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By-products of tuna processing

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By-products of tuna processing

by

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BY-PRODUCTS OF TUNA PROCESSING

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The global catch of the principal tuna market species (albacore, bigeye, bluefin (three species), skipjack and yellowfin) in 2010 was 4.3 million tonnes and they contributed to about 8 percent of global fish exports. Tuna is mainly marketed in fresh, chilled, frozen or canned form. However, the tuna loin and canning industry generates a considerable amount of by-products and the practice of utilization of these by-products varies in different geographical regions. In this publication, there are case studies of utilization from Asia, Europe and Latin America. Thailand is one of the largest producers of canned tuna and the by-products are mainly utilized as tuna meal, tuna oil and tuna soluble concentrate. In the Philippines, most of the canning industry by-products are converted to tuna meal, but black meat is also canned and exported to neighboring countries. Edible tuna by-products from the fresh/chilled tuna sector, like heads and fins, are used for making soup locally and visceral organs are utilized to make a local delicacy or for fish sauce production. Scrape meat and trimmings are also used for human consumption. In Spain and Ecuador, by-products go to the fish and oil industry and the increasing demand for these commodities, due to the growth of the aquaculture industry, drives the fishmeal and fish oil industry. However, since these are used mainly as animal feeds, they indirectly contribute to food production.

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PREFACE

According to FAO estimates, there will be a gap between demand and supply of over 50 million tonnes of fish to meet the global demand in 2030. The annual growth rate of the aquaculture sector, which was over 10 percent in the early 1990s, has slowed during the last decade and has stabilized at about 4 percent. Fish production, using capture techniques, has stagnated for over a decade. In this scenario, improving the utilization of available fish for human consumption becomes very important.

FAO estimates that about 875 million people are suffering from chronic malnutrition. Fish provides a source of easily digested, high quality protein containing the spectrum of essential amino acids, of fats that are high in polyunsaturated fatty acids, particularly omega-3 fatty acids, and of vitamins such as B12, A, D and E. Fish also contains important trace elements, such as iodine and selenium.

Important strategies that are used to improve fish utilization include minimizing post-harvest losses and wastes along the supply chain and utilizing by-products from processing activities for human consumption. While processing fish into products that have a high global demand, often the utilization could be as low as 30–40 percent and the waste could also be an environmental problem. The need to reduce post-harvest losses and waste has been highlighted in the FAO Code of Conduct for Responsible Fisheries.

Tuna and tuna-like species are of major commercial importance, accounting for over 8 percent of the global fish trade. Tuna is marketed in fresh, chilled, frozen or canned forms. The global production of canned tuna in 2009 was 1.7 million tonnes. The solid waste generated by the tuna canning industry could be as high as 65 percent of the original material and includes the head, bones, viscera, gills, dark muscle and skin. Canning involves pre-cooking and the cooking juice, a waste product created during this process, has a protein content of 2–5 percent but also has a very high chemical oxygen demand that causes problems in managing waste water discharge. The tuna loin industry generates over 50 percent of raw material as solid wastes.

In this context, this study was undertaken to review the current practices in the utilization of tuna processing by-products in different parts of the world. The countries chosen for this study were Thailand, the Philippines, Ecuador and Spain, as they are major producers of canned tuna, and India, as an emerging producer of tuna loins. The study illustrates different practices in these countries, with the Philippines providing a number of examples of the utilization of by-products for human consumption. The study indicates that the production of fishmeal and fish oil is becoming economically attractive, and the demand for this commodity is driven by the growth in the aquaculture industry. Hence, this commodity indirectly contributes to food production by aquaculture.

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OVERVIEW AND CASE STUDIES FROM INDIA

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SUMMARY

A significant quantity of solid waste is generated in the tuna processing industry. Value addition and proper utilization of fish processing waste can make a major contribution to minimizing loss of valuable protein. The waste from tuna processing plants, especially head, fins, bone and red meat are mostly utilized by converting them into valuable fishmeal to be used by the animal feed industry. There are some examples of direct utilization food by producing tuna oil and PUFA from eye and body, hydrolysate, tuna powder from cooking juice, enzymes from gut, fish protein concentrate, and fish gelatin based desserts. In India attempts have been made to produce extruded snacks incorporating tuna red meat, and calcium from tuna bones. These technologies would contribute to the effective utilization of tuna processing waste.

1. TUNA FISHERIES

Tuna is a commercially important fish species, widely distributed throughout tropical and temperate waters. The total catch of tuna and tuna-like species was about 6.6 million tonnes in 2010. It has shown an upward trend since 1950, when it was less than 1 million tonnes. Principal market species include skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), bigeye (*T. obesus*), albacore (*T. alalunga*) and three species of bluefin (*T. thynnus*, *T. orientalis*, and *T. maccoyii*). The first three species are tropical and the others are temperate. The principal market species are widely distributed in the Atlantic, Indian and Pacific Oceans. Most other species constitute different stocks in the different oceans. The principal market oriented tunas are the subjects of intensive international trade for canning and sashimi on a global scale. In 2010, the principal market tuna species caught amounted to 4.3 million tonnes. They are referred to as principal market species because of the intense worldwide demand for sashimi and canned products. Among the principal tuna species, one-third were estimated to be over-exploited, 37.5 percent were fully exploited, and 29 percent not fully exploited. In the long term, the status of tuna stocks (and consequently catches) may further deteriorate unless there are significant improvements in their management. This is because of the substantial demand for tuna and the significant overcapacity of tuna fishing fleets (FAO, 2012).

2. UTILIZATION OF TUNA

Tuna products play an important part in world trade, accounting for about 9 percent of total export value. Major importing countries of tuna products are Japan, the United States of America and several European Union countries. The trade includes sashimi tuna, raw material for canning and canned tuna. Japan continues to be the main market

for sashimi-grade tuna, while the European Union and the United States of America represent the major importers and Thailand the main exporter of canned tuna. In addition, specialty products are finding more and more niche markets in international fish trade (FAO, 2012).

3. BY-PRODUCTS FROM TUNA PROCESSING WASTE

Tuna is generally processed as raw meat and marketed as loins or steaks or as canned food. As a result of global competition, the profit margin on tuna loins and steaks is limited. In the canning process, only about one third of the whole fish is available for value addition. With profit margins getting slimmer because of global competition, the tuna industry would do well to look into the possibility of developing by-products from the waste from tuna processing. By-products from tuna include skins, heads, bone, viscera and muscle after loin preparation. The by-products from waste could be processed for the food, feed and pharmaceutical industries. Value addition and waste utilization are two areas in the tuna industry that have shown some interesting developments over the last few years. There has been significant growth in non-canned, innovative value-added tuna products in some major markets such as the United States of America, Canada, Japan and the European Union.

In the process of conversion to various products a large quantity of solid waste is generated from tuna. Guerard *et al.* (2002) reported that fish canning industries produce solid wastes such as fish viscera, gills, dark muscle, head, bone and skin among others. This waste matter can be as high as 70 percent of the original material. Sultanbawa and Aksnes (2006) reported that processing discards from the tuna canning industry were 4.5 lakh tonnes annually. During loin preparation 50–55 percent of the material is wasted. Protein-rich by-products from the canning industry, such as dark meat, have limited use because of their colour, susceptibility to oxidation and off-flavour. Tuna cooking juice, which is a by-product of canning, contains approximately 4 percent valuable proteins and other extracts. However, this is discarded in wastewater, and this causes an increase in the chemical oxygen demand (Hsu *et al.*, 2009). Designing and implementing appropriate measures to dispose of the waste generated during processing, increases cost and provides no significant income to the processing companies. With smaller profits resulting from global competition, the tuna processing industry will have to look at the possibility of utilizing these by-products for the production of value-added products. Value addition and proper utilization of fish processing waste can make a major contribution to minimizing loss of valuable protein. It can also result in the development of new products that have consumer appeal and demand in the market. This paper focuses mainly on the current and emerging trends towards utilization of tuna by-products for food and nutrition security. Such efforts can be broadly classified into direct (conversion to products for direct human consumption) and indirect ways (as feeds and fertilizers in agriculture and animal husbandry). Some practical examples of utilizing tuna waste for generating income by companies from different parts of the world are also discussed in this paper.

4. INDIRECT UTILIZATION OF TUNA BY-PRODUCTS

4.1. TUNA MEAL

The waste from tuna processing plants, especially head, fins, bone and red meat can be effectively utilized by converting them into valuable fishmeals to be used by cattle/poultry/pet food manufacturers (Srinivasa Gopal *et al.*, 2008).

4.2. SILAGE FROM TUNA WASTE

Ensiling is one of the best methods for utilization of tuna wastes. Fish silage is a liquid product made from whole fish or parts of fish to which no other material has been added other than an acid that allows for the liquefaction of the fish mass to be brought about by enzymes already present in the fish. The main benefit of silage is the high level of protein and essential amino acids in the proteins, particularly lysine (Sultanbawa and Aksnes, 2006). Comparison of silages obtained from the wastes (viscera and dark meat) of four tuna species, longtail (*Thunnus tonggol*), skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*) and kawakawa (*Euthynnus affinis*), showed that total lipid content of silages varied from 10.41 percent in skipjack dark meat silage to 22.01 percent in kawakawa viscera silage, but all lipids contained high percentages of docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA). Highest DHA ratio (15 percent of total lipids) was found in the lipid of skipjack viscera silage and the highest ratio of EPA (11 percent of total lipids) belonged to the lipids of kawakawa dark meat silage. Fish silage is usually added to pig, poultry and aqua feed to substitute for fishmeal, which is one of the most expensive ingredients added to feed. Studies at the Industrial Technology Institute, Sri Lanka, revealed that including silage in commercial pig feed at a 25 percent level was successful and better than feed with only fishmeal (Sultanbawa and Aksnes, 2006). Incorporation of tuna silage at 4 percent concentration in broiler feed yielded an optimal response on the final body weight, carcass percentage and the meat protein conversion (Tuti *et al.*, 2012).

4.3. TUNA PROTEIN HYDROLYSATE

Fish viscera and frames are used as a potential source of protein hydrolysate. Hydrolysates are defined as proteins that are chemically or biologically broken down to peptides of varying sizes. The fish protein hydrolysate is of increasing interest because it is a potential source of bioactive peptides. Studies conducted on the production of hydrolysate from tuna waste, using a mixed culture of *Lactobacillus brevis* LB43 and *L. plantarum* LP64 mixed with 10 percent molasses and its incorporation at a 12.5 percent level in black tiger shrimp larvae feed, increased larvae growth rate and survival rate. Furthermore, the addition of hydrolysate did not affect water quality in culture tanks, but decreased the number of *Vibrio* spp (Mangkorn and Thornthan, 2008). Dried skipjack tuna (*Katsuwonus pelamis*) waste (red meat, gills, viscera, fins, etc.), mixed with 25 percent wheat flour and inoculated with a starter culture of *Lactobacillus plantarum* and *Bacillus licheniformis*, after fermentation for 14 days was found to be effective as an aqua feed ingredient for different fish species (Vijayan *et al.*, 2009).

5. DIRECT UTILIZATION OF TUNA BY-PRODUCTS

5.1. TUNA OIL

Marine fish oils have been well documented with regard to their beneficial effects on health, for example the reduction of the risk of cardiovascular diseases and hypertension, and the treatment of autoimmune and inflammatory diseases. High amounts of long chain polyunsaturated fatty acids (PUFA) such as eicosapentaenoic acid (EPA, C20:5n-3) acid and docosahexaenoic acid (DHA, C22:6n-3), make marine lipids unique compared with other lipids (Sultanbawa and Aksnes, 2006). Tuna waste was found to be an excellent source of oil rich in free fatty acids. The PUFA content in extracted lipids accounted for more than 23 percent, while the monounsaturated fatty acids (MUFAs) made up about 20.82 to 24.2 percent of the total fatty acids. The SFAs content ranged from 47.02 to 55.2 percent. The greatest proportion of PUFAs was DHA (14.18 to 15.70 percent of total FA) followed by arachidonic acid (2.20 to 6.66 percent). The most abundant MUFA is oleic acid. Palmitic acid is the highest of the saturated fatty acids with the range of 27.63 to 32.74 percent followed by stearic acid (8.82 to 13.62 percent of the total fatty acids) (Khoddami *et al.*, 2012).

5.2. HYDROLYSATE FROM TUNA COOKING JUICE

Tuna cooking juice is a protein rich by-product from canning factories that is generally discarded. Recovering these proteins and utilizing them as food stuffs is essential for reducing waste-water treatment costs and for obtaining a higher profit. Tuna hydrolysate obtained from tuna cooking juice by using gamma irradiation showed superior antioxidant properties. Tuna cooking juice was filtered to remove the debris followed by precipitation with trichloroacetic acid. The precipitated protein was freeze-dried and re-suspended in distilled water to constitute a 4 percent tuna protein solution. The rehydrated protein solution was irradiated by a cobalt-60 irradiator. The results suggest that radiation technology can be used for the treatment of tuna cooking juice for its utilization as a functional additive to food-stuffs (Jong-il Choi *et al.*, 2012).

5.3. TUNA FLAVOUR POWDER FROM COOKING JUICE

Spray dried tuna flavour powder for human consumption, obtained from tuna precooking juice, is an effective way to utilize this waste from canning factories. The tuna precooking juice is centrifuged and concentrated to 15 percent total soluble solid (TSS) by flash evaporation. Maltodextrin (DE 9) is added to increase the TSS of tuna precooking concentrate and then dried by spray drying at 180 °C inlet air temperature. Based on composition and physical properties, the spray dried tuna flavour powder produced from 22 percent TSS tuna precooking concentrate made a desirable finished product (Kanpairo *et al.*, 2012).

5.4. ENZYMES FROM THE GUT OF TUNA

Rennet is a complex of enzymes produced in mammalian stomachs and is often used in the production of cheese. Rennet contains many enzymes, including a proteolytic enzyme (protease) that coagulates milk, causing it to separate into solids (curds) and liquid (whey). Resulting from a decline in the number of calves slaughtered and an increase in demand for proteases for cheese production, cheese makers have looked for other ways to coagulate the milk. There are many sources of enzymes, ranging from plants, fungi and microbial sources, that can substitute for animal rennet. Fish gut also has proven to be an excellent source of rennet. Six active proteolytic enzyme fractions were separated from bigeye tuna (*Thunnus obesus*) stomachs by isoelectric focusing. Comparison of the proteolytic activity of tuna gastric enzymes with commercial rennet enzymes on milk clotting showed that bigeye tuna protease can clot milk more efficiently at low temperatures (Tavares, 1996).

6. CONTRIBUTIONS OF CENTRAL INSTITUTE OF FISHERIES TECHNOLOGY, COCHIN

The Central Institute of Fisheries Technology (CIFT), set up in 1957, is the only national centre in India where research in all disciplines relating to fishing and fish processing is undertaken. The Institute has made a considerable contribution towards harvest and post-harvest aspects of tuna. The following are some of the findings related to the utilization of tuna waste

6.1. FISH PROTEIN CONCENTRATES FROM TUNA WASTE

Fish protein concentrate can be defined as any stable fish preparation intended for human consumption, in which the proteins are more concentrated than in the original fish. Mechanically separated mince from tuna is first washed with water and then with 2 percent (W/V) aqueous solution of sodium bicarbonate and finally with water again to remove pigments, lipids, colour, and odour-bearing compounds. Homogenization of the washed meat in water followed by acidification by dispersing in acetic acid produced a weak gel that was diluted and spray dried. The protein concentrate thus produced, contained 5 percent moisture, 1.2 percent lipids and 89.55 percent protein with good functional properties. The product did not undergo significant browning during three months storage at the ambient temperature in 300 gauge polyester/polythene laminated pouches.

6.2. HYDROLYSATE FROM TUNA WASTE

Hydrolysates have already been defined above and their use as a potential source of bioactive peptide noted. Hydrolysate prepared from tuna waste by hydrolysis using two commercial enzymes (Alcalase & Papain) showed that hydrolysate prepared by alcalase treatment produced a higher yield (11.49 percent) and sensory quality compared with those developed from papain (8.48 percent) (Thankappan *et al.*, 1998).

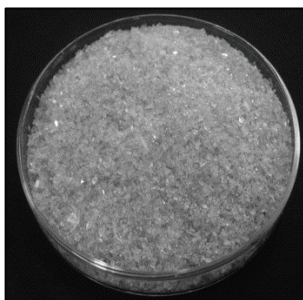
6.3. GELATIN FROM TUNA SKIN

Gelatin is a protein produced by partial hydrolysis of collagen extracted from the boiled bones, connective tissues, organs and intestines of animals such as domesticated cattle, pigs and horses. Gelatin is used mainly as a gelling agent in foods and has wide applications in the food and pharmaceutical industry, photography and cosmetic manufacturing. Gelatin from marine sources (warm or cold water fish skins, bones and fins) is a possible alternative to bovine gelatin. One major advantage of marine gelatin sources is that they are not associated with the risk of Bovine Spongiform Encephalopathy (BSE) and are acceptable in most religions (Sultanbawa and Aksnes, 2006). Extraction of gelatin from yellowfin tuna (*Thunnus albacares*) skin showed that it can be used as an efficient source of type B gelatin (gelatin obtained from alkali treated raw material). The yield of gelatin obtained from tuna skin is 20 percent. Tuna skin gelatin was found to be suitable for the production of gel based products.

Picture 1. Tuna skin



Picture 2. Yellowfin tuna gelatin



Picture 3. Yellowfin tuna gelatin dessert



6.4. SILO FEED (FISH FEED) FROM TUNA WASTE

Tuna waste obtained during processing can be used as a raw material for the production of fish feed. Waste generated during processing of tuna was converted into a liquid protein source by first converting it into silage. For the purpose of chopping tuna heads, a tuna head cutting machine was also developed by CIFT. The silage was mixed with cereal flours and followed by cooking and extrusion in a single screw extruder and drying at 60 °C. Feed after drying was packed in polyester/polythene laminated bags. Silo feed was found to be rich in protein (46 percent), fat (7 percent) and ash (7 percent) content. Feeding trials conducted by the Central Marine Fisheries Research Institute, Cochin, proved that it is a promising feed for seabass, grouper and cobia.

6.5. PIG FEED FROM TUNA WASTE

The red meat from the tuna fish is usually discarded during processing; this red meat has 18 percent protein and other essential nutrients. To utilize this red meat it was first converted into red meat silage. This silage can be stored in plastic drums and can be used as ready protein source for the preparation of pig feed. This is made by mixing rice bran and liquid red meat silage in different proportions to get different protein contents

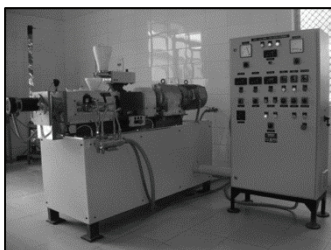
of finished products. This dried feed can be packed in moisture proof HDPE gusseted bags. Pig feed prepared by mixing 1 kg rice bran and 400 ml red meat silage has 20 percent protein, 23 percent fat and 8.8 percent ash content.

6.6. EXTRUDED SNACK “TUNA KURE” FROM TUNA RED MEAT

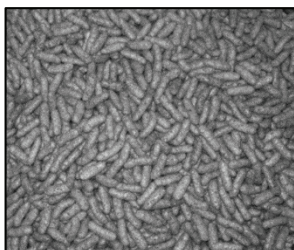
Tuna red meat from processing plants can be incorporated with cereal flours to develop a new ready-to-eat product by extrusion technology. Red meat obtained from tuna frames and bones is washed with potable water and minced well. The required quantity of the ingredients (cereal flours, red meat mince, salt and spices, etc.) is weighed and mixed in a silent cutter. After mixing, the ingredients are sieved through a 1mm mesh size sieve and kept for moisture equilibration for 45 minutes at 20 °C. After equilibration the mix is extruded at a temperature of 140 °C maintaining a screw speed of 360 rpm and feed rate of 200 g/minute using a twin screw extruder.

The product obtained is coated with chaat masala in a coating pan. Then the product is packed in a pouch made of 12μ metallized polyester film laminated with 60μ polythene with nitrogen gas filling. This innovative and convenient product has been named “Tuna Kure”. A study of storage times reveals that the product is acceptable up to 3 months at ambient temperature.

Picture 4. Twinscrew extruder



Picture 5. Tuna Kure



Picture 6. Tuna Kure packets



6.7. CALCIUM FROM TUNA BONE

Fish bone is rich in calcium as dicalcium phosphate, which has the ideal calcium phosphorus ratio of 2:1 (Chatterjee and Shinde, 1995). Calcium from fish is microcrystalline and is easily absorbed. The tuna processing industry generates a substantial quantity of bone as waste. This can be utilized as a cheap source of calcium and phosphorus for human nutrition. Tuna bones collected from canning factories are deproteinized by using papain. The deproteinized bones are washed thoroughly and dried. Fat content is removed either by KOH treatment or by extraction using petroleum ether. The remaining mass is again dried and pulverized to a fine powder. The powder thus obtained by the two methods has calcium content of 43.2 percent and 38.2 percent respectively. The calcium powder showed high solubility in dilute HCl and thus can be easily absorbed by the body because of the acid medium in stomach. This powder can

be incorporated in any preparation without affecting its sensory quality (Martin *et al.*, 2002).

6.8. NUTRIENT PROFILING OF TUNA EYE BALLS

Tuna eye is a delicacy in Japan. It costs less than a pound and tastes like squid. It is usually boiled and consumed flavoured with seasonings. Tuna eye was found to be rich in fat (12.04 percent), protein (10.17 percent) and ash (2.09 percent). Fatty acid profiling of tuna eyes showed that they are abundant in polyunsaturated fatty acids such as docosahexaenoic acid (35 percent of total fatty acid), eicosapentaenoic acid (7 percent), arachidonic acid (3.6 percent) and linoleic acid (1.3 percent). Among the monounsaturated fatty acids, palmitoleic acid (17 percent) and elaidic acid (1.3 percent) are found to be the highest. The major saturated fatty acid that is available is myristic acid (2 percent). Amino acid content in tuna eyes is dominated by glycine (19 percent of total amino acids) followed by glutamic acid (16 percent), aspartic acid (13 percent), alanine (12 percent) and leucine (10 percent).

Picture 7. Tuna eyes



6.9. NUTRIENT PROFILING OF TUNA RED MEAT

During the process of canning tuna fish, considerable amounts of red meat are left over (Bertoldi *et al.*, 2004). Red meat forms 9 to 11 percent of the total body weight of tuna (George, 1975). It contains 28 percent protein and 1 percent fat. Tuna red meat is usually converted to animal feeds because of its unappealing appearance and flavor. Nutrient profiling of red meat obtained from three species of tuna, skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*) and little tunny (*Euthynnus affinis*) was carried out. The analysis of amino acid content of red meat showed that it contains all the essential amino acids required by the body for growth and maintenance of muscle tissue. Essential amino acids contributed 49–52 percent of the total amino acids. Polyunsaturated fatty acids contributed 65 percent of the total fatty acids with minor variations among different species. Oil extracted from freeze dried tuna red meat by supercritical fluid extraction showed a high content of polyunsaturated fatty acids. Among the PUFAs, docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) were found to dominate. An analysis of mineral content showed that red meat is rich in potassium (549–624 mg/100g), sodium (49 mg/100g) and calcium (41 mg/100g). A feeding programme conducted at a kindergarten in association with Central Marine

Fisheries Research Institute, proved that a sweet porridge made from tuna red meat was effective in supplying essential nutrients for children of that age. Wafers produced from tuna red meat mixed with barracuda meat had excellent physical properties and good swelling characteristics (Thankamma *et al.*, 1975). Attempts were made to develop breaded and battered products from red meat (Thankappan *et al.*, 1998).

7. PRACTICAL EXAMPLES

7.1. BIORIGINAL FOOD SCIENCE & CORP., CANADA

Bioriginal offers a full range of essential fatty acid products. The company manufactures and markets omega-3, omega-6 and omega-9 oils, fatty acid concentrates, speciality nutritional oils, food products and nutraceutical powders from both plant and marine sources. The major sources of essential fatty acids include tuna, salmon and cod among others. “BioPureDHA” is premium grade fish oil produced by Bioriginal, which is rich in DHA, essential for neural development and cognitive function. The product guarantees purity with rigorous quality control and uses fish heads from an undisclosed location near Seychelles, which is free from industrial pollutants. Using fish heads as a source further reduces the risk of contamination from any ingested pollutants still in the digestive system.

7.2. AJINOMOTO CO., INC., JAPAN

One of Ajinomoto Co., Inc.’s main products is *HON-DASHI*, used as a seasoning to complement skipjack stock. For the sustainable production of *HON-DASHI*, the company has made a considerable effort, including monitoring the state of skipjack tuna resources and utilization of the resources without wastage, to ensure that resources remain sustainable. Ajinomoto Co., Inc. purchases dried bonito for use in *HON-DASHI* from a specialist dried bonito manufacturer. The head, bones and innards are removed during the production process. The company uses the bones as a raw material for calcium food products and the concentrated and refined broth as an extract ingredient in *HON-DASHI*. The heads and innards are also processed for use in seasonings, such as fish sauce and skipjack soy sauce. Moreover, recent research is looking at ways of using enzymes found in skipjack to decompose the residual parts of the fish and turn them into fertilizers and feeds. Currently, experiments are underway to test the efficacy of a liquid fertilizer on green tea fields.

7.3. TUNA ADVANCED FUNCTIONAL FOOD CO., LTD. IN SHIMIZU, SHIZUOKA, JAPAN

The company extracts oil from tuna heads by a unique Hybrid Extraction Method (Japanese Patent 4739297). The process includes decompressing and then pressurizing and heating in a container, without air contact, until the extraction process is finished. Resulting from the high vitamin E content, tuna oil is very stable against oxidation in spite of the abundance of omega-3 fatty acids such as DHA and EPA. It was found that consumption of 1.8 g/day of this tuna oil lowered systolic and diastolic blood pressure, as well as triglyceride and cholesterol levels. The company’s research wing is actively involved in finding better alternatives for the utilization of tuna waste.

7.4. SOUTH AUSTRALIAN MARINE PRODUCT INDUSTRIES (SAMPI), PORT LINCOLN, SOUTH AUSTRALIA

SAMPI commenced its activities in 2004 with the aim of recycling the large amount of waste material from the bluefin tuna, kingfish farms and the local tuna cannery. The company owns a purpose built modern factory on a new site, with the capacity to recycle in excess of 2 000 tonnes of fish waste per year. The major product of this company is an organic tuna hydrolysate prepared from tuna waste. The hydrolysate can be used as a fertilizer or as an animal feed supplement. No synthetic materials are used in the preparation. The process is natural and organic and has been certified as organic by the National Association for Sustainable Agriculture (NASAA), Australia. The company also markets fish bait developed from this hydrolysate. These baits combine the powerful attractive qualities of hydrolysed tuna and tuna oil with natural hardeners to form a long lasting berley or trap bait that does not require refrigeration.

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CASE STUDIES FROM THE PHILIPPINES

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SUMMARY

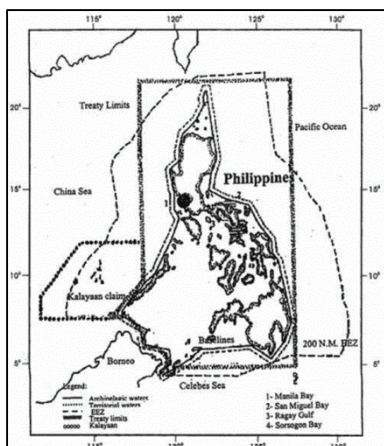
This study presents the manner in which the Philippines utilize by-products from the tuna processing industry. The three major tuna species, yellowfin (*Thunnus albacares*), skipjack (*Katsuwonus pelamis*) and bigeye tuna (*Thunnus obesus*), are generally processed as fresh/chilled/frozen, processed/preserved (canned) and dried/smoked. Tuna processors usually make use of only the muscle part (meat) for producing primary products. Tuna meat makes up 62 percent of the total fish composition; the other portions are head, visceral organs, bones, fins and skin. What is considered as waste in the production process is now called a by-product. To eliminate wastage in production, tuna by-products are being utilized as valuable raw material for further processing. Tuna by-products that are not suitable for human consumption are utilized in fishmeal production. By-products that are fit for human consumption undergo further processing such as further cooking (main ingredient of food product), freezing, and value addition. No tuna by-product is considered as waste except for blood that is being washed off during cleaning. Fishmeal production uses tuna by-products mainly from canned products and a small percentage from fresh/chilled/frozen products. At present, all tuna by-products from canned products are only utilized for fishmeal production. A small percentage of tuna by-products go to research institutions for studies on fish oil omega-3 and other nutraceutical products.

The study was conducted in General Santos City in South Cotabato, where 80 percent of the fresh/chilled/frozen tuna processors and seven out of eight tuna canneries in the Philippines are operating.

1. INTRODUCTION

The Philippines is an archipelago comprising of 7 107 islands. It is located in the tropical Western Pacific region, specifically in the northeastern part of Southeast Asia. Having vast territorial ocean waters, with a total area of 2.2 million square kilometres including an exclusive economic zone (EEZ) of 1 590 780 square kilometres (Figure 1), the country has a discontinuous coastline length of 36 286 kilometres.

Figure 1. Map of the Philippines showing the limits of archipelagic, Territorial Waters treaty limits, Exclusive Economic Zone (200 N.M. E.E.Z.) and Kalayaan Claim



Source: Bureau of Fisheries and Aquatic Resources, 2010 Philippine Fisheries Profile.

The country is richly endowed with fishery and aquatic resources. Productive grounds for tuna in the Philippine waters are the Sulu Sea, Moro Gulf and waters extending to the North Celebes Sea, off Mindanao Island. Tuna fisheries became the largest and most valuable fisheries during the mid-1970s. At one time in the 1980s the country was the number one producer of tuna in Southeast Asia. However, when the catch rates of tuna in Philippine waters started to decline, local fishing companies started to fish in international waters making the country one of the distant-water fishing nations in the Pacific, in addition to the USA, Japan, the Republic of Korea, Taiwan Province of China and China.

Large tuna landing areas are located in General Santos City in South Cotabato and in Zamboanga City, both on Mindanao Island. There are six tuna species that are caught in commercial quantities: bullet tuna (*Auxis rochei*), frigate tuna (*Auxis thazard*), eastern little tuna (*Euthynnus affinis*); with three considered as major species: yellowfin (*Thunnus albacares*), skipjack (*Katsuwano pelamis*), and bigeye tuna (*Thunnus obesus*). During the Fourth Tuna Fisheries Catch Estimates Review Workshop in May 2011, the Philippine catch estimates by species and by gear type were reviewed and validated. Table 1 shows the breakdown of tuna 2010 annual catch by gear and species.

Table 1. Tuna catch estimates (in tonnes) by gear and species, 2010

Gear/Species	Skipjack	Yellowfin	Bigeye	Total
Purse seine	77 532	14 061	2 166	93 759
Ringnet	26 417	5 363	218	31 997
Handline	131	11 314	284	11 729
Hook-and-line	25 200	43 400	1 400	70 000
Other	2 167	1 500	365	4 031
Total	131 448	75 638	4 432	211 517

Source: Fourth Philippine/WCPFC Annual Tuna Catch Estimates Review Workshop Report, May 2011.

With regard to the marketing of tuna, large tuna weighing 35 kilograms and up, depending on their classification or grade, are sold to export processors of fresh and frozen sashimi grade. Tuna caught by purse seine and ringnet vessels is bought by canneries.

In tuna processing, canneries and fresh/chilled/frozen processors not only utilize what is needed for the main product, but also make use of the by-products left over after primary food processing. In the past these were considered as “waste” but are now used as raw materials to make other products.

2. TUNA PROCESSING INDUSTRY

The three major tuna species are generally processed as fresh/chilled/frozen, processed/preserved (canned) and dried/smoked. Currently, there are seven tuna canneries operating in the Philippines, six can be found in General Santos City and one in Zamboanga. There are more than 15 fresh/chilled/frozen tuna processors in operation, 80 percent of which are located in General Santos City. The General Santos Fish Port Complex (GSFPC), the country’s major tuna unloading port with facilities of international standards for Hazard Analysis Critical Control Point (HACCP), Good Manufacturing Practices – Sanitation Standard Operating Procedures (GMP-SSOP) and accredited by European Union (EU), Japan and USA, is where tuna classification and grading is done. Grade A tuna is exclusively sold to the international market and is usually exported whole or headless and gutted (H&G). Processing is done in the unloading port itself. Most of the handline catch is supplied as fresh and frozen sashimi grade tuna to export processors. Most of the production is exported to Japan, USA, Thailand and European countries (Table 2).

Tuna processors make use of the muscle part (meat) of tuna for the production of their primary products. Meat from tuna makes up 62 percent of the total fish composition; the other portions are head (13 percent), visceral organs (8 percent), bones (6 percent), fins (1 percent) and skin (10 percent). The utilization of other fish components called “by-products” depends on how the primary product will be processed.

Table 2. Major destination of tuna exports by kind and quantity, 2010 (in tonnes)

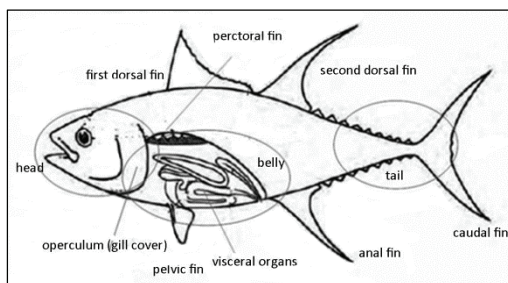
Product	Quantity
Fresh/chilled/frozen	29 644
Japan	3 112
United States of America	3 007
Indonesia	116
Thailand	2 287
Hong Kong SAR	93
Taiwan	3
Switzerland	190
Germany	101
United Arab Emirates	44
Hawaii	130
Other	20 561
Prepared/Preserved	76 801
United States of America	20 378
Singapore	1 008
Japan	404
South Africa	207
Canada	3 483
Germany	14 973
Taiwan PC	408
United Kingdom	13 996
Netherlands	2 387
Kuwait	1 482
Other	18 075
Dried/Smoked	4
Australia	1
New Zealand	2
Republic of Korea	1
Total	106 449

Source: Bureau of Fisheries and Aquatic Resources, Philippine Fisheries Profile 2010.

3. UTILIZATION OF BY-PRODUCTS IN TUNA PROCESSING

In tuna processing, apart from whole/H&G products, only 62 percent of the total weight is used for the production of primary products. Thus the fish is still not fully utilized. This is considered as waste but is also being productively used as a valuable raw material, or by-product, for further processing. The commonly used tuna by-products are head, collar bone, belly, tail, fins, bones, and visceral organs (Figure 2). Different tuna processing produces different by-products, therefore their further conversion into alternative products depends mainly on the product that was initially produced.

Figure 2. Tuna by-products



3.1 CANNED TUNA PROCESSING

The tuna canning industry only utilizes the meat for the production of tuna loins. These are used in canned tuna and in pouched tuna that can be found in different flavours, and also as frozen tuna loins. Tuna canneries supply both export and domestic markets.

The species of tuna processed by the canning industry are skipjack and yellowfin (maximum weight of 2.5 kilograms). Tuna by-products that can be identified are head (including eyes), tail, visceral organs, skin, bones, fins and black (dark/blood) meat. These by-products are generated during the process of tuna loining for canning or for freezing. The removal of these by-products occurs after the pre-cooking process, therefore all of these are already considered as “cooked”. The amounts of by-products generated comprise 35–40 percent of the total weight of the raw material. During the beheading and skinning process, the head, visceral organs and skin are removed; these make up 17–18 percent. Other tuna by-products removed during loining are black meat and bones, which make up 20–22 percent. Meat recovery for the final product is about 40 percent, while the other 20 percent is considered weight loss during pre-cooking, cooling, and retorting.

In the Philippines, the canning industry’s tuna by-products go to fishmeal production. Most of the tuna canneries have their own fishmeal production plants. While the tuna portion needed for primary product is being processed, these tuna by-products go directly to the fishmeal plant for processing. These by-products are put in separate containers. Of the tuna by-products, 40–45 percent of the total weight is produced as fishmeal products. The fishmeal product has 55–60 percent crude protein to be used by feed mills as the protein component. Fishmeal goes to both the export and domestic markets.

Black meat is also considered as a tuna by-product comprising 10 percent of the total weight of the raw material and is sometimes processed as canned product. Canned black meat is exported to countries such as Papua New Guinea. The product comes with 100 percent black meat, or a mixture of white meat and black meat, depending on the buyers’ requirements.

Fish oil production from tuna by-products is not yet available in the Philippines. The technology is considered very expensive for the industry. It is preferable to convert all

tuna by-products to fishmeal because of the high demand in domestic market. A small percentage of these tuna by-products goes for research study purposes.

3.2 FRESH/CHILLED TUNA, WHOLE/H&G PROCESSING

Tuna processed as fresh/chilled whole/H&G has a small percentage of waste. Whole tuna fish is utilized as primary product except for the head, fins, tail and visceral organs, which are considered as by-products and comprise 25–30 percent of the total fish weight. Visceral organs include heart, gills, intestines, roe, gonad and liver. These tuna by-products are classified as non-edible or edible. The non-edible by-products, comprising 3–5 percent of the total weight, include gills, operculum (gill cover) and the non-edible visceral organs. These non-edible by-products are utilized in fishmeal production. Tuna canneries with fishmeal processing plant buy these by-products to add to their raw material for fishmeal production. The edible tuna by-products, making up 22–25 percent, are marketed for human consumption. The head and fins are marketed locally and are purchased by local people who prepare and consume them as a special dish (mostly as fish soup). Visceral organs including heart, intestines and liver are made into *sisig* (a delicacy conventionally made of diced ears, bits of brain tissues and chopped skin from pig's head, cooked in oil and spices and sizzles while being served on a heated earthen hotplate). A variation uses fish meat and visceral organs, chicken meat and other meats as replacements. It is sometimes used for fish sauce production. Tuna roe, gonad and the tail parts undergo further processing into frozen products, which are sold on the domestic market.

3.3 FRESH-CHILLED/FROZEN TUNA PROCESSING

Tuna species used for fresh-chilled/frozen processing are yellowfin and bigeye. The meat portion of the fish is the only part utilized during production of the primary product. Products include fresh-chilled/frozen loins (with or without skin), fresh-chilled/frozen *saku* and other frozen tuna products (steak, ground meat, cubes, sushi slice, sashimi slice and *donburi* slice). Fresh-chilled tuna products are exported to the EU while frozen products treated with carbon monoxide (CO) are exported mainly to the USA, Japan, and the Republic of Korea. Products below export quality standards are sold in the domestic market. Raw materials received by these processing plants are already gutted and the fins already removed (first dorsal fin retained). Tuna by-products identified during the processing are head, *panga* (collar bone), belly, fins, ribs, tail, bones, black meat, scraps (white meat and trimmings) and skin, comprising 40–45 percent of raw material's total weight.

No tuna by-products are considered as waste in this kind of processing. These by-products are either sold in local or domestic markets. Tuna by-products such as the head, fins, bones, black meat and ribs are sold to village people for human consumption. Heads, bones and fins are prepared as main ingredient for soups, while others are prepared as fried products. These by-products have already become part of the usual daily fare of the local people in General Santos City. Other tuna by-products such as the tail, belly and *panga* are further processed as frozen products for the domestic market. These products can be seen vacuum packed in almost all supermarkets, grocery stores and seafood restaurants nationwide. They can be prepared as fried, grilled or stewed. Tuna skin is also processed further. It is prepared as “dried tuna skin” (when fried it

becomes crispy tuna skin called tuna *chicharon*). Scrap meat such as the white meat and trimmings are further processed as ground meat and “crazy” cuts for the domestic market. Excess trimmings are also processed into value-added products similar to those usually made of beef, pork and chicken meat, and that are popular well-known products, such as tuna sausage, nuggets, *siomai*, *embutido*, hotdog, burger patties, tuna ham, and tuna fingers. Most of the fresh-chilled/frozen tuna processors have their own processing plants for these tuna by-products.

4. CONCLUSION

In the past, materials that were left over after primary food processing were called waste. The portion of the raw material that is not needed for the production of main product was considered as waste. However, these tuna wastes can still be used as raw material to make other products and even be used for direct human consumption. Now they can be considered as tuna by-products that can be further processed as a tuna co-product.

Tuna by-products that are not for human consumption are utilized in fishmeal production. By-products that are fit for human consumption undergo further processing such as further cooking (main ingredient of food product), freezing, and value addition. No tuna by-product is considered as waste except for blood that is washed off during cleaning.

Fishmeal production uses tuna by-products mainly from canned products and a small percentage from fresh-chilled/frozen products. At present, all tuna by-products from canned products are only utilized for fishmeal production. Fishmeal goes to export and domestic markets.

Tuna by-products for human consumption can be found on local and domestic markets. People are slowly starting to consume these tuna by-products in place of other meat products.

A small percentage of tuna by-products goes to research institutions for studies on fish oil, omega-3s and other nutraceutical products.

5. ACKNOWLEDGEMENTS

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And lastly, a great thanks to INFOFISH for allowing this study to happen.

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CASE STUDIES FROM SPAIN AND ECUADOR

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SUMMARY

The tuna sector plays an important role in Spain and Ecuador, and this study represents how both geographic areas utilize tuna and manage cannery waste, since the main tuna product is canned tuna.

In both Spain and Ecuador, the fish from the tuna fleet goes directly to the processing establishments, and there is no tuna waste on board. The canning industry manufactures a wide range of product forms with an excellent quality-price ratio. The tuna waste, such as heads, guts, tails and dark meat, is transported to by-products factories, where it is processed into fishmeal and fish oil. Other useful materials are not extracted from the tuna waste because cooking is the first stage in the production of canned tuna. Spain's process is unique in that fishmeal and fish oil for animal feed are made only from by-products from canning and other seafood industries, and no other raw material supply is used.

1. INTRODUCTION

Tuna is the third most consumed seafood product worldwide and therefore the tuna market is of high global relevance. The main tuna species traded in Spain and Ecuador are yellowfin tuna, bigeye tuna and skipjack tuna.

There are a number of tuna products available in these markets, most of which play an important role in world trade. In Spain and Ecuador canned tuna in a variety of presentations is favoured by consumers. Tuna for direct consumption can be chilled, frozen, and/or processed into fillets or loins, among others. High demand for canned tuna increases demand for raw materials, catches and processing, and thus, pushes prices up.

Tuna imports have increased much more in value than in quantity. Although prices have increased significantly since the 1990s, prices have become more stable because of the nature of imports from Japan and the crisis in the canning industry in Thailand. Therefore, prices have experienced some ups and downs since the 1990s, and are higher in Europe than in North America.

Both in Spain and Ecuador the main product obtained from tuna is canned tuna. Tuna loins are used as raw material to produce canned tuna and therefore they are also an important product in both regions.

In the early 1990s, Spain became the third largest producer of canned tuna in the world. The creation of a cannery cluster led to improved efficiency. It is also the second largest

exporter, though Ecuador appeared as a new player in international trade in 2002 as a result of the consolidation of its cannery cluster.

2. SPAIN

According to the Ministry of Agriculture, Food and Environment, Spain is the second largest producer of canned tuna, after Thailand. The Spanish canning industry produces 15 percent of the canned tuna marketed worldwide. At the EU level, Spain has undisputed leadership in the production of canned tuna, and accounts for 70 percent of the European production.

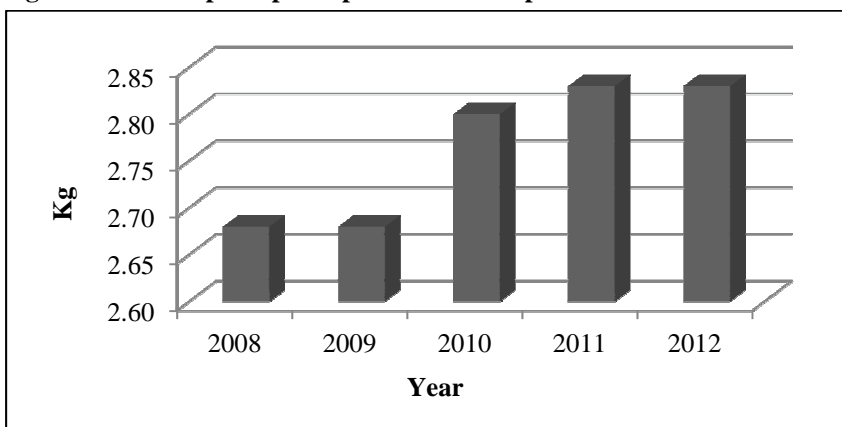
The largest importers of Spanish tuna are Italy, France, Portugal, United Kingdom and Germany. Spanish exports of canned tuna amount to around 100 000 tonnes with a value of EUR 400 million. According to INTERATÚN (Tuna Inter-branch Organization), Spain's freezer tuna fleet, represented by business organizations (Associated Producers Organization of Big Tuna Seiners and National Association of Tuna Freezer Vessels), captures about 60 percent of its catch in international waters and 40 percent in various national waters based on agreements with third countries.

The expansion of the Spanish fleet is largely the result of technological knowledge that shipowners have successfully applied to the fishing process, which has led the Spanish fishing sector to become the sixth major country in tuna catches. The seafood canning industry is made up of the integrated ANFACO – CECOPESCA (National Association of Fish and Seafood Canning Manufactures – Technical Centre for the Preservation of Fish, Seafood and Aquaculture products) and FEICOPESCA (Spanish Federation of Processing Industries and Marketers of Fisheries and Aquaculture Products) and tuna is currently their flagship product. This is especially remarkable as the canneries have a very wide range of products.

This situation in the sector has resulted in an increase in tuna consumption in recent years, from 2.68 kg per capita per year in 2008 to 2.83 kg per capita per year in 2012, which represents market growth from EUR 812 768 290 to EUR 917 013 200 in 2011 (Ramos-Rodriguez, D., *personal communication*, 2013).

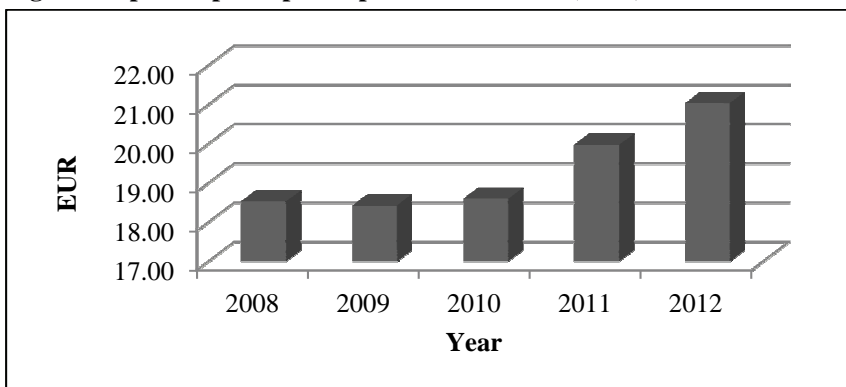
The following four figures show the development of tuna consumption in Spain over a period of 4 years, per capita expenditure on tuna, value of tuna traded and average price of tuna in Spain.

Figure 1. Consumption per capita of tuna in Spain



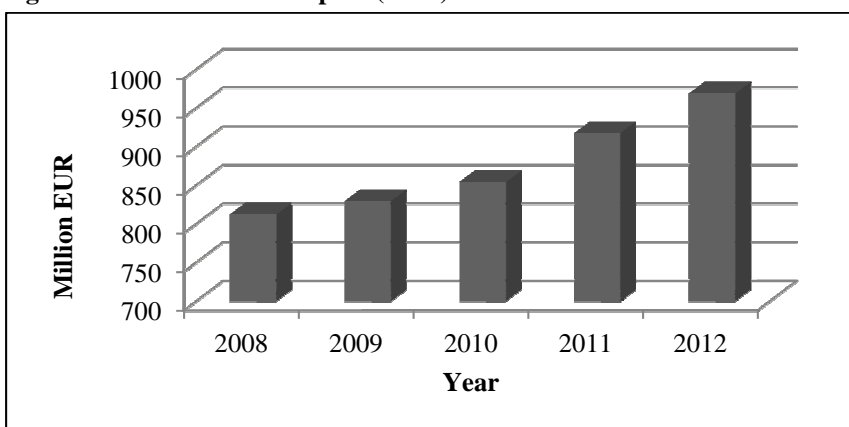
Source: Ministerio de Agricultura, Alimentación y Medio Ambiente de España, 2013.

Figure 2. Spanish per capita expenditure on tuna (EUR)



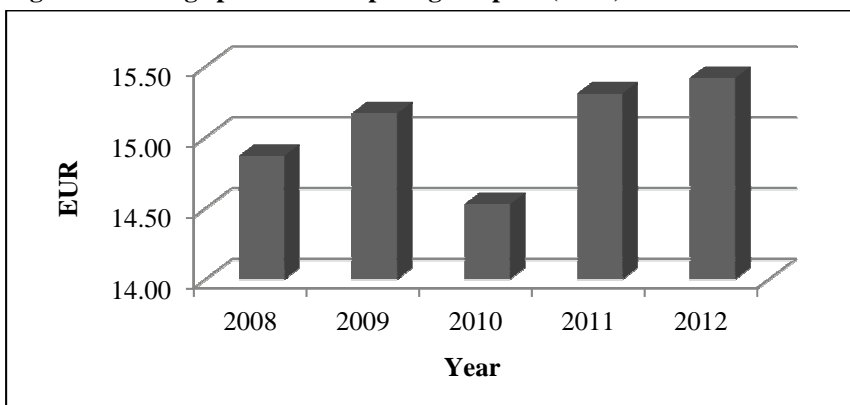
Source: Ministerio de Agricultura, Alimentación y Medio Ambiente de España, 2013.

Figure 3. Trade of tuna in Spain (EUR)



Source: Ministerio de Agricultura, Alimentación y Medio Ambiente de España, 2013.

Figure 4. Average price of tuna per kg in Spain (EUR)



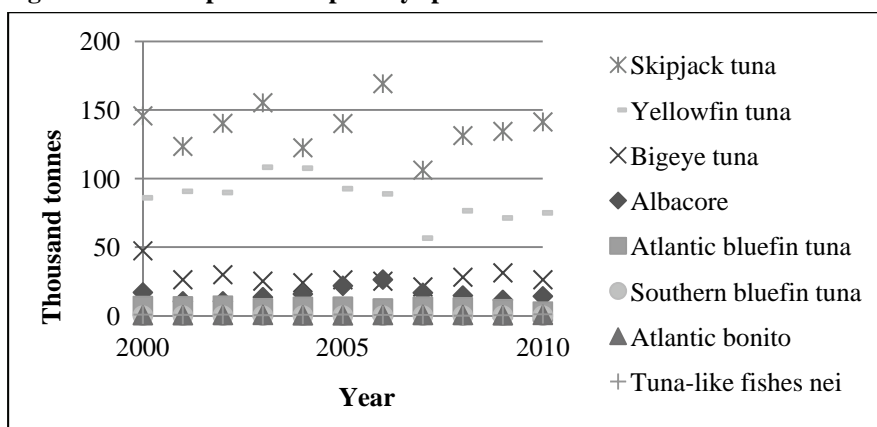
Source: Ministerio de Agricultura, Alimentación y Medio Ambiente de España, 2013.

The approval by the European Commission of a quota of 22 000 tonnes of tuna loins duty free applicable from 1 January 2013 until 31 December 2015 is expected to contribute to an increase in exports, considering that the quota for 2010–2012 was limited to 15 000 tonnes at 6 percent tariff.

2.1. TUNA SPECIES IN SPAIN

Numerous species of tuna are caught in Spanish waters, with skipjack tuna being the main species. Yellowfin tuna, bigeye tuna, albacore, Atlantic bluefin tuna and Southern bluefin tuna are also highly typical on the Spanish market. Figure 5 shows the tonnage produced for each species from 2000 to 2010.

Figure 5. Tuna captures in Spain by species



Source: Fishstat statistical database, 2013.

2.2. UTILIZATION OF TUNA

In Spain, the main product produced from tuna is canned tuna, for which tuna loins are used as raw material.

Spain manufactures a wide variety of products from tuna that are consumed nationally and, in recent years, also exported to other markets such as Asia and Europe. The quality of these products, which have been produced for many years, has a reputation that makes them commercially valuable.

While it is true that canned tuna is still the best-selling product, it is also important to note that canned tuna has become the main accompaniment to many ready-to-eat foods, enabling the industry to manufacture a wide range of very attractive products for the consumer, which are popular because of their excellent quality/price ratio. Examples of this include, tuna preserved in: olive oil, sunflower oil, tomato sauce and olive oil with spices.

The Spanish market offers traditional tuna products that are popular nationwide and are gaining ground internationally, such as salted tuna, hueva, smoked tuna and carpaccio of tuna.

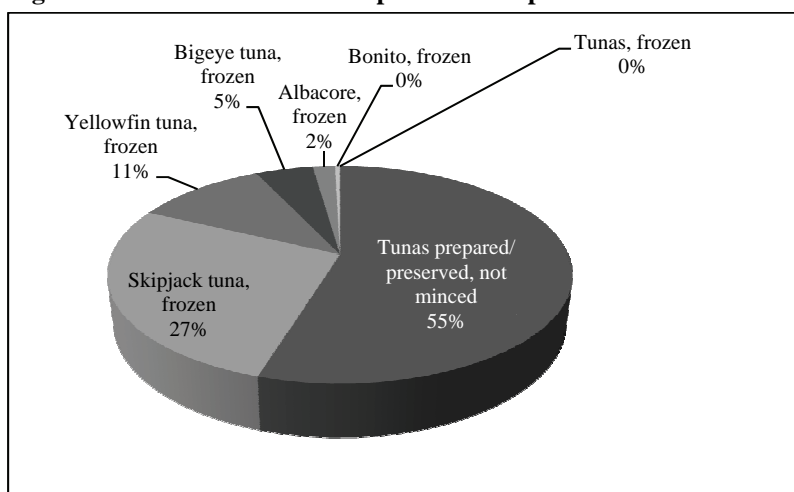
- The salted tuna (tuna loins cured for a period of time) is a new product in other markets such as Japan, Australia and France, but is very traditional in Spain.
- Hueva is a cured mass of tuna eggs, enclosed in an oval bag.
- Smoked tuna and tuna carpaccio, which are not traditional products in Spain, have been introduced into the market in Spain. These are widely available and are retaining their position.

There is a range of innovative products such as zero percent fat canned tuna that are aimed at a specific target market, also tuna pate, tuna burgers and tuna sausages, which are aimed at children, to introduce fish consumption from childhood. All these products are consumed nationally.

Vacuum packed sashimi and tuna tartar are products arising from the emerging taste for Asian cuisine. There are already some specialized companies in the sector, which sell a great variety of raw tuna formats.

Figure 6 shows the fresh and frozen tuna products in Spain. Frozen products account for 45 percent and the rest are fresh/prepared or preserved but not minced products.

Figure 6. Fresh and frozen tuna products in Spain



Source: Fishstat statistical database, 2013.

2.3. CONTRIBUTION OF RESEARCH CENTRES

A cluster of tuna canneries has been created in the north of Spain, to enhance their competitive position and to increase profitability in a sustainable manner. To support the sector, ANFACO – CECOPESCA came into being in 1904 as a private business organization, and now includes more than 200 companies linked to industrial processing and marketing of fishery products and aquaculture. This consortium has analytical laboratories and research and training facilities (Cano, M.A., *personal communication*, 2013).

The existence of this cluster has enabled the flourishing of research, development and innovation, as well as the improvement of capacity, productivity, marketing and access to new markets and promotion of business cooperation and networking.

Through the technical centre, member companies have carried out numerous studies including:

- The content of omega-3 fatty acids in different species of tuna, in anticipation of the possible application of nutrition claims on labels.
- Tracking the use of hydrolyzed vegetable protein in canned tuna sold in Spain.
- Study on the detection of *Anisakis simplex* and other parasites in viscera and muscle of tuna.
- Development of new products such as textured tuna, burgers and sausages.
- New packaging for tuna-based products such as pouch, easy-peel, tetra pack, plastic containers, among others.
- Research on industrial pollutants not included in EU legislation, such as polychlorinated naphthalenes (PCN) or polybrominated diphenyl esters (PBDEs).
- The nutritional role of tuna and its products (vitamins, minerals and other).

- The development of analytical techniques for fraud control, such as the detection of carbon monoxide (CO) in frozen tuna loins, or identification of tuna species by DNA analysis.

2.4. MOST REPRESENTATIVE COMPANIES IN THE SECTOR

The major companies are located in the north of Spain and some of the main ones are Canned Calvo, JEALSA Rianxeira, Northwest and Canned Frinsa Garavilla.

These companies have a range of innovative products such as tuna pate, zero percent fat canned tuna, tuna burgers and sausages. They are all processing companies whose main business is canned fish, which plays an important role as RTE (ready-to-eat food). Innovations can be seen in the recipes, not so much in the product itself, but in product components (such as salads, pastas and others), also pates and breaded products form a good percentage of the market.

Recently, some companies have emerged in Spain which have become tuna producers for a globalized market, offering a range of products of excellent quality, for example Balfegó and Intersmoked Grup. These companies are not part of the cluster of companies from the north and have demonstrated knowledge in new market trends.

2.5. BY-PRODUCTS

The Spanish tuna fleet captures around 400 000 tonnes annually, which accounts for 10 percent of the global catch. However, the Spanish tuna fleet does not process the tuna – it goes directly to the canneries – so there is no tuna waste on board. The by-products from processing of tuna are generated by canneries. Once the canned tuna is produced, heads, skin, bones, guts, tails and dark meat are transported to by-products factories where they are processed into fishmeal and fish oil (Porro-Quintanella, M.C., *personal communication*, 2013).

The main products made from tuna waste are fishmeal and fish oil. The relationship between the fish processing industries and the fishmeal and fish oil industry is particularly important, given that Spain is unique in manufacturing fish products only from by-products from the canneries and other fish processing industries and not from raw material supplies. Moreover, the fishmeal and fish oil industry in Spain promotes resource sustainability by leveraging and adding value to the products derived from the manufacturing process.

The end product in the form of fishmeal or fish oil closes the production cycle. The complete process can thus be seen as environmentally friendly and in line with ‘green’ solutions, as well as being a cost effective method for the treatment of such products.

According to the National Association of Manufacturers of Fishmeal and Oil (ANFAPHES), eleven companies grouped in this association produce 42 000 tonnes of fishmeal per year. For this production roughly 180 500 tonnes of raw material is used with a yield of 23 percent.

Meanwhile, in Spain there are two processing factories that produce about 6 700 tonnes of fish oil. These two industries provide an important service to the canneries and seafood processors through the recovery and collection of their by-products, which are then used as inputs to a great variety of feed products. Production of animal feed is the easiest and most profitable way to utilise this by-product.

Apart from the production of fishmeal and fish oil, it is difficult to extract other useful materials from the tuna wastes because they are already cooked. This is because cooking is the initial process in the production of canned tuna, the primary target of Spain's tuna canneries.

However, it is also important to highlight that the European Regulation (EC) No 178/2002 established that fish or other sea animals, except sea mammals, caught in the open sea for the purpose of fishmeal and fish oil production and fresh by-products from fish from plants manufacturing fish products for human consumption, are Category 3 material. Therefore, the fishmeal and fish oil coming from this category can be used for animal feed.

The high cost of the equipment and personnel to process the product inside the canneries makes it difficult to create by-products for human consumption as the material that comes out of the factories becomes Category 3 material. For this reason, the canneries attempt to maximize the quantity of product for human consumption that can be obtained by them and, as a result, the Spanish market has a large variety of tuna products.

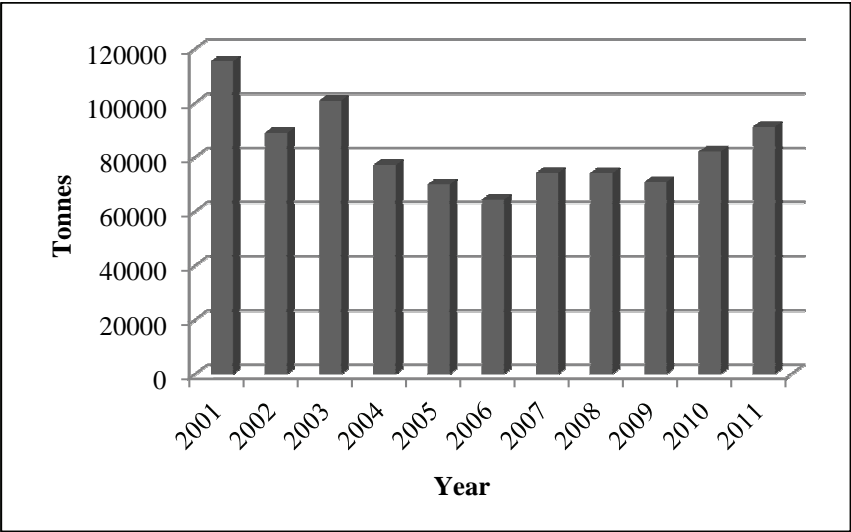
There are eight by-product factories in Spain, and four of them are located in Galicia, close to the canneries cluster. Although Spain is a big producer of canned tuna, the fact that a high percentage of raw material comes from other countries in smaller pieces ready-prepared to make the next production step easier, results in a smaller amount of tuna to process into by-products.

Globally, the Spanish by-product sector is an international reference at the technological level.

According to producers, around 70 percent of the production of fishmeal comes from tuna and most of the fishmeal production is sold in the national market to produce animal feed. However, the situation with fish oil is quite different, as 40 percent of the production goes to the international market and is used for the animal feed industry and also the chemical industry to produce lubricants and resins.

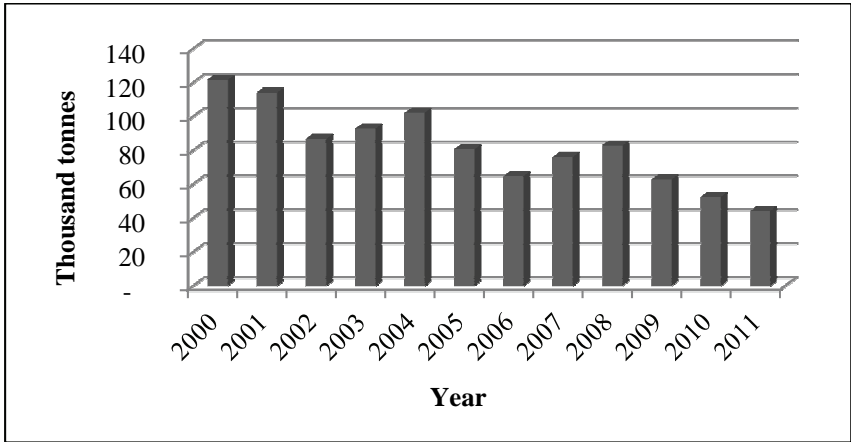
The demand for fishmeal in Spain is greater than that supplied by local production and imports are needed. Tuna fishmeals contain high levels of all essential amino acids, including methionine and lysine, which are low in most of the plants, hence tuna fishmeals are nutritionally important in animal feed production.

Figure 7. Production of fishmeal in Spain (tonnes)



Source: Fishstat statistical database, 2013.

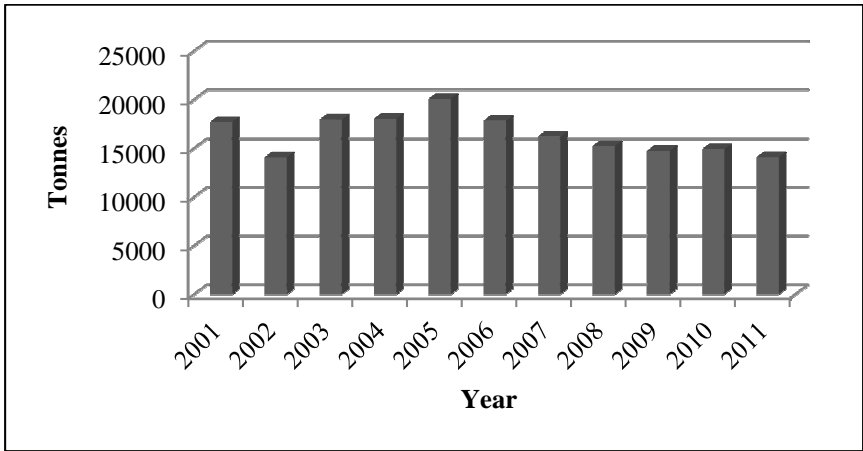
Figure 8. Spanish fishmeal imports (tonnes)



Source: Eurostat statistical database, 2013.

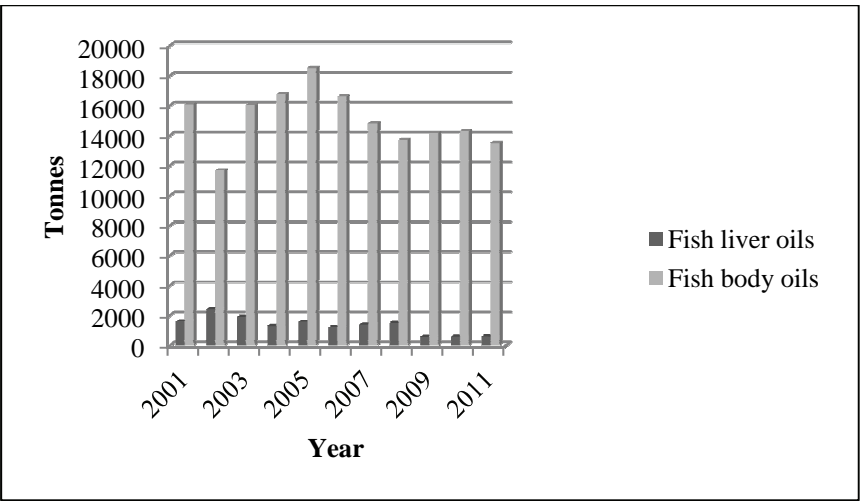
The research centres have suggested the possibility of the canneries processing the by-products themselves. More specifically, the tuna liver can be used for the extraction of high quality fish oil that could enable the commercialization of a co-product for human consumption as a functional food; however, this has so far not been regarded as economically viable by the sector, because the quantity of oil coming from the fish liver is very low compared with the quantity of oil coming from the fish meat. The figure 10 shows the differences in the production.

Figure 9. Production of fish oil in Spain (tonnes)



Source: Fishstat statistical database, 2013.

Figure 10. Production of fish oil from fish liver and fish meat in Spain (tonnes)



Source: Fishstat statistical database, 2013.

2.6. CERTIFICATION AS A WAY TO ADD VALUE TO THE FINAL PRODUCT

With the increasing role of supermarkets in the distribution of canned tuna and the demand for product differentiation through ecolabelling, tuna processors in Spain are trying to obtain labels such as the Marine Stewardship Council (MSC) label. There are already twenty six companies that produce products with ecolabel certificates in Spain (Marine Stewardship Council, 2013).

There is also a major demand in the Spanish market towards product certification and quality management system certification through food safety standards.

There are clear differences between Spain and Ecuador, two of the largest producers of canned tuna, with regard to certification; for instance, Spain is a country that counts on certification to add value to products.

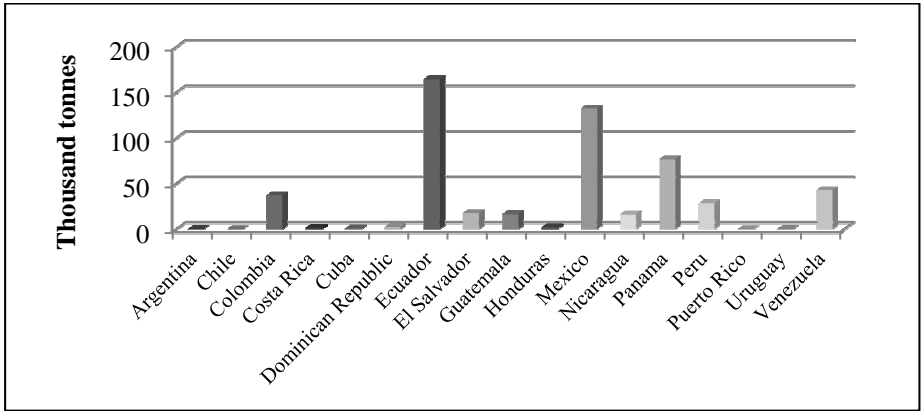
3. ECUADOR

The development of the tuna industry in Latin America began in the 1940s with a fleet from the United States of America. The situation evolved over the years in terms of production and technology, particularly with the introduction of the purse seine fleets.

Along with the development of the fleet, a processing industry for fresh, frozen and canned products also began to emerge in the region. Currently, there are many tuna canning plants in Mexico, Ecuador, Venezuela, Costa Rica, Peru, Colombia and Brazil. However, a considerable part of this production has been increasingly directed to domestic markets. This is the result of some restrictions on the export markets, for example, high production costs, low production rates, the imposition of embargoes for environmental reasons, high import tariffs, among others. As a result, strong intra-regional trade flows have developed over the past decades (Caro-Ros, S., *personal communication*, 2013).

The countries with the largest tuna captures in Latin America are Ecuador, Mexico, Panama, Venezuela, Colombia and Peru (Figure 12).

Figure 11. Total tuna production in Latin America in 2010



Source: Fishstat statistical database.

The species that are processed in Latin America are yellowfin tuna, bigeye tuna, skipjack tuna, although other species such as blackfin tuna, albacore and Eastern Pacific bonito may also be used.

The Ecuadorian tuna capture and processing industry emerged more than 50 years ago and has been one of the first to consolidate in Latin America. The industry initially

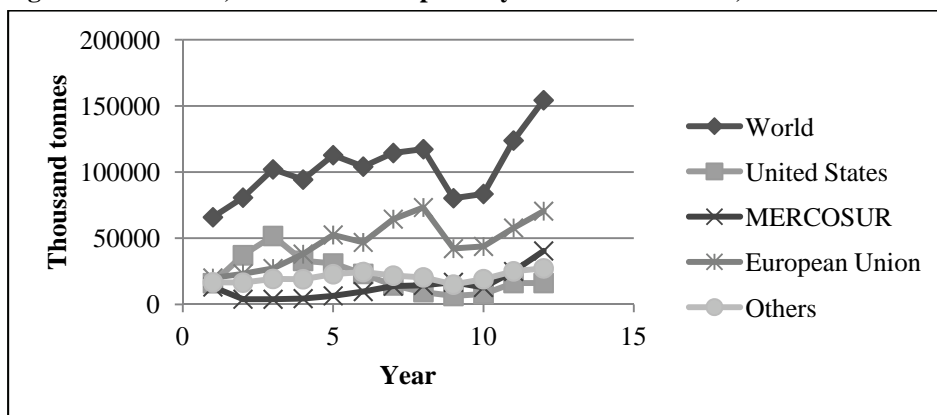
developed with strong support from US investment and currently the country has reached a high position in terms of infrastructure and well qualified personnel.

Although the industry was initially export-oriented towards the US market, intra-regional trade has grown in importance in recent years, both for raw materials and canned goods. At first, a substantial part of the raw material (35 percent) came from catches taken from the exclusive economic zone of Colombia. Later on, the situation changed completely when the Colombian authorities began to regulate access to the fishing grounds.

Ecuador has become the leading nation in tuna fisheries in the Eastern Pacific Ocean, overtaking Mexico (Caro-Ros, S., *personal communication*, 2013).

Ecuador is a country of great importance for the tuna supply for the Spanish industry, as evident from the fact that different tuna canneries from Spain have chosen this country for placing industrial plants, whose main purpose is to ensure the supply of tuna. Ecuador is the largest exporter of canned tuna to Spain, accounting for 65 percent in volume (17 680 tonnes) and 63 percent in value. As for tuna loins, Ecuador is also the largest exporter to Spain, accounting for 31 percent in volume and value, with a total of 21 425 tonnes exported in 2011 (Maldonado-Sabando, M., *personal communication*, 2013).

Figure 12. Ecuador, canned tunas exports by countries in tonnes, 2001–2012



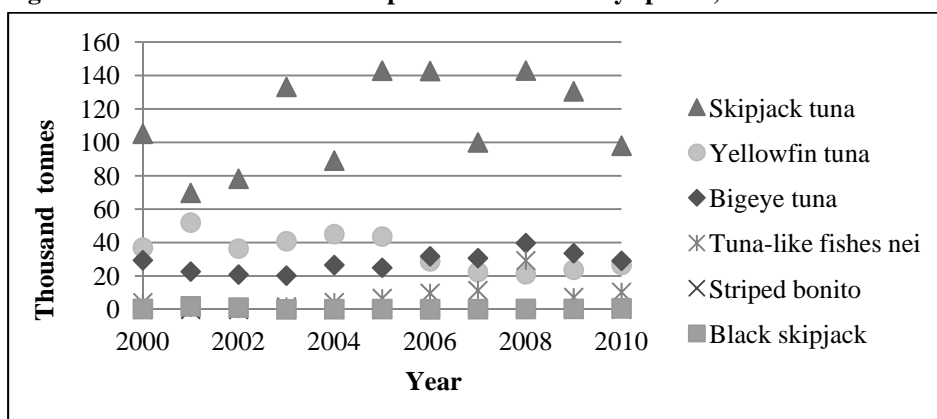
Source: La Cámara Ecuatoriana de Industriales y Procesadores Atuneros, 2013.

(*) Mercosur: Argentina, Bolivia, Brasil, Paraguay, Uruguay and Venezuela.

3.1. TUNA SPECIES IN ECUADOR

Numerous species of tuna are caught in Ecuadorian waters, with skipjack tuna, yellowfin tuna and bigeye tuna being the main species, although species such as black skipjack and striped bonito are also typical in the Ecuadorian market. The figure below shows the quantities produced for each species from 2000 to 2010.

Figure 13. Total tonnes of tuna captures in Ecuador by species, 2000–2010



Source: Fishstat statistical database, 2013.

3.2. UTILIZATION OF TUNA

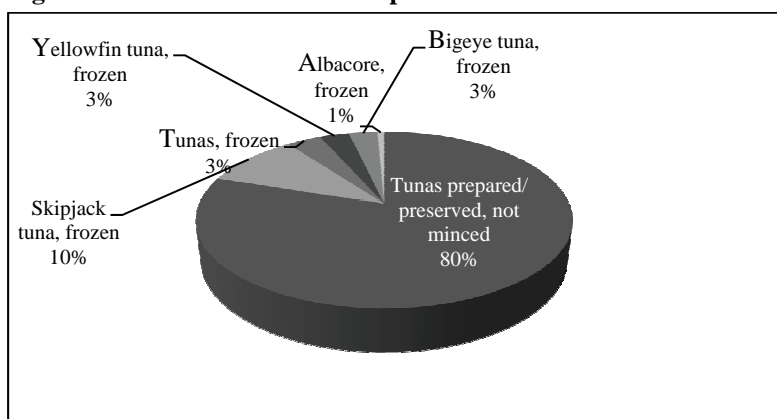
The main product produced is canned tuna, where tuna loins are used as raw material for the canneries.

Canned tuna has become the main export product, enabling the industry to manufacture a wide range of very attractive product formats for overseas markets as a result of their excellent quality/price ratio. The precooked tuna loins are sent to other markets to be reprocessed and transformed into canned tuna formats for the final consumer.

There is a great variety of canned tuna products that are processed, such as solid tuna, tuna loins, tuna chunks, grated tuna and tuna bellies, and the Ecuadorian market offers many different tuna products for the national market, for example, tuna loins, tuna steaks and tuna fingers, as well as tuna skewers and frozen breaded tuna chunks (nuggets).

Innovative packaging such as glass jars and aluminum pouches is also offered, which adds more interesting features to the tuna market. Different covering liquids are used by the canneries such as water, soybean oil, sunflower oil or olive oil. Both the covering liquid and the packaging change the price of the final product and also the target market.

Figure 14. Fresh and frozen tuna product in Ecuador



Source: Fishstat statistical database, 2013.

3.3. BY-PRODUCTS

Tuna by-products also play an important role in the market. In the case of Ecuador, fishmeal and fish oil are the tuna by-products that are developed for the market.

Once the canned tuna is produced, the waste, consisting of head, skin, bones, guts and tails, is transported to by-products factories where these materials are processed into fishmeal and fish oil.

The percentage of waste assigned for the production of tuna by-products in the factories always depends on the tuna species and the equipment. It is estimated that a total amount of 200 000 tonnes of waste is generated every year by the Ecuadorian canneries (Toppe J., *personal communication*, 2013).

There are twenty six by-product factories in Ecuador, but not all process tuna. The fishmeal and fish oil industry also uses species such as anchovy, mackerel and sand eel as raw material. There is a large demand for the product in Japan and even more in China, which consumes about 60 percent of global fishmeal production.

Fishmeal exports were 96 202.45 tonnes, which represented USD 116 889.51, in 2012, and fish oil exports were 15 831.15 tonnes and USD 25 331.80 in value in 2012 (Maldonado-Sabando, M., *personal communication*, 2013).

In Ecuador, this fishmeal and fish oil is used for the production of animal feed, and the regulation 472 establishes the specification of the fishmeal for animal consumption.

Fishmeal is in high demand for the production of poultry and pig feed, because fishmeal feed encourages faster growth and better feed conversion giving lower production costs and changes the composition of fat in meat to include low levels of long chain omega-3 fatty acids (DHA and EPA). It is the most effective ingredient to accomplish this without compromising meat quality.

The Ecuadorian sector has shown interest in improving and innovating, in order to make the production of tuna by-products more profitable. However, there have been no other products developed for the market so far (Toppe, J., *personal communication*, 2013).

3.4. CONTRIBUTION OF RESEARCH CENTRES

In Ecuador, there are two centres engaged in research on the issues of tuna. The first one is the Vice-Ministry of Aquaculture and Fisheries, which is in charge of fisheries resource management and the second is the National Fisheries Institute, which deals with sanitary and quality control and research.

It is important to highlight that innovation, research and development of tuna products are carried out by private companies from the tuna sector that look for product differentiation in the market.

3.5. MOST REPRESENTATIVE COMPANIES IN THE SECTOR

The Ecuadorian Chamber of Tuna Industries and Processors (CEIPA) is an association of 18 tuna processing companies located in Manabi, Guayas and Santa Elena, where most tuna processing companies are located. The biggest canneries are ASISERVY, Empacadora Bilbosa, Eurofish, Galapesca, Ideal, Inepaca and Marbelize, Nirsa, Pespesca, Seafman and Tecopesca, and Conservas Isabel Ecuatoriana S.A. and Sállica del Ecuador, S.A., which are Spanish privately funded companies.

It is important to note that some of these canneries process large pieces of precooked material for export and further re-processing and other companies process a great variety of products for the local market.

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CASE STUDIES FROM THAILAND

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SUMMARY

Thailand, the world number one canned tuna exporter, currently processes around half of the canned tuna consumed globally. That is approximately 500 000 tonnes annually. There are 26 tuna canning factories with a total capacity of 770 000 tonnes. In 2010, about 816 472 tonnes of fresh and frozen tuna were imported. Skipjack was the major species with 650 448 tonnes (79.67 percent) follow by yellowfin at 111 294 tonnes (13.63 percent), albacore at 48 892 tonnes (5.99 percent) and others amounting to 5 838 tonnes (0.71 percent). Tuna canneries generate a significant volume of by-products and would benefit environmentally and economically by full utilization of these products. Tuna meal, tuna oil and tuna soluble concentrate are the main outputs coming from these by-products. There are also several niche products that can provide a higher commercial value such as tuna calcium, DHA oil, enzymes, peptone, protamine and hyaluronan.

1. INTRODUCTION

The first Thai tuna cannery was set up in 1972 with the collaboration of an Australian, Thai, and Hong Kong partnership under the brand SAFCOL, namely SAFCOL (THAILAND), LTD., (name changed to Kingfisher Holding Ltd., in 1989) and intended for the export market (Kingfisher Holdings, 2006). Thai Union Manufacturing, one of the large tuna canneries in Thailand, began operating in 1977 to produce canned tuna using smaller sized fish to avoid direct competition with the large canneries in the US. However it was not until the mid-1980s that Thailand began to become a significant force in the world market by becoming the world's second largest canned tuna producer and the largest exporter. In 2001 the last large full scale cannery of the 'Chicken of the Sea' on the US mainland closed, providing the opportunity for Thailand to become the largest tuna producer. Thailand continues to be the world's largest producer and exporter of canned tuna (Globefish, 2012). Over 80 countries import tuna products from Thailand with the biggest market for canned tuna being the USA (23 percent) followed by the European Union (15 percent), the Middle East (12 percent), Canada (6 percent) and Australia (2 percent) (<http://www.fisheries.go.th/foreign/>).

The canned tuna industry is an important industry in Thailand. Canned tuna products, mainly for export, generated an annual income of more than THB 22 000 million during the years 1997 to 2001 and this increased to THB 38 000 million over the period 2002–2006. During the period 2007–2012 more than THB 59 700 million per year was achieved, equivalent to 509 923 tonnes and added-value earnings of THB 2 820 million per year, equivalent to 28 884 tonnes from export trade (see Tables 1 and 2).

Table 1. Quantity of tuna export products from Thailand in 2007-2012 in tonnes

Products	2007	2008	2009	2010	2011	2012
Canned tuna	451 094.35	494 486.03	494 322.17	535 480.08	535 490.49	548 666.83
Tuna value added	16 546.60	11 611.29	40 168.41	53 246.92	40 908.34	10 825.94
Total	1 965 184.53	1 907 056.79	1 874 852.63	2 058 353.73	1 974 965.40	1 908 099.56

Table 2. Value of tuna export products from Thailand in 2007-2012 in million Baht (THB)

Products	2007	2008	2009	2010	2011	2012
Canned tuna	46 072.68	62 516.52	52 863.40	53 172.41	63 205.16	80 804.87
Tuna value added	1 778.39	2 038.87	4 564.33	6 256.68	6 123.51	1 793.41
Total	205 866.70	228 217.64	224 512.64	236 902.14	259 863.80	264 766.34

2. TUNA CANNING FACTORIES AND PRODUCTION CAPACITY IN THAILAND

Data from the Department of Industrial Works in 2007 show 26 factories produced canned tuna with a total production of about 770 000 tonnes and a total capital investment of more than THB 7 600 million. The major producers are Unicord public company (Unicord), Thai Union Manufacturer Co., Ltd., Chotiwat Manufacturing Co., Ltd., I.S.A. Value Co., Ltd. and Thai Union Frozen Products Public Co., Ltd. (TUF) (Table 3).

Table 3. List of major tuna producer of Thailand

No.	Company	Capital (million THB)	Worker (person)	Capacity (tonnes)
1.	I.S.A. Value Co., Ltd.	2 636	5 667	79 224
2.	Thai Union Manufacturer Co., Ltd.	1 037	6 254	90 000
3.	Songkla Canning Public Co., Ltd	46	2 539	30 000
4.	Tropical Canning (Thailand) Public Co., Ltd.	525	2 150	30 000
5.	Thai Union Frozen Products Public Co., Ltd.	830	2 180	81 000
6.	Pattani Food Industries Co., Ltd	47	1 260	25 790
7.	Pataya Food Industries Ltd.	216	1 427	47 724
8.	Unicord Public Company (Unicord)	87	602	144 000
9.	Southeast Asian Packaging and Canning Co., Ltd.	470	1 060	31 200
10.	Chotiwat Manufacturing Co., Ltd.	507	1 665	70 000
11.	The Siam Tin Food Products Co., Ltd.	25	1 289	25 000
SubTotal		6 426	26 093	653 938
Others (15 companies)		1 319	6 352	132 680
Total		7 745	32 445	786 618

Source: Department of Industrial Works, Thailand (2008).

Thai tuna companies have expanded their investments through mergers, changing the name of the company or by buying foreign companies; for example after TUF bought MW Brands, it became the largest packer of private label canned tuna in the world. The firm's market power in negotiations with raw material suppliers has been significantly enhanced.

3. TUNA PROCESSING

3.1. RAW MATERIAL

Thailand is the largest raw tuna importer, with Japan the next biggest importer. The main sources of tuna are from the Indian and Western Pacific Oceans. Thailand imports more than 90 percent of fresh and frozen tuna for use as a raw material. The total imported in 2010 was 816 473 tonnes, valued at THB 35 816 million. Skipjack was the major species with 650 448 tonnes (79.67 percent) followed by yellowfin 111 294 tonnes (13.63 percent), albacore 48 892 tonnes (5.99 percent) and others 5 838 tonnes (0.71 percent) (Table 4.) The major importing countries were Taiwan Province of China with 212 256 tonnes, USA with 122 011 tonnes, Vanuatu with 101 945 tonnes, Republic of Korea with 87 486 tonnes, Japan with 63 558 tonnes and Maldives with 16 031 tonnes. The import prices vary according to the type of tuna.

Table 4. Thailand imported tuna in 2010

Species	Tonnes (percentage)
Skipjack tuna	650 448 (79.67)
Yellowfin tuna	111 294 (13.63)
Albacore tuna	48 892 (5.99)
Others	5 838 (0.71)
Total	816 472

Source: Department of Industrial Works, Thailand (2008).

3.1.1. Skipjack tuna

They live in a warm climate at temperatures between 15–25 °C. Most have been caught in the Western Pacific Ocean. The average length is 18–32 inches, weighing about 3–7 kg. Skipjack tuna is a major species making up about 79 percent of total imports. The meat quality is inferior to yellowfin and albacore tuna. The average price is cheaper because of the higher percentage of dark meat and the yield of about 45 percent.

3.1.2. Yellowfin tuna

They also live in warm water at temperatures between 18–25 °C. Most have been caught in the Western Pacific Ocean. The average length is 27–60 inches, weighing about 7–20 kg. Yellowfin tuna is the second most imported species at about 14 percent of total imports. The meat quality is quite suitable for the production of canned tuna. The

average price is higher than for skipjack tuna because there is more white meat and the yield is about 50 percent.

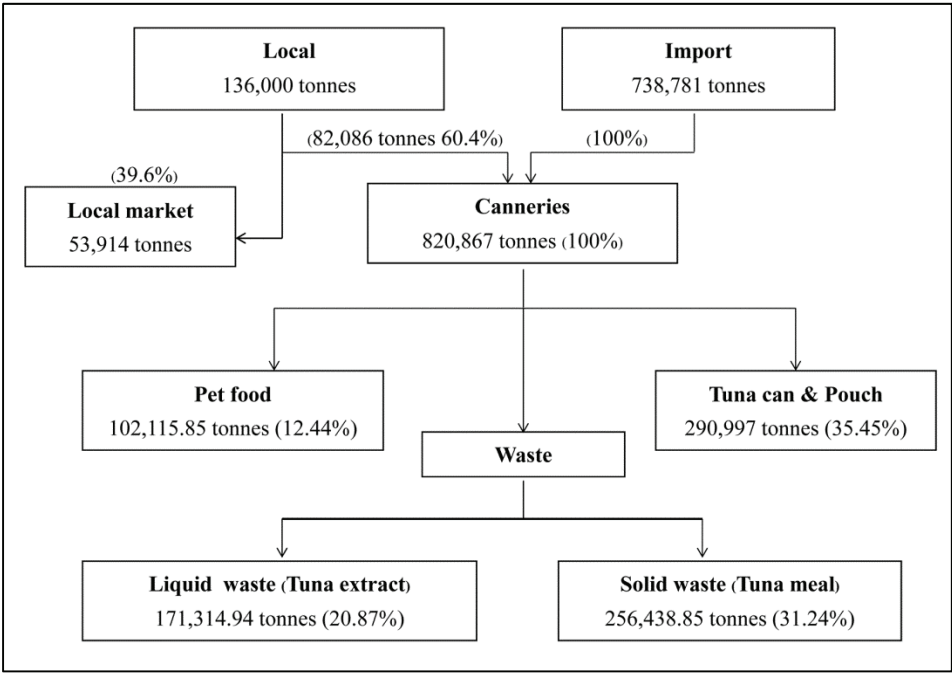
3.1.3. Albacore or long finned tuna

They live in surface and deep waters at temperatures between 13–25 °C. Most have been caught in the North Pacific Ocean. The average length is 35–72 inches, weighing about 8–19 kg. Albacore tuna is the third most imported species and makes up about 6 percent of total imports. The meat quality is the most suitable for the production of canned tuna. The average price is higher than yellowfin tuna because there is more white meat than either of the two previous species.

3.1.4. Local raw materials

They account for 10 percent (82 086 tonnes) of total raw materials. Thai tuna has an average length of 12 inches. About 40 percent of local raw material (53 914 tonnes) was consumed as fresh fish by local people in 2005 (Figure 1). The Thai people are more used to obtaining live fish rather than using canned products. Small tuna and tuna found on the surface differ from larger species and have fewer waste products. There are not many tuna fishing boats in Thailand and they cannot catch enough fish to meet demand.

Figure 1. Balance of tuna product materials and wastes in 2005



4. PRODUCTION

4.1. RAW MATERIALS

Prior to manufacturing the tuna, raw materials must be examined for good quality by looking at the physical properties of gills, eyes, skin, and texture of the fish. Histamine contents must be checked as well.

4.2. THAWING

After passing inspection frozen tuna is thawed at room temperature, by cold storage or using water. The duration will vary depending on the fish size. It usually takes about 2–3 hours to raise the temperature up to 5 °C. The temperature of the fish should be kept as low as possible because higher temperatures will cause the fish to deteriorate as a result of the activity of microbes and enzymes.

4.3. GUTTING

Thawed fish is gutted to remove blood (7–12 percent) and viscera (5–7 percent), then washed with water to reduce microbial growth and deterioration (Figure 2).

4.4. PRE-COOKING

Gutted fish is steamed in a pre-cooker at a temperature of about 95 °C and pressure of about 1–2 bar for 60–90 minutes depending on the size and species of fish. This process can help to remove skins and bones from fish meat more easily.

4.5. COOLING

Steamed fish is taken to the cooling area and sprayed with cold water to reduce the temperature to prevent overcooking. After this process, the weight of the fish will be less because a considerable amount of water will have evaporated.

4.6. TRIMMING

Cooled fish skin and bone are removed (20–30 percent). The white meat yield of about 32–40 percent will be used for human consumption in cans and pouched products (35.45 percent). The dark meat yield of about 10–13 percent will be used for animal or pet food in cans and pouched products (12.44 percent) (Figure 2).

4.7. PACKING

Canned fish is packed in various sizes using machine or by hand, followed by the addition of tomato sauce, vegetable oil, brine or other seasoning sauce for preserving fish quality and to meet customer's needs.

4.8. RETORTING

After steaming, the canned fish is heated at 116 °C for 90 minutes (commercial sterilization). If a higher temperature is used the fish losses its good physical characteristics as well as smell, taste and nutritional value.

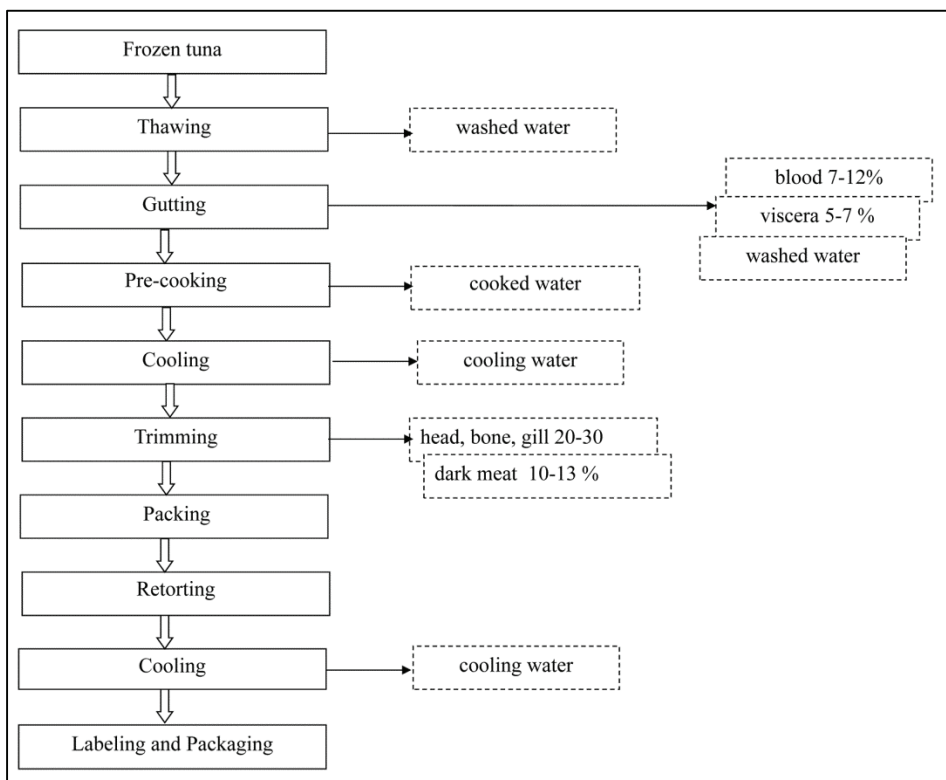
4.9. COOLING

After sterilization, the temperature of the canned fish should be reduced as soon as possible to prevent heat accumulation making the fish meat tender, changing the color, taste and decreasing nutritional value. It also prevents the growth of thermophilic microbes that may have been left after the heating process. The cans are cooled down to about 35–40 °C. The remaining heat helps to evaporate the water on the outside of the cans.

4.10. LABELING AND PACKAGING

After the dried canned fish has been cooled to room temperature, it is then labeled and packed in cardboard boxes for storage and further transportation.

Figure 2. Canned tuna production and wastes generated in some steps of the process



5. WASTE UTILIZATION

Prasertsan *et al.* (1988) conducted a survey of the waste left over from the production of canned tuna in the southern part of Thailand. The wastes were divided into two parts: the solid wastes and the liquid wastes.

Tuna solid wastes refer to that which remains after much of the tuna white meat has been removed and includes the head, bone, viscera, fin, tail, skin and red meat. Most of the solid waste is separated after cooking; only the viscera are separated from fresh fish or after thawing the tuna. The amount of solid waste is between 25 to 30 percent of the total fresh tuna weight. Most of the tuna solid by-products are used to make fishmeal and fish oil. Primary uses of fishmeals and oils are as aquaculture feed ingredients for fish and shrimp, and also as livestock and poultry feed ingredients.

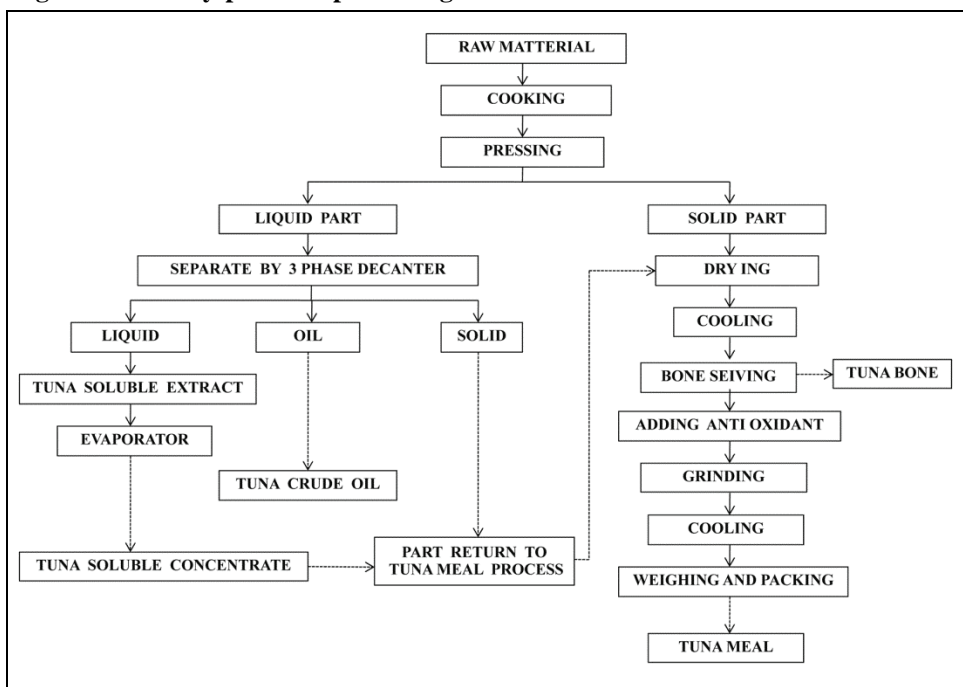
Figure 3. Tuna offal (head/bone/skin/gill)



The principle of fishmeal and fish oil production is to separate the three major fractions, solids, oil and water, from each other as completely as possible, with the least possible expense and under conditions rendering the best possible products.

Today most fishmeal and fish oil is manufactured by the wet pressing method. The main steps of the process are cooking to coagulate the protein thereby setting free bound water and oil, separation by pressing of the coagulate yielding a solid part (presscake) containing 60–80 percent of the oil-free dry matter (meat, skin and bones) and oil, and a liquid part (press liquor) containing water and the rest of the solids (oil, dissolved and suspended protein, vitamins and minerals). The main part of the sludge in the press liquor is removed by centrifugation in a decanter and the oil is subsequently removed by the centrifuge. The stickwater is concentrated in multi-effect evaporators to produce tuna soluble concentrate. The concentrate is thoroughly mixed with the presscake, which is then dehydrated usually by a two-stage drying process. The dried material is milled and stored in bags or in bulk. The tuna crude oil is stored in tanks.

Figure 4. Tuna by-products processing



5.1. TUNA VISCERA

Tuna viscera from yellowfin tuna (*Thunnus albacares*), skipjack tuna (*Katsuwonus pelamis*), and tonggol tuna (*T. tonggol*) removed during processing accounted for 7.05, 5.44 and 5.18 percent of the body weight, respectively (Prasertsan and Prachumratana, 2008). Edible parts of the viscera, such as the ovary and milt, are sometimes collected and sold or sent for the extraction of bioactive compounds. Fish eggs are reportedly rich sources of lectins, sugar-binding proteins that could be a source of useful bioactive compounds for human disease therapy (Bah, 2011).

Protamine is a naturally occurring cationic polypeptide of about 30–65 amino acid residues with over 80 percent arginine and is recognized in fish testicles in more than 50 species. Its unique properties, being stable at higher temperatures and preventing the growth of spores of *Bacillus* sp., make protamine an antibacterial agent for use in food processing and preservation (Islam *et al.*, 1986).

Fish viscera have proven to be an excellent source of enzymes as well. Whole viscera and individual viscera organ such as stomach, liver, pancreas and spleen of three tuna species, yellowfin tuna (*T. albacares*), skipjack (*K. pelamis*), and tonggol tuna (*T. tonggol*), were used as sources of enzymes. The protease and lipase from spleen were the most thermostable with a half-life of 120 and 90 min at 60 °C incubation, respectively. Protease activity from the spleen accounted for 45.6 percent of the total

protease activity of the whole tuna viscera (Figure 5) (Prasertsan and Prachumratana, 2008).

Figure 5. Tuna viscera



5.2. TUNA RED MEAT

Tuna red meat is left over after the canning process and can make up as much as 10 to 13 percent of the total body weight of tuna (Figure 6). Tuna red meat is mainly used for pet food because of its dark color and strong flavor. Nutrient profiling of red meat shows that it contains all the essential amino acids and polyunsaturated fatty acids and especially docosahexaenoic acid (DHA) was found to dominate. This red meat could be put to good use as tuna candy for human consumption or used as tuna protein concentrate (TPC) with or without solvent extraction. The improvement of the colour of cooked tuna red meat was undertaken by using the combined effect of ascorbic acid 1.0 percent plus sodium nitrite 0.05 percent by weight, which was found to increase the redness of the meat. Fish sausages were made by using a ratio of surimi to colour improved red meat of 85:15 by weight (Daengprok, 1995).

Figure 6. Tuna red meat



Liquid wastes comprise about 30–35 percent of tuna raw material weight. The majority of tuna processing plants did not utilize these parts but just released them into the waste water treatment system (Figure 7). The main components are blood (7–12 percent) and cooked tuna juice (10–14 percent), which contain organic compounds such as hemoglobin, enzymes, proteins and lipids that have a number of uses.

5.3. TUNA BLOOD

Animal blood can be used in food, feed, laboratory, medical, industrial, and fertilizer applications. Blood in food is used as a protein supplement, as a textured meat protein, to clarify liquid foods, or as a colouring agent for meat items. Blood albumin has been used as a substitute for egg albumin in food. It is also utilized in making sausage casings and incorporated into bread flour (Ockerman and Hansen, 2000).

It can also be used to add nutritional value to animal and fish feeds, and added to fertilizer it can improve soil structure. Blood also has many applications in laboratories, particularly as a culture medium, as well as numerous medical uses. Industrial uses range from adhesives to albumin substitutes and cosmetic formulations.

Figure 7. Tuna bleeding and washing



5.4. TUNA COOKING JUICE

Tuna cooking juice used to be discarded, which caused problems in the waste-water treatment system. Recovering soluble proteins such as gelatin and oil, then utilizing them as food stuffs can achieve a profitable outcome. The chemical composition and physical properties of tuna cooking juice from Chotiwat Factory Manufacturing Co., Ltd. and Tropical Canning (Thailand) Public Co., Ltd. are shown in Table 5.

Table 5. The chemical composition and physical properties of the tuna cooking juice

Composition	Range
pH	4.9–6.2
Protein (%)	2.11–4.81
Total solid (%)	3.2–8.7
Fat (%)	0.9–3.2
COD (mg/l)	70 000–157 000

5.4.1. The utilization of tuna cooking juice

Tuna cooking juice can be processed in a similar way to other fish by-products by using commercial enzymes to hydrolyze and concentrate the juice. The resulting hydrolysate can be used as a flavoring agent, as a sauce or condiment.

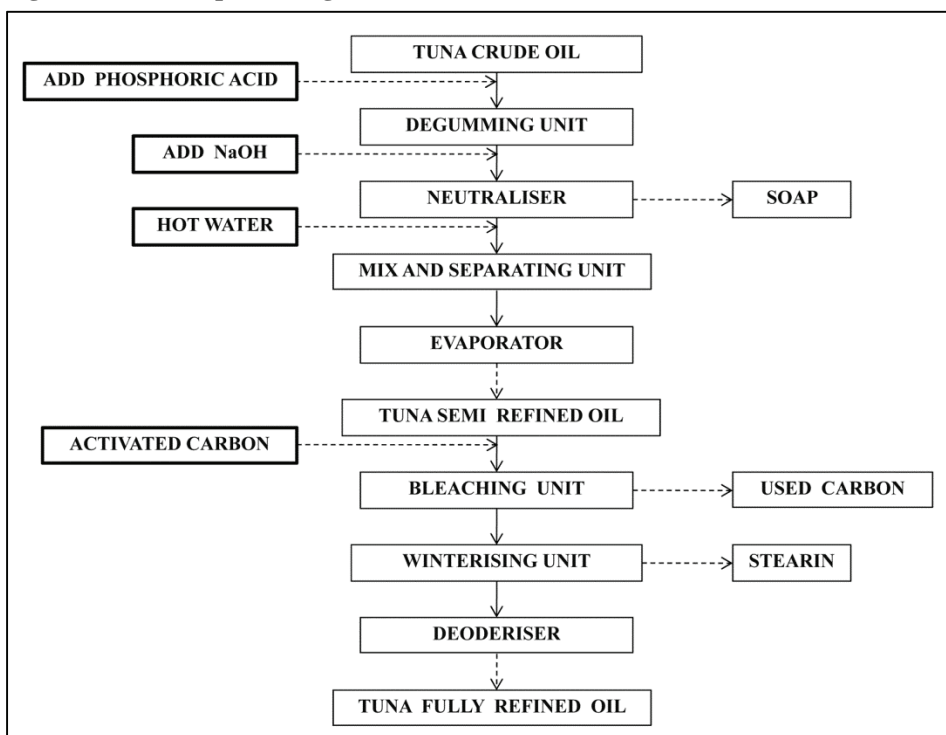
Several sources, including Jatupornpitat (1994) and Suwanno (1996), have cited the use of tuna cooking juice as a culture medium for the production of micro-organisms such as *Rhodocyclus gelatinosus* (a photosynthetic bacterium) and *Candida tropicalis* (a yeast) because it has high nutritional value. These organisms have uses in the treatment of waste water and the production of single cell proteins.

6. INDUSTRIAL PRACTICES IN THAILAND

T.C. Union Agrotech Co., Ltd. is the largest tuna by-products producer in Thailand and was established in 1987 with the primary aim of producing and supplying aqua-industrial by-products. The company is a subsidiary of the Thai Union Group, a world class group of companies in the tuna canning industry. The company's focus is on utilizing raw marine materials from the canning industry and developing them into nutritious products in various categories, including the health food and food supplements sector, feed ingredients and additives, as well as biotechnology products. High standard production processes are used to convert the by-products into tuna meal and tuna liver powder, as well as tuna soluble extract in liquid and powder form. These products contain highly digestible proteins combined with a full range of amino acids and they also act as palatability enhancers making them excellent sources for aquaculture feed.

Tuna oil production capacity is 2 000 tonnes/year of crude tuna oil, adequately supplying national and overseas markets. Apart from serving as a livestock and aquaculture feed additive, the oil is further refined to remove free fatty acids to produce a semi-refined tuna oil product, which is an excellent raw material for additional purifying processes (Figure 8). By enriching the fully-refined tuna oil with omega-3 fatty acids, especially high in natural DHA in the range of 25–30 percent, a highly nutritious health food and infant milk supplement can be produced. Tuna oil has very unique feature. It contains a very high concentration of DHA, part of a group of omega-3 fatty acids that are the most important fatty acids for marine fish and shellfish. DHA in tuna oil has been found to improve the growth rate and survival rate of young animals, fish and shrimp. Apart from serving as an aquaculture feed additive, the oil is refined further to produce fully-refined oil or so-called “DHA oil”. This product is beneficial to the functioning of the brain, eye and nervous system in the human body and has further applications as a nutritive food supplement in infant formulas and other functional foods. It can be used to fortify food products such as yogurt, milk, soft drink and can be mixed in different kinds of bread. Some factories remove the eyeball after thawing for producing high quality tuna oil and hyaluronan (Amagai *et al.*, 2009).

Figure 8. Tuna oil processing



Tuna calcium is derived from 100 percent natural tuna fish bone. It is hygienically processed to extract fat and protein, and then ground to a fine mesh powder to be used in calcium fortified food.

Tuna organic fertilizer is obtained from tuna soluble extract. It is 100 percent natural and contains essential elements that enhance nutrient absorption from soil microbial activity and improve soil structure, thus helping to rebuild soil condition.

7. CONCLUSION

Tuna canneries generate a significant volume of by-products and could benefit environmentally and economically by better utilization of these products. This industry produces a lot of waste water that must be treated prior to its release into the environment. Some is used to produce biogas and fertilizer. There are also remnants of solid wastes such as head, bone, skin and viscera. The main products from these wastes are used as feedstock for the production of animal feed in the form of fishmeal and pet food products. There are also many niche products that can provide a better commercial value such as tuna calcium, DHA oil, enzymes, peptone, protamine and hyaluronan. The liquid waste such as blood and cooked water can be used for human consumption and animal feed. For example, tuna cooking water after separation and hydrolyzation can

produce tuna essence or tuna flavor concentrate. The separated oil could be refined for use as a fish oil supplement or pharmaceutical grade fish oil.

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