

INNOVATIVE STRUCTURED FISH MEAT PRODUCTS FROM BALTIC SPRAT (*SPRATTUS SPRATTUS BALTICUS*)

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Abstract

Fish is very important in the diet, providing complete protein, unsaturated ω 3 fatty acids, calcium, phosphorus and vitamin D. However, Baltic sprat (*Sprattus sprattus balticus*), one of the most abundant fish stocks in the Baltic Sea, is underutilised due to its small size. The aim of the study was to develop structured fish forcemeat using whole fish from the Baltic Sea small *Clupeiformes* fish for further use in finished and semi-finished fish products. The testing of fish as raw material and developed structured fish forcemeat showed that all parts of fish can be used in the production as valuable ingredients. Due to the textural properties of the structured fish forcemeat, the possibilities of using it in finished and semi-finished fish products is wide. A total of seven basic product groups – sausages, terrines, frozen semi-finished products, fish meatballs and other culinary preparations, dumplings, pies, pasta and ravioli – were developed. Products made from structured fish forcemeat have a high nutritional value, particularly with regards to protein content and amino acid profile.

Keywords: structured fish forcemeat, semi-finished products, nutritional value, processing

Introduction

Fish is an important source of complete protein, unsaturated fatty acids, minerals (Ca, P) and vitamins (A, D) in the diet (Tilami, Sampels, 2017). One of the main catch in the Baltic sea is Baltic sprat (*Sprattus sprattus balticus*) (Ministry of Agriculture (2017), often underutilised due to its small size. Such minerals as calcium and phosphorus are concentrated in fish cartilage, scales, tail and bones (Stanek et al., 2013), thus suggesting the use of whole fish for production of high value products.

As shown by Proskina et al. (2018), the catch quotas available to Latvia (set by Council Regulation (EU) 2016/1903) were decreased for cod (-57%), Baltic herring (-1%) and salmon (-10%), while a significant increase of 20% was given to sprats in 2017. Economic consideration is one of the main reasons why the replacement of structured cod mincemeat with structured forcemeat from small *Clupeiformes* fish caught in the Baltic sea should be studied (Proskina et al., 2018).

The replacement of structured white fish mincemeat with small clupeid fish would also allow to reduce the production of traditional canned sprats, export of which have decreased by almost 25% due to Russian import ban on EU products (Russian embargo..., 2019).

The aim of the study was to develop structured fish forcemeat using whole fish from the Baltic Sea small *Clupeiformes* fish for further use in finished and semi-finished fish products.

Materials and Methods

Raw materials

Baltic sprat (*Sprattus sprattus balticus*) in two thermal

conditions was provided by Piejura Ltd. for the preliminary research: chilled fish 12 hours after catch and frozen fish in a flash freezer.

Experimental design

The laboratories of Faculty of Food Technology, Latvia University of Life Sciences and Technologies were used for raw material testing and innovative product development and quality analyses.

The preliminary research was carried out to determine: a) the possibilities to use whole fish for the development of new products and b) the effect of freezing on fish quality. A total of three fish samples and two thermal conditions were tested: chilled and frozen whole sprats, headed and gutted sprats, and sprat heads. The main part of the research was to develop structured fish forcemeat recipe and test the possibilities for its applications in new product development.

Development of structured fish forcemeat

When developing structured fish forcemeat from whole fish, two opposite tasks must be completed. Firstly, fish must be homogenised to the level where fish structure is not completely destroyed and consumer can notice fish taste and texture, however, in this case, it is possible that fish bones and other undesirable fish parts are present. Secondly, with a more intense homogenisation, a fine, highly homogeneous and paste-like texture is obtained, which becomes less viscous (overly fluid) due to the destruction of the muscles. To solve this problem, the addition of textured soy is suggested to substitute the lost texture from the intense homogenisation.

The main operations of structured fish forcemeat production are given in Figure 1.

For structured fish forcemeat production fresh, chilled or frozen fish can be used. When using frozen fish, there is no thawing, but frozen fish blocks are chopped in cylindrical or guillotine industrial blades. This allows to

reduce cutter-mixer blade load and speed up homogenisation. It also ensures a low temperature in the coarse-ground fish mincemeat, which has a positive effect on the colour and safety of the product. Emulsification in a high-speed cutter-mixer is performed until a rough consistency is obtained.

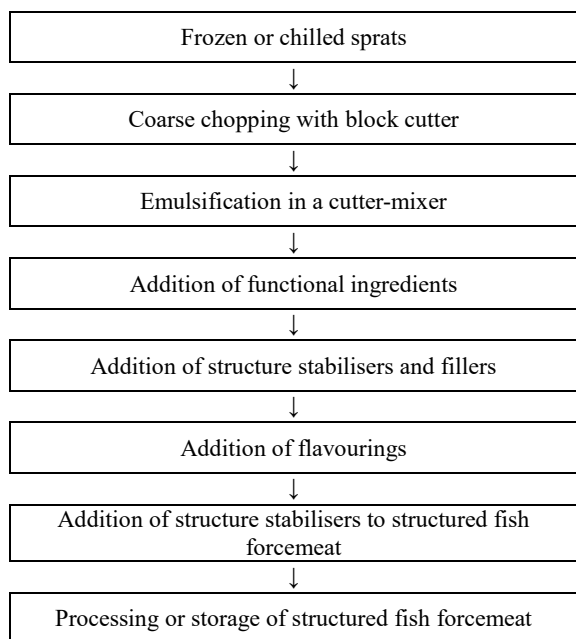


Figure 1. General process scheme of structured fish forcemeat production

Such functional ingredients as food-grade sodium phosphate (E339), salt and titanium dioxide (E171) are added. Titanium dioxide works as the colourant (EFSA, 2016) and should be added before other ingredients. Fish is crushed whole without heading and gutting, and fillet rinsing, therefore, such preservatives as microorganism inhibitors (e.g. potassium sorbate) can be used (Bashir et al., 2017).

Structure stabilizers and fillers of plant origin allow to stabilise low viscous consistency of emulsified fish forcemeat from sprats. According to the recipe, starch is added initially, followed by textured flour or semolina, then necessary consistency of the product is achieved by the addition of pea flour and food fibre.

Dried, fried or fresh onions are used as flavour additives. Before use, dried onions should be hydrated with water in a ratio 1: 2.

Coarse texture of sprat structured forcemeat is given by the addition of hydrated textured soy.

Structured fish forcemeat is then forwarded to production of new products or stored up to 24 h at 2–6 °C temperature.

Development of semi-finished products from structured fish forcemeat

The production technology and recipes of co-extruded fish meatballs with filling already implemented at the factory was adapted to substitute traditional fish minced meat (which is more expensive) with structured fish

forcemeat. As shown by Silovs and Dmitrijeva (2018), co-extrusion allows to obtain product, which is a combination of fish with sauce – structured fish products with various fillings. Such parameters as nutritional and amino acid profile were assessed in semi-finished products from structured fish forcemeat.

Quality analysis

Standard methods were used to assess nutritional composition of samples: protein content (PB-116 ed. II of 30.06.2014), fat content (PN-A-86509:1994), ash content (PN-A-79011-8:1988), amino acids (PB-53/HPLC ed. II of 30.12.2008), dietary fibre (AOAC 991.43:1993), fatty acid profile (ISO 12966-4:2015), salt content (PB-318/FAAS, ed. I of 27.07.2015). Carbohydrates were calculated by difference (FAO, 2003). Energy value was calculated according to EU Regulation No 1169/2011.

Data processing

MS Excel v16 software was used to process the obtained data; differences were considered significant at $p < 0.05$. All parameters were analysed in triplicate, mean values are given in tables. ANOVA and Tukey's test were applied to evaluate the results.

Results and Discussion

Quality of chilled and frozen sprats

The comparison of nutritional parameters of chilled and frozen sprats showed that there are not significant differences in protein, fat, ash content and energy value (Table 1). Literature studies show that there are several advantages of using frozen fish (Vanhaecke et al., 2010) if the production site is not close to water bodies: high microbiological quality, reduction of raw material costs, reduction of seasonal effect, increase in economic performance of production.

Table 1

Chemical composition of chilled and frozen sprat parts per 100 g

Samples	Composition parameters			
	Protein, g	Fat, g	Ash, g	Energy, kcal
AC*	14.9 ^a	5.0 ^a	2.0 ^b	104.2 ^a
BC	16.0 ^a	5.1 ^a	1.7 ^b	110.3 ^a
DC	10.8 ^b	4.9 ^a	3.8 ^a	87.3 ^b
AF	15.0 ^a	4.8 ^a	2.2 ^b	103.2 ^a
BF	15.5 ^a	5.2 ^a	1.7 ^b	108.8 ^a
DF	10.3 ^b	4.7 ^a	3.6 ^a	83.5 ^b

Values within the same column sharing the same letter are not significantly different ($p > 0.05$).

* A – whole sprats, B – headed and gutted sprats, D – sprat heads, C – chilled, F – frozen.

In addition, testing of separate fish parts – whole sprats, headed and gutted sprats and sprat heads – established that sprat heads have a significantly higher content of ash ($p < 0.05$) which represents total minerals. Fish heads make up 10–15% of the fish carcass (Smáráson et al., 2014) and contains around 10 g of protein (Table 1), therefore showing potential as a raw

material for structured fish forcemeat. Based on these results, whole sprats were used in the further experiments.

Development of structured fish forcemeat

Ground fish mincemeat is characterised by viscous consistency which must be stabilised with raw materials with good water binding properties. For this purpose, structural stabilizers (soy, carrot, wheat, beet, etc.), native starch (tapioca, potato, rice), textured flour (pea, rice, buckwheat, corn), semolina etc. can be used (Wild et al., 2014).

The flavour of the structured fish forcemeat depends on the percentage of fish in the finished product. By increasing the concentration of fish above 50%, the organoleptic quality indicators – taste and colour – decreased, whereas reduction of fish concentration to 40% improved the taste and colour. It is also possible to add various spices and herbs, onions (dried, fried, fresh) during structured fish forcemeat preparation, which greatly improves the taste of the finished product. The most effective additive that significantly improves the flavour of sprat structured forcemeat is onions and, with proper degree of shredding provides the product with a suitable texture. The final recipe of structured fish forcemeat from sprats is summarised in Table 2.

Table 2

Recipe of structured fish forcemeat

Ingredients	Amount, %
Frozen sprats	45.45
Wheat fibre	3.64
Water needed for wheat fibre	7.27
Titanium dioxide	0.91
Salt	0.45
Water-soluble food-grade sodium phosphate	0.45
Textured soy	4.55
Water needed for textured soy	10.91
Fresh onions	5.45
Semolina	3.64
Pea flour	3.64
Native rice starch	2.73
Water needed for fillers	9.09
Seasonings	1.82

Possibilities for structured fish forcemeat application in new product development

Due to the textural properties of structured fish forcemeat, its applications in food are wide. It can be used in at least seven product groups based on production specifics (Table 3, Figure 2). Sensory evaluation showed that new products from structured fish forcemeat were of good sensory quality and could compete with similar products (analogues from fillet minced meat) on the market (Straumite et al., 2018).

Quality comparison of raw sprats, structured fish forcemeat and semi-finished products

The comparison of nutritional and energy value of raw sprats, structured fish forcemeat and semi-finished

breaded fish meat balls showed significant differences in several parameters (Table 4).

Table 3

Use of structured fish forcemeat in production of various products

Product group	Developed products
Sausages (emulsified fish products)	Cooked sausage Frankfurters Cooked bratwurst
Pates (chilled fish culinary products)	Pâté Terrine (classic, in layers, with filling)
Semi-finished products (frozen)	Dumplings
Frozen and breaded / battered fish culinary products	Fish fingers Fish meatballs Burger patties
Frozen culinary products without breading	Cutlet Cutlet in sauce Meatballs
Pies (baked pastry with structured fish stuffing)	Puff pastry pies Yeast dough pies
Pasta (portion of pasta dough is replaced with structured fish forcemeat)	Pasta Noodles



Figure 2. Products developed from structured fish forcemeat

Protein content in raw sprats, structured fish forcemeat and breaded fish meat balls is high, providing 30.8%, 41.5% and 26% of energy value, respectively. All tested products are eligible for nutrient claim ‘high protein’ based on Regulation (EC) No 1924/2006.

All three samples also have a content of ‘high omega-3 fatty acids’ (Commission Regulation (EU) No 116/2010). The claim ‘high omega-3 fatty acids’ can be used when 100 g and 100 kcal of products contain at least 80 mg of the sum of long chain ω3 fatty acids – eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). Raw sprats contain 2100 mg EPA and DHA per 100 g and 1220 mg per 100 kcal, structured fish forcemeat – 1000 mg per 100 g and 567 mg per 100 kcal and breaded fish meat balls – 800 mg per 100 g and 329 mg per 100 kcal.

In addition, structured fish forcemeat and semi-finished breaded fish meat balls have a ‘high monounsaturated fat’ content, providing over 46% of fatty acids from

MUFA, and MUFA provides over 22% of energy (Commission Regulation (EU) No 116/2010).

Table 4

Nutritional parameters and energy value of sprats and sprat products per 100 g

Parameters	Samples		
	RS*	SF	FMB
Protein, g	13.20 ^c	18.30 ^a	15.80 ^b
Fat, g	12.10 ^b	9.40 ^c	14.00 ^a
Saturated (SAFA), g	3.40 ^a	2.00 ^b	2.70 ^{ab}
Monounsaturated (MUFA), g	4.40 ^b	4.40 ^b	7.30 ^a
Polyunsaturated (PUFA), g	3.70 ^a	2.80 ^b	3.80 ^a
– ω3, g	3.20 ^a	1.80 ^b	1.80 ^b
– eicosapentaenoic acid, mg	0.90 ^a	0.40 ^b	0.30 ^b
– docosahexaenoic acid, mg	1.20 ^a	0.60 ^b	0.50 ^b
– ω6, g	0.50 ^c	1.00 ^b	2.00 ^a
– ω9, g	3.10 ^b	3.50 ^b	6.40 ^a
Trans fatty acids, g	< 0.10 ^a	< 0.10 ^a	< 0.10 ^a
Ash, g	1.89 ^b	4.00 ^a	3.83 ^a
Carbohydrates, g	2.60 ^b	1.30 ^c	13.00 ^a
Dietary fibre, g	0.00 ^b	1.30 ^a	0.80 ^a
Salt, g	0.12 ^b	2.05 ^a	1.88 ^a
Energy value, kJ	716 ^c	737 ^b	1014 ^a

Values within the same row sharing the same letter are not significantly different (p>0.05).

* RS – raw sprats, SF – structured fish forcemeat, FMB – semi-finished breaded fish meat balls

The rest of the differences in nutritional parameters can be explained by the recipes of sprat products; higher content of protein in structured fish forcemeat is due to the addition of textured soy, while higher content of carbohydrates in breaded fish meat balls is due to the coating and filling of the product.

One of the important parameters to verify the quality of new products is amino acid profile, as additional ingredients and the coating and filling can reduce the qualitative and quantitative amino acid content.

Amino acid composition of raw sprats shows (Table 5) that the total amount of amino acids per gram of protein is 806.4 mg, and based on the essential amino acid profile sprat protein is complete. A study by Mohanty et al. (2014) reviewed the amino acid profile of 27 different food fish and their results on sprat amino acid content is comparable to our results.

The results of amino acid content in structured fish forcemeat and breaded fish meat balls in mg per g protein indicates (Table 5) that the total amount of amino acids in fish balls per 1 gram does not differ significantly from the content of amino acids in 1 g protein of structured forcemeat (p>0.05).

The added ingredients for optimum structured fish forcemeat production have a positive effect on the amino acid profile, and structured fish forcemeat protein retains its full value after these technological improvements. It can also be concluded that the coating and the filling of fish balls has an insignificant effect on

total amino acid content, especially with regards to essential amino acids.

Table 5

Content of amino acids in sprats and sprat products, mg g⁻¹ protein

Amino acids	Samples			MAAP (FAO, 2013)
	RS*	SF	FMB	
Ala	58.3	51.4	48.1	–**
Arg	47.0	68.3	63.3	–
Asp	72.7	96.7	92.4	–
Glu	129.5	177.0	188.6	–
Gly	53.8	49.2	46.2	–
Cys	5.6	12.6	10.8	–
Pro	34.1	49.2	52.5	–
Ser	30.3	45.9	44.3	–
Tyr	26.5	35.0	30.4	–
Phe ^x	38.6	45.9	43.7	38
His ^x	18.2	25.1	24.1	15
Ile ^x	35.6	39.9	38.0	30
Leu ^x	68.2	74.9	72.8	59
Lys ^x	76.5	75.4	61.4	45
Met ^x	28.0	20.8	19.6	16
Thr ^x	34.1	38.8	37.3	23
Trp ^x	n.d.	n.d.	n.d.	6
Val ^x	49.2	43.7	43.0	39
Total	806.4	949.7	916.5	–

* RS – raw sprats, SF – structured fish forcemeat, FMB – semi-finished breaded fish meat balls, MAAP – maintenance amino acid pattern.

** Pattern not defined by FAO.

^x Essential amino acids.

n.d. – no data

Based on the FAO recommendations for maintenance amino acid pattern, protein of structured fish forcemeat and breaded fish meat balls is also complete, indicating that processing and additional ingredients do not affect the protein quality of new products.

Conclusions

The results of the study show that it is possible to use whole sprats in structured sprat forcemeat production, however, it is suggested to use no more than up to 50% of sprats in total forcemeat composition. Structured sprat forcemeat can be labelled ‘high protein’, ‘high omega-3 fatty acids’ and ‘high monounsaturated fat’, in addition, products made from it could be eligible for these claims as well. Protein of sprats and structured forcemeat is complete based on essential amino acid profile. Semi-finished breaded fish meat balls made from structured sprat forcemeat have a high nutritional value, particularly with regards to protein content and amino acid profile.

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