FISH PROCESSING INDUSTRY MODERNIZATION AND CO-EXTRUSION METHOD IN FISH PRODUCT ASSORTMENT DIVERSIFICATION

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Abstract. In Latvia and across the world, modernisation of fish processing industry has been quite slow. The processing methods remain significantly based on the traditional approach and often cannot supply products which are demanded by a modern consumer. The need for innovative solutions is shaped by the highly increased pace of a daily life and changing eating habits, especially in big cities, which created an upward trend in demand for diversely processed value added, convenient, fish-based products. From the producers' perspective, innovative fish processing provides an access to a value added production and profit increase. The paper aims to explore the potential of the co-extrusion method implementation in the fish processing industry. The scholarly arguments and empirical evidences advocate the importance of innovative techniques to the food processing arena, and particularly to the fish industry and represent the scientific background for the implemented project on an innovative fish-based product, *fish bites*, obtained by using the co-extrusion method. Commercialisation potential of the innovative method introduction to the expanding segment is also explored in the article.

Key words: co-extrusion method, fish processing, food industry, profit improvement.

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Introduction

One of the most important factors pushing fish processing industry modernisation is a reshaped eating behaviour associated with the rapid changes of a daily life tempo, especially in the Western world. This factor created a pronounced upward trend in demand for diversely processed value added, convenient food, nutritious snacks and semi-prepared dishes, including frozen food. In addition, the common habits of eating away from home has spurred the demand in the HORECA sector. The hotel, restaurant and catering sector is one of the fastest growing in Europe. In Latvia, this tendency is even more apparent because the sector itself is relatively new (Diedzina, 2004). This determined the expanding demand for food products diversification aimed at addressing the current needs of customers, especially in big cities.

Another associated tendency among customers is pursuing modern understanding of a healthy diet and routinely choosing healthier options, as well as demanding value for money. Consumers around the world increased consumption of fish and fish product in recent years due to recognition of their nutritional value (Wang et al., 2009). As described by Abramova (1997), for modern consumer the importance of products from hydrobionts, fish-based products in particular, is that they contain high value proteins of animal origin (content 16-20 %), fats - the only natural sources of unsaturated fatty acids, minerals, as well as group B vitamins, and, PP and A vitamins. Thus, there is wide scope to increase the consumption by developing value added products. For instance, there is a great demand for seafood based products, especially value added products, ready-to-eat convenience form, prominent among them is the group of battered and breaded products (Pagarkar et al., 2013). According to FAO (2017) projections, fish consumption will reach 177 tons by 2026 with more pronounced upward trends in developing nations compared to the developed world, where the decline in consumption trends will maintain. Due to fast population growth (2.3 % per annum during 2010-2030), total fish consumption will increase significantly, by 30 % until 2030 (The World Bank, 2013). For these purposes, fish based products is a promising option for assortment diversification given its steady demand increase.

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On the other hand, estimated production rise is marginal, which indicates the potential of innovative fish processing techniques in meeting market demand. The fish processing industry is constantly exploring new techniques to improve and increase the supply to meet the rising market demand for convenience products. Currently, many research on food products diversification are looking for the development of such products that combine both the notion of proper nutrition and address traditional consumer needs, as well as have a strong economic rationale.

As noted by Vanshin (2011), one of the main directions of the technological processes intensification in the food industry is the change in the physicochemical properties of raw materials when exposed. Co-extrusion is a progressive method of obtaining high-quality and balanced food products, the main advantages of which are the flexibility of its technological schemes, high productivity and compactness of equipment, process continuity, low production costs. Today, the use of the co-extrusion technology is common across such segments of food manufacturing as meat processing and confectionary production due to a number of advantages over traditional food and feed processing methods. Fish-based engineered food items also have significant health and economic implications, *inter alia*, high productivity and quality, lower production cost, product shape, energy efficiency, new food items, no effluents. As a result of the project, the efficiency of the co-extrusion technique has been demonstrated for fish product assortment diversification. Namely, a nutritious snack *fish bites* has been developed and introduced to production as well as to the market. Nonetheless, it should be noted that principles of modelling products with predetermined indicators of nutritional value and specific technological properties based on fish raw materials are insufficiently studied and needs further development and concretization.

Fish processing industry modernization and profit increase driven by assortment expand

The modernization of fish processing technologies mainly refers to up-gradation of existing technologies, assurance of quality, and diversification; thus, there has been a rising demand for fish/fish-based convenience food items in ready-to-eat or ready to-cook forms. Another factor refers to value addition activities that have generated important international conversations within the food manufacturing industry, including the fish processing sector, primarily in light of major opportunities to earn foreign exchange. Value addition is a good approach to increase the profitability of the fish processing sector, which presently is focused on quality assurance. Although product range diversification into niche offerings has begun, it has not yet achieved critical mass.

Despite being a driver of income increase, product assortment diversification in the fish processing segment is particularly difficult because a number of factors must be considered before making any decision, potentially more pronounced than in other food industry. Some major market participants have explored product diversification options by using the same fish species. However, a vast majority of companies are reluctant to operate substantial changes because these require investment, studies, and risks. In this sector, market diversification needs to be approached carefully in the sense that businesses must examine consumer preferences and taste adaptation, and consequently adjust the current supply or develop new products.

Starting from the seminal work of Markowitz (1952), originally focused on portfolio analyses in the *securities market*, scholars have extended the theory to various assets such as agricultural crops and natural resources, and proved its applicability to downstream market segments, including the food processing industry. By engineering a more diverse product portfolio, processors

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can achieve two goals. First, profits can be maximized via a larger array of production options, matched with the intrinsic features of the raw product. These companies would be positioned to modify the structure of output-products to best manage the risk and profitability related to the natural variability in fish characteristics; such a strategy can lead to profit growth and decrease the risks attached to seasonal volatility in the biological features of raw inputs.

Co-extrusion method potential in fish food industry

Fish, a raw material with a very sensitive market in fresh condition, can be efficiently used for co-extrusion. Fish minced meat is one of the most convenient products for combining with other raw materials, which makes it possible to obtain a diverse range of finished products with good taste qualities (Dementieva, 2005). To prepare forcemeat usually is used fish which, for certain reasons, is unsuitable for canned products requiring defined pieces or carcasses (Pankina, 2007). At present, a large number of methods for processing minced fish meat have been developed: lobules of minced fish in tomato sauce, cabbage rolls, fish cutlets with vegetable garnish, various meatballs, etc. The sharp evolution of minced fish technology over the past decades is likely to make a significant contribution to the rising exploitation via value addition of sea varieties.

The two models that are becoming highly popular within the worldwide food processing arena, especially in the food and feed segments are extrusion and co-extrusion methods. For instance, in countries with a developed food industry, there has been a steady increase in the consumption of extruded food products. The statistics shows that in Europe the consumption is between 3 and 7 kg per year per person (Vanshin, 2011).

Rigorous analyses on the extrusion process that engineers new fish-based products can be traced back to the 1980s. Various scholars (e.g. Gogoi et al., 1996; Suknark et al., 2001) detailed the successful incorporation of fish into starch-based foods via extrusion techniques to deliver nutritious new products. Extrusion is a continuous process that combines heating a raw material above 100°C with a subsequent subjecting to increased pressure and forcing through one or more restricted openings (dies). Extrusion processes lead to granular or powdered raw material transformation into pieces of larger size. The examples of the technology implementation include low-density ready-to-eat products such as fish pastes, surimi, semi-moist and expanded pet food. This method has been exploited for fish product processing due to comparatively low producing costs and a wide variety of potential products that can be obtained (Gry, 1981; Fellows, 2009).

Co-extrusion process is an extrusion process aimed at obtaining a product combining two different textures: that is, two different materials are extruded to produce one combined product enabling a sweet, savoury or fruit centre filling to be added to the extrudate before it is shaped into pillows, tubes, bars or wafers. For example, a crispy cereal outer shell can be co-extruded together with sweet or salty stuffing. Coated food products can be obtained, for example, by co-extruding the shell material and the food material based on meat, fish, fruit or other vegetables through concentric conduits into the co-extruder, such that, at the coextruder outlet, the extruded food product is covered with a thin film of the shell material. Then the shell material is converted into a durable shell material by treating it with suitable chemicals (Wianecki, 2007).

In the fish industry, the co-extrusion method has not yet been widely implemented, however, there are several examples being found. Murray et al. (1980) produced co-extrudates from a combination of soy and fish proteins and explored the impact of source and protein level of processing components. The study highlighted that co-extrudates texture is highly influenced by

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both the ratio of protein to water and vegetable to fish protein, suggesting a significant potential to final product diversification by changing raw material combinations. However, as the authors mention, the sensory analysis indicated that the final product would probably be rejected by consumers because of too intense persistent fish flavour and odour, thus, further experiments are required. Gry (1981) work described a standard framework for the optimal co-extrusion of minced cod, and wheat and potato flour. Maga and Reddy (1985) underlined that the co-extrusion of rice flour and varying amounts of minced carp (10 %-35 %) led to a precooked product with no detectable odours with a shelf life of six months stored at room temperature.

Choudhury (1994) detailed the co-extrusion of pink salmon muscle and rice flour to obtain a new product. Years later, Choudhury et al. (1998) documented that the co-extrusion of fish mince with starchy components with the use of single and twin-screw extruders increased the nutritional value of products. Rhee et al. (2004) produced a snack food by applying the co-extrusion method to a blend of minced catfish, corn and soya flour, largely accepted by consumers, and argued that co-extrusion techniques diminish the distinct odour of fish.

Using of co-extrusion method for the innovative product, *fish bites*, allowed to produce restructured fish products with fillings, thus combining both the fish itself and the garnish/sauce. In contrast with the extrusion process, co-extrusion does not involve pressure or temperature impact, but rather a product moulding by forming. The organoleptic testings demonstrated that the product is quite welcomed by potential customers, indicating its potential.

Thus, given the versatility of the co-extrusion technique allowing a quick change of key parts, the innovative approach opens up a completely new niche in the fish processing sector. Nonetheless, despite co-extrusion technologies being widely used by the food processing sector, within the fisheries market these are still at an early stage (Surasani, 2016). Many scholars advocate for the development of sensorially acceptable fish-based co-extruded food items; however, some technical issues such as fish odour and flavour and oxidative changes need to be removed for the successful exploitation of the co-extrusion method. One of the main advantages of producing fish-based food products by the co-extrusion method is the savings due to the fact that the final product is obtained via single process. In addition, co-extrusion technology provides non-waste production and allows to significantly expand marketing opportunities along with a product range.

Commercialization potential

Co-extrusion techniques are used worldwide in the food processing industry to obtain new products with unique characteristics. This method enables the delivery of a myriad of co-extruded food items via the manipulation of structure and process variables. Given that within the fish market a large amount of fish catch is not used for human consumption because of a number of unattractive features, co-extrusion technologies, for instance, allow for the utilization of the fish mince/muscle recovered from such underutilized batches (Choudhury et al., 1996). On the other hand, the usage of high quality fish (i.e. cod) with no undermining features unfolds a new niche of superior quality range products addressing the demands of a modern consumer living in a high-pace environment.

The application of co-extrusion method to offer fish-based snacks and texturized protein has a vast commercial and economic potential, which has not been yet exploited at its full. For instance,

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practical evidences indicate that twin screw extruders are highly promising in the creation of snacks and other food-based items (Pagarkar et al., 2007).

The development of innovative products using cereal flours and fish mince improves the nutritional value of the final food item. The mixing of these via co-extrusion techniques delivers nutritionally balanced food items with various properties. In some regions, co-extrusion of fish with carbohydrate ingredients can also be largely accepted as finger snack foods or as products that need little preparation before consumption. These techniques increase the economic value of such fish catch.

On the retail market, the co-extruded fish-based products, including *fish bites*, provide an alternative for traditional and currently growing market of frozen semi-finished products like fishfingers, semi-prepared fish and meat dishes, etc. Conducted market research data (2017) show that, i.e. in store chain "Maxima" alone, in the Latvian market, the sales of the indicated product group amounted to more than 250t per year. According to Popluga et al. (2012) calculations, the market share of "Maxima" is approximately 20 %; other main retail chains ("Rimi", "Vesco", "Mego", "LaTS", "Elvi") constitute up to 50 % of the market together. Taking into account that co-extruded innovative fish-based products has not been extensively present on the market yet, but on the other hand there is a pronounced demand for this kind of products, the most realistic market share within 2 years is estimated at 15 % of the frozen semi-finished products segment. Based on these calculations, the company profit is expected to reach EUR 1.6 mln on the Latvian market and up to EUR 4.8 mln in the Baltics. Thus, the modernisation of fish processing industry, in particular, introduction of the innovative co-extrusion method, holds a significant economic potential.

Table 1

Economic potential of innovative fish-based products as substitutes for frozen semi-finished products in Latvia and across the Baltic region

Market	Consumption of frozen semi-prepared products, tonnes per year	Substitution tonnes (15 %)	Substitution items	Turnover, m EUR	Profit, m EUR
"Maxima", retail chain	250.62	37.59	4 26 965	€ 839 177.01	€ 266 907.22
Main retail chains, total	751.86	112.78	1 280 895	€ 2 517 531.02	€ 800 721.66
Market, total	1503.71	225.56	2 561 790	€ 5 035 062.05	€ 1 601 443.32
Baltic region (6.1 mln people), total	4 511.14	676.67	7 685 370	€ 15 105 186.15	€ 4 804 329.96

Source: authors' calculations based on the data of retail companies' websites, conducted market research

To the authors' knowledge, both on regional and on the global market there are no analogues for the products developed within the project. The co-extrusion method has not yet been implemented anywhere in the world for the production of preserved products and specifically for the production of HoReCa fish-based products. Structured products are much more complex in manufacturing, because it requires more advanced equipment, food additive systems (containing more than 15 substances). In addition, given that the raw material parameters are often changing both equipment and the additives should be adjusted accordingly. Nonetheless, the new product has already proved its ability to penetrate new unconventional market and offer a high profitability. Currently, it has been already successfully exported to Poland, Estonia and Netherlands and proved

its potential. The target markets include Scandinavian and Central European markets, as well as Asian markets. The demand for innovative fish-based snacks is on the rise particularly in developing nations, where fish-based snacks are commonly known as fish crackers (Suknark et al. 1998), more common across Asian consumers compared to American consumers. Co-extrusion technologies that enable the combination of various ingredients to develop new products can also serve the developing functional food markets (Pagarkar et al., 2007).

The scholarly arguments and empirical evidences advocating the importance of the co-extrusion technique to the food processing arena, and particularly to the fish industry detailed above represent the scientific background for the implemented project on an innovative fish-based product, *fish bites*, by using the co-extrusion method.

Conclusions

- 1) Food co-extrusion is a highly versatile technique used to develop convenient and nutritious food items with a peculiar taste and texture via combining two different products. Virtually it allows to produce an endless assortment of filled products. Commercially available co-extruded products are mainly found in confectionary and meat processing industries. The use of fish and fish portion within co-extrusion processes have not been yet so widespread, however, the existing evidence suggests that this approach implementation increases the nutritive parameters of such products and adds value to the fish catch of both premium and lower value.
- 2) Co-extruders enable the development of innovative food items of high nutritional importance. The ability of co-extruders to mix various ingredients to create novel products is essential in the creation of functional foods meeting the demands of contemporary customers, especially living in big cities in the western countries.
- 3) Co-extrusion represents a major avenue for new fish uses and increased consumption. Fish-based co-extruded products have an impressive marketing potential, but are yet to gain popularity across the world. The product developed within the project has demonstrated its exporting potential, however, much work is still needed in terms of developing appropriate types of foods based on different fish mince blends, eye-catching packages or market researches to achieve mass acceptance.

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