Chapter 3
Prospective Utilization of Fishery By-products in Indonesia

Hari Eko Irianto, Ariyanti Suhita Dewi, and Giyatmi

Contents

1 Introduction

Indonesia is one of the main fish-producing countries in the world, in which the total production volumes of capture and aquaculture fisheries in 2009 were 5,109,980 tons and 4,708,957 tons, respectively. Around 67 % of the total production of capture

H.E. Irianto (✉)
Research Center for Fisheries Management and Conservation,
Jl. Pasir Putih I – Ancol Timur, Jakarta 14430, Indonesia
e-mail: harieko_irianto@yahoo.com

A.S. Dewi
Research and Development Center for Marine and Fisheries Product Processing and Biotechnology (RDCMFPPB), Jl. Petamburan VI, Jakarta 10260, Indonesia
e-mail: ariyanti.dewi@kkp.go.id

Giyatmi
Food Technology Department, Jakarta Sahid University,
Jl. Prof. Supomo 84, Jakarta Selatan 12870, Indonesia
e-mail: giyatmi@hotmail.com

S.-K. Kim (ed.), *Seafood Processing By-Products: Trends and Applications*,
DOI 10.1007/978-1-4614-9590-1_3,

fisheries was marketed as fresh and the remainder was processed into traditional products (19.38 %), frozen products (10.56 %), canned fish (1.53 %), and fish meal (0.76 %) (Ministry of Marine Affairs and Fisheries 2011). Important fisheries commodities coming from aquaculture, such as shrimp, crab, and seaweeds, are mostly exported. Shrimps are exported as frozen products, i.e., head on (HO), headless (HL), peeled tail on (PTO), peeled tail stretch (PTOS), peeled deveined tail on (PDTO), peeled and deveined (PD), peeled undeveined (PUD), and breaded products (Carita 2004).

Fisheries industries including capture, aquaculture, and processing activities produce both by-products and fish wastes. Fishery by-products, produced by modern and traditional industries in Indonesia, have not been utilized optimally, thus leading to the production of waste. Most of them contain organic substances that may cause environmental problems when not treated properly. Fishery by-products should be distinguished from fishery industrial waste due to their economic potential. If by-products are not utilized to produce a product having economical value, they can be classified as waste. Fish waste can be disposed to the environment and landfill, as well as used for direct animal feeds; therefore, sometimes, they can cause environmental problems.

Furthermore, fishery industries are required to optimize their products and performance efficiency, in order to compete in the global market. The government of Indonesia encourages the fishery industries to implement a "zero waste concept" in order to create green industries that are friendlier to the environment. Therefore, by-products should be processed into value-added goods. In the process of the utilization of by-products, consideration needs to be given to the availability of required technology, human resources, and financial support.

2 Fishery By-products

According to the facts in the field, there are five types of fishery by-products, as follows:

1. **By-products from the utilization of fisheries resources**. In marine and freshwater resources, there are various kinds of fish that can be categorized as by-products, mainly from the activities of capture fisheries. The type, size, and the quantity of by-products depend on the types of fishing gear and mesh size. By-products usually consist of different types of fish and whole fish. In aquaculture fisheries, by-products are rarely encountered and there may even be none. So far, there are no by-products produced from the activities of monoculture of shrimp, carp, and Nile tilapia.
2. **By-products from processing industries**. The remaining processing industries of shrimp, frog, and fish fillet for frozen products purposes may reach up to 35 % of the initial weight. Freezing industries in Indonesia have been developing rapidly, especially for tuna, skipjack, red snapper, and shrimp industries. Tuna loin industries usually produce skin and red meat as by-products, whereas red snapper industries produce heads, bones, skin, and tails as by-products.

Additionally, by-products from shrimp industries are heads and skin. The export volume of shrimp and tuna, including skipjack and Eastern little tuna, in 2009 was 150,989 tons and 131,550 tons, respectively (Ministry of Marine Affairs and Fisheries 2011).

Furthermore, canning industries are also developing in Indonesia, although some of them are currently facing raw material supply problems. By-products from canning industries consist of heads, tails, guts, and bones. These by-products are further utilized as fish meal, while liquid by-products consisting of water, oil, and protein from pre-cooking processes are collected for fish oil production.

The processing activities of traditional products, such as dried or smoked rays' meat, also produce skin and bones as by-products. These by-products depend on the raw material and the types of processed products.

3. **By-products as secondary products in addition to the main products**. Some fish processing industries have secondary products in addition to the main products. For instance, fish meal factories produce pressed liquor that can be further processed through centrifugation or other separation methods to obtain fish oil.
4. **By-products from surplus during fishing season**. In the peak fishing season, the number of fish landed is greater than usual, so there is a surplus that can be categorized as a by-product due to limitations of the industry's capacity to absorb as raw material. This usually occurs from the fishing activities of small pelagic fish, such as mackerel, scads, and sardines.
5. **By-products as the remainder of distribution or marketing**. This occurs when handling practices used during the distribution and marketing of fish or processed products are inadequate. So, finally, there are some products that do not deserve to be marketed. For example, dried salted fish in a long period of storage at ambient temperature waiting to be sold bring about quality deterioration, so it is not suitable for human consumption.

3 The Utilization of By-products

The utilization of by-products depends on the types of targeted processed products, such as food, feed, pharmaceutical, cosmetic, and non-food. Moreover, the types of products are determined by the types of by-products and their quality, target market, consumer, and available technology.

3.1 The Utilization of By-products from Shrimp Trawl

Generally, these by-products, which are commonly known as by-catch of shrimp trawl, consist of fish from several species with various sizes and chemical compositions. Previous reports stated that fish by-catch have a length of 6.9–48.7 cm and weight of 8–2,600 g. Meanwhile, their proximate compositions are 15.80–21.62 % protein, 0.22–5.53 % fat, 1.63–5.63 % ash, and 70.68–79.54 % moisture.

With their low fat content, fish by-catch does not cause any processing problems. Furthermore, the proportions of edible and non-edible parts are 51.1 % and 48.9 %, respectively (Nasran and Irianto 1988).

3.1.1 Minced Fish and Surimi

The processing technology and equipment required for processing both products are very simple. However, both products have a wide application, especially for dishes such as meatballs, fishcakes, fish burgers, fish sticks, fish chips, *kamaboko*, *chikuwa*, and *hanpen*, as well as Indonesian traditional products "*otak-otak*" and "*pempek*". Usually, 20–30 % minced fish and surimi are added to processed products. However, there is an exception for fish snacks and chips, in which the proportion of minced fish and surimi should not exceed 20 %, in order to avoid hard-textured products (Fawzya and Irianto 1997).

3.1.2 Food-Grade Fish Flour

Surimi can be processed further by means of steaming, pressing, and drying to produce food-grade fish flour. For example, food-grade fish flour from muraenesox has 9.31 % moisture, 85.68 % protein, 0.93 % fat, and 1.78 % ash (Fawzya et al. 1997). This product has been explored to use as a fortificant in the processing of several products, i.e., 10 % fish flour added to extrusion products and breads; 20 % added to biscuits and crackers, as well as 13 % added to jam.

3.1.3 Fish Meal for Feed

Fish meal is mainly used for the production of fish, shrimp, and livestock feeds. Indonesia's demand of fish meal is about 100,000–120,000 tons per year and 75,000–80,000 tons of that is imported. The processing capacity of Indonesian fishmeal factories is around 175,000 tons per year, but due to raw material supply constraints, they only operate at 25,000–50,000 tons capacity per year (Anonym 2012). The supply problem of raw material can be overcome if by-catch of shrimp trawl can be collected or landed and then used for fish meal processing. Fish meal factories should optimize the surplus of fish during the peak fishing season by properly managing the processing into fish meal. The basic principle of fish meal processing includes boiling, pressing, drying, and grinding (Arifuddin and Murtini 1993).

3.1.4 Fish Silage

Silage is a liquid product that is made from the addition of acids to fish, such as formic acid and propionic acid. Also, it could be produced biologically by using acid-producing bacteria (Kompiang 1977). Silage can be further processed into silage flour by drying (Yunizal 1985) or by adding filler, such as corn meal, prior to drying.

3.1.5 Traditional Products

Several traditional products, such as dried salted fish, moist fermented fish ("peda"), fermented rice-added fish ("bekasam"), fish sauce, and dried spiced fish ("dendeng"), can be produced from the by-catch of shrimp trawl. Those products have a unique flavor, which is able to increase the appetite of the consumer.

3.2 The Utilization of By-products from Fisheries Processing Industries

3.2.1 By-product of Shrimp Processing Industries

The amount of by-product from shrimp processing varies from 40 % to 80 % of raw material, depending on the shrimp species and the types of processed products. Traditionally, this by-product is processed into sticky shrimp extract ("petis"), fermented shrimp paste ("terasi"), and shrimp crackers. Previous research by Suparno and Nurcahya (1982) showed that the potential utilization of shrimp comb is for shrimp paste production. With the addition of 20 % tapioca flour and 30 % fat, consumer-preferred shrimp pastes are yielded.

Protein hydrolysates can be obtained from the hydrolysis of shrimp comb by using strong acid (6N hydrochloric acid) (Suparno and Susana 1984). Ariyani et al. (1986) suggested the use of shrimp comb for shrimp meal processing, while Ariyani and Buckle (1991) introduced the use of shrimp meal in the formula of both fish and shrimp feeds. The proximate compositions of shrimp meal processed using shrimp heads or skin are 35.90 % protein, 4.96 % fat, 9.40 % moisture, 29.7 % ash, and 20.04 % other substances (Basmal 1993).

Other than shrimp meal, Ariyani and Buckle (1991) also proposed the processing of silage from shrimp heads. Furthermore, a stable silage can be produced by using an 8 % mixture of formic and propionic acids at the ratio of 1:1.

Basmal (1993) reported the use of shrimp skin for chitin and chitosan production. Bastaman (1989) outlined the processing procedure of chitosan. Firstly, dried shrimp skin is deproteinated by using 3 % of sodium hydroxide at 80–85 °C for 30 min. After cooling, it is then drained and washed until neutral, followed by demineralization with 1.25N hydrochloric acid at 70–75 °C. Chitin is obtained after drying. Further deacetylation of chitin was carried out by using 50 % sodium hydroxide at 120 °C for 60 min and then drying, leading to the production of chitosan.

Chasanah (2010) offers an idea to produce chitooligosaccharide from chitin using chitonase. Indonesia has an abundance of shrimp waste, which can be used not only for raw material in the production of chitin and its derivates, but also for a source of chitin-degrading enzymes including chitonase. The Research and Development Center for Marine and Fisheries Product Processing and Biotechnology (RDCMFPPB) has a collection of potential chitin-degrading microbes for producing functional chitooligosaccharides for food, pharmaceutical, and biocontrol applications.

Astuti (1996) produced artificial flavoring from shrimp heads by extracting them with water (1:2, w/v) at 121 °C for 2 h to obtain shrimp filtrate. It is then added with sodium proteinate and 40 % maltodextrin as filler, followed by spray drying. Pyrazine compounds are assumed to contribute to the formation of the flavor.

3.2.2 By-product from Fish Canning

Sardine canning yields heads, tails, fins, bones, guts, and rejected sardine as by-product. Meanwhile, by-product produced by tuna and mackerel canning consist of heads, tails, fins, and red meat. They are usually further processed for fish meal, whereas red meat is used for pet food.

Blue crab canning produces used water from the pasteurization process containing 0.67 % protein, 0.12 % fat, 0.33 % ash, 98.76 % moisture, and 52 mg/l total suspended solid. Uju et al. (2009) studied the recovery and concentration of flavorings from the used water by a reverse osmosis membrane. An approximate composition of concentrated flavorings is obtained as 1.2 % protein, 0.21 % fat, 0.33 % ash, and 97.21 % moisture.

3.2.3 By-product from Tuna Loin Processing

Heads, tails, bones, red meat, and skin are produced as by-products in tuna loin industries. Heads, tails, bones, and red meat can be processed into fish meal, while skin can be further processed into tanned skin by using 5 % chrome solution (Herawati 1996). Moreover, this tanned tuna skin can be used to produce bags, shoes, and wallets. Red meat has been developed to be used for making fish spread.

Tazwir et al. (2009) studied the use of tuna bones as raw material in gelatin production. Principally, the processing steps of gelatin are degreasing, washing, soaking in NaOH solution, soaking in HCl solution, extraction, filtration, evaporation, and drying. Gelatin which is processed using 0.4 % NaOH as the soaking solution results in a product with the best properties, i.e., 8.37 % yield, 3.27–3.37 cPs viscosity, 5.03 pH, and 1.57.8 g Bloom gel strength.

Ikasari et al. (2011) utilized trimmed tuna meat from loin processing to produce fermented fish sausage. A mixture of *Lactobacillus plantarum* and *L. fermentum* are added to the dough as a starter culture to accelerate the fermentation process and to improve sausage properties. The approximate composition of the sausage was 54–58 % moisture, 3.54–3.85 % ash, 7.97–12.92 % fat, and 13.65–18.39 % protein.

3.2.4 By-product from Red Snapper Processing

Fresh heads by-product from red snapper processing are usually sold directly to the market, whereas meat still attached to the bones can be processed into fish balls and fish sausages. Fish meal, on the other hand, is obtained from the processing of heads, tails, bones, fins, guts, and skin. Similar to that of tuna loin, according to Tambunan (1993a), skin from red snapper can also be used to produce a qualified tanned skin by using 10 % chrome tanning solution.

3.2.5 By-product from Frog Leg Processing

By-product from frog leg industries can reach up to 70 % of the whole frog (Ariyani et al. 1984). Research on the use of this by-product has focused on the processing of frog meal and silage. Ariyani (1993) produced frog meal from frog leg by-product through the following processing steps: boiling, pressing, drying I, pelleting, drying II, and grinding. The approximate composition of frog meal was 8.25 % moisture, 61.26 % protein, 11.29 % fat, and 16.37 % ash.

Murtini et al. (1984) produced silage from the by-product of frog leg processing by using lactic acid bacteria from several sources and added molasses as the carbohydrate source. Furthermore, Rabegnatar et al. (1988) used frog silage for shrimp feed. It was shown that no negative effects were found in the use of the silage on the growth of giant freshwater prawn (*Macrobrachium rosenbergii*).

Frog skin has the potential to be processed into tanned skin, especially due to its unique characteristics. It can also be used to make skin crackers, although production is hampered by limitations of the market.

3.2.6 By-product from Freshwater Fish Processing

Freshwater fish is usually marketed as live and fresh fish. However, if the processing industry of freshwater fish is developed, by-products such as heads, scales, guts, bones, and tails are expected to be generated from fish canning, smoking, drying, and other value-added product processing activities. To anticipate this, the processing of by-products from common carp, Nile tilapia, and tilapia can be used to produce fish meal and silage (Ariyani et al. 1986a, b). Both products can be further processed into fish and shrimp feeds. Feeding trials on common carp and giant freshwater prawn showed that the use of feed produced from Nile tilapia meal leads to higher growth rates compared to controls.

3.2.7 By-product from Traditional Products Processing

Traditional industries produce a small quantity of by-products. It is normally buried or disposed into the sea or rivers as waste that contains heads, guts, bones, scales, tails, and gills.

In the North Sulawesi, there is a traditional processing practice, i.e., smoked skipjack called *cakalang fufu*, in which no waste is generated. Prior to smoking, skipjack is eviscerated to remove the guts. Skipjack flesh is then smoked to produce

Table 3.1 Chemical and physical analyses as well as visual observation of fish oil from canned sardine and fish meal processing at Muncar and Negara (Indonesia)

Analysis	Canned fish processing	Fish meal processing	
		Whole fish	Canning by-product
FFA (% oleic acid)	0.06–1.15	0.08–55.68	6.99–25.72
Absorbance	0.22–0.48	1.45–2.56	1.34–2.29
Visual color	Yellow	Orange-blackish brown	Reddish brown-dark brown
Fatty acids (relative %)			
Omega-3	23.7–27.2	20.6–29.5	25.1–26.5
EPA	15.4–17.6	9.2–20.1	15.2–17.2
DHA	4.9–6.0	3.5–12.2	5.8–6.0

Source: Irianto (1992)

cakalang fufu, whereas the guts are fermented with salt addition to prepare *bekasang* and also steamed with spices to make *woku* (Wudianto et al. 1996).

According to Nurhayati and Peranginangin (2009), fish heads, fins, bones, scales, and skins from fish canning and filleting industries can be processed into collagen having high economic value. Collagen can be found in connective tissues in skin, tendon, skeleton, and cartilage. Dissolving non-collagen protein, mineral, and fat is necessary to simplify the process of collagen extraction. Generally, the extraction of collagen is conducted in acidic conditions. However, the use of pepsin in the extraction process may increase the yield.

3.3 *The Utilization of By-products from Secondary Products*

A secondary product that attracts various interests is fish oil from the process of canned fish and fish meal. Fish oil contains omega-3 fatty acids that play significant roles on the development of the human brain and have benefits to reduce the risk of degenerative diseases (Irianto 1992). The quality of fish oil depends on the type of processing practices generating the secondary products and the raw material used, as shown in Table 3.1. Chemical and physical analyses showed that oil from fish meal processing required further quality improvement by reducing the free fatty acids content, as well as improving its color and odor performance.

Degumming, neutralizing, washing, and bleaching by applying the alkali refining method can be carried out to improve the performance of fish oil. Moreover, fish oil is widely applicable for pharmaceutical, feed, food, and non-food industries (Irianto 1995).

3.3.1 Fish Oil in Pharmaceutical Industries

Pharmaceutical industries use fish oil in the form of omega-3 fatty acids concentrate that can be produced by means of the urea crystallization method. Yongmanitchai and Ward (1989) informed the use of supercritical fluid carbon dioxide to concentrate omega-3 fatty acids. However, this method is cost-inefficient when applied in the industries.

A research on the use of enzyme catalyst has been conducted to produce triglycerides that are rich in omega-3 fatty acids. Basically, fish oil and omega-3 fatty acids are mixed and then lipase enzyme is added to catalyze the acidolysis process.

3.3.2 Fish Oil in Food Industries

In food industries, fish oil can be used mainly for two purposes, i.e., to replace vegetable oil and animal fat, as well as to improve the nutritional value of food products. Research on the use of fish oil in food products has been carried out, especially for the production of sausage (Irianto et al. 1996), canned fish (Irianto 1992), and mayonnaise (Putri 1995).

The hydrogenation process at several degrees of homogenization inducing physical and chemical changes in fish oil may result in the various characteristics of fish oil, thus, a wider application of fish oil can be explored. Other food products which can be processed from fish oil are margarine, table spread, biscuit shortening, pastry fat, bread fat, emulsified shortening, biscuit filling, icing shortening, and salad oil (Bimbo 1989a). Barlow et al. (1990) developed fish spread, peanut butter, coleslaw, yoghurt, and salami using fish oil as one of the ingredients.

3.3.3 Fish Oil in Feed Industries

Fish oil is a good calorie source and growth stimulant for livestock. A homologue of linoleic acid at high concentration is responsible for the growth stimulant characteristic in fish oil. Fish oil added to feed should be fresh, because oxidized fish oil would be toxic. Fish oil has been added into animal and fish feeds, such as feeds for laying hens, broilers, shrimp, and fish. The addition of fish oil in hens feed could enhance the content of omega-3 in eggs and meat, as well as improve their immune system (Bimbo and Crowther 1992).

3.3.4 Fish Oil in Non-food Industries

Fish oil is used in non-food industries to produce elastic and long polymers due to its uniqueness and high unsaturation degrees of fatty acids. This unique composition causes fish oil to have flexible applications. Fish oil-based non-food products that have been developed are fatty acid products and their derivatives, with applications such as detergents, tanning oils, protective coatings in varnish and paint, lubricant oils, plastics, pesticides, fungicides, and polyurethane foam (Bimbo 1989b).

3.4 *Shark and Rays Utilization*

3.4.1 Shark

Sharks can be captured purposefully or otherwise. Those which are accidentally captured are by-products from other fishing activities. Meanwhile, for those which are purposefully captured, their fins are the main target. The utilization efforts of sharks have been conducted as follows.

Shark meat. Shark meat has been used in the processing of dried salted fish and boiled salted fish ("*pindang*"). The main obstacle of shark utilization is its ammoniac odor and flavor originating from urea decomposition. Priono et al. (1986) has conducted an effort on the reduction of urea content in shark meat by boiling in 2.5 % potassium hydroxide solution for 35 min. This method was able to reduce the urea content by up to 70 %. Washing with cold running water (8–10 °C) may reduce the urea content by up to 58 %. Soaking in 5 % acetic acid solution for 36 h could decrease its urea content by up to 80 %; however, this method may affect the meat structure.

Furthermore, Yunizal et al. (1984) found out that heating shark meat by using high-temperature steam for 90 min could reduce the levels of urea by up to 90 %, whereas Nasran et al. (1986) suggested that washing minced meat with cold water for five times may decrease the urea content of shark meat by up to 95 %. Shark meat has been investigated for use as dried spiced fish (Nasran 1993), shredded fish (Fawzya 1993a), fish balls (Fawzya 1993b), fish sausage (Irianto 1993a), and dried salted fish (Irianto 1993b).

Skin. Research on the tanning process of shark skin has been conducted intensively (Haq 1993). Chrome tanning method with 4 % syntan addition is respected as the best treatment that has been employed to obtain a qualified tanned shark skin. Tanned skins from shark have been introduced to make bags, shoes, and wallets. Furthermore, these products have been disseminated to craftsmen in Jakarta, Bogor, as well as Bandung and received positive feedback. Meanwhile, shark skin crackers have been produced by a small-scale processor in Pelabuhan Ratu, West Java.

Liver. Shark liver oil has been used as a source of squalene, vitamin A, as well as vitamin D and marketed worldwide. Shark liver oil could be extracted by means of boiling, steaming, acid or alkali cooking, rendering, and silage. The last method tends to produce a lower yield of oil but a higher content of vitamin A (Yunizal et al. 1983). Furthermore, alkali cooking produces oil with higher squalene content compared to other methods, i.e., boiling, rendering as well as the chemical and biological silage process (Yunizal and Nasran 1984).

3.4.2 Rays

Rays meat has been used for salted and smoked fish products. The by-products generated from processing activities are skin, bones, and guts. Fishermen at Muara Angke, Jakarta, have used ray's skin for the manufacture of artificial shark fin strings called as "*hisits*". Tambunan (1993b) has developed the storage and tanning method of rays' skin. The resulting tanned skin has an attractive surface appearance and is used in the production of bags and wallets. Meanwhile, its cartilage is used in wood glue (Embun 1995).

Basmal et al. (1995) processed a mixture of viscera, head, and trimmed meat of rays into silage by the addition of 4.5 % (w/w) formic acid. The silage obtained has a solid and liquid ratio of 40:60 %, while the pH and non-protein nitrogen content of the silage was 3.75 and 2.32 mg% N, respectively.

4 Challenges

According to Irianto and Giyatmi (2004) the use of by-catch of shrimp trawl is a dilemmatic issue because the design and construction of trawl vessels is generally compact. Space inside the vessels is very effectively used for the operational purposes of capturing, handling, and freezing the shrimp. Facilities for catch handling and vessel crew movements are, in fact, specially designed to handle shrimp, not for by-catch.

The great distance between the fishing ground and landing area, as well as unpredictable weather and ocean waves are other challenges that hamper the collection of by-catch for further processing and utilization. Processing industries are usually not paying proper attention to by-products generated from their activities, thus, no preservation efforts, such as freezing, are made. Consequently, these by-products are facing deterioration of freshness or even decomposition. This fact further complicates the challenge to obtain processed products with acceptable quality.

Similar problems also arise when it comes to the processing of fish oils that are categorized as secondary products. Despite the fact that the benefits of fish oil in pharmaceuticals have been widely known, the quality of produced and marketed fish oil is still lower than the expectation. This is mainly caused by the low quality of raw materials used for fishmeal processing generating fish oil as a secondary product. Therefore, in the near future, fish oil needs to be shifted into main products and fish meal as a secondary product. However, a special incentive and market as well as a better fish oil price need to be created in order to implement this idea.

Generally, processing industries are located in remote areas; as a result, it is difficult to collect by-products from those areas. Moreover, due to its characteristics and forms, by-products consisting of visceral, heads, fins, bones, and tails need to be adequately and cautiously transported in order to avoid decomposition as well as disturbance to the surroundings.

References

Anonymous (2012) Limited local fish meal, rampant imports. TROBOS Aqua 1(2):18–21, in Indonesian

Arifuddin R, Murtini JT (1993) Fish silage. In: Suparno, Nasran S, Setiabudi E (eds) Compilation of research results on fisheries post-harvest. Puslitbang Perikanan, Jakarta, pp 149–152, in Indonesian

Ariyani F (1993) Frog waste meal. In: Suparno, Nasran S, Setiabudi E (eds) Compilation of research results on fisheries post-harvest. Puslitbang Perikanan, Jakarta, pp 160–162, in Indonesian

Ariyani F, Buckle KA (1991) Ensiling of prawn heads. ASEAN Food J 6(2):58–63

Ariyani F, Haq N, Putro S (1984) Utilization of frog waste for feed. Lap Pen Teknol Perik 36:1–7, in Indonesian

Ariyani F, Irianto HE, Asastyasih M (1986a) Fresh water fish waste utilization as meal. J Pen Pasca Panen Perik 53:17–26, in Indonesian

Ariyani F, Murdinah, Putro S (1986b) Feeding trials using feeds supplemented with fish meals and silages. Proceedings of the first ASEAN workshop on fish and fish waste processing and utilization, Jakarta, 22–24 Oct 1986, pp 292–299

Astuti S (1996) Studies on the processing of shrimp flavourings from by products of frozen shrimp industry. Sarjana thesis, Faculty of Agricultural Technology, Bogor Agricultural University, Bogor, in Indonesian

Barlow SM, Young FKV, Duthie IF (1990) Nutritional recommendations for n-3 polyunsaturated fatty acids and the challenge to the food industry. Proc Nutr Soc 49:13–21

Basmal J (1993) Extraction of chitin – chitosan from shrimp shells. In: Suparno, Nasran S, Setiabudi E (eds) Compilation of research results on fisheries post-harvest. Puslitbang Perikanan, Jakarta, pp 184–186, in Indonesian

Basmal J, Murtini JT, Tazwir, Indriati N (1995) Effect of formic acid concentration on silage processing from waste of rays (*Trigon* sp.). Jurnal Pen Pasca Panen Perikanan 84:1–7, in Indonesian

Bastaman S (1989) Degradation and extraction of chitin and chitosan from shells of prawn *(Nephrops norvegicus)*. Warta IHP 6(2):1–8, in Indonesian

Bimbo AP (1989a) Fish oils: past and present food uses. J Am Oil Chem Soc 66(12):1717–1726

Bimbo AP (1989b) Technology of production and industrial utilization of marine oils. In: Ackman RG (ed) Marine biogenic lipids, fats and oils. CRC Press, Boca Raton, pp 401–431

Bimbo AP, Crowther IN (1992) Fish meal and oil: current uses. J Am Oil Chem Soc 69(3):221–227

Carita (2004) Studies on yields of various processed tiger shrimp (*Penaeus monodon*) of each size. Sarjana thesis, Faculty of Fisheries and Marine Sciences, Bogor Agricultural University, Bogor, in Indonesian

Chasanah E (2010) Development of enzymatically produced chitooligosachharide from shrimp industrial waste. Squalen 5(2):44–50, in Indonesian

Embun RS (1995) Studies on the effects of acetic acid on yield and quality of fish glue from rays (*Trygon* spp) bones. Faculty of Agricultural Technology, Bogor Agricultural University, Bogor, in Indonesian

Fawzya YN (1993a) Processing of shark meat ball. In: Suparno, Nasran S, Setiabudi E (eds) Compilation of research results on fisheries post-harvest. Puslitbang Perikanan, Jakarta, pp 248–249, in Indonesian

Fawzya YN (1993b) Processing of shredded shark meat. In: Suparno, Nasran S, Setiabudi E (eds) Compilation of research results on fisheries post-harvest. Puslitbang Perikanan, Jakarta, pp 256–257, in Indonesian

Fawzya YN, Irianto HE (1997) Food fortification by using nutrition source from fish for increasing fish consumption and health. Warta Penelitian Perikanan Indones III 1:2–6, in Indonesian

Fawzya YN, Rufina M, Sugiyono, Irianto HE (1997) Quality of extruded food product made from corn, rice and fish flour mixture. Summary report and papers presented at the tenth session of the working party on fish technology and marketing, FAO fisheries report no. 563, Colombo 4–7 June 1996, pp 265–269

Haq N (1993) Tanning of shark skin. In: Suparno, Nasran S, Setiabudi E (eds) Compilation of research results on fisheries post-harvest. Puslitbang Perikanan, Jakarta, pp 240–242, in Indonesian

Herawati SY (1996) Effects of Cr_20_3 concentration on the quality of tanned tuna *(Thunnus albacares)* skin. Sarjana thesis, Faculty of Fisheries, Bogor Agricultural University, Bogor, in Indonesian

Ikasari D, Syamdidi, Suryaningrum TD (2011) The use of lactic acid bacteria and beef fat in the processing of fermented sausage made of tuna waste. Jurnal Pascapanen dan Bioteknologi Kelautan dan Perikanan 6(2):101–110, in Indonesian

Irianto HE (1992) Fish oil: refining, stability and its use in canned fish for the Indonesian market. PhD thesis, Massey University, New Zealand

Irianto HE (1993a) Processing of shark meat sausage. In: Suparno, Nasran S, Setiabudi E (eds) Compilation of research results on fisheries post-harvest. Puslitbang Perikanan, Jakarta, pp 252–253, in Indonesian

Irianto HE (1993b) Processing of dried salted shark meat. In: Suparno, Nasran S, Setiabudi E (eds) Compilation of research results on fisheries post-harvest. Puslitbang Perikanan, Jakarta, pp 258–259, in Indonesian

Irianto HE (1995) Utilization of fish oil for pharmaceutical, food, feed, and non-food. Warta Perikanan Laut 1(2):10–19, in Indonesian

Irianto HE, Giyatmi (2004) Utilization of fisheries by-products. Jurnal Widya Kesehatan dan Lingkungan VI 2:136–147, in Indonesian

Irianto HE, Fawzya YN, Sugiyono, Tentri J, dan Ibrahim B (1996) Utilization of fish oil in chicken and beef sausage production. Paper presented at the tenth session APFIC working party on fish technology and marketing, Colombo, 4–7 June 1996

Kompiang IP (1977) Nutritional value of fish silage processed with the addition of formic acid. J Pen Teknol Perik 2:34–39

Ministry of Marine Affairs and Fisheries (2011) Marine and fisheries statistics 2009. Ministry of Marine Affairs and Fisheries, Jakarta

Murtini JT, Budhiyatni S, Yunizal, Hanafiah TAR (1984) Processing of silage from frog waste using biological method. Lap Pen Teknol Perik 30:1–8, in Indonesian

Nasran S (1993) Processing of dried spiced shark meat. In: Suparno, Nasran S, Setiabudi E (eds) Compilation of research results on fisheries post-harvest. Puslitbang Perikanan, Jakarta, pp 254–255, in Indonesian

Nasran S, Irianto HE (1988) Studies on the utilization of by-catch of shrimp trawl in Arafura. Proceeding of seminar on agricultural posh-harvest. Bogor 1–2 Feb 1988, Agency for Agricultural Research and Development, Jakarta, pp 29–37, in Indonesian

Nasran S, Irianto HE, Fawzya YN (1986) Efforts of urea content reduction in shark through mincing and washing for fish ball processing. Bull Limbah Pangan II 2:144–148, in Indonesian

Nurhayati, Peranginangin R (2009) The prospect of fishery waste as collagen source. Squalen 4(3):83–92, in Indonesian

Priono B, Suparno, Sudrajat Y, Haq N (1986) Physical and chemical treatments for urea content reduction in shark meat. Lap Pen Teknol Perik 35:19–23, in Indonesian

Putri JWS (1995) Effects on antioxidant addition and vacuum condition on the quality of sardine (*Sardinella longiceps*) oil as raw material for mayonnaise making. Sarjana thesis, Faculty of Fisheries, Bogor Agricultural University, in Indonesian

Rabegnatar LNS, Hadie LE, Hadie W, Heruwati ES (1988) Effects of frog waste silage as substitute fish meal in feeds on the production and growth of giant shrimp *(Macrobrachium rosenbergii)*. Proceeding of seminar on agricultural posh-harvest, Bogor 1–2 Feb 1988, Agency for Agricultural Research and Development, Jakarta, pp l85–204, in Indonesian

Suparno, Nurcahya SF (1982) Utilization of shrimp waste: I. Shrimp paste processing. Lap Pen Teknol Perik 28:1–7, in Indonesian

Suparno, Susana (1984) Utilization of shrimp waste: II. Processing of protein hydrolysate using acid hydrolysis. Lap Pen Teknol Perik 28:9–16, in Indonesian

Tambunan PR (1993a) Tanning of red snapper skin and similar type of fish. In: Suparno, Nasran S, Setiabudi E (eds) Compilation of research results on fisheries post-harvest. Puslitbang Perikanan, Jakarta, pp 230–236, in Indonesian

Tambunan PR (1993b) Tanning of rays skin. In: Suparno, Nasran S, Setiabudi E (eds) Compilation of research results on fisheries post-harvest. Puslitbang Perikanan, Jakarta, pp 223–229, in Indonesian

Tazwir, Amiruldin M, Kusumawati R (2009) Effects of tuna (*Thunnus albacares*) bone soaking in sodium hydroxide on the quality of gelatin produced. Jurnal Pascapanen dan Bioteknologi Kelautan dan Perikanan 4(1):29–36, in Indonesian

Uju, Ibrahim B, Trilaksani W, Nurhayati T, Purbosari N (2009) Recovery and concentration of flavorings from blue crab processing wastewater using reverse osmosis. Jurnal Pascapanen dan Bioteknologi Kelautan dan Perikanan 4(2):177–186, in Indonesian

Wudianto, Naamin N, Susanto K, Irianto HE, Pranowo SA (1996) Survey of fisheries and socio-economic in MCMA Karakelong Manado, North Sulawesi. Agency for Agricultural Research and Development, Jakarta, in Indonesian

Yongmanitchai W, Ward OP (1989) Omega-3 fatty acids: alternative sources of production. Process Biochem 1989(8):117–125

Yunizal (1985) Technology for silage processing. In: Suparno, Nasran S, Setiabudi E (eds) Compilation of research results on fisheries post-harvest. Puslitbang Perikanan, Jakarta, pp 117–125, in Indonesian

Yunizal, Nasran S (1984) Preliminary studies on squalene content of shark liver oil. Lap Pen Teknol Perik 32:17–21, in Indonesian

Yunizal, Nasran S, Murtini JT (1983) Studies on extraction methods for shark liver oil. Lap Pen Teknol Perik 22:35–37, in Indonesian

Yunizal, Suparno, Nasran S (1984) Efforts to reduce urea content in shark meat using boiling with superheated steam. Lap Pen Teknol Perik 28:27–30, in Indonesian