3,366,000
Protein	- 560 tons at $US 1,300 per ton	$US	733,000
Total income		$US	4,099,000
Expenditures			
Manufacturing cost	- 450 tons at $US 3,390 per ton	$US	1,522,350
Costs related to sales	- 15 per cent of sales	$US	614,860
Total expenditure		$US	2,137,210
NET INCOME BEFORE TAXES		$US	1,961,790

Source: Johnson, Edwin Lee and Quintin P. Peniston, "The Production of Chitin and Chitosan", in Proceedings of the First International Conference on Chitin/Chitosan, Massachusetts Institute of Technology Sea Grant Report No. MITSG 78-7, Cambridge, MA, 1978, pp. 80-87. Recalculated to 1990 $US.

Although the plant as envisioned by Johnson and Peniston required a 13,440 ton crab harvest and a $US 1,020,000 initial investment, practical experience indicates: 1) that to produce 450 tons of chitosan an even larger crab harvest would be required, and 2) that is is possible to produce chitosan profitably in much smaller, less expensive plants. Actual experience indicates that chitin yields amount to only 5-6 per cent of waste, rather than the 8.33 percent envisioned by Johnson and Peniston.61/ Thus a plant producing 450 tons of chitosan annually would actually require a crab harvest of close to 20,000 tons. On the other hand, a company in the United States that has been involved in supplying technology for protein and chitin extraction believed that a profitable chitin/protein extraction plant could be built for $US 425,000 in 1990.62/

61/ Freyer, Lee, "Protein Extraction", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 68-73.

62/ Ibid., p. 73.

8. COSTS OF WASTEWATER TREATMENT

No studies of actual costs encountered in treatment of seafood processing wastewaters are reported in the literature. In 1975 Battelle Laboratory made estimates of what it would cost for small seafood processors to screen their wastewater. They estimated that small finfish plants would have initial capital costs of some $US 55,000 and annual operation and maintenance costs of $US 9,200. Small crab processors would have capital costs of $US 33,000 and annual costs of $US 8,200. The capital costs for small clam processors would be $US 22,500, and for small oyster processors $US 16,100. Both clam and oyster processors would have operation and maintenance cost of $US 8,100 annually.63/ To estimate costs for other types of wastewater treatment and to relate costs more specifically to plant size and volume of wastewater flow, the United States Environmental Protection Agency provided formulas. The formulas are based on costs calculated in 1990 dollars. Consequently, use of these formulas in 1987 in countries outside of the United States must be undertaken with extreme caution. The formulas are presented in tables 8.1 and 8.2. Table 8.1 gives formulas for plants with flows under 190 liters per minute; table 8.2 gives the corresponding formulas for plants having flows of over 190 liters per minute.

Table 8.1 Formulas for calculating wastewater treatment costs - plants with flows under 190 liters per minute

	Capital cost, 1990 $US	Operation and maintenance costs per day, 1990 $US
Screening	2.5 5,000 + (760)F	3 (6 + .08F)A
Lagoon	2.5 [5,000 + (3,410)F]A	3 (7 + .12F)A
Extended	2.5 [22,000 + (7,880)F]A	7 (10 + .26F)A
Flotation	2.5 15,000 + (2,270)F + (7.9)S	4 (20 + .55F)A

F = wastewater flow in liters per minute
A = number of hours of operation per day divided by 16
S = dry weight of solids removed per day in kilograms

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 229. Recalculated to 1990 $US.

63/ United States Environmental Protection Agency, Waste Treatment and Disposal from Seafood Processing Plants, Robert S. Kerr Environmental Research Laboratory Office of Research and Development, Ada, Oklahoma, 1977, EPA-600/2-77-157, pp. 3 and 39.

Table 8.2 Formulas for calculating wastewater treatment costs - plants with flows over 190 liters per minute

	Capital cost, 1990 $US	Operation and maintenance costs per day, 1990 $US
Screening	2.5 12,330 + (200)F	3 (6 + .08F)A
Lagoon	2.5 [46,600 + (250)F]A	3 (7 + .12F)A
Extended	2.5 [110,000 + (1,210)F]A	7 (10 + .26F)A
Flotation	2.5 35,000 + (760)F + (7.9)S	4 (20 + .55F)A

Source: Ibid. Recalculated to 1990 $US.

In addition to providing formulas to calculate the costs of wastewater treatment systems, the United States Environmental Protection Agency made estimates of the costs involved in reducing water flows. The costs represent initial investment required to replace flumes with dry handling systems such as tote bins or pneumatic conveyors, costs for high pressure hoses with spring-loaded nozzles or similar devices to reduce water used in washdown, and the costs to operate and maintain such equipment. Any savings that might accrue to processors from reduced water bills have not been factored in. Table 8.3 summarizes the estimates made by the United States Environmental Protection Agency in 1975 for implementing water reduction measures.

Table 8.3 Costs for water reduction systems

	Goal	Capital cost ($US)	0 + M cost per day ($US)	Flow reduction achieved (percentage)	Plant size[a/]
Conventional finfish	Reduce wash water	5,100	2	20	43
Mechanized finfish	Elimiate flumes	8,500	2	20	49
Mechanized clams	Reduce wash water	25,500	22	12	265
Oyster	Reduce wash water	25,500	24	14	8
Conventional salmon	Reduce wash water	27,200	130	10	35
Mechanized salmon	Reduce wash water	25,500	34	15	40
	Eliminate flumes	20,400	6	7	

a/ Plant size is given in tons of final product produced per day.

Source: Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 229. Recalculated to 1990 $US.

The reduction of water used in washdown shown in table 8.3 for a conventional finfish plant is estimated to result in 15 per cent reduction of BOD_5 in the wastewater stream. The elimination of flumes in a mechanized finfish plant would lead to a 20 per cent reduction of BOD_5. Significant reductions in wastewater BOD_5 would also be achieved in the case of oyster plants (a 30 per cent reduction), and in conventional salmon plants (a 10 per cent reduction). Only 7 per cent reduction in BOD_5 is expected in the case of mechanized clam plants, and only 4 per cent in the case of mechanized salmon plants.64/

64/ Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979, p. 229.

9. HEALTH AND SAFETY

The primary health problems in the seafood processing industry are dermatological. Skin infections, warts and various rashes may result from viruses and bacteria in the fish and from various chemicals used in preservation. In order to reduce the incidence of dermatological problems, as well as to protect the quality of the fish product, the highest sanitary standards should be maintained. Showering facilities should be provided, workers should be encouraged to wash before eating, and an eating area separated from work areas should be provided. In addition, walls, floors, work areas and equipment should be washed with hot, pressurized water daily. Disinfectants should be used regularly.

Where canning and retorting operations are present, high temperatures and humidity levels, as well as excessive noise can also cause health problems. To reduce ill effects of high temperatures and humidity, cool drinking water and salt tablets should be available to workers. If high temperatures and/or humidity continue to cause problems, efforts should be made to improve ventilation systems. Noise levels above 90 decibels lead to increased accident rates. Workers should wear ear muffs when they have to work close to machinery creating noise at or above 90 decibels. If it is necessary to station workers close to such machinery for extended periods of time, they should be provided with a noise insulated room. Efforts should also be made to reduce noise levels. Noise levels can be reduced through good maintenance of mechanical equipment, the use of sound absorbent materials, nylon-coated cables and proper adjustment of can conveyor systems.

Most accidents in the seafood processing industry are due to falls, cuts and strains from lifting. In canning procedures accidents also may result from falling objects, burns from hot liquors and equipment, and from spills of acids and alkalis. The thorough, daily cleaning of floors required to maintain high sanitary standards will help reduce falls by eliminating grease and other slippery materials. In addition, floors should be covered with non-slip materials and be well drained. In order to reduce injuries from cuts, broken glass and tin scraps should be cleaned up promptly. To prevent injuries due to lifting, mechanical equipment should be provided wherever heavy loads must be moved. Table 9.1 summarizes additional procedures recommended by the World Bank to protect the health and safety of workers. Due to the need to maintain the highest sanitary standards, the World Bank also recommends that seafood processing facilities be subject to frequent government inspection.

Table 9.1 Health and safety maintenance procedures

1. Walls should be of ceramic material to allow for complete cleaning.

2. Mechanical equipment must have guards to protect workers from injury. Drums, pulleys and gears should be protected. In canning operations filling and closing machines should be totally enclosed except for intake and discharge openings.

3. All electrical installation and equipment should be in accordance with National Electrical Code standard. Electrical equipment should be grounded and checked regularly for defective insulation.

4. Steam pipes should be provided with thermal insulation.

5. Windows should be provided with screens to prevent insects from entering.

6. Elevated platforms, walkways, stairways and ramps should be provided with handrails, toeboards and non-slip surfaces.

7. Passage-ways for carts and workers must be adequate, and signs for exits and doorways easily visible.

8. Where boilers are used, workers responsible for cleaning them should be provided with protective clothing, masks and footwear. Emergency eyewash and shower facilities should be available.

9. Where workers have to enter tanks or other enclosed areas, they must be provided with self-contained air respirators or with a respirator that receives air from the outside through a supply hose. A second worker should be stationed outside the tank or enclosed area to watch to see that the worker inside is safe.

10. All workers should be given pre-employment and periodic medical examinations. To avoid tetanus, workers should obtain immediate first aid after any cut.

11. Employees should be instructed in personal hygiene, sanitation and safety practices. They should be given instruction in the proper use of all equipment including equipment for their personal protection, in safe lifting practices and in the location and handling of fire extinguishers.

Source: The World Bank, Office of Environmental Guidelines, Environmental Guidelines, Washington, D.C., 1984.

10. CONCLUSIONS AND RECOMMENDATIONS

10.1 For governments and industry

(1) Fish processing industry is dependent on fish stocks which are frequently threatened by overfishing, destruction of coastal spawning grounds or pollution. Governments should take the necessary steps to protect the resource base.

(2) Aquaculture is potentially a complementing source of raw material of high quality and high price species for the fish processing industry. Development planning should seek to maximize the mutual benefits between fishing, fish processing industry and aquaculture.

(3) In most cases, only a smaller part of the raw material in the form of fish and shellfish delivered to the fish processing industry end up in products. Traditionally, the large rest ends up as waste and may result in intense local pollution, and contribute to regional pollution such as coastal eutrification. Process technologies that allow e.g. better use of by catches, a wider size distribution of fish and that reduced spoilage should be encouraged as they both promote profitability and contribute to environmental protection.

(4) In addition, to increase the proportion of landings that can be used for human consumption (recommendation 3) fish silage production provides a way to utilize most of the catches for animal consumption and aquaculture. The use should be encouraged.

(5) Biogas production in anaerobic reactors provide a source of low cost energy from fishing industry waste and wastewater, and contributes very much to environmental protection. The use should be encouraged.

(6) Shellfish processing industry generates waste, e.g. shells that cannot be utilized in process recommended under 4 and 5 above. Local markets, however, often exist and should be identified.

(7) When much waste is produced despite attempts to utilize processes recommended above, disposal methods should be carefully selected, and monitoring should be carried out to ascertain that environmental effects remain small.

10.2 For UNIDO

(1) Assist member countries in planning the development of fish processing industry to make the best sustainable use of the fisheries' resources, taking into full account the possibilities of complimentary integration of aquaculture.

(2) Inform member countries and involved industries about the techniques available for fish silage production and anaerobic biogas reactors; also assist member countries with feasibility studies on the enclosing of these processes in existing industries and encourage demonstration units for these techniques in developing countries.

10.3 For developing countries

(1) Increase refrigeration capacity to reduce spoilage and to take care of by-catches.

(2) Introduce technologies to turn by-catch and processing wastes into food products: minced fish, pulp, protein concentrates, etc.

(3) Introduce technologies, for instance fish silage to produce additives in feed for poultry, hogs and fish farming.

(4) Combine processing plants with aquaculture and/or production of poultry and hogs.

(5) It should be possible to decrease the demands for waste water treatments if the wastes were considered to be resources as above.

(6) Wastewater treatment should be done in simple ways like screening, filtering and by the use of dams or lagoons.

(7) Possibly could biogas production from macrobic wastewater treatment be further developed like in New Zealand.

(8) Sludge from dams, lagoons, screening, etc. could be used as fertilizers to reduce imports of artificial fertilizers.

(9) Recipients should be thoroughly investigated to avoid entrophication.

References

UN documents

United Nations Economic and Social Commission for Asia and the Pacific, Industrial pollution control guide-lines, VIII, Fish processing industry, Bangkok, 1982.

United Nations Food and Agriculture Organization, Fisheries Technical Paper No. 110, Fish and fisheries in the context of environmental concern, by H. A. Regier and D. W. Kelley, Rome, 1971, FIR/T 110, Accession No: 96013.

United Nations Food and Agriculture Organization, Report on the marketing study of fish protein concentrate (FPC B), Rome, 1980, FAO TF/INT 268 (FH).

United Nations Food and Agriculture Organization, Minced fish technology: a review, Rome, 1981, FIIU/T216.

United Nations University, Food and Nutrition Bulletin, Supplement No. 7, Utilization of trash fish and fish wastes in Indonesia, by I. P. Kompiang, Tokyo, 1979, FAO Accession No: XF8332089.

Non UN documents

Asano, Takashi, "Chitosan Applications in Wastewater Sludge Treatment", in Proceedings of the First International Conference on Chitin/Chitosan, Massachusetts Institute of Technology, Cambridge, MA, 1978, Sea Grant Report No. MITSG 78-7, pp. 231-241.

Aung, L. H., et.al., "Fish and Seafood Wastes as Nutrients for Agricultural Crop Fertilization", Florida Sea Grant College, Report No. 40, 1981, pp. 275-279.

Austreng, E., "Fish Silage and Its Use", Il Pesce (Italy), Vol. 1, No. 4, December, 1984, p. 29.

Avault, James W., "'Wastes' Can be Turned into Cash", Aquaculture Magazine (USA), March-April 1981, pp. 38-39.

Bough, Wayne A., et.al., "Utilization of Chitosan for Recovery of Coagulated By-products from Food Processing Wastes and Treatment Systems" in Proceedings of the Sixth National Symposium on Food Processing Wastes, 9-11 April 1975, Madison, WI, EPA-600/2-76-224, p. 31.

Brinsfield, R. B. , P. N. Winn, and D. G. Phillips, "Characterization, Treatment, and Disposal of Wastewater from Maryland Seafood Plants", Journal of the Water Pollution Control Federation (USA), August 1978, pp. 1943-1952.

Brooks, Clayton, "A Historical Perspective", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 6-10.

Cantor, Dr. Sydney, "Chitin-Chitosan Production", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982 Report No. UM-SG-MAP-81-03, pp. 74-83.

Carter, P. M., et.al., Recent Developments in the Utilization of Meat and Fish Wastes in the Tropics, Tropical Development and Research Institute, London.

Church, D. C., "Byproduct Protein Sources for Supplementing Forages", Agricultural Experimental Station, University of Arkansas, Report No. 113, 1983, pp. 146-171.

Conley, Weston, "Running a Crab Meal Plant", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 35-37.

Dressel, David, "Scrap Handling Practices Nationwide", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 26-30.

Ertz, D. B., J. S. Atwell and E. H. Forsht, "Dissolved Air Flotation Treatment of Seafood Processing Wastes - An Assessment", in Proceedings 8th National Symposium on Food Processing Wastes, Cincinnati, Ohio, 1977, EPA/600/2-77-184, pp. 98-118.

Fryer, Lee, "Protein Extraction", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 68-73.

Green, John H. and Joseph F. Mattick, "Possible Methods for the Utilization or Disposal of Fishery Solid Wastes", Journal of Food Quality (USA), 1977, pp. 229-251.

Hang, Y. D., E. E. Woodams, and G. F. Parsons, "Isolation and Chemical Evaluation of Protein from Clam Wash Water", Journal of Food Science, Vol. 45, 1980, pp. 1040-41.

Hood, L. F. and R. R. Zall, "Recovery, Utilization and Treatment of Seafood Processing Wastes", Advances in Fish Science and Technology, Department of Food Science, Cornell University, Ithaca, New York, 1980, pp. 355-361.

Johnson, Edwin Lee and Quintin P. Peniston, "The Production of Chitin and Chitosan" in Proceedings of the First International Conference on Chitin/Chitosan, Massachusetts Institute of Technology, Cambridge, MA, 1978, Sea Grant Report No. MITSG 78-7, pp. 80-87.

Katsuyama, Allen M., A Guide for Waste Management in the Food Processing Industry, The Food Processors Institute, Washington, D.C., 1979.

Keay, J. N., "Aspects of Optimal Utilization of the Food Fish Resource through Product Innovation", Advances in Fish Science and Technology, Torry Research Station, Aberdeen, UK, 1980, pp. 275-278.

Kompiang, I. Putu, "Utilizaton of Trash Fish and Fish Wastes in Indonesia (as Animal Feeds)", in Food and Nutrition Bulletin, United Nations University, Tokyo, 1983, pp. 131-137.

Learson, Robert J., "A Look at the Options", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 109-112.

Litchfield, John H., "Meat, Fish and Poultry Processing Wastes", Journal of the Water Pollution Control Federation (WPCF), Vols. 53, 54, 55, and 56, No. 6, June 1981, 1982, 1983, 1984.

Machin, D. H., R. H. Young, and K. Crean, "The Use of Formic Acid Prepared Fish Silage Made from Shrimp By-Catch in the Diets of Fattening Pigs", Tropical Animal Production, Vol. 7, 1982, pp. 120-126.

Meyers, Samuel P., "Utilization of Shrimp Processing Wastes in Diets for Fish and Crustacea", Florida Sea Grant College, Report No. 40, 1981, pp. 261-274.

Middlebrooks, E. Joe, Industrial Pollution Control, Volume 1: Agro-Industries, John Wiley and Sons, New York, 1979.

Murray, Thomas, "Crab Meal Production: Costs and Returns", in Crab Byproducts and Scrap 1980: A Proceedings, Maryland University, College Park, MD, 1982, Report No. UM-SG-MAP-81-03, pp. 38-45.

Ooshiro, Zentaro, et.al., "Approaches to the Use of Plastein Reaction in Oily Fish", Memoirs Faculty of Fisheries, Kagoshima University (Japan), Vol. 30, December 1982, pp. 369-382.

Salassa, L. L. and J. F. Prudden, "Applications of Chitin and Chitosan in Wound-Healing Acceleration", in Proceedings of the First International Conference on Chitin/Chitosan, Massachusetts Institute of Technology, Cambridge, MA, 1978, Sea Grant Report No. MITSG 78-7, pp. 296-304.

Simpson, Kenneth L., "The Recovery of Protein and Pigments from Shrimp and Crab Meals and Their Use in Salmonid Pigmentation", in Proceedings of the First International Conference on Chitin/Chitosan, Massachusetts Institute of Technology, Cambridge, MA, 1978, Sea Grant Report No. MITSG 78-7, pp. 253-262.

Swanson, G. R., E. G. Dudley and K. J. Williamson, "The Use of Fish and Shellfish Wastes as Fertilizers and Feedstuffs", in Bewick, Michael W. M., Handbook of Organic Waste Conversion, Van Nostrand Reinhold Company, New York, 1980, pp. 281-322.

U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Assessment of Seafood Processing and Packing Plant Discharges and Their Impacts on Georgia's Estuaries, Rockville, MD, 1982, NOAA-82073007.

United States Environmental Protection Agency, Environmental Assessment of Alternative Seafood Waste Disposal Methods at Akutan Harbor, Alaska, Seattle, WA, 1984, EPA/910/9-83/114.

United States Environmental Protection Agency, Section 74 Seafood Processing Study Executive Summary, Washington, D.C., 1980, EPA 440/1-8-/020.

United States Environmental Protection Agency, Waste Treatment and Disposal from Seafood Processing Plants, Robert S. Kerr Environmental Research Laboratory Office of Research and Development, Ada, Oklahoma, 1977, EPA-600/2-77-157.

United States Federal Register, Vol. 45, No. 154, Thursday, August 7, 1980, pp. 52411-52416.

United States Federal Register, Vol. 45, No. 166, Monday, August 25, 1980, pp. 56374-56376.

Wah-On, H. C., et.al., "Protease Production by Fermentation of Fish Solubles from Salmon Canning Processes", Canadian Journal of Microbiology, Vol. 26, 1980, pp. 1049-1056.

World Bank, Office of Environmental Affairs, Environmental Guidelines, Washington, D.C., 1984.

World Health Organization, Coordinated Mediterranean Pollution Monitoring and Research Programme, First Report on Coastal Quality Monitoring of Recreational and Shellfish Areas (Med VII), Copenhagen, 1978.

SOMMAIRE

Cette étude constitue un document technique sur le traitement des rebuts dans l'industrie des fruits de mer. Elle se concentre sur les moyens d'utilisation des débris dans la production alimentaire et insiste particulièrement sur les méthodes de transformation des fruits de mer telles que pratiquées dans les pays en développement.

Le document fournit des données sur ce qui caractérise les eaux usées et les rebuts solides, le choix des recyclages possibles et les méthodes de traitement et d'évacuation. Il fait également mention du coût de traitement des eaux usées et des paramètres économiques relatifs aux options de recyclage.

Les effets primaires liés aux effluents des industries de transformation des fruits de mer résultent de la biodégradation des déchets et eaux usées. En outre, des effets secondaires importants sont dûs aux éléments nutritifs, huile, particules en suspension, bactéries, à la chlorination des eaux usées et aux hausses de températures enregistrées à proximité des déversoirs.

Les débris de fruits de mer ont une valeur potentielle très élevée grâce à leur important contenu protéinique. Ils peuvent être utilisés dans la fabrication de produits alimentaires pour la consommation humaine, comme additifs dans la consommation animale et pour certaines spécialités chimiques. La production de poudre de poisson se faisant souvent dans de larges appareils n'est pas à conseiller pour de petites usines. Par contre, la production de hachis d'aliments à base de poisson et l'ensilage de poisson est recommandable.

L'étude conclut en soulignant l'existence de réelles opportunités de recyclage des rebuts et déchets industriels en produits alimentaires, tourteaux pour bétail ou encore production de biogaz. L'ONUDI est à même d'assister les pays membres à orienter le développement de l'industrie des fruits de la mer dans le sens d'une utilisation rationelle des ressources marines.

EXTRACTO

El estudio presenta información técnica sobre la gestión de desechos en la industria de elaboración de pesca y mariscos. El interés prioritario está en los procedimientos de aprovechamiento de desechos en otros productos alimenticios. Se da particular relieve a los datos relativos a los fabricantes de productos derivados de la pesca en los países en desarrollo.

Se suministran datos sobre las características de los desechos líquidos y sólidos, sobre las opciones de reciblado y sobre los métodos de tratamiento y eliminación de desechos. Se incluyen también los costos de tratamiento de los desechos líquidos y los parámetros económicos de las opciones de reciclado.

Los efectos primarios de las descargas de las industrias basadas en la pesca se refieren al BOD de los desperdicios, y desperdicios del agua. Hay otros efectos secundarios importantes que se refiere a los nutrientes, aceites, sólidos flotantes, bacterias, clorinación de los desechos de agua y los aumentos de temperatura en los recipientes.

Los desechos de los productos pesqueros tienen un potencial muy valioso debido a su elevado contenido proteínico. Entre las opciones de reciclado cabe citar la fabaricación de productos alimenticios para el consumo humano, aditivos para los piensos, aditivos, y algunos productos químicos especiales. Los grandes fabricantes suelen elaborar harina de pescado, pero esta práctica no se recomienda para la pequeñas instalaciones. Se recomienda en cambio la producción de alimentos y piensos de pescado desmenuzado.

El estudio concluye indicando que existen buenas posibilidades en los países en desarrollo para convertir los desechos de captura y procesamiento, en productos alimenticios, aditivos y piensos para la alimentación animal o la producción de biogas. ONUDI podría asistir a los países miembros en el planeamiento del desarrollo de las industrias basadas en la pesca, para alcanzar un uso sostenible de los recursos pesqueros.