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Viewpoint

Challenges and realistic opportunities in the use of by-products from processing of fish and shellfish☆

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By-products may constitute as much as 70% of fish and shellfish after industrial processing and much focus has been on converting these into commercial products. The aim of this paper is therefore to evaluate important challenges and to consider the most realistic options in the use of by-products. Certain by-products like heads, frames and off-cuts from filleting of fish may be used directly as food while by-products in general can be transformed into feed ingredients e.g. for the expanding aquaculture industry. Although sometimes suggested, it is unlikely that by-products can be used to any large extent to produce high-priced products.

Introduction

The total capture of wild fish has been around 90 million tonnes (Mt) each year during the last 3 decades while the aquaculture production of fish has shown an average annual increase of 8–9% in the same period. In 2010, 68.4 Mt (76%) of the wild caught fish was used directly for human consumption while 15 Mt (17%) was used for fishmeal and oil production. The total amount of farmed fish for human consumption, which also includes other aquatic animals like crustaceans and molluscs, was 59.9 Mt in 2010 (FAO, 2012). The use of the term "human consumption" is not strictly correct since fish are processed to different degrees before being purchased or eaten by consumers. Depending on the market, some species are not processed at all, while others, especially larger fish, are often extensively transformed to fillets or parts of fillets before reaching the end user. By-products are mainly a result of processing fish from industrial scale fisheries and aquaculture. In small scale fisheries, which mostly occur in developing countries, fish is often not processed at all before being offered to the consumer. In small scale fisheries in other countries like Spain, Portugal and Norway, the fish may be processed at sea and the by-products may commonly be discarded or the round fish may be brought ashore and subsequently processed in plants making the by-products available for useful purposes.

In many markets, particularly in developed countries, fish fillets or parts of the fillets are regarded as convenience products since no further processing is required before preparing a meal. Lack of time or skills to eviscerate or fillet fish at home have in recent years resulted in higher demands for convenience fish products in these markets (Gofton, 1995; Olsen, Scholderer, Brunsø, & Verbeke, 2007). Processing earlier in the supply chain is therefore now more common, making larger amounts of by-products available for other uses.

Fish may be processed by bleeding, gutting, beheading, filleting, skinning and trimming before being bought by consumers. The fillet yield in industrial processing is species-dependent and is often in the range of 30–50% (Gildberg, 2002; Rustad, Storrø, & Slizyte, 2011). The remains of the fish are commonly called by-products and if treated correctly, classified as category 3 by-products according to EU regulation, meaning parts of animals that are fit for, but not intended for human consumption (EC No 1774/2002). By-products were traditionally considered to be of low value or as a problem and were used as feed for farmed animals, as fertilizers or discarded. Improved utilization of by-products has for several reasons, including

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environmental, economic and the possibilities to produce more food from limited resources, been much focused in the last couple of decades (FAO, 2012).

In addition to the use of by-products directly as human food or for producing preserved feed ingredients like fishmeal, fish protein concentrates and fish oil, much focus has been to transform this biomass into isolated functional or biologically active (bioactive) components, so-called value-added products, to be used for example as dietary supplements (nutraceuticals), as processing aids and even as pharmaceutical products. As in all kinds of production, transformation of by-products into commercial products must be market-driven or create a product that has a realistic possibility of being sold with an economic margin within a reasonable time period.

The aim of this paper is to evaluate challenges and possibilities in producing commercially viable products from by-products obtained after processing fish. Particular emphasis will be on how more of the fish can be used for human consumption.

Recovery of by-products

Fish by-products especially when containing viscera deteriorate very rapidly, and it is therefore important that they are preserved as soon as possible after being produced. This is not always possible due for example to inadequate processing facilities or limited volumes making recovery of the by-products non-profitable. Modern industrial processing is usually carried out in a stepwise manner, creating separate streams of by-products that can be taken care of and diversified into different end products. This may be carried out in land-based processing facilities, but is more of a challenge if the fish are processed at sea, mainly due to lack of space and not enough manpower on-board most fishing vessels. When fish are gutted at sea, the viscera are often discarded since available ice, refrigeration or freezing facilities are used for the most valuable product; the gutted fish. The same is often the case with heads and frames if the fish is further processed to fillets on-board. Higher yearly quotas or more fishing days to fishing vessels which do not discard by-products at sea might be one way to encourage landings of by-products. Some species like Atlantic cod (*Gadus morhua*) and Argentine hake (*Merluccius hubbsi*) caught in coastal waters, are often brought ashore fresh for processing, enabling complete the utilization of the by-products (Ramirez, 2013; Rustad *et al*., 2011).

In Norway, about 200,000 tonnes of by-products from wild fish, caught and processed at the high seas, were dumped, while all of the by-products from processing of farmed fish were utilized in 2011 (Ramirez, 2013). Larger trawlers can have facilities for industrial processing on-board and the solid by-products are often turned into fishmeal in modern vessels, most commonly by a simplified process to a so-called press cake meal. The press juice containing soluble nutrients and lipids is often discarded at sea.

By-products as food

By-products containing meat such as heads, frames and belly flaps, and parts of the viscera like liver and roe are of good nutritional value, containing high quality proteins and lipids with long-chain omega-3 fatty acids. In addition, they are also often rich in micronutrients like vitamins A, D, riboflavin and niacin as well as minerals such as iron, zinc, selenium and iodine. An essential step in up-grading by-products to co-products for human consumption is that systems such as Good Manufacturing Practice (GMP) and the Hazard Analysis and Critical Control Point (HACCP) used in food production, are applied. This is currently not always possible due to unsuitable processing facilities, lack of relevant equipment or labour costs.

One example where good progress is being made in turning traditional by-products into food for humans is in the tuna processing industry. The harvest of tuna species is one of the most important global fisheries with catches of more than 4 Mt annually (Globefish, 2012). Most of the tuna is processed to canned or loin products using the light muscle only, resulting in as much 60 or even 70% of by-products (Herpandi, Rosma, & Wan Nadiah, 2011; Sultanbawa & Aksnes, 2006). These include viscera, head, backbone, skin, belly flaps and dark muscle and have traditionally been transformed into fertilizers and fishmeal which are often stated to be low-value products (Herpandi *et al*., 2011; Kim & Mendis, 2006). The dark muscle (dark meat) present in relatively large amounts in tuna may however be of even better nutritional quality than the light muscle due to the higher content of long-chain omega-3 fatty acid, certain vitamins and metals like iron and copper (Dulavik, Sørensen, Barstad, Horvli, & Olsen, 1998; Sánchez-Zapata *et al*., 2011). However, the large content of lipids and transition metals makes the dark meat especially prone to oxidation and it should therefore be preserved under antioxidative conditions like canning. This is actually done in the Philippines where canned dark tuna meat is exported. In addition, several other value-added co-products derived from tuna processing are processed and sold for human consumption in the domestic market. Some examples are traditional by-products like heads, tails, livers, hearts and roes (Sentina, 2013). A recent study has shown that traditional dishes with dried and milled tuna frames included were very well accepted by school children in Ghana (Glover-Amengor *et al*., 2012).

Iceland and Norway have long traditions in utilizing by-products from processing of wild Atlantic cod for human consumption. Cod heads are often dried and exported to Africa while chin medallions and tongues obtained from larger heads are highly regarded domestically by many people (Rustad *et al*., 2011). In 2011, 11,540 and 3100 tonnes of dried cod heads were exported respectively from Iceland (G. Stefánsson, Matis, Iceland, pers. comm.) and Norway (L. Martinussen, Norwegian Seafood Council, Norway, pers. comm.). Roes from sexually maturing cod are canned,