Département amélioration des méthodes pour l'innovation scientifique

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Ready to use bibliography of South-East Asian fish processing pollution from a EU perspective and proposal for existing or research solutions

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Coordinator Dr Didier MONTET (CIRAD-AMIS)
Didier Montet (1), Marie-Dominique Lafond (1), Sudip Rakshit (2), Thiery Goli (1), Daniel Pioch (1), Shri Mukku Rao (2), Nadine Zakhia (1), Willem Stevens (2)

1. **CIRAD-AMIS/PAA, TA 40/16, 34398 Montpellier Cedex 5, France**
2. **AIT/BPT, PO box 4, Klong Luang, Pathumthani 12120, Thailand**

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1. INTRODUCTION

About 150 million people in Asia are economically dependant on fishing and its related activities (Infofish International 4/98). Although Asian fisheries contribute substantially to the worlds fish catch, one of its unique characteristics is that its fisheries tend to be dominated by small scale coastal fisheries. Management policies have thus tended to be ad hoc in nature and to a large extent a political exercise.

This trend is slowly changing with the coming of the new millenium and new management strategies are being implemented in response to market demands. In the post harvest sector the importance of a well trained and efficient workforce for processing and quality control for marketing products to the US, Japan and the EU is of great importance. This has been realized following major setbacks, both financially and commercially, due to detentions and import bans in these traditional markets. The immediate positive effect of these problems has been awareness and urgency felt by the exporting countries to upgrade facilities and train personnel to achieve minimum standards of sanitary safety, quality, Hazard Analysis Critical Control Points (HACCP) programs, etc.

In order to meet more recent ISO 14001 standards these processors will in addition to satisfying product quality will have to ensure that the processing does not cause environment pollution and other socio-economic problems down stream.

The major aims and goals of this report will be to make available a ready to use bibliography of South-East Asian fish processing and allied industries from a EU perspective and try to propose existing solutions or research ways to get adapted solutions.

While considerable data is available on the amount and type of catch, the fish processing industry in Asia has not been categorized systematically. The geographical repartition and volume of processed fish of all major types is done. They are classified into scale of production of the different types of products, the in built quality management functions, export levels at present, capacity for increased production, etc.

A overview of food processing industry in general in Asia indicates that though the importance of waste treatment requirement is understood by the governments agencies, enforcement is not done in a systematic manner. However, this is also changing and it will not be long before industry will have to put in place waste treatment facilities. They will then be looking for available expertise and processes which can be implemented efficiently.

The traditional byproducts of the fish industry has been fish meal and related products for a long time. The major market holders for these products have been from South America and Europe. However, it has been realized that the number of fishery byproducts can be much beyond this. Production of fish oils, useful molecules like chitin and chitosan from the large crustacean (shrimp, crab, squid, etc) and a host of other valuable products can change the type of waste treatment processes and their volumes to large extent.

While a number of technologies are available for the production of such useful byproducts, these are not being used in Asia to a great extent. Valorization of such material which can be used in a food, feed, pharmaceutical, cosmetic and other industries have been proposed and the feasibility of which have to be accessed in the context of S.E.Asia.

This report gives the status of sea food industry in S.E.Asia with a survey of the pollution it causes and the possible routes of value addition of the by-products towards a cleaner production scenerio.

2. OVERVIEW OF FISHERIES IN SOUTH-EAST ASIA

2.1 World fish catch

Preliminary estimates point to an increase in the world fish catch in 1997 to about 113.2 million tons, slightly more than the record 1996 level (25 million tons) (Table 1). The decrease accounted for by a smaller pelagic catch in South America due to the adverse affects of the El Niño weather phenomena was counterbalanced by the expansion of China. This country remains the world's major fish producer with a catch of more than 30 million tons in 1997. The contribution of aquaculture, in general, to the world fish catch continues to expand, but growth rates of shrimp culture are levelling off. After years of continuous decline, the Japanese catch seems to have stabilized at 5.8 million MT (www.fao.org, 1999).

	1994	1995	1996
	(. . millions tons . .)		
China	20.7	24.4	25.0
Peru	11.6	9.0	9.6
Chile	7.8	7.2	6.9
Japan	7.4	6.8	6.6
United States	5.9	6.0	5.9
India	4.5	4.9	5.1
Indonesia	3.9	4.0	4.2
Russia	3.8	4.2	4.6
Others countries	44.0	46.5	45.3
TOTAL	**109.6**	**113.0**	**113.2**

Table 1 : World fish production, source: FAO, 1999

Table 2 shows that the total catches of all Asian countries increased between 1990 to 1997. Among South-East Asian countries, Laos increased its total catches from 18,000 tons in 1992 to 26,000 tons in 1997, Vietnam increased production from 787,147 tons in 1992 to more then 1 millions tons in 1997. Production in Philippines, Thailand, Cambodia and Malaysia are quite stable.

Developing countries overtook developed countries in 1995 as major fish exporters. Statistics show a recovery of developed countries fish exports 1996. But some of this might be due to statistical problems of developing countries supplying export statistics for the year.

During the period 1984-1992, production of inland capture fisheries stagnated, while inland aquaculture increased by more than 40%. In a number of countries the natural inland fish stocks are fully exploited. However, in most countries water resources as a habitat for fish are deteriorating, both qualitatively and quantitatively. The worst situation is in some natural lakes where the combination of very high fishing pressure with environmental degradation has resulted in decline in fish species diversity and the dominance of small fish in catch. In several countries of the sub-region the requirement of an environmental impact assessment for any new major development has led to better harmonization of fishery needs with those of other users of water resources. FAO has produced guidelines on optimizing inland fisheries in multiple-use contexts, which are to assist both the fisheries and non-fisheries planners in a better understanding of the specific requirements of fisheries in regulated waters and in otherwise modified conditions. In many waterbodies of the sub-region, introduction of exotic fish species and culture-enhancement have assisted in increasing the inherent low fish species diversity and in raising fish production. It is now recognized that impacts of human activities on nature need to be monitored to allow for the implementation of timely mitigating measures with the objective of safeguarding the sustainability of inland capture fisheries in the sub-region (Petr et al., 1994).

Countries	1990	1992	1994	1996	1997
Bangladesh	653 552	709 332	770 790	814 787	829 992
Bhutan	300	315	310	300	300
Brunei	2 348	1 692	4 445	7 405	4 521
Cambodia	105 000	102 600	95 000	94 710	102 800
China	6 654 440	8 322 552	10 866 836	14 222 306	15 722 344
Hong Kong	224 237	220 181	211 010	183 856	186 000
Taiwan	1 110 939	1 063 947	967 209	967 483	1 038 048
India	2 782 586	2 844 102	3 209 969	3 474 064	3 601 500
Indonesia	2 544 365	2 889 046	3 315 629	3 557 623	3 649 200
Japan	9 549 979	7 683 898	6 617 308	5 936 130	5 882 290
Korea DPRp	1 300 000	900 000	371 961	253 125	236 460
Korea Rep	2 466 583	2 321 079	2 357 891	2 413 756	2 204 050
Laos	18 000	18 000	22 200	25 850	26 000
Macau	2 583	2 668	1 890	1 418	1 500
Malaysia	952 581	1 025 289	1 067 650	1 130 689	1 172 930
Mongolia	124	120	184	231	190
Myanmar	736 731	748 124	750 820	804 830	830 300
Nepal	5 288	5 895	7 340	11 230	11 200
Pakistan	469 036	540 552	537 277	537 432	575 000
Philippines	1 828 883	1 885 041	1 845 331	1 783 593	1 805 000
Singapore	11 491	9 201	11 301	9 943	9 250
Sri Lanka	160 897	202 668	221 500	226 000	240 000
Thailand	2 498 234	2 875 456	3 012 256	2 963 399	2 912 203
Vietnam	752 465	787 147	960 498	1 028 500	1 066 000
World Total	85 463 100	85 263 000	91 397 900	93 177 300	93 329 200

Table 2: Asian nominal catches of fish, crustaceans, molluscs... by countries (in tons)
(FAO yearbook, fishery statistics vol. 84, 1997)

2.2 Situation by product

2.2.1 Shrimps

According to recent estimates (FAO, 1999), the world production of shrimps in 1996 was three million tons. The production of aquaculture shrimps reduced in 1996 due diseases. Thailand remained the largest world producer, in spite of a clear decline in its production, which after having reached a volume of 220,000 tons in 1995, fell to 160,000 tons. In Indonesia and Vietnam, the breedings were also struck by diseases which led to a fall in production in 1996. China and India maintained their level of production, of approximately 80,000 and 70 000 tons respectively. In Bangladesh, where the breedings were not touched by the virus, the production reached some 35,000 tons. The year 1996 was characterized by cold water shrimp (*Pandalus borealis*) superabundance, which was mainly due to the increased capture in the Flemish Bonnet. Therefore, cold water shrimps prices dropped during the year. In December 1996 they were lower by 23 percent as compared to that of the previous year. This change continued during the first months of 1997. The low total availabilities of shrimps led to a decline in the imports of Japan and the United States. In 1996, the shrimp imports of Japan fell to 289,000 tons as compared to more than 300 000 tons in 1993 and 1994. This contraction of the imports is explained by the generally dull situation of the Japanese market in 1996, when the traders were not willing to pay the high prices required by the market. The principal supplier of the Japanese market remains Indonesia, in spite of the problems encountered by its shrimp aquaculture industry there. Exports from Thailand to the Japan market decreased considerably due to the problems of diseases to which the producers were not able to overcome.

The shrimp imports of the United States fell in 1996, for the second consecutive year, to 264 000 tons. This was a fall by about 3 percent compared to 1995 and 8 percent less than in 1994. Thailand remained the principal exporter to the United States, although its sales dropped in 1996. The three principal suppliers to the United States market all recorded a contraction of their exports in 1996 compared to 1995 (Thailand -7 %, Ecuador -8,5 % and Mexico -7 %).

2.2.2 Tuna

In 1996, the Japanese tuna imports at 326 000 tons which was slightly lower in volume than the 333,000 tons which had been imported in 1995. However, the yellow fin tuna imports marked a certain recovery in 1996, after the strong contractions of the years 1994 and 1995. In addition, the obese tuna imports was somewhat reduced after the acceleration recorded in 1995. This situation indicates that in the sashimi market, the obese tuna is used to replace yellow fin tuna. Taiwan remains the principal exporter towards the Japanese market, although its exports reduced in 1996, falling to some 96 000 tons, that is to say a lowering of 6 percent compared to 1995 and 33 percent less than the maximum exports acheived in 1993.

The weakening of the demand for canned tuna in the United States, to which the problems of UNICORD are added, effected the Thai supplier principally. It resulted in a fall of American imports of canned tuna to 88 000 tons in 1996, which was 10,000 tons less than in 1995 and very much lower than the record of 160 000 tons reached in 1991. However, Thailand remains the principal supplier of the United States, in spite of a decrease of 26 percent of its exports in 1996. In the United States, canned tuna consumption dropped by 5 percent in 1996 to about 2 kg per capita.

Taiwan is the principal frozen tuna exporter towards the United States having 40 percent of the market share. The tuna captures were as disappointing in the Indian Ocean as in the Pacific during the second quarter of 1997. So the prices of the listao and yellowfin tuna increased on the world market. In Thailand, the price of the listao reached 1300 dollars E.-U. per ton in July 1997, against 850 dollars US/ton earlier in the year. The canning factories had currently only limited stocks and had to get raw materials at the strong price. This increase was also reflected on to the importers. Certain countries already look for other sources of supply. The countries of the EC, for example, negotiate more and more with the ACP States from which the canned tuna can be imported without taxes.

2.2.3 Cephalopods

China has played an important role in the market for cephalopods in the last few years, mainly due to its permanent investments in its deep-sea flotilla. The Chinese fishing vessels have now started to fish in South-western Atlantic, which will result in an increase in the availabilities of squids coming from this zone. However, other than the Chinese flotilla, all the other nations have indicated disappointing catches of cephalopods. Certain catch like the the Altantic Center East *Octopus* seem under considerable pressure. The prices of the cephalopods could increase further. At the beginning of the year 1997 (March-April), a prohibition on fishing of octopus was accepted in Las Palmas in order to to protect this species. At the end of prohibition, stock was still on an exceptionally low level, which proved that the pressure exerted on this species was much stronger than estimated previously. The prices of octopus on the world market remain high, in spite of a certain changes compared to the particularly high levels reached during the second half of 1996. With the liberalization of the economy in Eastern Europe, the trade of the seafood with Western Europe has quickly developed.

The three products discussed above namely shrimp, tuna and cephalopods constitute a major part of the exports of sea food products from S.E.Asia. Measures required to prevent such accidental catch have been made by upgrading equipment used for the same. This is required by some importing countries like the US.

The rejections of accidental capture as tortoises, birds, etc were evaluated by FAO in 1994. These rejections lay between 17.9 to 39.5 million tons per annum. 20 million tons corresponded to 25 % of the annual known fish catch (FAO, 1998).

2.3 Fisheries by country

2.3.1 Fisheries in Malaysia

Fishing at sea is a growth sector in Malaysia in which the total catch was 1 170 000 tons in 1994. Fish constitutes an important part of the Malaysian diet (Yusoff et al; 1994), with annual consumption of 36 kg per capita providing about 60% of total animal protein intake. The fisheries industry supports over 103,000 people which is 1.4% of the total Malaysian labor force. Annual fish production, per capita fish consumption and employment in the fisheries sector have been increasing over the last decade to reach 1 172 930 tons of production in 1997 (FAO yearbook). Trends in consumption have recently moved towards freshwater fish, mediated largely by the introduction of modern aquaculture technologies using better fish stocks, feeds and fish health management practices. Growth in recreational fishing has also enhanced the potential of inland fisheries. Aquaculture production contributes about 7% of total fish production, through pond, cage and aquarium fish culture. Future development of inland fisheries demands a multi-disciplinary approach embracing pollution mitigation, stock enhancement and management.

Aquaculture is a relatively young industry in Malaysia but it has developed rapidly in recent years. It contributes 80 000 tons annually to total fish production of the country. The culture of marine finfish in cages, floating *kelongs* in Johor, and floating fish farms in Selangor is described by Wan (1994). This industry already plays an important role in the national economy (Tan et al., 1992). The present thrust of the Malaysian government is to further promote the development of the aquaculture and turn it into a major industry. The objective is to produce more fish for the increasing domestic demand and for export to earn foreign exchange. A series of programs have been planned by the government to support aquaculture, including an inventory of resources, research and development, extension and training, and market promotion. Environmental degradation and seed production are becoming constraints to continued growth of the industry.

2.3.2 Fisheries in Thailand

The annual catch of shrimps, fish and shellfish reached 2.9 million tons in 1997 (Encarta 99, FAO yearbook). Thailand is the third Asian producer in the field of fishing, after China and Japan. Its sea products processing industry is largely recognized at the regional and international levels. Thailand is classified among the first world canning exporters of sea products and is the first world tuna can exporter. Industrial manufacturing or processing the sea products is a very large exporting sector. (Loubet, www.dree.org/thailande, 1999).

With production of 168 000 tons in 1993, Thailand has become the world's leader in aquaculture shrimp production. The total acreage under shrimp production is approximately 60 000 ha. Kongkeo (1995) discusses the key factors contributing to the success of the Thai shrimp farming industry. These are natural advantages, good infrastructure, good support industries, unique culture techniques, flexibility of the industry, site rotation, small scale industry, low environmental impact, and closed water systems.

Shrimps represent the third largest export of Thailand and makes the country the world's major producer and exporter. In 1998, Thai exports of frozen shrimps rose to 147.385 tons with an increase in volume of 15% in annual production (+ 25% in value, 57.418 million Baht in 1998). This strong increase in value is explained mainly by the increase of competitiveness of the Thai shrimps export, which was indirect effected positively by the baht devaluation. In 1996, shrimp exports were 162.000 tons for a value of 42.306 million Baht. In addition, canned tuna exports, which increased in volume and value, occupies the 10th place among the most exported products of Thailand. This rose in 1998 to 227.319 tons and represented a rise of 12% compared to 1997 (25 billion Bahts, + 45%). In 1996, 188.464 tons of canned tuna were exported from Thailand for a value of 12 billion Baht.

The industry has developed from an extensive to semi-intensive and to intensive systems with high inputs of feed, energy and water management. High profits have induced rapid growth of the industry which in 1992 harvested 185 000 tons of shrimps and prawns from some 728 sq.km. of coastal ponds, with average annual yields of 2539 kg/ha and maximum yields of 9945 kg/ha. Fresh and frozen shrimps and their products are among the country's three largest exports and are valued at $1583 million. The industry and its supporting services, etc. provide about 200 000 jobs, mainly in rural areas and regional centers. The industry has had a number of negative environmental and ecological effects mainly due to poor planning and short term profit seeking. A more conservationist approach along with enforcement of protective regulations such as Thailand is now developing is needed if the industry is to continue in the long term on a profitable and sustainable basis (Uthoff and Scholz, 1994)

Shrimp production and exporter depends on various external parameters (Kwei-Lin et al., 1995), this includes the fall in the demand in certain Asian countries, in particular China and Japan, the increased competition from countries like India, Bangladesh or Malaysia, and the launch of the products of the sea from the European System of Generalized preferences. The companies also have increasing difficulties in meeting the challenge of the low Vietnamese production costs. Within the country, aquaculture is characterized by a surplus of production capacity due to market contraction. This inadequacy between supply and demand is added to the problems arising from the shrimp farms of the central plains which have been the object of considerable criticism, since last quarter 98. They are shown in bad light supposedly for the bad management of water which pollutes the surrounding ground water which in turn destroys rice harvests of the area.. The government has taken certain actions in 1999 to curb inland shrimp production due to these reasons.

Being the products of the sea, the profits conferred by the Baht devaluation will be counterbalanced by the competition of the Philippines, Malaysia and Indonesia whose currencies were also depreciated. In addition, contrary to Thailand where most of the raw material must be imported (Thai fishing represents only 20% of its consumption), the catches of these three countries are sufficient to satisfy the needs for their own processing and export industry (Loubet, www.dree.org/thailande, 1999).

The seafood industry of Thailand is economically important as it provides job opportunities and foreign currency. The government has put strong emphasis on the development of this sector in the National Economic and Social Development Plans.

Suwanrangsi (1992) describes the development of the seafood industry in Thailand, focusing particularly on fish production, utilization, the fish processing industry, and exports of a range of different seafood products including shrimp, tuna, cephalopods and fish and the most recent development objectives for the industry.

The main thrust of recent development has been in the freezing of tuna and canning of shrimp of export quality for sophisticated markets while the traditional processing of fish ball and dried shrimp have also picked up substantially (Krishnasamy, 1993).

2.3.3 Fisheries in Philippines

The annual catches exceed the 1.80 million tons in 1997 (FAO yearbook).

The catch from coastal fisheries in the Philippines has declined to a third of the yields at the beginning of the century. The causes for this include heavy population growth, uncontrolled land settlement/urbanization of coastal regions and erosion from neighboring farmland and forests. Also, conditions detriment to coastal regions and waters is mainly attributable to uncontrolled agricultural and silvicultural activities and to the results of erosion, which in turn causes the siltation/alluviation of rivers and coastal waters leading to extensive impairment of the marine environment. Due to sustained population growth, no reversal of this trend is anticipated (Pauly et al., 1998).

The Philippines is among the world's top ten aquaculture producers and is a net exporter of fishery products. The aquaculture industry has significant potential for accelerated expansion and development. Specific extension policy directions, plans and programmes for the different key resources are summarized by Rabanal (1995) covering milkfish and shrimp, tilapia and carp, seaweeds, and crabs. Aquaculture extension services cover the brackish water and freshwater fish ponds, rice fish culture projects, sea farming projects, fish pens and fish cages, mariculture for molluscs and seaweeds and other related endeavours involving husbandry and culture of aquatic animals and plants. Extension methods employed by individuals and group extension workers are documented in the report. Aquaculture extension is having a positive impact in the Philippines by creating jobs, additional household income and providing nutrition.

The shrimp hatchery industry in Panay Island, Philippines, experienced significant growth during the 1980s. This was primarily due to growing export market, high economic returns, and improved technology. Hatchery numbers grew from 38 in 1985 to 224 in 1992. Of these, 56% were medium scale, 27% small scale, and 17% large scale. Ownership types were 48% single proprietorship, 40% partnership, and 12% corporation. In terms of profitability, only medium scale hatcheries registered a positive return on investment (21.81%), with small and large scale hatcheries showing returns of minus 4% and minus 3% respectively.

Analysis of risk caused by market fluctuations and production shortfalls due to technology, environment and other climate-related factors revealed that medium scale hatcheries were the most stable in terms of economic returns. The uncertainty of a stable demand for shrimp fry has discouraged many hatchery operators from expanding and improving their facilities (Agbayani, 1994).

More than 80% of an estimated 721 000 metric ton of culture shrimp produced worldwide in 1992 was farmed in Asia. With its long tradition of brackishwater pond culture, the Philippines was among the first countries in the region to venture into shrimp farming. Its shrimp industry took off in the early 1980s with the commercial availability of hatchery-reared seed.

While shrimp farming has brought much benefit and bounty to the Philippines, it had some less desirable consequences, especially where improper planning and management occurred. Primavera (1994) gives an account of more than a decade of shrimp farming in the Philippines, with emphasis on the ecological and socioeconomic impacts of the industry.

Mangrove areas in the Philippines are now a visible and highly valued resource, principally as a consequence of the emergence of the shrimp culture industry. This has resulted in a conflict with the traditional uses of the mangrove areas, as unmodified ecosystems, including firewood gathering, thatch material (Nypa species) for homes and mangrove poles for lumber and construction materials, and nursery grounds for the small scale and commercial marine fisheries. In effect, mangrove forested areas in the Philippines have been steadily transferred from a common property resource, of multiple use and benefit to a large number of people, to private properties for single use as shrimp ponds, whose profits are narrowly channelled to the benefit of a select few (Nickerson, 1999).

2.3.4 Fisheries in Cambodia

Tonlé Sap represents one of the greatest freshwater fish reserves of S.E.Asia. Fishing, especially out of fresh water, remains an important economic activity, even though, the fishery product (102 800 tons in 1997, FAO yearbook) is not sufficient for export.

Cambodians, are big eaters of fish (36 kg per person per annum) and practice fishing everywhere - in the ponds, the brooks an by offshore family fishing. They do this by gathering or trapping. On the other hand commercial fresh water fishing is done by the Cham community and especially by the Vietnamese. The natural conditions are exceptional. The lakes (*bengs*) surrounded by the forests is, for fish, a remarkable zone of reproduction and nutrition. Certain migrating species, at the time of the laying, follow the waters of the Mekong in flood and arrive via Stung Treng to the lakes in Tonlé Sap. The fish varieties doing this include the *trey pruol* and *trey riel* (*Cirrhinus auratus* and *Cirrhinus Julienni*) and even the *trey pra* (*Pangasius sutchi*). When the water level decreases, the fish leave the flooded forests for the deep water of the lakes, or with regard to the migrating ones, leave the lakes and the *beng* to join the river. In the latter case, the migration is closely related to the three nights which precede full moon in the months of December, January and February.

Maritime fishing is practised, between Réam and the Thaï border. From November to March this is due to migrating fish benches, in particular of *plathou (Rastrelliger brachysoma)*. These fish, formerly fished by fixed stoppings have since the sixties been caught using drifting gill nets on board motor boats. The majority of the fishermen are of Chinese origin. Most of the production (25 000 tons) was exported, fresh, under ice and more or less clandestinely towards Bangkok and Singapore by Chinese tradesmen (Encyclopedia Universalis, 1998). Fischeries represent 3.2% of GNP of Cambodia (www.dree.org/cambodge, 1999) and production levels do not seem to follow any trends as shown in Table-3.

	1988	1989	1990	1991	1992	1993	1994	1995	1996
Sea fishes (000T)	21	26.1	39.9	36.4	33.7	30	30	30.5	31.2
Water fishes	61.2	50.5	111	118	103	94	65	72.5	39
Aquaculture	4.6	5.5	6.4	6.7	8.5	8	8.2	8.7	9.6

Table-3 : Cambodia catch in thousand tons (www.dree.org, 1999)

Deforestation during the period of the civil war took place in order to increase the amount of agricultural land, as well as logging for fuelwood or timber. The relations between flooded forests, fish and traditional fishing techniques, and the effect of pesticide use on fish resources are discussed by Grunewald (1993).

2.3.5 Fisheries in Indonesia

Indonesia has an excellent opportunity to develop its aquaculture industry since extensive mangroves, coastal areas and open water areas are available. The role of aquaculture in Indonesia is becoming increasingly important, as domestic fish consumption increases and international market demand becomes more significant. Between 1980 and 1987, fishery output increased by 6% per year to keep up with this demand, and prospects for the industry continue to be good (Supardan et al., 1993). In 1994, the total of the catches rose to 3,59 million tons including 2 million tons for industrial fishing and 638 000 tons for inshore fishing. In 1997, catches of fish, crustaceans and molluscs rose 3.65 millions tons. As in most countries of Asia, fresh water aquaculture is very developed (Encarta, 99). Naamin (1994) gave an overview of the fisheries in Indonesia and reported that possible marine area is 5.8 millions km^2 . The landings were made up of 87% finfish, 6% crustaceans, 4% seaweed and 2 % molluscs. Over 90% of fisheries production is consumed domestically with over half of the catch consumed as fresh fish as fish is the most important protein source in Indonesain diet. However, Indonesia still has large fish, shrimp and others seafood export (Table-4).

Mariculture also contributes to the Indonesia's economic development strategy as seaweed and giant clam culture (Firdausy et al., 1992) are harvested in large quantities.

Years	1992	1993	1994	1995	1996	1997
Shrimps Fishes Oysters and seafood	757,4 326,4 38,0	871,6 361,2 39,8	1005,1 323,8 49,2	1033,9 371,7 54,6	1015,6 375,4 54,4	1008,0 383,6 40,6

Table-4 : Indonesia Exportations 1992-1997 (in Millions US$)

2.3.6 Fisheries in Vietnam

The extent of the littoral and the many rivers make of Viêtnam a country favorable for fishing. The southernmost China Sea is particularly rich in all kinds of fish. Fishery undertakings also exist inland in flooded zones. The Ministry of Fisheries plays a central role in the seafood industry of Vietnam (Gutting, 1998). It regulates fishery activities (including aquaculture), and oversees the operation of seafood companies. Seafood processing companies are state-owned enterprises controlled by the Ministry. Most are managed by local government. Individual fishermen and farmers, on the other hand, own most harvesting and aquaculture operations. Larger, commercial-scale fishing and aquaculture operations, however, are state owned.

Foreign investors typically form joint ventures with state-owned firms rather than establish independent operations. Vietnam's foreign investment laws give foreign investors the right to remit profits, the principal and interest on loans, and their own assets.

To promote the seafood industry and increase exports, the Ministry of Fisheries encouraged the establishment in June, 1998 of a non-governmental organization of Vietnamese seafood companies called The Vietnam Association of Seafood Exporters and Producers (VASEP). One of its activities is to provide foreign firms with information about Vietnamese firms.

Total annual potential yield of marine fisheries is between 1.0 and 1.2 million tons in 1997 (FAO year book). Of this total, shrimp accounts for 50,000 to 60,000 tons and squid accounts for 30,000 to 40,000 tons. Recent production levels from both marine and fresh water fisheries are given in table-5.

YEAR	MARINE (metric tons)	FRESH WATER (metric tons)	TOTAL (metric tons)
1980 1985 1990 1995 1997	398,743 576,860 672,130 982,860 1,078,000	558,743 231,150 306,750 415,140 492,000	160,000 808,010 978,880 1,344,000 1,570,000

Table-5: Recent production levels from both marine and fresh water fisheries

Most fishing vessels are small with little or no electronic navigation and communication equipment. 30 percent of the fleet have no engine and most of the remaining vessels have engines of less than 60 horsepower. These vessels are owned by non-state enterprises such as cooperatives and by individual households. Ocean fishing operations, for the most part, are limited to nearshore waters (less than 50 meters).

Vietnam has a long tradition of producing fish through aquaculture and have substantial areas suitable for it. Officials report that there are 1.4 million hectares of inland waters (300,000 tidal; 400,000 in reservoirs, and the remainder in rivers and lakes) and 800 thousand hectares of sheltered marine waters in bays and lagoons.

Aquaculture operations are expanding. In 1990, more then 492 thousand hectares were utilized for production. This total increased to 576 thousand in 1994. Brackish water operations increased from 187 thousand to 250 thousand hectares during the same time period.

Traditional aquaculture operations are mostly privately owned, extensive and self-sufficient. More recently, however, state-owned commercial operation has been established with more intensive-type operations.

In 1997, there were 1,115 hatcheries that produced more than 7 billion fish fry and 2.2 billion shrimp. These hatcheries want to increase production, promote the production of high-quality feed and boost the production of high-value export products.

In Vietnam, there are 342 seafood processing plants. Some of these plants have been upgraded in the past five years and have diversified their products for the purpose of export. 47 enterprises operating 60 plants have implemented U.S. sanitation and HACCP procedures, and 27 enterprises are EU approved exporters.

Seafood exports, mainly shrimp and tuna, have been growing. Government officials say exports totaled $11 million in 1980, $90 million in 1985, $205 million in 1990, $440 million in 995 and $776 million in 1997. The Ministry of Fisheries had set a goal of exporting $850 milion in 1998 (www.dree.org, 1999). These statistics indicate the rapid increase in exports achieved by Vietnam.

2.3.7 Fisheries in Brunei

Agriculture does not play an important role in the economy of the country. Rubber is produced in the districts of Brunei and Tutong. Rice is the primary agricultural product of the country but the production (1 000 tons in 1993) does not meet the needs for the sultanate. The exploitation of the forest reserves (36 % of the grounds) is on the increase but fishing (1770 tons in 1993) remains artisanal. Total sea food catches rose 4521 tons in 1997 (FAO year book).

2.3.8 Fisheries in Singapore

The fishing industry is centered around the port of Jurong, in the south-west of the island of Singapore. Built on 20 ha in 1969, it is the principal industrial base of Singapore. It shelters a flotilla which brings back around 9 000 tons of catches per annum (9 250 tons in 1997, FAO year book). Naval construction and repair constitute an important sector of the activity. Singapore has the greatest world capacity of repair in the dry and floating hold.

2.2.9 Fisheries in Myanmar

Freshwater fish is mainly fished for local consumption and offers an important source of proteins. The government encourages sea fishing today and there is good potential for higher production. The Food and Agriculture Organization (1996) reported that the potential for the development of the fishery industry of Myanmar appears to be good as the resources are at present under exploited. Aquaculture activities are currently confined to freshwater species and thus could be further developed. An overview of marine fisheries in Myanmar is given by Kunhimohamad and Daud (1998). Total sea food catches attain was 830 300 tons in 1997 (FAO year book).

3. SEAFOOD WASTE CLASSIFICATION

3.1 Acceptable waste and acceptable waste

Solid waste management is a big industry at present and such wastes are classified as acceptable and unacceptable depending on the constraints on disposal. For example, the Southeastern Public Service Authority (SPSA, www.spsa.org, 1999) classifies waste as follows. Acceptable waste include household, municipal and commercial solid waste which meet SPSA's standards.

The acceptable Wastes as specified by this organisation include :

- Commercial and municipal tires
- Earthmover, agricultural equipment and industrial tires
- Dust or severely dust laden waste
- Heavy construction and demolition debris
- Large tree trunks, stumps and timber over six inches in diameter
- Household pet carcasses
- Commercial seafood waste
- Animal manure
- PCB waste
- Special waste including contaminated soil, triple rinsed pesticide containers, loads of drums or paint cans, sandblast, sludge, etc.
- Auto, truck, boat and other vehicular batteries.

The unacceptable Wastes include :

The following waste is not accepted at any SPSA facility:

- Hazardous waste
- Materials containing asbestos
- Appliances containing freon gas
- Unsterilized medical waste
- Large animal carcasses
- Slaughter-house waste
- Liquids
- Cable, wire, rope and similar materials over six feet in length unless securely bundled
- Timbers, pipe, metal rods and shapes and similar materials over six feet in length
- Drums or paint cans not emptied and opened
- Petroleum products except household generated engine oil (up to five gallons per trip)

As we see sea food processing waste is classified as an acceptable waste. In fact, as indicated in the latter part of this report, there are a large of number of useful products into which the by-products of the sea food industry can be valorified.

3.2 Shrimp pond wastes

Serious production losses have occurred in shrimp-producing countries around the world, principally due to poor rearing environments and pathogenic diseases. In response to this, shrimp farmers are changing their culture methods. To understand the source and dissipation of nutrients that affects pond water quality and effluent impact, measures for N, P and solid entrapment have been constructed for water exchange systems. These reveal the contribution of the pond bottom soil to the accumulation of sediment and P and its potential contribution of N to the pond system. A survey of shrimp farm water quality and management practices in southern Thailand has also been completed. This reveals a high proportion of farms using low water exchange methods of shrimp culture but without the ability to maintain suitable water quality in the production ponds. Shrimp production in these systems is variable due to high incidences of disease and slow growth rates. Alternative culture systems such as lined ponds, low salinity rearing and recirculation farms are described by Funge et al.(1998). in relation to their potential for remediating problems within the shrimp culture industry. Effects of zeolites and other alumino-silicate clays on water quality at various salinities are also studied by the same team (Briggs and Funge-Smith; Cowan et al., 1999).

The nature of the same organic and inorganic residues in shrimp pond effluents in Malaysia is reviewed by Sze (1998) following an overview of the different culture systems operated (extensive, semi-intensive and intensive). The effect of cutting mangrove on organic pollution of a shrimp pond was studied by Eguchi et al .(1997) in Maeng District, Cholburi Province, in the coastal zone of the Gulf of Thailand.

Economic feasibility of five intensive shrimp production systems was evaluated by Thongrak et al. (1997) using farm survey data for 20 contract farms and 31 independent farms in the Ranot District of Songkhla Province in southern Thailand. Water samples drawn from pond sediments are tested for 12 water quality indicators. Production system used by independent farms is the most profitable system for all risk preferences evaluated. It was reported that the system generates highly polluted waste water. One production system used by contract farms provides the best overall quality of water, but has a low economic return. Not all production systems that improve water quality result in lower economic returns. Getting shrimp producers to adopt production systems that improve water quality will require effective regulations and/or economic incentives. Similarly, Dierberg and Kiattisimkul (1996) studied the effects of intensive shrimp aquaculture in Thailand on water quality and salt water intrusion.

Water quality is deteriorating at the estuary and coastal regions where most of the fish and prawn farms in Singapore are located. Treatment and recycling of water are essential to maintain the water quality at an acceptable level. A system consisting of preliminary settling, biofiltration, secondary settling and final polishing with a biofilter was tested in an experimental farm. Pond water quality was maintained at relatively good level after a 120-day growing period. The growing facilities continued to show good performances after four growing cycles with a 2-week rest period between each cycle. A similar system was installed at a 26 ha farm site having several ponds with sizes varying from 0.7 to 2.5 ha. No disease outbreak occurred after the installation of the treatment and recycling facilities (Chin et al., 1997).

3.3 Shrimp head and shells

Head and shell comprise approximately 55% of the total weight of a shrimp (Rao and Stevens, 1997). Shrimp and crab shell contain chitin (No et al. 1995), protein and inorganic compounds such as calcium carbonate (Wang et al., 1998). Chitin is the major structural component of the exoskeleton of invertebrates. The biodegradation of chitin is very slow in crustacean shell waste. Accumulation of large quantity of shell from seafood processing has become a major concern (Shahidi et al., 1999). The head and shell is either dried and sold as raw material to the feed makers or in some instances dumped into the soil. This shell and head contain 30-50 % protein, 18-22 % ash, 20-25 % chitin and 1-5 % fat (Leggretta et al. 1996).

Cruz (1997) estimated that approximately 45-75% and 85-95% of the feed ingredients currently used for commercial fish feeds (mainly tilapia and milkfish) and marine shrimp were composed of imported feed ingredients, respectively, compared with only 20-30% for livestock and poultry feeds. He proposed to use the available shrimp head and shell as aquaculture feed and fertilizer for the Philippines.

Thailand has become the world's major producer and exporter of shrimps and prawns. It produces more than 300,000 tonnes of shrimps every year and is 10 % of the total world production (FAO, 1998). In view of this Thailand produces almost 100,000-150,000 tonnes of waste per year or more than 300 tonnes of waste per day. The industry has developed from an extensive to semi-intensive and intensive systems with high inputs of feed, energy and water management. High profits have induced rapid growth of the industry which in 1992 harvested 185 000 tons of shrimps and prawns from some 728 sq.km. of coastal ponds, with average annual yields of 2539 kg/ha and maximum yields of 9945 kg/ha. Fresh and frozen shrimps and their products are among the country's three largest exports and are valued at $1583 million. The industry and its supporting services, etc. provide about 200 000 jobs, mainly in rural areas and regional centers. The industry has had a number of negative environmental and ecological effects mainly due to poor planning and short term profit seeking. A more conservationist approach and enforcement of protective regulations such as Thailand is now developing are needed if the industry is to continue in the long term on a profitable and sustainable basis (Uthoff and Scholz, 1994).

The shellfish farming industry in Thailand is a big employer, providing 80 000 jobs. But farming prawns in man-made coastal lagoons covering 5300 ha has transformed large areas of mangrove swamps. The chemicals and feed used are causing pollution. Until 1987, traditional methods of fish farming were extensive, in natural lakes. Recent rapid increase in demand has led to enormous intensification of the industry. Between 1987 and 1990, production trebled. Large producers are trying to squeeze out smaller businesses by, for example, controlling 80% of the feed market. New environmental regulations introduced in 1992 are expensive, and easier for large concerns to absorb than small ones. Attempts to preserve remaining mangroves have led to further intensification. Competition is also beginning from neighboring countries such as Vietnam, Myanmar, Indonesia and Malaysia (Weigel, 1993).

3.4 Squid waste

Ink and protein are the most important waste from squid industry. Pete Guglielmo, owner of Santa Barbara's Southern California Seafood, said his company had cut its waste water discharge by 90%, by capturing tainted water and pumping in back into boat holding tanks for disposal at sea (John Sackton at www.seafood.com). Similar work on the production from ink from squid waste is going on in Thailand. Joseph et al. (1987) used squid waste as meal.

3.5 Fish scrap, bones and heads

The use of agricultural, domestic and animal farm wastes in fish culture is an ancient practice in SE Asia and in some parts of Africa because fish are efficient converters of low grade feeds into high grade animal protein. These wastes increase the biological productivity in fish ponds (natural food of fish) which in turn reduce the cost of supplementary feed and fertilizers, increasing profits by up to 30-40%. In rural areas in most developing countries, organic fertilizers are more easily available and relatively less expensive to use. Moreover, utilization of organic manures in fish culture is an environmentally friendly farming operation with a major advantage in removing the problem of waste disposal, resulting in a better ecological balance. Such a farming system on scientific lines is of considerable value in developing tropical countries like India where the temperature is favorable for better utilization of these wastes in fish ponds (Dhawan et al., 1998).

The fish muscle represents between 35% (black place, whiting, cabillaud) to 70 % (herring, carp, anchovy, vieille) of the weight of the fish (Saintclivier, 1993). Fish scrap, bones and heads represent 65 % to 30% of total fish weight. There are usually recycled as organic fertilizers for sustainable aquaculture.

Kim et al. (1998) reported the component characteristics of fish bone as a food source from cod, Alaska pollack, yellowfin sole, hoki, conger eel and mackerel. The crude protein (40.7%, dry basis) and collagen contents (5.86%, dry basis), amino acid composition (189 residues/1000 residues) of hoki bone were higher than those of the other fish bones, but were lower than those of animal bone. The crude lipid contents, and total EPA and DHA composition of yellowfin sole, conger eel and mackerel bones were between 22.8-43.9%, and 15.6-23.8%, on dry basis respectively. These values were lower than those of squid viscera. The major ash components of fish bones were Ca and P, and contents of these minerals in 100 g crude ash were 37.1-38.6 and 18.0-18.5%, respectively. The Ca and P contents in 100 g crude ash of cod and Alaska pollack bones were greater than those of animal bones. It is concluded that hoki bones may be effectively utilized as a processing material for collagen or gelatin, and cod and Alaska pollack bones as a calcium source.

Pongchawee et al. (1995) found that on 3 farms in Bangkok, hybrid *catfish (Clarias macrocephalus X C. gariepinus)* fed on diets containing a mixed complete pelleted feed, ground chicken carcasses and intestines, and chicken intestines, pond water quality was poor on all farms due to high ammoniacal nitrogen and low dissolved oxygen. However, the condition was better with pelleted feeds than fresh feed.

3.6 Wastes from processing industries

Shrimp is mostly canned before export to European and American markets. Surveys in canning plants in shrimp industries indicate that the seafood wastes waters appear to be about 10 times as strong organically as normal domestic sewage. This additional strength is principally related to dissolved organic material. There was no indication of materials toxic to treatment organisms in the seafood wastewaters. The seafood waste waters tended to spoil rapidly and become odorous even when stored under refrigeration. Maximum waste water is produced during peeling (58 %), cooling and retort (12 %), and washers (8.8%). Water is also utilized at separation, grading, de-icing and final washing. To avoid movement of solids with the flowing waste waters, different types of screens are used. The water filtrate is subsequently sent for secondary and tertiary treatment.

4. DISEASES, CHEMICALS AND POLLUTION AFFECTED FISH

4.1 Diseases

4.1.1 Shrimp viruses

There are 5 viruses currently being studied for impact on commercial farming of the black tiger prawn (*Penaeus monodon*) in Thailand. Some of these virus cause disease in the penaeid shrimp species and others in the crustacean species. In order of their economic impact on the Thai shrimp industry, the 5 viruses are (Wongteerasupaya et al., 1996):

- white-spot baculovirus,
- yellow-head virus,
- hepatopancreatic parvo-like virus,
- infectious hypodermal and haematopoietic necrosis virus
- monodon baculovirus.

Flegel (1997) summarized recent work on these virus and suggests future directions of research that may be useful in the effort to develop a sustainable shrimp industry

A disease survey was also conducted in shrimp farms in North East Sumatra, Indonesia, during June and July 1991. Shrimp were sampled for histopathological examination and details of the farm management and environment were recorded. The stocks sampled included some shrimps with diseases and others were in good health. Samples were taken from 24 ponds, five hatcheries and a broodstock fisherman. All farms and hatcheries cultured *Penaeus monodon*, one farm also cultured *P. merguiensis*, and two cultured *Metapenaeus spp*. Several wild caught *P. monodon* female broodstock and some wild rice shrimp (*Acetes spp.*) were also sampled. The disease conditions detected *in P. monodon* were monodon baculovirus (MBV), hepatopancreatic parvo-like virus (HPV), septic hepatopancreatic necrosis (SHN), bacterial septicaemia (BS), haemocytic enteritis (HE), lymphoid organ pathology (LOP), external fouling organisms (EFO), and a single unconfirmed case of infectious hypodermal and haemopoietic necrosis (IHHN). The Acetes spp. from one site had a microsporidean infection in the striated muscle of the abdomen.

EFO was the commonest disease condition, and was identified in 16 farms and 3 hatcheries. MBV was detected in 14 farms, 3 hatcheries and in 1 broodstock. SHN was found in 13 farms with 1 case of concurrent BS and LOP was found in 8 farms. HE was found in 4 farms and HPV was identified in shrimp with MBV on 2 farms and as the only disease in 1 broodstock. The significance and implications of these findings on industrial growth in Indonesia are discussed by Turnbull et al. (1994). Large amount of research work is going on in exporting countries like Thailand to detect, control and eradicate shrimp diseases.

4.1.2 Bacteria

In 1992 and 1993, a study on the prevalence of *Vibrio cholerae* and *Salmonella* was conducted for 7 months in a major shrimp producing area in Southern Thailand. A total of 158 samples were examined including water, sediment, shrimp, pelleted feed, shrimp gut, and chicken manure. *Salmonella* was not recovered from any sample type studied. *V. cholerae* O1 was isolated from 2 (2%) and V. cholerae non-O1 was isolated from 35 (33%) of 107 samples examined. The occurrence of *V. cholerae* was not significantly influenced by water salinity, temperature, dissolved oxygen or pH. There was no correlation between feacal coliform counts and the prevalence of *V. cholerae*. The results indicate that *V. cholerae* non-O1 is ubiquitous in aquatic environments where shrimp culture is practised under a variety of environmental conditions. The public health significance of non-O1 *V. cholerae* in shrimp culture remains to be determined. *V. cholerae* O1 and *Salmonella* do not appear to constitute a hygienic problem even if chicken manure was used as fertilizer (Dalsgaard et al., 1996).

Sung et al. (1999) reported the changes in the composition of *Vibrio* communities in pond water during tiger shrimp (Penaeus monodon) cultivation.

Andresen and Rasmussen (1990) reported that oxolinic acid and flumequine are used widely in fish farming for the treatment of bacterial infections of fish. They describe the optimisation of a method for the determination of these coumpounds in salmon liver that uses on-line dialysis and column-switching HPLC.

4.1.3 Dengue

Yeong Ren et al. (1994) reported that storage water containers and waste vessels are good larval habitats for *Aedes* vectors of dengue. Surveys taken since 1988 show that dengue occurs mainly in the urban and coastal areas where *A. aegypti* is prevalent. This species is most prominent, although others are often present. It appears that the types of Aedes 'breeding' have changed quickly. In dengue epidemic areas, the most popular breeding sites are ornamental containers (38.8%), storage water containers (30.1%), discarded containers (25.4%), receptacles (3.3%) and water collection in the basement (2.2%). On the other hand, Mulla et al. (1997) show the positive effect of fish in contaminated mosquito area near Bangkok.

4.1.4 Toxins

Tetrodotoxin (TTX) and paralytic shellfish poison (PSP) are the 2 most toxic marine toxins as Na+-channel inhibiting neurotoxins. Recently, several cases of food poisoning due to ingesting marine animals were reported in Taiwan (Hwang, 1994; Hwang et al., 1995 1-2). The causative agent in these food poisoning cases was found to be TTX or PSP. Twenty four species of puffer collected in Taiwan were examined for toxicity and toxic components. It was found that toxicity of puffer collected in

Taiwan was quite different from that of others reported. All the toxins obtained from several toxic puffer species showed to be TTX, anhydrotetrodotoxin (anh-TTX) and 4-epi-TTX. Some products manufactured from puffer also showed mild toxicity. Further, marine and freshwater mollusk had higher susceptibility to TTX and PSP than did fish and crustacea. Meanwhile, several species of the gastropod mollusk *Naticidae* (moon shells), *Nassariidae* and *Muricidae* were found to contain TTX and anh-TTX.

4.2 Chemicals

Fish industry uses chemicals to stabilize their products which could be found in the water if their dosage is not well estimated. Chemicals which are the most time cited are antioxidants, stabilizers and salts.

4.2.1 Antioxidants

Hwang et al. (1995) measured the level of synthetic antioxidants and lipid quality in fish feeds and in cultured fish in Taiwan. 68 samples of 6 fish species, 37 feed samples for 7 fish species and 33 samples of fish meal from 6 countries were collected from markets and/or from manufacturers for analyzed. It was found that dibutylated hydroxytoluene (BHT) is the major antioxidant in cultured fish, fishery feed and fish meal, ranging from 0-12.3, 0-59.8 and 0-150.0 mg/kg in fish liver (or shrimp hepatopancreas), feed and fish meal, respectively. There was no residue of antioxidant in fish muscle. Lipid quality of fish feed was: peroxide value 0.2-60.8 meq/kg, thiobarbituric acid value 6.4-45.6 mg/kg and acid value 9.8-66.6 mg/g. Corresponding values for fish meal were 5.6-85.6, 4.6-88.6 and 6.2-70.1. It was suggested that there was no safety concern regarding antioxidant residue in cultured fish, fish feed and fish meal. However, the lipid quality in fish feed and fish meal should be improved.

Synthetic antioxidants in fish feeds and in cultured fish in Taiwan are a source of pollution. 68 samples of 6 fish species, 37 feed samples for 7 fish species and 33 samples of fish meal from 6 countries were collected from markets and/or from manufacturers and analyzed. Hwang (1995) found that dibutylated hydroxytoluene (BHT) was the major antioxidant in cultured fish, fishery feed and fish meal, ranging from 0-12.3, 0-59.8 and 0-150.0 mg/kg in fish liver (or shrimp hepatopancreas), feed and fish meal, respectively. There was no residue of antioxidant in fish muscle.

4.2.2 Salts

In the proceedings of an international workshop held at Jakarta (Indonesia) in 1994, Highley's team from the Australian Centre for International Agricultural Research (ACIAR) reported the problems associated with dried fish agribusiness in Indonesia.

In Indonesia, processing of traditional fish products, especially dried salted fish, faces various problems (Soegiyono et al., 1995). The problems are those commonly associated with small scale fishery agribusiness, such as lack of capital, low skill and knowledge in processing techniques, use of poor quality raw materials, inadequate infrastructure and facilities, and an ineffective marketing system. Government support for small scale fish processing industries has been less than for other fishery activities such as fish capture and aquaculture. Fish drying, as other traditional fish processing, is an important economic activity in coastal village communities. It provides employment opportunities, adds value to products, improves fishermen's income, and has multiplier effects on economic activities in the area. For dynamic development of small scale fish processing industries, Soegiyono et al. (1995) proposed to set up an industrial estate and a cooperative organization specially designed for the activities.

The same team (Champ and Highley, 1995, Abdullah et al., 1995) gives an overview of the fisheries and fish processing industry and the problems associated with dried fish processing; the status and prospects of salted fish consumption in Indonesia.

Fegan et al. (1995) describes the socioeconomic component of a project set up to translate the concept of a low technology, low capital, low fuel cost fish drying apparatus using agricultural waste as a fuel into a design suitable for adoption by artisanal-scale fish processors in Java. The goal of the socio-economic research was to guide the main technical sections of the project in order to develop an appropriate technology with maximum chance of adoption, while avoiding adverse effects on vulnerable sectors of the population. Based on this goal, the research sought to describe the socioeconomic features of the processors and their place in the salted dried fish industry. It included supply, demand, quality and price of their raw materials and products, losses of quality and quantity in the industry, and the implications of these for derived demand for, and optimum design of, improved drying technology.

4.2.3 Cyanide

To catch fish in Indonesia, fishermen use cyanide to stun the fish and make them more easy to catch. The issue of cyanide fishing in the Indo-Pacific, and its environmental implications, are explored by Barber and Pratt (1998). The market for fish caught using cyanide fishing is the aquarium market and the restaurant market in districts where fish are chosen live from tanks. There is widespread concern that use of cyanide is having a deleterious effect on coral reefs as well as on fish stocks and other marine life. The live reef fish trade in Southeast Asia is outlined. Measures that can be taken by the countries in which live reef fish are caught were outlined in the report.

4.2.4 Antibiotics

Thai fishers have shown that they are capable of responding to environmental measures, when inevitably forced. Antibiotic use in aquaculture has dropped in response to Japanese restrictions on additives. Additional costs of these practices have successfully been absorbed, and the industries is continuing to prosper. Thailand's tuna-canning industry (world's largest exporter of canned tuna) has successfully accommodated US dolphin-safe tuna requirements.

4.3 Pollution affected fish

Toxic and hazardous pollutants are discharged into waterways. The material comes from factories, farms, roadways and some of it comes from the kitchen sinks and cleaning cabinets of ordinary homes. Some fish populations are showing the effects of these poisons in their environment. In highly polluted areas, some fish show liver tumors and damaged reproductive organs. Studies of juvenile salmon in Puget Sound migrating though polluted urban estuaries as compared to clean estuaries on their way to the sea show damage to their immune and reproductive systems. Apparently pollutants are being concentrated in the small aquatic insects that are the food of the hungry and quickly growing salmon. It is not yet exactly clear which chemicals or environmental factors are responsible. Many of the hazardous chemicals in the water are exotic combinations that emerge from factory pipes. But some are from domestic outputs like lye, boric acid, chorine, petroleum-based cleansers and polishes, fertilizers and pesticides, roach powder and other materials stored under the sink or in the garage of most homes.

While households play a comparatively minor role in adding pollutants to our waters, even small amounts can contribute to water quality problems and are highly toxic to fish and the aquatic insects on which they prey. Substances washing down the drain can affect water quality in other ways too. Material in the water can increase turbidity, limiting biological activity and in extreme cases even clogging fish gills. Ammonia and phosphates in everyday household cleansers can spur algae growth beyond normal levels, a process called "eutrophication", possibly depleting oxygen levels in the water and threatening fish survival (Pacific States Marine Fisheries Commission, 45 SE 82nd Drive, Suite 100, Gladstone, OR 97027-2522).

4.3.1 Eutrophication by lack of oxygen

A red tide of dinoflagellates was observed in brackish water fish ponds of *Terengganu* along the coast of the South China Sea during a study period between Jan. 1992 and Dec. 1992. The nearby coastal water facing the South China Sea is the source of water for fish pond culture activities of sea bass. An examination of water quality in fish ponds indicated that the organic nutrients were high during the pre-wet monsoon period. The source of the nutrients in coastal water was believed to be derived from the agro-based industrial effluents, fertilizers from paddy fields and untreated animal wastes. This coincided with the peak production of dinoflagellate in the water column in Oct. 1992. The cell count ranges from 8.3 to 60.4 X 10.4 X 104/litre during the bloom peak period and the bloom species were composed entirely of non-toxic dinoflagellates with *Protoperidinium quinquecorne* comprising >90% of the total cell count. Both cultured and indigenous fish species suffered from oxygen asphyxiation. The bloom lasted for a short period (4-5 d) with a massive cell collapse from subsurface to bottom water on the 6th day. The productivity values ranged from 5.25 C g/litre/h with a subsurface maximum value in Oct. 1992. Two species of *Ciliophora, Tintinnopsis* and *Favella*, were observed to graze on these dinoflagellates at the end of the bloom period (Shamsudin et al., 1996).

Palma et al. (1994) reported that in Mindanao (Philippines), Lake Buluan is a shallow eutrophic lake whose condition is deteriorating primarily due to silting. This is caused by erosion from the deforested catchment area and exacerbated by the use of static structures for fishing. Eutrophication is also accelerated by decay of the remanants of dry season drawndown agriculture which are flooded as the waters rise in the wet season. Catches of fish have declined and some species have disappeared from the catches. Two attempts to establish cage culture have failed. The most urgent need is for rehabilitation of the catchment area. It is recommended that fishing be restricted to capture fisheries which could be enhanced by more rigorous regulation, establishment of fish sanctuaries and further stocking of the open water with rohu and tilapia, which are presently the main component of the catch. Aquaculture in cages or pens should not be allowed at present to avoid any further increase in eutrophication and siltation which would result from their installation. It is also suggested that the fishermen should form a cooperative and be represented on a management committee which should be set up to review the current situation of the lake and formulate a comprehensive plan for the future.

Santos et al. (1995) during a study of wastewater generation in 2 processing seafood plants, one inland city-based and one coast-based, found that no significant difference was found between fresh water consumption levels in 2 surimi lines. The coastal plant consumed more fresh water (526 000 vs. 167 000 liters daily). Wastewater discharge (BOD, COD and TS levels) were significantly higher in the coastal plant.

4.3.2 Pesticides and insecticides

In many underdeveloped countries where fish are routinely dried, the insects incorporated in the dried product are important. In certain cases, it has been estimated that over 20 % of the protein in dried fish comes from insects (Regenstein and Regenstein,1981). The Tropical Product Institute (London) recommends that pyrethrins and piperonyl butoxide be applied directly on fish. They also recommend fumigation with phosphine.

The extensive use of pesticides of all kinds in Thailand has created some severe problems related to pesticide residues, pest resistance to pesticide and health hazards. In order to clarify the nature and behaviour of pesticide in the tropical environment of Thailand, Tayaputch (1996) did a survey of pesticide residues in soil, water, sediment, fish during 1987-89. The results revealed that several organochlorine pesticides, some of which are no longer in use (organophosphorus pesticides) were found at trace concentration in environmental samples.

The levels of organochlorine and polychlorinated biphenyl compounds in the aquatic ecosystems of the Red River delta (Vietnam), were determined during November 1995 (dry season) and July 1996 (rainy season) by Dang Duch Nan (1998). The cyclodienes aldrin, dieldrin and endrin were not detected. The concentrations of isomers of HCH were generally low (<2 ng/g dry weight) and were similar in inland rice fields and the coastal marine environment. Concentrations of DDT in sediment and biota were the highest of the chlorinated hydrocarbons detected. DDT was used during the rainy season on rice fields in the Red River valley. DDT levels in carp farmed near rice fields were very high and concentrations of DDE (13 µg/g lipid weight) were greater than the maximum permissible concentrations in food.

Bagarinao and Lantin-Olaguer (1998) studied the sulfide tolerance of milkfish (*Chanos chanos*) and *Oreochromis mossambicus* in a 25 liters aquarium with flow-through sea water (100 ml/min) at 26-30°C. They used sulfide stock solutions pumped at 1 ml/min. Four experiments showed that the 2 species had similar sulfide tolerance. In sea water at pH 8-8.5, about 5.2 mg/liter total sulfide or 313 mg/liter H_2S was lethal to 50% of the fish in 4-8 h.

Guerrin et al. (1990), during a study of heavy metals and organochlorine pesticides levels in a wastewater treatment pond, presented a 4 year study on 14 tench (*Tinca tinca*) and 4 rudd *(Scardinius erythrophthalmus*) reared in a wastewater treatment pond. Levels of Cd, Pb and Hg and of 6 organochlorine pesticides (DDT, heptachlor, aldrin, dieldrin, hexachlorobenzene (HCB) and HCH) found are compared with levels in natural water fish reported in the literature and discussed in relation to international recommendations concerning food product quality. Cd and Hg were below detection limits in water of wastewater treatment ponds and Pb levels were 0.2-3.0 µg/l. The levels of Cd, Pb and Hg in the rearing pond sediment were less than or equal to 1, 46.0 and 0.08 µg/g dry weight, respectively. After 4 year in ponds, levels of Pb and Hg were undetectable in tissues of rudd and tench while mean Cd levels (and ranges) in rudd were (µg/g wet wt.), liver 0.056 (0.013-0.107) and kidney 0.157 (0.134-0.190) and in tench, liver 0.058 (0.13-0.113) and kidney 0.149 (0.019-0.237). In both species, Cd was not detectable in muscle tissue. Compared to data on Cd levels reported in various natural aquatic ecosystems, these levels are similar to those found in non-polluted areas.

Among pesticides, only HCH and HCB were found and these only in tench liver. Mean total HCH (males and females) was 0.11, mean gamma-HCH (lindane) 0.075 and mean HCB 0.014 MUg/g wet weight. Compared with concentration usually found in food products of animal origin only lindane was at a significant level, and even this was low compared with the acceptable daily intake of 0.01 mg/kg recommended by FAO.

4.3.3 Blast fishing

Characteristics, impacts and economic costs and benefits of blast fishing are studied in Indonesia, at the scale of individual fishing households and of Indonesian society as a whole. Although illegal and highly destructive to coral reefs, blast fishing provides income and fish to a vast number of coastal fishers who claim that they have no alternative to make a living. Crew members in small-, medium- and large-scale blast fishing operations earned net incomes per month of US$55, 146 and 197 respectively. Boat owners in the same types of operations earned US$55, 393 and 1100 respectively. These incomes were comparable to the highest incomes in the conventional coastal fisheries. At the individual household level, the differences between the three types of operations show clear incentives for scale enlargement. The cost-benefit balance at the society level was calculated with an economic model. This analysis showed a net loss after 20 years of blast fishing was US$306 800 per km2 of coral reef where there is a high potential value of tourism and coastal protection, and US$33 900 per km2 of coral reef where there is a low potential value. The main quantifiable costs are through loss of the coastal protection function, foregone benefits of tourism, and foregone benefits of non-destructive fisheries. The economic costs to society are four times higher than the total net private benefits from blast fishing in areas with high potential value of tourism and coastal protection. This analysis of characteristics, impact and economics of blast fishing should help to raise the political will to ban blast fishing from Indonesian waters. Moreover, it allows for an evaluation of possible management solutions, taking into account their costs and the socioeconomic framework that caused coastal fishers to start using explosives (Pet-Soede et al., 1999).

5. PROPOSITIONS FOR WASTE UTILIZATION AND REDUCTION

There have been many suggestions to the problem of waste produced during fish production and processing. To make shrimp culture more environmentally friendly, Kwei-Lin et al., (1995) proposed to farmers to minimize water exchanges, develop in-pond water treatment methods and design water recycling systems. Another solution proposed by Shei and Rae (1993) consists to use the 'polluter pays principle' in aquaculture production. While these will help in the reduction in waste streams and improve the quality of fish farms, the wastes or the so called by products of the fish processing have necessarily to be used as raw material for the production of value added systems. In the following sections the utilization zation of these byproducts for food and non-food purposes will be discussed.

5.1 Food uses

The fishery by-products, i.e. raw materials which for reasons of species, size, quality, availability of processing capacity, etc., are unsuitable for direct human consumption, represent almost a third of the world fish catch. The possible food uses of these by-products allows an added economic value and reduced waste and environmental pollution. Windsor and Barlow (1981) report the use of by-products in fish meal and oil production, silage, hydrolysates and protein concentrate, with an emphasis on the process and quality control. The different ways of using and adding value to the fishery by-products in food applications are reported below.

5.1.1 Textured and snack products

Borisochkina (1984) reported many experiences from the USA, Japan, England, Norway and Canada about the rational utilization of small fish and the use of waste materials in the food industry. A high diversity of semi-finished and finished products, such as fillet blocks, textured and flavoured analogues of fish delicatessen, protein concentrates with various functional properties, could be developed with either minced fish mass or edible parts from fish heads and cooked minced filleting waste materials. The fat find use for medical and other purposes.

The industrial fabrication of surimi from small fish fillets or meat with low value is presently controlled. The use of fish by-products for surimi fabrication is being adapted through the control of manufacturing equipment problems (Cornell and Hardy, 1982) which allows a great reduction of waste and pollution. The filleting waste meal was reported to contain 44-50% of crude protein, with great variations in acid-insoluble ash and fat contents (Perigreen *et al.*, 1979).

On the other hand, the use of under-utilized fish species or fish processing waste for elaboration of fish chewies is described by Karmas (1985). The process includes fermentation and extrusion steps and results into a jelly-bean or beef-stick texture end-product. The fish chewies might be used as soup or salad ingredient or might be processed into snacks.

Oil frying is another technique used for adding value to the by-products from meat, fish or vegetable processing, along with retaining valuable nutrients. The end-products could be used as snacks, fillers or nutritional supplements into other foods. Nakazono (1987) described a process claimed to be inexpensive consisting of mixing first and steaming the by-products, then introducing them into a heated oil-containing cooking chamber and cooking them through a 2-stage pressure reduction within the cooker. The oil could then be removed either by centrifugation (to keep the original product shape) or through pulverization screw (to obtain a powder-type end-product).

The fish 'dust', obtained through sawing fish sticks and squares, is being less and less discarded and finds more and more use in food processing. The 'dust', also named granulated fish muscle, has a bland flavour and grainy texture which progressively firms up on storage. The use of fish 'dust' is presently performed in the formulation of patties (up to 70% dust), hot dogs, soups and fish-on-a-stick products (Anonymous, 1984).

Zall and Cho (1977) describe the process diagram, cost and yield for food production from the discarded clam meat fractions in shellfish processing plants where shucking operations are manual. By the means of shell separation and retort heating of the materials culled from an outgoing waste stream, it was possible to recover about 77% of the meat discarded with waste shells or 5% of the total amount of saleable meat processed.

5.1.2 Fish sauce

Fish sauce, well known and widely consumed in South East Asia is a clear, straw-yellow to amber coloured liquid, with a fishy odour, salty taste and cheesy flavour. It is prepared through a long fermentation of fish with salt. The concentration of water-soluble substances, such as peptides and amino acids, varies with the fish species used. The daily consumption of 40 ml fish sauce could supply about 4 g of protein (Velayutham *et al.*, 1987).

The filefish (*Novodon modestus*) processing into sauce was described by Lee *et al.* (1988). Chopped filefish scrap was mixed either with high concentrations (koji) of salt and glucose and fermented at 25±4°C for 120 days or with low salt concentrations in which salt was replaced by a sorbitol, lactic acid, ethanol mixture. During fermentation, proximate composition, microbial flora, and levels of pH, reducing sugars, protease activity, peroxide value, TBA value, fatty acids, free amino acids, nucleotides and related compounds, N-compounds and sensory scores (for taste, odour, colour and overall acceptability) were determined. Major free amino acids in the final products were glutamic acid, alanine, leucine, lysine and aspartic acid. The predominant fatty acids in the final products were C16:0, C18:1, C16:1 and C22:6.

Velayutham *et al.* (1987) propose that fish sauce could be prepared from trash fish, which constitute about 30% of marine fish landings in India. The sauce could be prepared by the slow fermentation of a mixture of whole fish (or its components such as gills, viscera, head, roe, etc.) and salt.

5.1.3. Protein recovery

Moorjani (1982) reviewed the research and development work on fish-enriched protein foods from inexpensive varieties of fish. This review described efforts to produce and use different types of acceptable fish protein concentrates (FPC) from inexpensive varieties of fish by-catches. FPC are used in a great variety of finished products such as bread, chapaties (flattenned Indian bread) and biscuits, fish-enriched farinaceous products particularly in fish wafers (20% protein) made from cassava starch and fish or partly shrimp meat, fish noodles and fricola made from minced fish muscle, cooked rice (at a ratio of 3:1) and shredded coconut (4% dry matter basis). Soluble FPC also found used in beverages.

It is possible to recover different types of proteins from fish processing wastes and add value to them either through food or non food uses. Eriksson (1978) reviewed the recovery of edible protein from food processing waste, including whey, blood, offal, fish offal, keratin, potato protein, tomato cannery waste, and waste from wheat starch and gluten production. Techniques used, expected yields and nutritional properties of recovered proteins are briefly covered for each type of waste.

Systems for recovery of organic matter from fishmeal factory wastewaters and particularly the protein recovery for use in fishmeal manufacturing have been investigated. The most efficient system was recirculation of effluent followed by flocculation with ferric chloride until reaching pH 4.3. A protein recovery of 71-87% was obtained on an industrial scale. As the treated effluent still contained a large organic load, ultrafiltration was carried out to remove remaining proteins. Ultrafiltration reduced protein and fat content of the supernatant by 80%. However, a fall in the permeate flux rate would require the use of large membrane area and frequent washings making ultrafiltration inappropriate as a secondary treatment of fishmeal factory wastewaters (Marti *et al.*, 1994).

Collagen was isolated from fish waste materials such as the skin, bones and fins (Nagai and Suzuki, 1999). This collagen can also be converted to gelatin at 30-35°C, opening the way to many food uses as the viscosity curve of fish gelatin is very similar to that of others animals (Regenstein and Regenstein, 1991).

The preparation of soluble protein isolates from low cost fish and fish wastes by hydrolysis with papain is possible (Lekshmy Nair and Gopa Kumar, 1982). Fresh fish such as lizardfish, jewfish, threadfin bream, catfish, perch and milkfish was comminuted, hydrolyzed with papain and stored at –23°C. The yield of protein isolate from catfish and jewfish waste was 4.0 and 7.8% resp., and ranged from 7.5 to 13.3% for the other species. The proximate analysis showed that isolates contained about 90% protein in dry weight. Most samples were rich in lysine, the limiting amino acids being tryptophan and threonine. Rat feeding studies showed that the protein efficiency ratio (PER) of these protein isolates was inferior to casein, but supplementation with the limiting amino acids at 0.1% level or admixture with casein gave PER almost equivalant to casein.

In another study, Das *et al.* (1979) also reported the preparation of fish protein concentrate (FPC) from catfish (*Silurus glanis*) by hydrolysis with papain and pepsin. Washing raw fish with 0.5% salt solution removed the outer string-like material whereas steaming for 5 min helped in easy separation of flesh from bone. Among the 3 solvents used, (i) isopropyl alcohol, (ii) petroleum ether and (iii) carbon tetrachloride, (i) at 65°C for 20 min removed fat and deodorized the FPC completely. Papain and pepsin were added at 0.01, 0.005 and 0.001% levels at 35°C and pH 2.0-8.0 to effect partial hydrolysis. Specific activities of papain and pepsin were 15.8 and 24.5 units/mg enzyme. Results showed that hydrolysis does not increase at 35°C or when pH is increased from 2 to 4 for pepsin and from 2 to 5 for papain. Hydrolysis was greater but mild at higher levels of enzyme and with longer treatment time (1/2-4 h). The dispersion and foaming characteristics of the protein concentrates were studied, those with higher level of hydrolysis showed more dispersion ; at 18.7 the hydrolysis dispersion was 80%. Acetification and whipping for 8 min improved the dispersion. Foaming also increased with higher percentage of hydrolysis and whipping.

A pilot plant production of functional protein from fish waste by enzymatic digestion was studied by Bucove and Pigott (1976). Both technical and economic aspects were treated. Adequate enzymes were highlighted and the process was proved to be efficient for seafood waste treatment.

Crustacean waste generated from the fishing industry represents approx. 70% of total landings. This abundant waste may pose an environmental hazard due to the ease of deterioration of the fish tissue in the landfill sites. Therefore, the waste disposal is to be achieved at considerable cost to the industry. Waste can be utilized by extracting useful components and incoporating them into desirable seafood products. The composition of raw and cooked waste should be determined and economically viable methodologies developed to extract the important components. Proximate analysis of commercial shrimp waste indicated the presence of 94.6% protein and 4.2% fat on dry basis. HPLC analysis indicated 17 amino acids (Asp, Glu, Ser, Thr, Arg, Gly, Ala, Pro, Val, Met, Leu, Ile, Phe, Cys, Lys, His and Tyr; proline being most abundant) and 7 sugars (ribose, xylose, fructose, mannose, glucose, glucosamine and galactosamine; ribose being most abundant). Changes in the amino acid and sugar concentrations after heat treatment occur through Maillard reaction and by thermal hydrolysis of the tissue proteins and polysaccharides (Mandeville *et al.*, 1992).

Uchida *et al.* (1988) described a process for preparing pasty proteinous material or proteinous food from crustaceans. The efficient use of residual crustacean flesh from trunks, carapaces and heads was pointed out. The crustaceans were boiled and milled to inactivate endogenous enzymes, and the slurry so produced was treated either with proteolytic enzymes and/or microorganisms to give a pasty proteinaceous food material.

Protein powders were prepared from prawn processing waste either by mechanically squeezing the shell and freeze drying the resultant aqueous extract, or by treating the shell with 0.5% sodium hydroxide, filtering and freeze drying the filtrate (Nair and Prabhu,, 1989). The yield of shrimp extract powder from prawn shells ranged from 7.41 to 8.00% with a moisture range of 3.56-4.44%. The powder is high in lysine, phenylalanine, tyrosine and valine are present in more than the required amounts and threonine and tryptophan are present in adequate amounts. Consumer acceptance and nutritional quality of the dried protein showed that expeller-separated powder is better than powder extracted with mild alkali.

As 67% of the original weight of shrimp is waste and according to the relatively high (22-27%) protein content of this waste, the recovery of protein from waste of 2 shrimp species (*Pandalus borealis* and *P. montagui*) was attempted at laboratory scale by boiling water extraction. The shrimp waste (40 g) was boiled with calcium hydroxide and the supernatant was evaporated to recover the protein. The crushing of shrimp waste in a Waring blender improved the protein recovery, this latter increased with boiling time of crushed waste up to 90 min. The optimum calcium hydroxide level was 6 g in 400 ml extraction mixture. The recovered dry matter by evaporation was 43.53-45.83% protein and 6.23% lysine; the major amino acids were glycine as well as aspartic and glutamic acids. A 90 min extraction recovered 70% of protein present in the shrimp waste (Bataille and Bataille, 1983).

The optimum parameters for protein isolation from krill (Euphasia superba) wastes were determined by Romo and Anderson (1979). Extraction of about 90% of the protein from uncooked krill wastes, produced by mechanical peeling, could be achieved using alkaline extraction at pH 10.5 and ambient temperatures. The extracted protein could be recovered by isoelectric precipitation at pH 5.7.

Alternatively, the waste can be utilized by extracting useful components such as flavour-active compounds and incorporating them in desirable seafood products. Mandeville *et al.* (1992) determined the flavour profile of cooked shrimp waste by GC/MS. The results revealed the presence of 44 compounds of different functional groups including fatty acid esters, long-chain alcohols, aldehydes and heterocyclic compounds. 29 compounds were tentatively identified by their mass spectral data, and 15 were identified by both mass spectral data and retention times. Many components provided desirable aroma (nutty, fruity, floral, green woody, meaty) indicating the presence of important flavour compounds in commercial shrimp waste.

The recovery of aminoacids from seafood processing waste waters with a dual chitosan-based ligand-exchange system was detailed by No and Meyers (1989). Chitosan prepared from the crawfish shell chitin, was an effective ligand-exchange column material for recovery of amino acids from seafood processing wastewater. In comparison with commercial chitosan, crawfish chitosan, loaded with copper or amino copper, showed higher recovery rates of amino acids. Recovery from amino copper-crawfish chitosan columns was pH dependent, with reduction at higher pH values. Eluate was completely free of copper ions when treated with a second crawfish chitosan column. The amino acids recovered had potential as seafood flavours, in terms of their sensory attributes.

On the other hand, membrane techniques were used for separation of water soluble proteins from the fish paste processing waste waters. The effect of ceramic support size on the self-rejection characteristics of the dynamic membrane formed from the water soluble proteins was evaluated by Shoji *et al.* (1988). Ziminska and Zygadlowska (1983) tried to develop an economically viable process for recovering fat and protein from effluents generated by fish processing plants. The process basically involved chemical precipitation followed by separation. Of the coagulants tested, $FeCl_3$ (added at the rate of 100 mg/l effluent) was the most effective with regard to solids recovery and COD reduction. Addition of an anionic polyelectrolyte (Rokrysol WF-2) at the rate of 4-10 mg/l effluent improved the properties of the precipitate. The precipitate was effectively separated by settling or dissolved air flotation. The composition of the recovered solids varies widely and depends on effluent composition; ranges found for crude protein, fat and ash were, resp., 23-45%, 20-50% and 11-40%.

5.1.4. Fish oil

Madrid and Madrid (1986) evaluated the production of fish liver oil and presented different extraction processes. The conventional processing of fish liver oil was outlined and compared with a continuous production system. In the former case, the livers were either mechanically disintegrated or cooked whole by steaming at 95-100°C to separate the oil from the tissues. Most cookers function horizontally but vertically operating ones are available. The vertical cookers require only a couple of minutes for cooking as compared to 15-20 min in a traditional cooker. The reduction in cooking time being due to the higher heat transfer coefficient of the vertical cooker (heating from 5 to 95°C takes less than or equal to 100 s without affecting the extractability of oil). After cooking, the oil was separated from the solid parts, which were pressed to extract remaining oil. The defatted meal was then dried to 6-10% moisture content. Two quality-grade oils were obtained, e.g. 1000 kg fish livers yielded 540 kg top quality oil and 50 kg lower quality oil.

In the continuous cooker the residence time of the starting material was very short, and quality and yield were superior. The process involved the following steps : manual separation of livers from the intestines, disintegration of whole livers in a disintegrator, transfer to an agitator, heating to about 80°C with or without steam, pumping the heated mixture into a net to remove membranous and coarse parts, then quickly heating the resulting mass to 90-95°C and finally separating in a centrifuge. The separated oil might be quickly cooled in a plate heat exchanger prior to storage. Flow charts of both processes were included.

Haq *et al.* (1972) also reported a process for adding value to the by-product, residue from fish liver oil extraction. Fish liver residue was dried, freed from residual oil by extraction with petroleum ether, and ground. Extracts were prepared from the dried, defatted ground product by (i) pressure cooking at 15 lb/in2 pressure for 30 min, (ii) digestion with papain and (iii) digestion with papain/trypsin. The resulting extracts were analysed for B-group vitamins and amino acids. Results showed that (ii) gave the highest yield of vitamins, closely followed by (iii). (i) gave relatively high losses of vitamins, but was probably the most feasible process for industrial use. The extracts contained all the essential amino acids; quantitative amino analyses were not carried out. The fish liver extract contained less than half the amount of histamine present in a commercially-available beef liver extract.

A method for the production of fish meal and oil from high-fat material was outlined by Nilsen (1974). Fish meal and oil were obtained from capelin, herring, mackerel and other fatty fish or wastes, by repeatedly pressing the cooked fish material. The press cake was mixed once with lime water or press liquor, cooled to 20-65°C, pressed further in a screw press, and then dried in the usual manner. This process achieved a high degree of oil separation, together with a correspondingly higher protein content in the press cake.

An attempt was made to recover fish oil from the manufacturing process of highly nutritional fish meal (HNFM) for food use (Hirata *et al.*, 1993). The newly devised method applied consisted of first centrifuging at high speed the waste fluids discharged during sardine processing. The floating oil layer of the waste fluid discharged from the HNFM plant was heated to 40°C and instantly centrifuged at 10 000 times gn to collect oil. The obtained sardine oil was light yellow, clear and had a slight fishy odour. This oil contained much less volatile compounds than the conventionally extracted sardine oil in fish meal processing plants. It also contained nutritive components such as eicosapentaenoic and docosahexaenoic acids and vitamin E. The authors recommended that the simultaneous preparation of HNFM and fish oil would thus allow to recover about 30% of nutritive components from the sardine meat raw material.

The fatty acids recovered from the triglycerides and wax esters of common northwest Atlantic copepods were compared with the fatty acids of wax esters recovered intact from certain fish skin and body lipid, and from commercial fish oils (Ratnayake and Ackman, 1979). According to the fact that fish species such as herring, capelin and mackerel were all fed on copepods, and that the copepod lipid fatty acids were shown to have similar proportions in different seasons and areas, it was thus suggested that the basic dietary fat input for herring, capelin and mackerel might be quite constant. The analyses of two copepod fatty acid differed quantitatively in triglycerides 20:1 and 22:1 and also in 20:5 N-3 and 22:6 N-3, confirming the primary role of the wax esters in copepod lipids. Selectivity factors were discussed in terms of comparison of the wax ester fatty acids of copepods with those recovered intact from the fish lipids and oils. The basic role of copepods in supplying all types of fatty acids to fish depot fats was considered to be strongly supported by these findings.

Budwig (1969) described a method for producing a spreadable fat containing the unsaturated fats of various fish liver oils or other fish oils having highly unsaturated fatty acids. Stable, spreadable compositions were produced by mixing (and slightly heating if required) vegetable fats such as coconut or palm oil (or optionally other hard fats in combination with vegetable oils) with compounds or products containing sulfhydryl groups. 20-30% oils from aquatic animals, particularly cold-pressed liver oils, were then added, preferably in the cold state. Sulfhydryl compounds from vegetable or animal extracts or natural mercapto-amino acids might be used. The taste of the obtained healthy food was not influenced by the added fish oil.

Along with fish meal, the other major byproduct that can be obtained from fish wastes is fish oil. When obtained from good quality fish or wastes kept under appropriate conditions, oil almost free of any fatty acid can be obtained. This can be further modified by hydrogenation to margarine and enter the market as a source of food. However, when it is contaminated by microbes some of the sulfur compounds formed inhibit the hydrogenation process. The required refining can then be done by first washing the crude oil with a concentrated solution (80-85%) solution of phosphoric acid for degumming. A four normal sodium hydroxide solution in 20% excess can then be added to remove the free fatty acids (FFA). (Regenstein and Regenstein, 1991). Our own experience in the laboratory is that care should be taken for the refining conditions depending on the source of the oil, namely, the type of fish and quality required (Pioch and Rakshit, 1998).

The use of fish oils for human consumption requires regulatory reviews in many countries. While the strong flavour acts as a deterrent for direct consumption, the health benefits of the polyunsaturated fatty acids (PUFA) or omega-3 fatty acids have made marine fish oils the focus of considerable research. Marine fish oils contain the highest levels of long chain fatty acids namely eicosapentanoic acid (EPA, C20:5) and docasahexanoic acid (DHA, C22:6) in nature. Recent clinical studies have shown that omega-3 fatty acids are important in the treatment of cardiovascular diseases, arterioscelerosis, arthritis and cancer (Drevon et al 1993; Simopoulos et al 1991).

In many parts of the world a balance of fish intake is possible to get sufficient supply of the PUFA for a health person. But for a persons not consuming marine fish or for a person who has a health problem requiring additional supply of PUFA for therapeutic purposes, a concentrated form of the PUFA needs to be obtained. Further, the addition of PUFA to infant foods and people more advanced in age who require the same to better memory the use of a fractionated high concentration form of PUFA obtained from fish oils is necessary. This is besides the problem of fishy flavor in products into which unconcentrated oil is added.

A number of methods have been tried for preparing an enriched products of n-3 fatty acids from fish oil, which has the highest concentration of these fatty acids in nature. (Shahidi et al, 1998) These methods include chemical and physical methods such as urea inclusion, solvent extraction, molecular distillation, liquid chromatography and super critical extraction. (Zuti and Ward, 1993). However, the exposure of fish oils to high temperatures during these processes may result in degradation and oxidation of the n-3 PUFA (Stout et al, 1990).

An alternate approach for enrichment of fish oils is based on lipase catalyzed refinement of fish oils. Fish oil triglycerides contain a higher percentage of saturate and monounsaturated fatty acids in the alpha position. PUFA such as EPA and DHA are in the beta position. (Haraldsson, 1992). Higher selectivity of some lipases for specific substrates and position make them highly preferred tools for production of glycerides with high PUFA content. A number of studies using enzymes with different specificity have been attempted as they addition bring about the reaction under much milder conditions.

The Thailand-Japan symposium on effective utilization of tropical oil resources held at AIT Bangkok, Thailand in 1998 gave a good summary of what could be done with fish oil. (Kosugi and Rakshit, 1998). Fish oil is now commonly produced in many developing countries like Thailand. This oil is generally sold to industrialized countries for cosmetic and medical purposes. Kungsuwan et al (1998) showed that eyes and head from tuna contains 14 to 18% oil rich in eicosapentaenoic acid and docosahexaenoic acid. Lawan and et al (1998) found 13.1% of ω 3 fatty acids in fresh water fish oil from northeast Thailand. The special feature of this work was that PUFA was found in fish caught inland as compared to normally reported sea or marine fish. In the course of the same seminar Srikumlaithong et al (1998) reported that there are 21 tuna factories in Thailand with total capacities of 640 000 tons producing 130 000 tons of boiling water as waste annually. This boiling water contains 0.1% fish oil with DHA and EPA to levels of 4.4-6.7% and 22.5-26.9% respectively. These worker also described the procedure for efficient fish oil separation from the boiling water waste stream.

Takahashi (1998) reported the possibility of producing a 'super fish oil preparation' by using a phospholipase mediated transesterification employing transesterification between fish oil and DHA and/or EPA enriched free fatty acid mixture. Rakshit and Rasanayagam (1998) used lipases for fish oil bioconversion to produce oil with high content of polyunsaturated fatty acids demonstrating that the same lipase can bring about hydrolysis, esterification and transesterification with different levels of selectivity depending on the conditions used. However, Shimada(1998) who reported on the various options possible for enzymatic concentration and fractionation seemed to be closest to an industrial process for the same. Using Lipase-AK and Lipase6PS (Amano Pharmaceutical Co.) for hydrolysis of tuna fish oil a second enzymatic selective esterification reaction was done on the free fatty acids obtained using lauryl and alcohol and *Rhizophus delemar* lipase. The contents of DHA and gamma linolenic acid was as high as 70% levels.

Another source of fish lipids is obtained when fish meat is washed during surimi processing. Approximately 50% of lipid is lost in the effluent during this process. This lipid can be recovered by centrifugation or filtration of the wash water (Suh et al., 1995). Major fatty acids of the recovered lipid were C16:0, C18:0, C16:1, C20:5 and C22:6. The polyenoic fatty acids constituted 33.6% of total fatty acids. When recovered lipid was substituted for soybean oil in mayonnaise production, the optimum substitution rate was found to be 30%, on the basis of viscosity, color and emulsion stability.

Similarly, Liu and Pigott (1995) developed a process to separate fish oil from primary fish wastes (head, viscera, trim and tail) from fresh cultured King salmon and Atlantic salmon minced and mixed in various ratios, with or without TBHQ. Best results were obtained using lower proportions of head and viscera and inclusion of TBHQ, at pH 5, temperature 32-36 C and 10 hours of exposure.

While the commercial price of the oil in the unconcentrated PUFA capsules from fish oils is very high compared to the factory price of refined fish oils, the price of the concentrated PUFA (or a product with high DHA separated from the EPA) will be manifold more.

5.1.5. Flavouring and Aromas

The use of canned tuna cooking waste as flavourings was reported by Tze-Kuei Chiou (1995). Changes in extractive nitrogenous components and overall preference of tuna cooking waste as a result of enzyme hydrolysis and concentration were studied. Overall preference was improved by proteinase hydrolysis and concentration (heating at 55 or 85°C for 2 or 6 h). The level of preference was affected significantly by concentration conditions. As the temperature and period of concentration increased, the colour darkened and the flavour became increasingly undesirable. Contents of free amino acids (FAA), especially histidine, decreased markedly during concentration, suggesting that a Maillard reaction might be involved in the process. Cooking waste contained 891 mg/100 ml of FAA, of which histidine, taurine, anserine, glutamic acid, leucine, threonine and lysine were predominant. Inosine monophosphate (76 mg/100 ml), trimethylamine oxide and creatinine were also present in high levels, ranging from 45 to 76 mg/100 ml. After enzyme hydrolysis, levels of FAA, particularly histidine and taurine, were greatly increased. Sensory evaluation suggested that tuna cooking waste processed under the study optimal conditions could be used as a flavouring agent.

Volatile components in fresh-picked blue crab (*Callinectes sapidus*) meat and its processing by-product were extracted by simultaneous steam distillation/solvent extraction (Chung and Cadwallader, 1993) (Chung, 1995). Compound characterization using instrumental analysis with GC/MS and GC/Fourier transform IR spectroscopy allowed to identify 77 compounds in the crabmeat and 80 in its by-product, of which 58 were common to both. 54 compounds were identified for the first time in crab. Trimethylamine, alkanes (C15-C17, C19) and indole content (more than 50 ng/g) were highest for crabmeat while the trimethylamine, carbon disulphide, dimethyltrisulphide, alkanes (C15 and C17), geranylacetone and 1-dodecanol contents were highest for the by-product. Concerning the common compounds to both crab meat and its by-product, 23 were higher in the by-product and 7 higher in the meat. GC/olfactometry allowed to determine crab meat aroma on the extracts obtained by atmospheric and vacuum simultaneous steam distillation and solvent extraction. Crab meat aroma was defined by 7 common aroma compounds, of which the following 5 were identified: 2,3-butanedione, pyrrolidine, (Z)-4-heptenal, 2-acetyl-1-pyrroline and 3-(methylthio)-propanal. Results indicated that 3 aroma compounds were essential in crab meat aroma and could serve as markers for evaluating the flavour quality in the by-product. These markers were pyrrolidine, 2-acetyl-1-pyrrolidine and 3-(methylthio)-propanal. The by-product of crab processing proved to be a good source for volatile flavour recovery.

The use of crayfish hepatopancreatic extract (CHE) was investigated for improving the extractability of nitrogenous compounds and flavour components of the crab hard tissue (CHT) (Kim *et al.*, 1994). The volatile flavour compounds in CHE-treated CHT were compared with untreated hard tissue. The incorporation of CHE improved the extraction of volatile flavour compounds and increased the extractability of nonvolatile nitrogen compounds obtained from CHT by mechanical separation of the composite crab processing by-product (primarily shell, viscera and legs). The optimum conditions for hydrolysis of CHT protein were 2 h reaction with 1 ml CHE/10 g CHT at 45°C. Concentrations of volatile flavour compounds increased significantly in CHE-treated CHT compared with those from untreated substrate. However, the concentration of dienals and aromatic hydrocarbons decreased. Pyrazines, especially 2-ethyl-6-methylpyrazine and 2,3-dimethylpyrazine, were in markedly higher concn. due to CHE treatment. The authors concluded that the processing by-product of CHT, if treated by enzymic hydrolysis with CHE, might be useful as a crab flavouring agent.

Volatile components of crayfish processing waste were analysed by dynamic headspace/capillary GC-MS and chromatography-coupled aroma perception analysis with simultaneous photoionization detection (Tanchotikul and Hsieh, 1989). 117 compounds were identified. The majority of the flavour compounds previously identified in freshly boiled crayfish tail meat and hepatopancreas were also detected in the crayfish waste. Many areas in the headspace profile contained good nutty, green woody, sweet fruity and very desirable salty meaty aromas, indicating the presence of important crayfish flavour components in the sample. These findings might facilitate the selection and recovery of such flavour components from the crayfish processing waste, thus enhancing its economic value.

Pairat Narkviroj and Buckle (1987) worked on the preparation of prawn head powder (PHP) suitable for inclusion in oriental prawn crackers, according to the quality criteria for the end-product acceptability. Cooked prawn heads were processed either by (i) cook/dry/grind or (ii) cook/blend/dry/grind techniques and then stored before analysis or use in the preparation of prawn crackers. The prawn powder was blended with tapioca flour at 6, 10 and 12% w/w, and prawn crackers were prepared and evaluated chemically and organoleptically. Proximate composition and some quality attributes of PHP and prawn crackers were tabulated. The PHP obtained from method (ii) had higher protein and fat contents that that produced by method (i): protein 64.56±1.27 and 57.67±0.3%, respectively; and fat 6.66±0.18 and 5.66±0.30%, respectively. The sensory evaluation showed that PHP significantly influenced the flavour and texture of prawn crackers. The colour of 6% prawn powder crackers was less preferred than samples containing higher amounts of PHP. Considering all organoleptic parameters, the crackers containing 10% PHP were the most acceptable.

Takeshita (1982) proposed to add value to shrimp processing wastes by the preparation of a flavour extract for food industry. Various types of processing wastes were examined. Best results were obtained by pressure cooking. Undersized or damaged shrimps gave higher flavour intensity than residues from manually peeled shrimps or shells from mechanical peeling. Corn oil and maltodextrin were used as flavour fixatives and allowed to keep and even improve the flavour quality. A small amount (1.5% of the freeze-dried product) was shown to be enough for impacting the characteristic shrimp flavour to soups and crackers.

The flavour profile of cooked commercial shrimp waste was determined by GC/MS analysis (Mandeville *et al.*, 1992). Results revealed the presence of 44 compounds of different functional groups including fatty acid esters, long-chain alcohols, aldehydes and heterocyclic compounds. 29 compounds were tentatively identified by their mass spectral data, and 15 were identified by both mass spectral data and retention times. Many components provided desirable aroma such as nutty, fruity, floral, green woody and meaty, indicating the presence of important flavour compounds in the commercial shrimp waste.

Manufacturing of dried shrimp, a popular food in Asian countries, leads to the production of high amounts of wastewater containing flavour and flavour-enhancing compounds. The recovery of these compounds is hampered by the presence of salt in the water. Lin and Chiang (1993) evaluated the feasibility of membrane techniques for desalting of shrimp processing wastewater and recovery of flavour compounds. Both of membrane diafiltration by reverse osmosis and electrodialysis were considered for this purpose. The reverse osmosis was judged unsuitable as it did not allow a good separation between salt and flavour compounds, and led to a loss of around half the flavour compounds. The electrodialysis was found to be more effective, with an efficiency of over 90% throughout the process.

Oyster liquid wastes including shell and blood liquors, original liquid and wash water were collected from laboratory and commercial oyster shucking operations. Physicochemical characterization of these liquid wastes showed 0.01-0.36% nonprotein-Ncomponents, 0.03-0.44% total-N, 0.13-1.64% salt along with an identical protein profile with a molecular weight around 20-25 kD as major proteins. Total solids could be used to predict the levels of total-N, nonprotein-N, ash, salt, total suspended solids and COD. Heating with a steam-jacketed kettle was an easy method to concentrate liquid wastes for production of oyster soup. Chemical, physical and sensory properties of processed oyster soup were analysed and compared with a commercial product. Results indicated that oyster soup products prepared from oyster waste water would be as acceptable as traditional oyster soup (Shiau and Chai, 1990).

Metabolites of several 2- and 3-ring aromatic hydrocarbons were found in livers of English sole exposed to No. 2 fuel oil. Four metabolites of the C_2H_5-naphthalenes, six of the C_3H_7-naphthalenes and one each of fluorene, phenanthrene and anthracene were partially characterized and quantified. Their concentrations ranged from 50 to 1100 ng/g. The metabolites were separated from the liver matrix using an automated extractor/concentrator. The resulting extract was then purified by HPLC, and the metabolites were characterized and quantitated by gas chromatography-MS (Krahn and Malins, 1982).

5.1.6. Pigments

Crustacean wastes present a high potential for protein concentrate recovery and in the same time, show to be a great source for extracting useful components such as pigments, lipids and flavour active components which could be reincorporated into seafood products, according to the required functional and organoleptics characteristics. Carotenoid pigments, such as ß-carotene, canthaxanthin, astacene and astaxanthin monopalmitate, were extracted from raw commercial shrimp waste and separated by thick layer chromatography using silica gel, and their structures were tentatively identified by TLC. The identifications were subsequently confirmed using the Fourier Transform InfraRed (FTIR) spectroscopy. The lipids were separated and classified into glycerides, sterols and phospholipids using TLC. The flavouring active components were extracted by different organic solvents and separated into acidic, weakly acidic, basic and neutral fractions before sensory determination of their organoleptic characteristics (Mandeville *et al.*, 1991).

The Louisiana crawfish industry comprises the largest concentration of crustacean aquaculture in the United States. Processing plants throughout the culture region annually generate as much as 80 million pounds of peeling waste during recovery of the 15% (by weight) edible tail meat. A commercial oil extraction process was reviewed for recovery of the carotenoid astaxanthin from crawfish waste (No and Meyers, 1992). Crawfish pigment in its various forms finds applications as a source of red intensifying agents for use in aquaculture and poultry industries. Crawfish shell, separated in the initial pigment extraction step, was an excellent source of chitin. Applicable physicochemical procedures for isolation of chitin from crawfish shell and its conversion to chitosan were developed. Crawfish chitosan demonstrated to be both an effective coagulant and ligand-exchange column material for recovery of valuable organic compounds from seafood processing wastewater.

Methods for adding value to the crawfish waste carotenoids were investigated by Omara-Alwala *et al.* (1985). Pigmented and feed grade oil was produced by extraction from an acid-treated crawfish ensilage. Results suggested that both of astaxanthin-enriched oil and astaxanthin esters could be a beneficially nutritious component and effective pigmenting agent of dietary formulations for aquaculture.

Cano-Lopez *et al.* (1987) used the Atlantic cod trypsin or bovine trypsin to aid the extraction of carotenoprotein from shrimp processing wastes at 4°C. When 25 mg% cod trypsin was added to an extraction medium containing 0.5N ethylene diaminetetraacetic acid (EDTA), 64% of the astaxanthin and 81% of the protein of shrimp waste were recovered as carotenoprotein content within 24 h. With 25 mg% bovine trypsin, under otherwise same conditions, the carotenoprotein recovered represented 49% of the astaxanthin and 65% of the protein of the waste. The semi-purified cod trypsin was not as effective as pure trypsin in facilitating recovery of carotenoprotein from shrimp waste. The recovery of carotenoprotein from shrimp waste by extraction at 4°C was facilitated by EDTA addition, either with or without trypsin presence.

A procedure for pigment extraction from frozen prawn tail shells was described by Spark (1981). The major component of the pigment was found to be astaxanthin, which occurred in amounts of 3.2 mg/100 g shell. Economics of pigment recovery from prawns appeared to be more viable than from crab or lobster .

A process for the utilization of shellfish waste was described by Meyers and Chen (1985). Extraction of the red carotenoid pigment astaxanthin from chitinous shells and proteinaceous tissues of shellfish, in presence of edible oil, produced an astaxanthin-enriched dietary food ingredient, and other food-type products. Crustaceans (mainly crawfish) waste was ground in an attrition mill to separate the tissue from the shell, the shell was removed and the tissue was acidified to a pH value ranging from 4 to 5.5, which is enough to inhibit the microbial development and improve overall pigment recovery. The acidified tissue was cooked in a kettle to a puree stage and extracted with edible oils, at specific and critical conditions of concentration and temperature/time couple. The cooked product was centrifuged in a decanter. 2 effluent streams were recovered: (i) an aqueous effluent which was separated in a 3-phase separator (liquid-liquid-solid) to provide an astaxanthin-enriched oil, along with a flavoured water extract and some demineralized solids, and (ii) an effluent consisting of demineralized solids. All of solids from both (i) and (ii), the astaxanthin-enriched oil and the flavoured water extract were shown to find use as food supplements.

A rapid quantitative method for determination of the astaxanthin pigment concentration in oil extracts was developed by Chen and Meyers (1984). Power models were elaborated to demonstrate relationships between absorption maxima (Lambda max) and specific extinction coefficient (E1%1cm) for the carotenoid astaxanthin and astacene in different oils (soybean, cottonseed, herring, menhaden, salmon oils) and organic solvents. An accurate and rapid determination of the concentration of astaxanthin-enriched oil could be achieved using the predicted E1%1cm value based on the absorption maxima in the visible light spectrum. Several vegetable or fish oils were shown to be comparatively efficient in extracting astaxanthin pigment from crustacean waste in a pilot plant.

Lobster waste (including the head and hard carapace, viscera, mandibles and gills) contains approximately 54 MUg/g total astaxanthin, 29% protein, 23% chitin, 34% ash and 2.2% crude fat on a dry wt. basis. Carotenoproteins from lobster waste were considered as a potential feed supplement for cultured salmonids. Tu Ya *et al.* (1991) used trypsin from bovine pancreas to facilitate the recovery of carotenoid pigments and protein as carotenoprotein complex, which was subsequently air-dried to a stable powder form at 45 C and 15% RH. The product obtained was found to contain 60% protein, 15% crude fat, 6% ash, 8% chitin and 295 MUg/g total astaxanthin. The process achieved a substantial reduction of the antinutrient -ash and chitin- levels associated with lobster waste, whereas elevating the levels of carotenoid pigments and essential nutrients such as proteins and fat in the recovered product. These characterisics of the final product suggested that lobster waste could be used as an inexpensive source of pigments and proteins in the diets of cultured salmonid species.

Drying characteristics of carotenoproteins recovered from lobster waste were evaluated in an air-drier using air temp. (45, 55 and 65°C) and relative humidity (5 and 15%) as main factors (Ramaswamy *et al.*, 1991). The study indicated that the carotenoprotein slurry exhibited a short constant rate period drying followed by classical diffusion drying. Higher temp. achieved faster drying rates, but adversely affected its nutritional composition and/or quality. The proximate composition of the air-dried carotenoprotein was comparable to the freeze-dried one.

Hama and Nakamura (1988) reported the identification of a new conjugated carbonyl in autoxidized tuna liver oil. They proposed a mechanism for the formation of 6 red pigment-forming substances (RPS) by autoxidation of eicosapentaenoate, of which 4 have been previously characterized. The presence of a fifth, 3-(5-hydroxy-2-octa-2,5-dienyl-3-oxocyclopentyl)-2-propenal (V), detected in autoxidized tuna liver oil, was described. Triglycerides of the oil purified with activated carbon were oxidized at 40° C for 72 h in the dark. Preparation and identification of RPS were conducted by purification using gel chromatography on Sephadex LH-20 with chloroform/methanol ($CHCl_3$/MeOH) (2/1, v/v) as the eluent, followed by column chromatography on Silicagel 60 with $CHCl_3$/MeOH (97/3, v/v). After reduction with $NaBH_4$ or $NaBD_4$ and subsequent trimethylsilylation of the purified fraction, RPS were analysed by GC-MS. In addition to V, 2 of the other 5 RPS were also detected. Quantitative estimation using mass fragmentography showed the formation of 0.05% total RPS containing 0.01% V in autoxidized tuna liver oil.

Acid ensilage has been reported as a means of protecting shellfish processing waste from bacterial decomposition. The effects of long term silage preservation on astaxanthin (free, mono- and diesterified-forms) and n-3 polyunsaturated fatty acids in shrimp (*Pandalus borealis*) waste were studied with regard to the use of these components as value-added nutrients in the aquaculture industry (Guillou *et al.*, 1995). Comparative tests carried out on defrosted shrimp waste (SW) and 14-wk-old shrimp waste silage (SWS) revealed no significant in the total extracted lipids. The extracted crude oil from SWS contained significant higher concentration of total astaxanthin (4.57 as compared to 3.99 mg/g), this could be possibly due to a small amount of red pigment, presumably astaxanthin, which remained bound to shrimp carapace, after the solvent extraction of SW, but which was fully received from SWS. Higher amounts of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) were found in the esterified astaxanthin from SWS (43.9 and 45.5%) compared with the SW counterparts (respectively 24.7 and 20.3%). Results suggest that EPA and DHA are the principal fatty acids to be esterified with the chitin-linked astaxanthin portion in the shrimp carapace.

The acid ensilage treatment of crawfish waste was tested by Chen and Meyers (1983) for improving the astaxanthin pigment extraction. This treatment proved to be efficient for preservation of the crawfish heat-processed waste under ambient temperature with stabilization of the present astaxanthin pigment. Implementation of acid ensiling prior to the pigment extraction increased the concentration astaxanthin oil extract by 40-50%, and the oil recovery by 10%. A 2-fold increase in free amino N, and a 70% reduction in exoskeleton $CaCO_3$ were observed in crawfish silage (pH 4.2) obtained through acid/enzymic hydrolysis, compared with the controls. A correlation was shown between $CaCO_3$ solubilization and pigment release in relation to the silage pH value. The role of acid-resistant proteolytic microorganisms in the breakdown of carotenoprotein complex was discussed. The use of ensilage process was recommended as a means for widening the commercial production of either astaxanthin-enriched vegetable or fish oils derived from high-pigment content crustacean wastes.

5.1.7 Vitamins

Many studies dealt with the identification and determination of the vitamin content of fish and seafood and their processing wastes. Feldschreiber and Sinclair (1987) pointed out the nutritional and healthy effect of fish liver concentrate and cod liver oil in terms of vitamin content.

The vitamin A and related compounds contents (A_1, A_2, A_1 aldehyde, A_2 aldehyde, and C_{22} vitamin A) were determined in the liver oil of 5 species of Brazilian freshwater fish (*Leporinus copelandi*, *Salminus maxillosus*, *Pimelodus clarias*, *Prochilodus scrofa* and *Leporinus piapara*). The high nutritional value of these fish species was highlighted (Yasaka *et al.*, 1973). Zawadzki (1975) also determined the vitamin A content and its stability in fish oils, pointing out the potential applications and the economics of vitamin extraction.

Vitamin A concentrates were obtained from fish liver oil by molecular distillation (Maksimov *et al.*, 1970). The used apparatus (Spidivak GB) was equipped with trituration module which made possible the formation of either thin and turbulent layers of the distilled liquids. This allowed the production of vitamin A concentrates from low vitamin A content raw materials (5000-15000 CIU per g). The use of the apparatus was well described. At oil (**???**) temperature of 160-200°C, vitamin A yields were greater than or equal to 95.1% whereas there were losses of retinol at higher temperatures. Lower temperatures had unfavourable effects on the sensory characteristics of fat fractions giving them a bitter flavour.

The liver of fish such as sharks and rays are a potentially valuable source of vitamin A. The work carried out by Hole and Taylor (1996) aimed at evaluating this potential source in dogfish (*Squalus acanthias*) and comparing oil yield, composition and oxidative stability for different extraction methods. Bligh and Dyer, Soxhlet and direct steaming methods were used to extract oil from the dog fish liver. Solvent-based techniques gave higher oil yield and higher vitamin A concentration than steaming method. The oils extracted by Bligh and Dyer method seemed to be the most stable. The results were largely discussed and the authors concluded that steaming was likely to be the most feasible commercial extraction process.

Kobayashi *et al.* (1976) determined the vitamin D_3 content in tuna liver and resin oils using the gas-liquid chromatography, whereas Takeuchi et al. (1984) proposed a high-performance liquid chromatography method, combined with UV spectra and/or GC-MS, for identification and determination of the vitamin D_3 (or D_2) and 25-hydroxyvitamin D_3 (25-OH-D_3) contents in fish liver and eel body oils by. The assayed values of vitamin D_3 in skipjack and tuna liver oils were 57 760 and 16 200 IU/g respectively, they were much higher than those found in cod and pollack liver oils. The assayed values of vitamin D_3 in eel body oils were very low (16-43 IU/g) and showed no appreciable change despite differences in the farming conditions. The 25-OH-D_3 was only identified in skipjack liver oil ; the assayed value was 1.8 MUg/g, about 1/800 of that of vitamin D_3.

The optimal vitamin E concentration and status in the tissues is highly influenced by various polyunsaturated fatty acids (PUFAs). Farwer *et al.* (1994) quantified the effects of 3 different high-PUFA diets on the vitamin E nutritional status of rats. The diets contained linoleic acid and alpha-tocopherol and various amounts of fish oil, linseed oil or sunflower-seed oil. Serum alpha- and gamma-tocopherol, triacylglycerol, liver alpha- and gamma-tocopherol and fatty acid composition of liver triacylglycerol and phospholipids were determined. Liver and serum alpha-tocopherol levels were positively correlated with dietary DL-alpha-tocopheryl acetate whereas liver and serum gamma-tocopherol levels were negatively correlated with. The rats fed with fish oil-based diets showed reduced liver and serum tocopherol levels compared with the groups fed with the other high-PUFA diets. The results highlighted the influence of different PUFAs on the nutritional vitamin E status.

5.1.8 Antioxidants

The antioxidant activity of water-soluble fractions of chum salmon spermary tissue, a by-product of the salmon industry, was evaluated by Sasaki et al. (1996), using a sardine triacylglycerol emulsion system. The intact and high-molecular weight water-soluble fractions of spermary tissue accelerated both autoxidation and iron/ascorbate-catalysed oxidation. The low-molecular weight (LMW) fraction inhibited autoxidation and oxidation catalysed by iron/ascorbate and 2,2'-azobis(2-amidinopropane) dihydrochloride (AAPH). Inhibition of iron/ascorbate-catalysed oxidation by the LMW fraction decreased with decreasing pH until no activity was observed at a pH value less than or equal to 6.4. Activity of the LMW fraction was not strongly influenced by the pH value (5.0-7.0) in the presence of AAPH. The antioxidants of the LMW fraction, including spermine, putrescine, hypoxanthin, xanthine and glutathione, either separate or combined, exhibited less antioxidative activity than the LMW fraction, indicating that other unidentified antioxidants were present. It was concluded that the salmon spermary tissue could be used as a source of water-soluble food antioxidants.

Li and Morrissey (1995) followed the effect of natural antioxidant from shrimp waste on lipid oxidation and color stability of fish. The antioxidant fraction from shrimp waste was extracted in ethanol and purified using a silica gel glass column chromatography, before being tested for its effect at various concentrations on sablefish minces stored at 4°C/8 days or –20°C/4 months. The TBA and peroxide values along with the free fatty acids were determined during storage. Both crude and purified extracts at 0.2-0.5% significantly reduced the TBA and peroxide values, but had no effect on the free fatty acid levels, for the different storage conditions. The same experiment was reported for rockfish and showed that the TBA values also were significantly reduced with the antioxidant extract treatment.

Two different methods, the Rancimat and the hypochlorite-activated chemiluminescence technique, were compared for determining the effectiveness of different antioxidant systems in cod liver oil (Burkow *et al.*, 1995). A stability test was carried out at 5°C in the dark. The correlation between the Rancimat results and the chemiluminescence data was low. According to the Rancimat results, the most effective antioxidant systems were lecithin and delta-tocopherol-rich systems. However, according to the chemiluminescence results, tocopherols were pro-oxidant. Both methods showed a beneficial effect for rosemary and sage extracts, and the stability testing showed the best results for the rosemary extract. The authors discussed the reasons for the differences between the methods and the practical implications of this.

5.1.9 Nutraceuticals

Industries and consumers presently show increasing interest towards nutraceuticals and natural products. In this sense, the marine resources constitute a great potential, mainly for the food industry, enzymes and pharmaceuticals, bioactive and health-enhancing molecules and effects of marine toxins on ion channels. Some products originated from marine resources are already developed and on trade, these include chitin and chitosan, fish oils, liquid crystal, protamines from fish testicles for use as food antibacterial, growth hormones for use in fish farming and several pharmaceutical compounds extracted from marine organisms. Ohshima (1998) described the recovery and use of neutraceuticals from marine resources, focusing on the development in Japan of a variety of marine by-products for use in nutraceutical foods.

5.2 Non food uses of fishery by-products

There are a number of traditional uses of waste from the fish processing industry and the so called trash fish. These include the production of fish meal, fish oils, etc. But with increase awareness of environmental needs and the use of cleaner production methods the use of the by-products of the fish processing industries for the production of valuable food and non-food applications is gaining further importance. A number of value added products are already in the market and many more are in the pipeline. These include products like the chitin and chitosan obtained from crustacean wastes, the fractionation of high production of high value polyunsaturated fatty acids from fish oils, enzymes and other biochemicals from the viscera and other internal parts of fish wastes, etc.

Processing discards account for for upto 75% of the total weight of the fish. Only about 25% of the fish is used as fillets. Another 25% of mince could be obtained using mechanical deboning procedures. The resultant minced meat can be used for the preparation of fish cakes or surimi. Hence a large part of the fish by-product needs to be value added instead of being disposed as waste.

5.2.1 Fish meal

Fish meal and fish oil are the two major products obtained from the wastes of fish processing industry. These products of such importance that they are also produced deliberately from the oilier pelagic fish which may not be used for human consumption. The meals that are produced from the by-products of the traditional fish filleting industry are sometimes known as white fish meals.

The production of fish meal and fish oil are done simultaneously. The substrate is first cooked with water to coagulate the proteins so that they do not emulsify the oil. The press water and the press cake are separated by using a press. While the press cake can be dried to produce the fish meal; the press water is centrifuged to separate the oil from the water phase. The wet meal is dried and bagged and ready for the feed market. Details of a typical industrial fish meal producing plant may be obtained from Aitken et al (1982).

A process for odor free processing of fish wastes to fish oil and fish meal is described by Suesse (1997). The fish waste processing unit is coupled directly to fish processing section. The fish waste is rapidly separated into liquid and solid phases by mechanical pressure. Subsequently higher temperature is applied and the fish meal and fish oil separated. They are then sterilized to avoid any virus hazard, and the fish meal is dried. The process has low energy consumption, and does not produce offensive smelling waste gases.

The worlds major exporters of fish meal are Peru, Chile, Denmark and Iceland. These same countries are among the worlds major producers along with Japan, Norway, Thailand, USA and USSR, which consume domestically most of their production and this do not have a significant export. Total production of fish meal in 1993 was 6.2 million tons of which the export was 3.6 million tons (IFOMA, 1993). A large part of this is from waste fish, while a small part of this is white fish meal at this time. With the increase in fish catch, inland aqua culture and yields the latter is likely to become more and more significant.

Because of its amino-acid content, fish meal can complement other feed sources very effectively. While it has been used in a number of applications, care should be taken as regards it effect on the product concerned. Large quantities in poultry diets for example has led to gizzard erosion, caused by components of fish meal called gizzerosine (Rengenstein & Rengenstein, 1991). Recommended methods of processing and use compositions of the feed should be applied in order to overcome such problems.

The fish meal industry is a large well established one. Markets trends like all other large commodities have ups and downs. The journal INFOFISH International gives a good update on current production, export, prices, etc; in all their issues.

5.2.2 Visceral wastes

The internal organs of fish are quite small, intestines are very short, stomach is very stretched or nonexistent, kidneys are not distinct organs. There has been an attempt to develop chitterlings form sunfish intestines in southern US. Chitterlings are normally made with pork intestines (Regenstein and Regenstein, 1991). Livers are very rich in oil and vitamins and the cake obtained after pressing them could lead to valuable products. Pan et al (1995) isolated 150 H2S producing bacteria from shrimps and fish purchased in the fish market at Keelung, Taiwan. The objective was to screen eicosapentaenoic acid (EPA) producing *Shewanella putrefaciens* from marine fish intestines. 74 isolates identified as Shewanella putrefaciens contained eicosapentaenoic acid (EPA, 4-5% of total fatty acids). Most EPA was contained within phospholipids.

Mizhueva et al (1994) described a method for utilization of sturgeon waste (stomach and intestine scraps) using blanching of small pieces of these products and removing extraneous matter with the addition of catamine AB (alkyldimethylbenzylammonium chloride). No pathogens were detected, and the material was recommended for use in minced and brined fish products.

5.2.3 Shells, skin and scales

Gelatin and Glue are water soluble hydrophilic products obtained by the hydrolysis of the fibrous connective tissues of skin and bones. The quality of the gelatin or glue depends on the molecular weight distribution and other factors. Besides addition into food like in jells, candies, whipped creams and glues, these substances may also be used in light sensitive coating or as a base for photo resistant products (Holahan, 1965). It is also used in the manufacture of lead frames that hold the silicon chip in computers and microprocessors. Its application in color video cameras has also been reported (Norland, 1990). Isinglass, made from the swim bladder of fish is a high grade fish gelatin used in the clarification of cider, wine, beer and vinegar.

Kim et al. (1995) used succinylated gelatin from yellow fin sole skin as a clarifier for chewing gum base. Proximate composition and amino acid composition of succinylated gelatin were similar to those of untreated gelatin except that lysine content of succinylated gelatin was lower than that of untreated gelatin.

Modified gelatin from marine animal skins (conger eel (*Astroconger myriaster*), filefish (*Navodon modestus*) and arrow squid (*Loligo bleekeri*) are communly used as a source of raw material for edible gelatin (Kim et al., 1993-1/2; Kim and Cho, 1996). Conger eel skin had the highest collagen content, followed by file fish and then arrow squid skin. They did not find difference in amino acid composition of soluble and insoluble collagens. Collagen from animals caught in coastal and offshore water in Korea contained ALPHA- and BETA-chains. The sum of proline and hydroxyproline contents in conger eel skin collagen was higher than that in the other collagens, but was lower than that of swine skin collagen. Conger eel skin collagen exhibited a higher denaturation temperature in solution and a higher degree of proline hydroxylation, compared with skin collagen of the other species. Physical properties such as gel strength, melting point and gelling point of conger eel skin gelatin were superior to those of file fish and arrow squid skin gelatins.

A patented process for the production of gelatin from fish skins is available (Grossman and Bergman, 1992). Their process consists of a final extraction step of pretreated skin with water at elevated temperature not above about 55 C. The process results in a high quality product with absence of a fishy smell.

Croda Colloids (Anon, 1997) has introduced a range of fish skin gelatins including non-gelling spray-dried fish gelatin, non-gelling spray-dried hydrolysed fish gelatin and gelling fish gelatin; all types are available in Kosher and Halal grades. The non-gelling gelatins from cold-water fish are useful as stabilizers whilst the gelling gelatins from warm-water fish gelatins have properties similar to those of mammalian gelatins.

In The South of East Asia, fish skin are used to make bags or purses. In some part of Southern China, cuttlefish pen has been used as antacid for gastric problem. They are just grind into powder and it is ready for ingestion. The extraction of a shiny lacquer, called pearl essence, from the scales of fish besides its direct use ornamental purposes has been reported (Ramachandran and Nair (1989). Dried scales have also been used as a flocculating agent that can be used as part of a waste water treatment system to precipitate solid materials especially proteins (Regenstein and Regenstein, 1991). The advantages of fish scales over chitosan which can do the same job is that the precipitate can be used directly as a feed and that fish scales are much cheaper than chitosan.

Ockerman and Hansen (1988) have reviewed the production of surimi, fish protein concentrate, fish meal and fish oil; use of fish offal in animal feeds; production of fish silage; fish liver preservation; production of fish gelatin and glue; leather from fish skins. Fish skins produce leather with excellent properties but do not occupy a large market because they are not economically competitive with synthetics and land-animal leather.

5.2.4 Substrates for fermentation

A number of byproducts from the fish and marine product industry has been used as substrates for fermentation to value added production. These fermentations are used for the production of organic acids, peptones, etc.

Utilization of mussel processing effluents as a substrate for gibberellic acid (GA3) fermentations has been reported by Pastrana et al (1993). The protein and glycogen rich effluent was concentrated by ultrafiltration and partially hydrolysed by *Aspergillus oryzae* alpha-amylase prior to use. The concentrated, saccharified effluent was then used as the substrate.

A similar waste stream was used by Pintado et al (1999) as a substrate for lactic acid production by *Lactobacillus plantarum* A6, an amylolytic bacterium. Amylase productivities by this strain were similar for starch and glycogen-containing MRS medium, although sugar consumption was lower with the latter substrate, and approx. 20% of sugars remained undegraded. This difference was ascribed to the higher level of branching in glycogen. Fermentation of mussel processing wastes caused a pH drop and an uncoupling of lactic acid and biomass production. Use of pH control and a higher initial protein concentration avoided this uncoupling effect and resulted in comparable levels of lactic acid production (8.41 g/l) on the waste substrate compared to starch.

Suresh and Chandrasekaran (1998) utilized prawn waste for chitinase production by the marine fungus *Beauveria bassiana* by solid state fermentation. The chitinous prawn solid waste of the shellfish processing industry was used as a substrate for chitinase (EC 3.2.1.14) production by the marine fungus *Beauveria bassiana* BTMF S10, in a solid state fermentation culture. A maximum. chitinase yield of 248.0 U/g initial dry substrate was obtained in a medium containing a 5:1 ratio (w/v) of prawn waste/sea water.

Single cell protein was produced from the hydrolyzate of shrimp-shell wastes by Ferrer et al (1996) Shrimp shells, which contain 39.6% protein, 22.6% chitin and 28.1% ash, were treated in a 2-stage pretreatment process to remove protein (achieved by extraction at pH 12 for 2 h at 30 C), followed by acid hydrolysis with concentrated HCl to hydrolyze chitin to glucosamine; Greater than 90% of the protein, and 80% of chitin were recovered by these pretreatments. The chitin hydrolysate was used as a substrate for production of *Saccharomyces cerevisiae* K1V-116 biomass in batch and continuous fermentations. Batch culture resulted in biomass yield coefficient and max. specific growth rates of 0.58 g dry wt. cells/g glucosamine consumed and 0.23/h, respectively. Continuous cultivation had a maximum specific growth rate of 0.389/h and a biomass yield coefficient of 0.447 g dry wt. cells/g glucosamine consumed. The highest biomass production rate (0.423 kg dry wt. cells/m3/h) was achieved at a dilution rate of 0.25/h. This indicated that shrimp wastes are suitable for production of yeast biomass.

Bough et al. (1977) used shrimp and crab wastes for microbial media.

Industrial fish peptone (prepared by autolysis of fish viscera followed by ultrafiltration and permeate concentration) was an excellent substrate for biomass production in solid and submerged fermentations (Vecht-Lifshitz et al., 1990). The maximal growth rates of several microorganisms were 2-3 times higher and the final biomass concentration. were almost twice than those grown on beef (bacto). Fish peptones did not, however, increase the production of secondary metabolites relative to those produced on beef peptones in some specific fermentations tried.

Tahajod and Rand (1996) used fish waste effluent as a fermentation medium for production of antibacterial compounds by lactic acid bacteria. Media were prepared from lactose solutions and fluid recovered from red hake fillets. Starter cultures were *Bifidobacterium bifidum*, *Lactobacillus acidophilus* and *L. helveticus*, with incubation at 37 C for 40 h. Activity of supernatant against growth of *Bacillus subtilis* was examined using the agar diffusion assay. *L. acidophilus* showed most growth in the fish medium; all starters produced similar levels of acidification, and *B. bifidum* exhibited maximum potential for production of antimicrobial compounds.

5.2.5 Enzyme and biochemical production

Fish processing wastes provide large amounts of gut enzymes which have potential use in a variety of applications (Simpson and Haard, 1987; Haard, 1998). The enzymes obtained from fish guts are significantly different from other sources and offer certain distinct advantages. For example, fish pepsins have been found to have a higher pH optima, are active at lower temperatures and resistant to autolysis at lower temperatures (Raa, 1990). The Unique properties of fish enzymes have been attributed to their unique amino-acid composition (Gildberg and Overbo, 1990).

Application of fish enzymes as processing aids for the preparation of caviar from a variety of fish species, for cleaning of scallop and de-scaling of fish has been successfully done. In these cases the enzymes break the linkage between the eggs, proteins and other connective tissues without damaging the desired product (Raa, 1990).

Several authors have reported the isolation and purification of fish enzymes for different commercial and biotechnological purposes. These include pepsin from cod (Alams, 1990), typsin and catespin from the digestive glands of squid (Martinez et al 1988 and Gildberg, 1987) and alkaline phosphatase from shrimp (Olsen et al., 1991). The latter may have use in the preparation of diagnostic kits. A large-scale process for the recovery of enzymes in wastewater from the shrimp processing industry was described by Olsen et al (1990). This water, used in the thawing of the frozen, raw shrimp, is flocculated by ferric chloride, concentrated by cross-flow ultrafiltration, and then freeze-dried. The enzymes analyzed (alkaline phosphatase, hyaluronidase, BETA-N-acetylglucosaminidase and chitinase) were recovered in very good yield.

Fisheries by-products such as guts, seal stomachs and clam bellies contain some interesting enzymes (Reece, 1988). Bakar and Hashim (1996) found crude protease in sardine (*Sardinops melanastictus*) offal which has milk curdling ability and can be used in the production of a yoghurt-like product dadih. A proteinase extract in dried acetone form was prepared from sardine offal. It had an optimum pH of 5.0 and an optimum temperature of 60°C. The proteinase was able to coagulate milk in the absence of CaCl2. At 0.6% of the extract containing 11.22 mg/ml protein with a proteolytic activity of 54.43 u/min per ml on haemoglobin or 11.32 u/min per ml on casein was required for milk coagulation. It is concluded that the proteinase may be used in the manufacture of the yoghurt-like product, dadih.

Extraction and activation of the tuna zymogen obtained from wastes is influenced by temperature, pH, salt concentration and freshness of the stomach tissue in its use a rennet substitute Tavares et al (1997). The presence of 25% NaCl in the extraction process markedly enhanced the yield of tuna gastric enzyme. The milk-coagulating time for both tuna protease and rennet, at an incubation temperature of 32 C, was dependent, at similar level, on the pH (5.5-6.4) of the milk as a substrate. Tuna protease was less sensitive to losses of activity than rennet at pH values above 6.4. Both enzymes became unstable beyond pH 7.0 and completely lost their activities at pH 8.0.

Le Gal et al (1994) extracted enzymes from fish and crustacea and tested them in the preparation of different products. The constraints and competitiveness of the processes and an inventory was made of available raw materials, including underutilized species, fish withdrawn from auctions, and fish and crustacea wastes from processing factories. Trends in the enzyme market and in enzyme applications including an assessment of the industrial use of fish enzymes and an estimate of production costs were also reported.

5.2.6 Chitin and chitosan

Crustaceans like shrimp, crab; squid, etc produce in there solid waste streams a lot of a substance called chitin. This material was orginally considered a major environmental problem. More recently, the possibility of using chitin and its deacetylated derivative chitosan in a number of applications has been realized . (Muzzarelli, 1977).

Chitin is one of the most common organic compounds in nature, second in amounts only to cellulose. Chemically, both cellulose and chitin are polysaccharides polymers or long molecules consisting of sugar molecules strung together. Only one side group distinguishes chitin from cellulose, creating a whole new material for scientist to exploit (Pennisi, 1993). Chitin is a naturally occurring polymer constituted of N-acetlyglucosamine units, some of them being deacetylated (Sannan et al., 1976). The monomer of chitin is 2-acetamido-2-deoxy-β-D-Glucose. Chitosan, which occurs in smaller amounts naturally in nature and which can be obtained from chitin by deacetylation is 2-amino-2-deoxy-β-D-glucose. Officially, chitin is denoted as (1-4)-2-acetamido-2-deoxy-β-D-glucan and chitosan as (1-4)-2-amino-2-deoxy-β-D-glucan. The stoichiometry of chitin is $(C_8H_{13}NO_5)_n$. Authors have estimated that chitin contains 82.5 % acetyl glucosamine, 12.5 % glucosamine and 5 % water. (Muzzarelli, 1977).

Chitin has a polycationic structure that varies considerably in molecular weight, degree of acetylation, secondary/tertiary structure and crystalanity (Domard, 1997). Chitin can be completely acetylated, partially deacetylated (PDC). According to one definition the completely deacetylated form is known as chitosan (Figure-1). The degree of crystallinity may vary considerably affecting its chemical resistance and reactivity (Belamie et al. 1996). The chitin in shrimp forms a α helix structure whereas chitin in cuttlefish and squid has a β structure (Roberts, 1994).

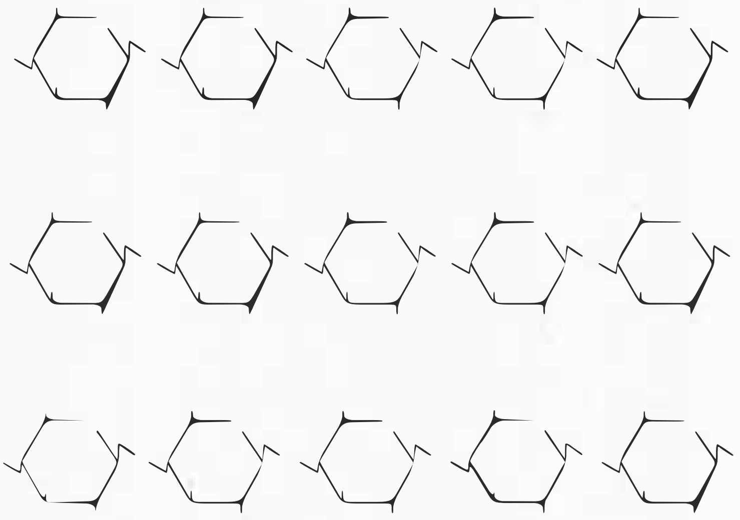

Fig 1 Chemical Cousins (a) Chitin (b)Chitosan (c)Cellulose

The nature of the chitin - protein association is poorly understood, primarily because the form of the linkage between the two polymers has not been characterized completely. The predominant amino acids in residual chitin after partial alkaline hydrolysis were aspartic acid, serine and glycine. This suggested that these amino acids may be involved in the chitin protein linkage (Austin *et al.*, 1981).

The application of chitin and chitosan has been slow and still has not reached its maximum potential. Manufacturing technology of chitosan has been developed to the level of acceptability for most applications. Natural products tend to vary seasonably in chemical composition and structure. This variability requires processing changes and large storage for lots to meet demanding customers for various applications.

Chitin is usually insoluble in common solvents but dissolution in Dimethyl Acetyl-Lithium Chloride (DMA-LiCl) mixture is possible. Controlled deacetylation to produce derivatives with approximately 50 % free amine can be used to produce water soluble chitin (Sannan *et al.*, 1976).

Chitin normally cycles through the environment decomposing naturally into its hydrogen, carbon, nitrogen and oxygen building blocks. Chitin is non toxic to the human immune system. Studies suggest that when chitin like chemicals break down in the body, their by-products are used by the body (Pennisi, 1993).

Chitosan can be distinguished from chitin because of its solubility in dilute acetic or formic acid. Chitin is also a product that contains less than 7 % nitrogen while chitosan contains 7 % or more nitrogen (Muzzarelli, 1977). The amino groups of chitin and chitosan are exceptionally stable in 50 % sodium hydroxide, even at 160°C, at which most amines liberate ammonia or yield degradation products.

The free amine group gives chitosan its primary properties useful in application development. When solubilized in dilute acid, chitosan becomes a cationic polymer, linear in structure, with a high positive charge density. This electronic charge can then be used in flocculation processed, film forming, or immobilization of various biological reagents including enzymes. Other chemical properties of chitosan include its ability to act as a moisture barrier in cosmetics, chelation of multivalent cations, and an encapsulation agent within positive charge is removed (Ornum, 1992) The specific applicability of chitosan depends on its various properties such as molecular weight, viscosity, degree of acetylation, transparency, particle size etc. Chitosan fibers or granules applied to skin seem to keep fungi and microorganisms from growing. It even appears to stimulate the growth of beneficial bacteria in digestive tracts (Pennisi, 1993). These properties are used in wound healing, blood clotting, lowering cholesterol and other medical applications These properties are affected by the quality of chitin material used. Realizing this chitin-chitosan product chain, it is necessary to develop methods, which would enhance the properties of chitin and chitosan and broaden their application.

The production of chitin from the crustacean wastes involves de-mineralization, followed by de-proteination which are done consecutively done by acid and base treatment. The production of chitosan from chitin on the other hand requires a much higher level of alkalinity (40% sodium hydroxide).

Procedures for the isolation of chitin from crab (Chionoecetes opilio) shell waste containing 26.6% chitin (dry basis) required 1N HCl at room temp. for 30 min, with a solids to solvent ratio of 1:15 (w/v).for demineralization. Optimal deproteinization involved treatment with 5% NaOH at 65° C for 1 h, with a solids to solvent ratio of 1:15 (w/v). Effective decoloration was achieved by bleaching with 0.32% sodium hypochlorite solution for 3 min, with a solids to solvent ratio of 1:10 (w/v) (Lee, 1997). The characterization of the physicochemical properties (nitrogen, fat and ash content, viscosity, solubility, color and bulk density) of such products are important.

However, use of such methods are costly from environmental point of view. The possibility of using lactic acid bacteria for de-proteination was reported by Zakaria et al (1998). Lactic acid fermentation of scampi (Norway lobster, Nephrops norvegicus) waste was done in a rotating horizontal bioreactor for chitin recovery.| Minced scampi waste was mixed with 10% (w/w) glucose and an inoculum of Lactobacillus paracasei strain A3 and placed in the basket. Batch fermentation was performed at 30°C for 5 days with rotation of the basket. During fermentation, a protein-rich liquor (pH 5 after 2 days) was formed and the Ca component of scampi shells was rapidly solubilized. It was is concluded that, provided the process can be made cost effective, lactic acid fermentation of crustacean waste products may be useful as an environmentally friendly method for generation of products such as chitin.

As mentioned earlier the production of chitosan from chitin requires highly caustic conditions. While this might be possible using deactylase enzymes, no such process has been reported and industry continues to use high levels of sodium hydroxide for this purpose.

The protein extracted from the shrimp waste can be used as food additive and flavouring agents. The other substances that can be extracted from the shrimp wastes includes coloring agents like asthaxanthin and natural antioxidants. These have already been covered in the earlier section on food uses of fishery by-products.

Professor Hirano, one of the best specialist in chitin chemistry of the world, from Tottori University (Japan) gave an overview of what it is possible to do with chitosan (Table-6) in The Nation (Thailand, 1999).

5.2.7 Animal feed

The potential of the seafood industry of by-products, their processing and utilization in the animal feed industry are highlighted by Le Van Lien *et al.* (1996). Various processes for production of blood meal, bone meal and silage made either from shrimp heads or animal blood allow to add value to these wastes and to enhance their nutritional value (high contents of protein in blood and shrimp head meals and calcium and phosphorus in bone meals). The nutritional value of these processed fish wastes was compared with fish meal by examining growth responses in pigs, chickens and ducks. It was suggested that 3-5% of the processed meals could be used in pig and poultry diets. Molasses could undergo an anaerobic fermentation or ensiling process to preserve animal blood or shrimp heads with potential on-farm applications.

Function	Applications and utilization
Chelator	Coagulant, flocculating agents
Polyelectrolyte	Cationic for polluted water
Molding or casting	Fibres and textiles
Hydrogelation	Cells and enzymes immobilisation. Gel chromatography
CO_2 fixation	In atmosphère and composite
Moisturing	Cosmetic
Thickener	Food processing
Molecular affinity	Affinity chromatography
Molecular reactions	Flavoring, deodorant
Conductance	Chitosan film-lithium, electrolyte in battery
Coating	Paint, print and dying additives
Elicitor	Plant seed coating, leaf surface sprinkling
Antibacterial	Storage of fruits and foods
Biological defense	Enhancing activities in tissue
Wound healing	Burns and skin lesions, bone, tendon and ligament repairing
Biodegradable	Surgical suture, vehicle of drugs
Hypocholestorelemic	Health food and additives
Hemostatic	Heparinoids
Antithrombogenic	Blood vessel, contact lens
Bio-compatibility	Sutures

Table-6 : Applications of chitosan (Hirano, 1999)

Alwan *et al.* (1993) investigated the chemical and microbiological aspects related to the fresh fish waste processing into silage. Formic acid was used to reduce the pH value to 3.5. The pH remained less than 4.0 for up to 30 days. The chemical composition (g/kg) of silage varied with the type of raw material (round-fish heads or flat-fish frames); moisture 726 to 803 (mean 764); oil 3 to 71 (mean 38); ash 35 to 72 (mean 51); protein144 to 161 (mean 147). During the first 8 days after silage manufacture, the concentration of low-salt-soluble and insoluble protein fractions decreased while non-protein N content increased. Silage viscosity continued to decrease with time up to day 15. The ensiling process caused a sharp initial decrease in total number of bacteria, in lactic acid bacteria and in coliform species followed by a more gradual decrease up to 48 h. A comparative study of silage manufactured from flat-fish frames (A) and round-fish heads (B) at pH 3.5 or 4.5, showed chemical composition (g/kg) of 726 and 777 moisture; 70 and 3 oil; 55 and 70 ash; 149 and 150 protein for A and B, respectively. Silage viscosity showed greater decreases at pH 3.5 than at pH 4.5. Silage manufactured from round-fish heads showed greater viscosity decreases at both pH levels.

The use of fish waste for animal feeding was investigated by several authors. Hammoumi *et al.* (1998) investigated the feasibility of fish waste fermentation. Chopped pilchard sardine (*Sardina pilchardus*) waste was mixed with 15% cane molasses, inoculated with a starter culture of *Lactobacillus plantarum* and fermented at 22°C for 20 days. The nutritional quality and biochemical properties of the fish waste were monitored during fermentation. The fermented product served as a basis for developing three recipes which were assessed in broiler feeding trials. Results indicated a considerable potential for use of the fermented fish waste for poultry feeding.

The biotransformation of fish waste into a stable feed ingredient was developed by Faid *et al.* (1997). Wastes from *Sardina pilchardus* processing underwent a biological fermentation by a starter co-culture of *Saccharomyces sp.* and *Lactobacillus plantarum* for use as high-protein content feedstuffs. Pilchard viscera, heads and tails were chopped and mixed with 25% cane molasses, while the starter culture was grown on molasses supplied with 0.2% yeast extract for *Saccharomyces sp.* and on molasses supplied with 0.3% yeast extract and 1% peptone of casein for *L. plantarum.* The fish mixture was inoculated with 5% of the starter culture and incubated at 22±2°C. The changes of nutritional characteristics and biochemical properties were evaluated and repeated twice over a period of 15 days. Microbiological analysis was performed for identification of coliforms, *Clostridium*, as well as lipolytic and proteolytic microorganisms. It was concluded that the fermentation due to mixed pure strains of yeasts and lactic acid bacteria was essential for the preservation and improvement of the end-product quality.

The ensiled fish waste was shown to be efficient in swine diets (Tibbetts *et al.*, 1981). Fish by-catch from shrimp boats was ground, mixed with corn and molasses, inoculated with *Lactobacillus acidophilus* as fermenting agent, ensiled for around 30 days or even more, then stored at 5°C. The effect of feeding fish silage on the performance of sows, weanling and growing/finishing pigs was determined. 64 growing/finishing pigs were fed diets containing 0, 3, 6 or 9% fish silage. At market weight, pigs fed the different diets showed no significant differences in carcass length, backfat, dressing %, longissimus area, colour, marbling or firmness, or differences in weight of ham, loin, shoulder or belly. Consumer taste panel tests found no differences in tenderness, juiciness, connective tissue, flavour or overall acceptability between the groups.

Hassan and Heath (1986) reported the biological fermentation of fish waste for potential use in animal and poultry feeds. The use of *Lactobacillus plantarum* for the biological fermentation of whole fish waste, including viscera and heads, was evaluated. A minimum level of 5% lactose was found necessary for performing a successful pilot-scale fermentation.

The disposal of crab waste (80-90% of the original crab) presents problems due to the high moisture content. A possible method of adding value to this disposal involves ensiling crab waste with wheat straw. However, additives are required to produce large amounts of lactic acid to reduce pH and stabilize the product. Abazinge *et al.* (1993) investigated the additives necessary to produce acceptable silages of crab waste in presence of wheat straw.

5.2.8 Fertilizers

Hector Tirado, an Arizona Entrepreneur in U.S., has successfully developed a company to market Mexican fish waste in the U.S. The company, Marlindo Products, sells over 500,000 gallons of fish solubles to Bioflora, which is the largest maker of organic fertilizer in the U.S. This is an example that can be follwed as S.E.Asia works towards cleaner production technology in the fish processing industry.

Other seafood companies have experimented with using fish waste to produce organic fertilizers, but Marlindo seems to be doing it on the largest scale. This is remarkable, considering that the raw material supply comes from Mexico, several hundred miles away. Tirado admits that his biggest problem is educating fish processors to handle the waste properly so that it retains its value. He is now branching out into adding crab shells and shrimp heads to his line of soluble fertilizer ingredients.The success of Marlindo, which took six years to grow from $11,000 in annual sales to more than $4 million, points to the growth of the organic fertilizer market in the U.S., and the role of fish wastes in its manufacture.

Considering the large volumes of the waste streams involved in these in these streams a number of attempts have also been made in composting (Line *et al.*, 1992; Kuo *et al.*, 1999; Minkara *et al.*, 1998; Laos *et al.*, 1998).

The manner in which the fish offal can be used for the production of value added non-food products as discussed above, is not comprehensive. There are further applications that are being studied and it is certain that with appropriate application the fish processing industry can not only overcome the environmental problem but also benefit monetarily as well.

5.3 Waste treatment methods

5.3.1 Waste water treatment

Beaufort Fisheries Inc.(Hunt, 1988) which processes menhaden for meal, oil, and solubles, did a feasibility study identified sources of water waste and recommended improved practices for handling and water use. Recommendations included redesigning of off-loading, using shipboard containers for refrigerated storage, integrating spent rinse water and recovered solids with existing meal and oil operations, efficient water use systems, and employee training to emphasize waste reduction. Changes could result in a waste load reduction of 248,000 pounds of BOD, 15,000,000 gallons less of water per year, and $900,000 in savings per year. The cleaner production benefits as a result of better handling methods and more efficient water use could result in a waste load (BOD) reduction and lower water requirement. Modified processes to reduce waste generation would work to upgrade the market value of current production and provide the capacity for expansion. As environmental concerns increase in S.E.Asia this the type of overall strategy that has to be applied.

Removal of solids from fisheries waste waters by coagulation have been proposed by Genovese and Froilan-Gonzalez (1998). Use inorganic and organic coagulants to flocculate particles as a way of reducing solids content in fish processing plant effluents have been reported. The performance of 2 inorganic compounds, ferric chloride ($FeCl_3$) and aluminium sulphate ($Al(SO4)_3$), and 2 organic materials, chitosan and ground fish scales (from hake, *Merluccius hubbsi*) have been assessed. FeCl3 showed maximum removal (30-31%) of solids at pH 5.5 and 60 mg/l. Al(SO4)3 showed no definite relationship between concentration and solids removal, but maximum removal (31% of solids) was observed at pH 7.2 and 60 mg/l. Chitosan showed maximum removal (26-28%) of solids at pH 5.5 and 60 mg/l and ground fish scales showed maximum removal (26% of solids) at pH 7.2 and 40 mg/l.
Similarly Gandurina et al. (1995) reported the treatment of fish processing waste water using coagulation and flocculation techniques. A system plan based these methods resulted in treated water contains 10 mg/l suspended matter and less than 1 mg/l fat which is suitable for reuse for fish processing. Rooney(1994) described the so called Chadburns Aminodan system process operates on the principles of precipitation, flocculation and air concentration for treatment of fish factory waste. In addition to purifying effluents, the system produces a protein-rich by-product, which may be sold for use as animal feed. The use inorganic and organic coagulants and flocculants for effective reduction in solids content in fish processing waste water can thus be carried out as appropriate depending on availability and costs of the raw material.

Bioremediation treatments of effluents from fish meal processing plants were studied to determine biodegradability, continuous bioremediation treatment characteristics in a mesophilic anaerobic filter under conditions of high ammonia and salinity by Guerrero *et al.* (1997). It was found that the treatment of saline wastewaters from fish meal factories in an anaerobic filter under extreme ammonia concentrations was possible. With suitable choice of recycle ratios and acclimatization of the microbial biomass developed in the anaerobic filter effective processes can be developed as required by the specific industry.

The ability of upflow anaerobic sludge blanket (UASB) technology to treat wastewaters from a number of industries have proved successful. Boardman *et al.* (1995) used this system to treatment of clam processing wastewaters. The UASB system proved to be effective, accomplishing soluble BOD5, soluble chemical oxygen demand and TSS removals of 87, 83 and 83%, respectively, under the best conditions considered Average conversion of wastewater organics to methane was in the area of 80%. This technology can certainly be used in other types of fish processing wastes.

High pressure treatment of water generated during the manufacture of minced fish meat was examined with a view to reducing the waste content of the water by Kajiyama *et al.* (1992). Protein and solid matter content of the waste water was reduced considerably by treatment with pressures up to 300 MPa when accompanied by filtration, centrifugation, pH adjustment and coagulation with sodium polyacrylate or aluminium sulphate. Optimum conditions for effective use of recovered materials were pressure treatment at 400 MPa, followed by pH adjustment to 5.0 and centrifugation at 3000 g for 5 min. This treatment reduced biological and chemical oxygen demand and solid and fat contents of the water and increased water transparency. Additionally, *Escherichia coli* was eliminated and levels of other microorganiams were greatly reduced using 300 MPa.

Ultrafiltration was tested as a method of waste disposal in a fish processing plant by Kuznetsov(1988). Using effluent containing 0.018% N-based substances, 0.025% lipids and 0.038% mineral matter, the filtering power by 4 types of cellulose acetate membranes (UAM-100, UAM-200, UAM-300 and UAM-400), fluoro-plastic membrane (F-1) and polysulphonamide membranes (PSA) with the pressure and temperature in the range of 0.1-0.4 MPa. And 20-40 C respectively was investigated. Ultrafiltration enabled recovery of proteins and lipids from the effluent for use as animal feed.

Andersen and Jespersen (1995) discussed some some cleaner production options available to the sea food industry, which is facing demands to establish environmental protection measures, are discussed. The aspects considered included environmental demands on the sea food industry, what cleaner production achieves, cleaner production in hake processing; water saving activities, waste treatment, cleaner production in a herring filleting factory and aquaculture. They concluded that the knowledge and technology required for cleaner production in the sea food industry are already available. The time is now right for the next important step and that is to make sure the relevant information reaches the industry and authorities.

5.3.2 Microbial processes

Prasertsan et al.(1993) optimized the growth of a photosynthetic bacterium *Rhodocyclus gelatinosus* on sea food processing with the aims of reducing the pollution potential of the waste and for producing cell biomass. Tuna condensate was found to be a better substrate than shrimp-blanching water or effluents from a frozen sea food plant for this organism. growing Rhodocyclus gelatinosus under anaerobic conditions in the light. A maximum cell mass concentration of 5.6 g/l (containing 50% protein) and 86% chemical oxygen demand removal were obtained after 5 days' incubation under optimal conditions.

Bioremediation of saline effluents from a fish canning factory was investigated by Omil et al. (1996). Anaerobic treatment of these waste waters was studied in a 15 m^3 industrial pilot-plant. These effluents have a high organic content (10-60 g chemical O2 demand/l), with protein contents of between 25 and 70%, and a salinity similar to sea water: Na+ (5-12 g/l), Cl- (8-19 g/l) and SO42- (0.6-2.7 g/l). At such high concentrations of salts, together with the production of sulphide and ammonia due to sulphate reduction and protein breakdown, inhibitory or toxic effects for a non-adapted biomass are produced. After an initial start-up procedure, to ensure biomass acclimation, 70-90% organic matter removal was achieved, operating at dissolved sulphide, total ammonia and sodium concentration of 0.25-0.5, 1.0-3.0 and 6-10 g/l, respectively. Adaptation of biomass to salinity and the antagonistic effects on Na+ toxicity caused by the presence of other ions made it possible for them to operate at these high sodium concentration. However, control of the influent protein content was necessary, since values higher than 200 mg/l of free ammonia were inhibitory to this bioremediation process.

5.3.3 Ensiling processes

The smell produced by the sea food processing wastes is often a cause for great concern. Ensiling the waste streams containing some organics that can help naturally available or innoculated microbes grow is often a easy method for smell reduction. The final product can be useful as an input to feed production. Ayangbile et al. (1997) studied the effects of chemicals on the preservation of crab-processing waste. Reductions in pH and water soluble carbohydrates (WSC) and an increase in lactic acid were achieved in silages made with waste was ensiled with wheat straw, sugarcane molasses, and water (32:32:16:20, wet basis) with or without 0.1% microbial inoculant. The concentration of trimethylamine (TMA), which indicates offensive odour in marine products, increased from 3.70 to 12.85 mg of N/100 g in NaOCl-treated waste, compared to no change (2.66 vs. 2.71 mg of N/100 g) for H2O2-treated waste. Addition of some chemicals during the ensiling process show promise for preserving crab and other crustacean wastes.

7. **CONCLUSION**

The statistical data collected in the course of compiling this report indicates that the potential for further expansion of aqua culture, marine fishing and fish processing in S.E. Asia is very high. Many of the countries of the region have realized this and have put emphasis on the development of these sectors. The production figures are only indicative of the volumes of product and should not be used as exact. Some of the values obtained from the FAO are constantly being updated.

The present report also indicates the problems faced by the exporters in this region due to diseases, use of chemicals and practices that are not acceptable by the fish importing countries. Due to the large volumes of export some of these countries have focussed on the ways and means of overcoming these difficulties. However, a number of these contraints have yet to be overcome. It has been the endeavour of this work to bring these difficulties to light so that a solution may be sought through the participation of scientists, governememt agencies and other stakeholders.

The processing of fish leads to the production of large amount of byproducts or wastes. Even though the governments in S.E.Asia do realize the importance of environmental treatment, the manner of implementation of the laws and rules have not been to acceptable levels. The treatment of the wastes is often left to take place naturally, if at all. Fish and seafood is very important for a number of Asian governments from an economic point of view and with pressures from the developing countries the producer is slowly coming to terms with the need for total quality management including the effect of the production process on the environment. They realize that it is time they take the initiative to solve the pollution problems and utilize the byproducts for the production of value added substances in order to be economically viable.

A number of suggestions and solutions have been proposed by local universities and institutes within the region. European companies and organizations with practical experience in the field also have some ready to use solutions for improving plants, reducing waste by microbial processes or filtration and valorization of wastes. The members of the teams preparing this report have wide experience in this type of activity and desire to desalinate available knowledge to the end user. They are also in the process of developing new techniques for this industry wherever necessary.

It is with this background that they would desire to distribute this report to as large an audience as possible so that a feed back could obtained from the fish processing and other related industries. While this report in no way intends to be comprehensive, with the feed back obtained it would be possible to put together a book dealing exhaustively with the problem of seafood waste management.

A large section of this book deals with the possible use of fish by-products for production of substances that can be used for food and non-food purposes. While of some of the suggestion application are already in use in European and other developed fish producing countries it needs to be implemented in S.E. Asia at the earliest. The authors of this report, who have been involved in this field in various capacities. They would be glad to make possible collaborations between European and Asian factories and research institutions involved in fish processing waste processing and management, so that the implementation of cleaner production systems in the fish processing industry becomes a reality in the countries of S.E. Asia.

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