Developing functional sterilised products technology using microwave-cooked semi-finished cod liver products

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Abstract. Cod liver which is extracted in significant amounts from fish during the process of gutting and harvesting by fishing vessels in the North Atlantic and Barents Sea is a very valuable raw material for producing 'natural' tinned foods that have not undergone any additional treatment and which do not have any additional ingredients, but its use is limited due to lipid instability in long-term storage in a frozen state. The authors advise that the production and use of pre-treated semi-finished products which are based on the use of cod liver is managed by means of a microwave-cooking process which results in a product that is more stable for frozen storage. Any semi-finished fish oil product that is extracted during microwave processing can also be used in food production.

The variants that can be included in using these semi-finished products are discussed here when it comes to the technology that is involved in functional multicomponent products (such as natural and paste tinned foods with the addition of sauces, vegetables, mushrooms, meat, and fish protein isolate).

Key words: tinned foods, cod liver, functional products, meat and fish products, polyunsaturated fatty acids.

Terms and abbreviations:
Generalised sensory score – a complex of sensory characteristics joined together into one value by considering their significance, and recalculated to percentage values according to (2);
MCSCL – Microwave cooked semi-finished cod liver product;
Full-grade protein – protein containing all essential amino acids in adequate quantities (the scores for all amino acid must be no less than 100%);
FPI – fish protein isolate;
PUFA – polyunsaturated fatty acids;
SCLO – Semi-finished cod liver oil product;
TG – triglycerides.

INTRODUCTION

Fish oils have a wide range of use both in terms of therapeutic and prophylactic purposes in the food industry, as well as in veterinary and medicinal fields. Fish oil is obtained during the processing either of fish liver (from the *Gadidae* family) or whole fish (herring, capelin, etc) (Rzhavskaya, 1976).

Fish oil is a rich source of ω-3 polyunsaturated fatty acids (PUFA), and fat-soluble vitamins (Petracci et al., 2009). It is known that fish oils from fishes which are caught in the northern seas are richer in valuable components than those from fish which live in warm water (Rzhavskaya, 1976).

Fatty acids of the ω-3 group have a very high biological value as well as therapeutic and prophylactic effectiveness against a series of diseases, especially cardio-vascular ones (Marventano et al., 2015). An optimum ratio between ω-3 and ω-6 is not absolutely clear at present, but nowadays researchers recommend increasing it to at least 1:4; some researchers refer to a range between 1:4 and 4:1 (Simopoulos, 2011).

Fish ('Food enrichment with Omega-3 fatty acids', 2013) and marine products (Patten et al., 2017) are a traditional and extremely well-known source of ω-3 PUFA.

Including PUFA (especially ω-3) in the composition of functional foods during their creation and production clearly holds a very high level of importance.

One of the main producers of the aforementioned valuable components is cod liver. The feature of its lipids is the high amount of PUFA (46.7–47.4%). The eicosapentaenoic (18.8–19.4%) and docosahexaenoic (19.1–19.6%) acids dominate amongst the polyenoic acids. Monounsaturated fatty acids form between 30–33% of cod liver oil, and almost half of them consist of oleic acid, while 25% are formed of palmitoleic (Konstantinova et al., 1997)

However, the hydrolytic and then oxidative processes occur even during long periods of frozen storage for products that are rich in ω-3 PUFA (Jacobsen, 2015), because free fatty acids are much less stable when it comes to oxidation than are triglycerides (TG).

It is possible to protect PUFA not only by storing the oil itself for a short time, but also by producing and storing the sterilised tinned foods from raw, chilled, or fresh-frozen cod liver (Gladyshev et al., 2009). It was experimentally proved that fatty acids are comparatively stable under high temperatures used during the sterilisation of tinned foods in the absence of oxygen (Karlsdottir, 2016). So producing delicious tinned cod liver is the most acceptable way of processing cod liver. One of the most popular tinned foods in the northern basin is 'natural cod liver', which can be produced from raw, chilled, or frozen liver.

The proportion of liver in the cod is known to be about 5% (Konstantinova et al., 1997). Considering that the total catch of cod in the northern basin alone is more than 500,000 tons, it is possible to calculate the total volume of extracted cod liver, which is around 25,000 tons. But it is impossible to immediately process this large volume of cod liver on the fishing vessels themselves or in the onshore factories, so the most part of caught liver goes to freezing. Thanks to this, the production of high quality tinned cod liver which comes from frozen raw materials is actually quite a demanding task, especially in light of increasing demand for such a product.

However, the frozen storage of cod liver results in the occurrence of negative processes which are related to lipid hydrolysis, followed by oxidation. It was noticed

that the acid value significantly increases during frozen storage; moreover, the growth of peroxide value, the content of hydroxy acids, and aldehydes were all also noted. Sensory tests of natural tinned foods which came from frozen cod liver have confirmed a rancid taste and the dark colour of the product's surface due to oxidised lipids. Moreover, a significant quantity of free oil has been found in each tin which can result in quality being decreased. Another problem is related to any increase of the liquid content of the tinned foods (Volchenko et al., 2013).

It is possible to partially prevent such degradation in frozen cod liver using surface heating (blanching) before freezing, but the texture both of such semi-finished products and the resultant quality of tinned foods was poor (Grokhovsky & Volchenko, 2003). Therefore it is reasonable to use volume heating for this purpose.

It can be seen that the high quality of tinned foods that use such cod liver can only be provided by means of the utilisation of frozen storage at a temperature that is not higher than minus 18 °C and not for a period of more than one month. Therefore, the most valuable tinned foods that are in high demand can either be obtained from raw cod liver direct from the fishing vessels themselves, or from chilled cod liver with a storage time of four days, or from frozen liver with a very short storage time. All of this results in something of a headache for many producers, especially when taking into account the time it takes to ship frozen cod liver from possibly far-flung fishing areas to onshore canning facilities (Volchenko et al., 2013).

Tinned cod liver is traditionally consumed in small amounts due to its very high oil content (even despite the extremely high nutritional value of such oil), and the minimal content of protein and water with a complete absence of carbohydrates, so it is not a particularly good way of consuming it when it has been separated from the liver 'residue'. It can also be used as a raw material for producing a wide range of functional resources, mostly culinary (salads, fillings, etc). Despite its unique biochemical characteristics, tinned cod liver has a specific taste and flavour, one which serves to decrease the attractiveness of the product. So research that is directed towards the development of new forms of food items that can mask these specific characteristics are also of some importance.

All of these problems make it quite reasonable to conduct research that can be directed towards finding ways in which cod liver and its oil can be placed in frozen storage for extended periods of time, and for finding a rational use for this raw material when it comes to producing functional foods.

For that reason the goal of this research is to develop a form of technology that can be used in cod liver processing and which can preserve the quality of the cod liver in its frozen state for a longer period of time, and to find ways of using the obtained semi-finished products for the production of new, functional food items which have a high biological value.

MATERIALS AND METHODS

Preparing the raw materials
Blue whiting (*Micromestius poutassou*) was caught by the fishing company, JSC Murmansk Trawl Fleet OAO, in the central eastern Atlantic, subsequently being frozen and shipped to the port of Murmansk. It was stored at a temperature that was no higher than minus 18 °C. The vegetables, salt, and spices were purchased on the local market.

The chilled liver of Atlantic cod (*Gadus morhua*), which is shipped out by fishing companies all year round, was used as the source of the PUFA.

Producing fish protein isolates (FPI)

FPI was obtained by dissolving the muscle tissue of blue whiting in an alkaline solution, followed by sedimenting the protein in the isoelectric point and in a slightly acidic solution (Gholam, 2008). The temperature of the alkaline dissolution was 98 °C, while the pH level was 11.75. The isoelectric sedimentation was provided at a temperature of between 40–50 °C, while the pH was about five (the maximum for the sediment).

Choosing and preparing the reagents

All of the reagents that were used in this research were of an analytical grade (or higher). The standard samples of fatty acids were marked 'for chromatography'.

Analytical methods

The Kjeldahl method (FAO, 2003) uses Selecta Bloc Digest and Selecta Pro-Nitro modules (Spain). The nitrogen content that was obtained was recalculated to the raw protein value (P) using the following formula:

$$P = N \times K_P \qquad\qquad (1)$$

where N – total nitrogen content; K_P – recalculation coefficient, and $K_P = 6.25$ for fish and some other products (Kondratyeva & Garkotina, 2014).

The lipid content in the samples of raw material, FPI, and foodstuffs which were produced from them (in the form of tinned foods) was determined by using a Selecta DET/GRAS extractor (Spain) by using the Soxhlet method (de Castro & Priego-Capote, 2010).

The fatty acid composition of lipids was determined by using the high-performance liquid chromatography method (HPLC), with an Agilent 1100 (USA) following the saponification of lipids with an alcohol solution of 2N KOH and pre-column derivatisation with bromophenacyl bromide and triethylamine (Gratzfeld-Huesgen, 1997).

The volume of secondary products from the lipid oxidation was estimated by means of the aldehydes content (by reaction with benzidine) which was recalculated to cinnamic aldehyde (Holm et al., 1957).

The acid value for lipids was determined after their extraction using a mixture of chloroform and ethyl alcohol by titration with 0.1M NaOH (phenolphthalein was used as an indicator). The peroxide value was determined by titration of the iodine displaced with peroxides from the potassium iodide with 0.01M sodium thiosulphate (Chakrabarty, 2003).

Sensory studies were carried out using the response scales (ISO 4121:2003) for the following characteristics: taste, odour, texture, state of product (large or small pieces, coarse or fine mince, etc), and colour. Tinned foods were checked for any absence of defects, and were opened and prepared prior to a sensory analysis being carried out. Every value was estimated using a five-point scale (between 1 to 5), considering the significance coefficients that were determined with the expert method. The result was a 'generalised sensory score' q, %, which was determined by the following formula:

$$q = \frac{\sum_{i=0}^{i=n}(B_i - B_{min}) \cdot K_{Si}}{\sum_{i=0}^{n} K_{Si} \cdot (B_{max} - B_{min})} \cdot 100 \qquad (2)$$

where K_{Si} – the significance coefficient of i-th sensory value; B_i – the average mark by all tasters for the i-th sensory value; B_{min} – minimum possible mark from the scale (1); B_{max} – maximum possible mark from the scale (5); and n – number of sensory values in the scale.

Experimental planning and statistical data processing

The one-factor experimental design was also used. It contained five levels of factor variants. Statistical data processing (regression analysis) was carried out using an Oakdale DataFit 9.1. Common statistics were also used (involving a determination of confidence interval using the t criterion). All of the experiments were carried out in no less than three parallels.

Experimental order

The cod liver specimens were processed using a preliminary microwave treatment. The authors advise that such a treatment be used before freezing the cod liver in order to be able to prevent disadvantages arising – such as lipid oxidation during frozen storage and extra liquid oil from being collected in packaging tins – according to preliminary experiments. This method makes it possible to keep the partial integrity of the semi-finished product, and to make inactive lipolytic enzymes in the entire volume which would result in a slowing down of the hydrolytic and oxidative processes. It is also possible to select a lipid excess fraction following microwave cooking to be able to prevent any undesirable oil separation during the tinned food sterilisation process. Preliminary experiments have determined the most acceptable mode of microwave treatment for the liver, with a layer that is no thicker than 40 mm for 2.5 minutes at the specific power setting of 2000W kg^{-1} according to the inherent features of the microwave heating process (a thicker layer results in less uniform heating) and the sizes of cod liver being processed (less thickness requires additional cutting which results in a decreasingly impressive appearance). The microwave-cooked semi-finished cod liver product (abbreviated as MCSCL) was produced using this mode, and then was frozen and stored at a temperature of minus 18 °C in polymeric packaging for further research.

The tinned analogues of natural tinned cod liver were produced from the MCSCL. The sensory characteristics of this product have met the requirements that have been set out for the assortment of such tinned foods that are produced from chilled cod liver.

The semi-finished cod liver oil product (SCLO) which was separated during the microwave treatment was stored at a temperature that was no higher than plus 10 °C and for no more than a period of twelve months.

MCSCL (including frozen materials that were stored for a period of less than four months) was used in the production of tinned foods which are very similar to natural tinned cod liver in terms of composition and the method of production being used.

However, such a single-component form of production is not the only possible way in which processing can be handled, and is not even the most optimum way of doing it. Enriching such tinned foods with carbohydrates and proteins can be seen as being quite reasonable, by adding vegetables, mushrooms, tomato and sour-cream sauces, meat, and FPI.

The small assortment of tinned foods that are based on MCSCL with different sauces being added (sour-cream, and tomato and sour-cream), and with additional ingredients being added (champignons) was also developed. A new form of fish and vegetable tinned food was also developed which included minced MCSCL, vegetables (onion and carrot), champignons, and tomato and sour-cream sauce.

This brand new form of tinned food – tinned paste from cod liver and meat – has been developed during experimental research. The optimisation of its composition has been carried out during this research. Preliminary experiments proved that such tinned foods have excellent sensory characteristics despite the probably high cost of producing them. The optimum composition of such foods has been further developed following these preliminary experiments. The proportion of the main ingredients was around 60% despite different ratios being used. Other ingredients included vegetables (carrot and onion), and tomato and sour-cream sauce; their proportions have not been changed.

RESULTS AND DISCUSSION

Developing the technology involved in microwave-cooked, semi-finished cod liver products (MCSCL)

The hydrolytic and oxidative processes being used in the MCSCL have been researched. The objective characteristic of hydrolysis is the acid value, so it is this that has been determined in most experiments. Oxidative spoilage has been estimated by means of the content of the primary oxidation products (peroxides and hydroperoxides) and secondary products (aldehydes).
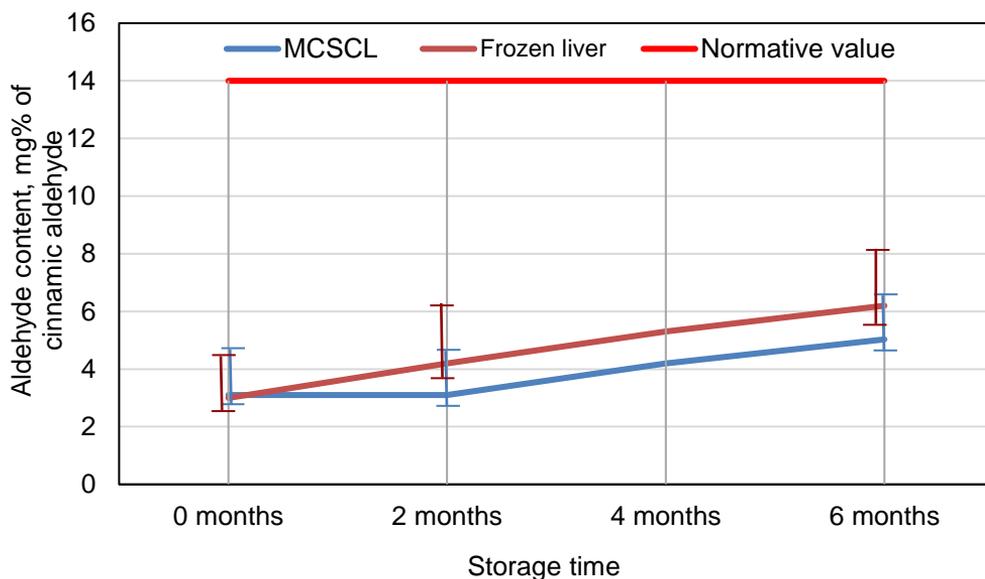

Figure 1. Dynamics for aldehyde content changes during the frozen storage of the cod liver.

The regression of aldehyde content on storage time was carried out. An equation for the total content of aldehydes was increasing by an insignificant amount during storage and did not exceed 7mg% of cinnamic aldehyde (Fig. 1), so the dynamics both for hydrolytic and primary oxidation products has been researched. The results for the comparative experiment in terms of storing frozen cod liver and MCSCL are shown in Fig. 2.
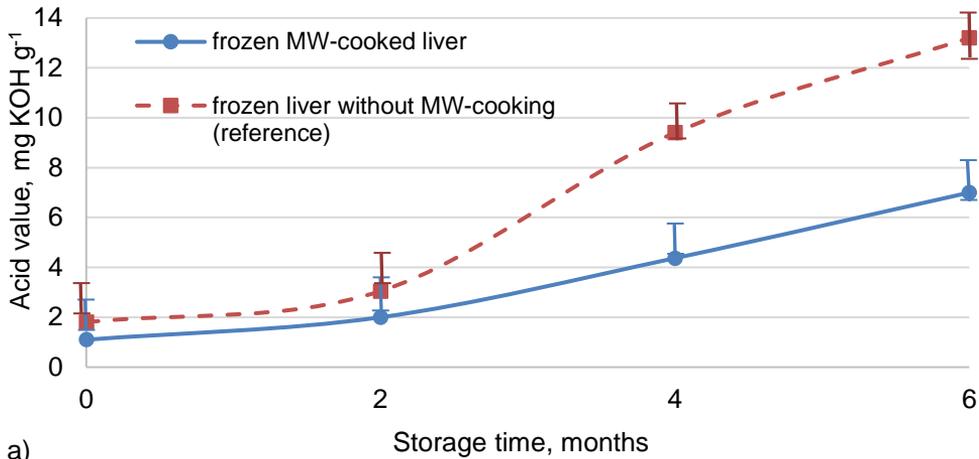
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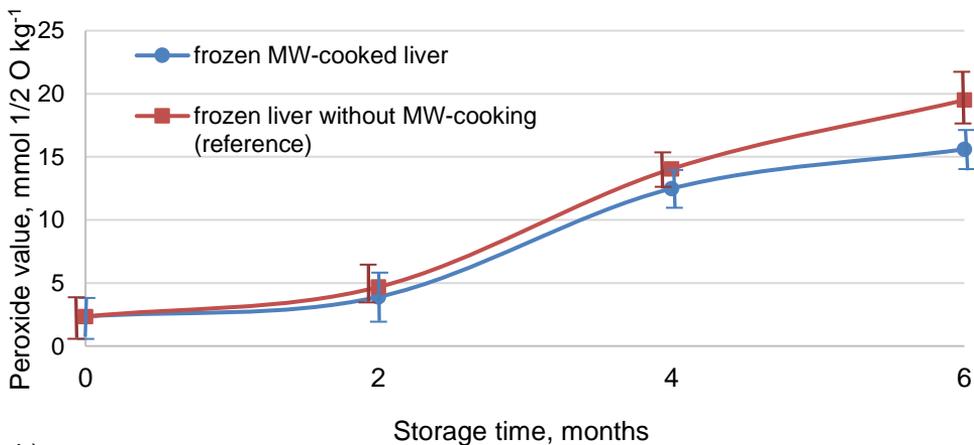
b)

Figure 2. Dynamics for acid (a) and peroxide (b) values during frozen storage.

It can be seen that the use of the microwave method for cod liver treatment before being placed into frozen storage is rational in terms of slowing down the process of hydrolytic and oxidative spoilage in this raw material. Therefore the recommended shelf life at a temperature of no higher than 18 °C is no more than four months. A higher shelf life will result in undesirable acid values (6 mg KOH g and higher), the increase of the peroxide value (15 mmol 1/2O/kg and higher). This shelf life is also proven by microbiological tests (Volchenko et al., 2013), as shown on Fig. 3.
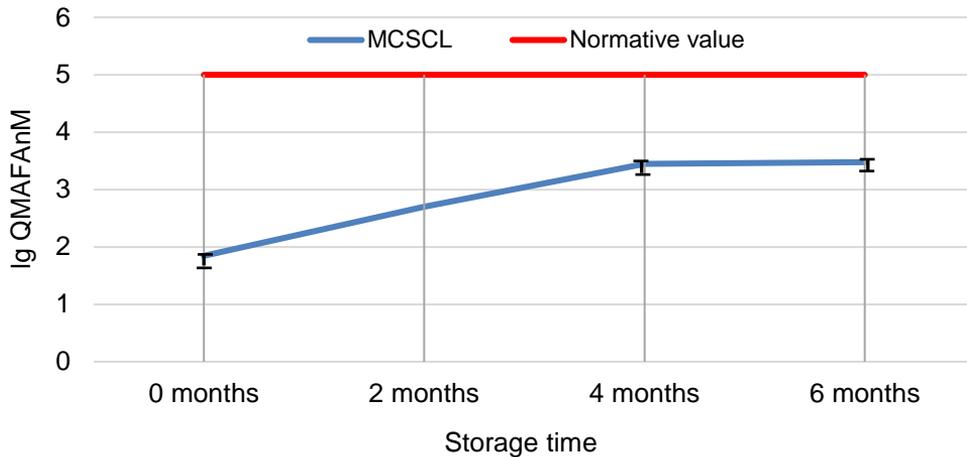
Figure 3. Dynamics of microbiological growth in the MCSCL.

Developing new forms of tinned foods with MCSCL

The experiment which involved optimisation has been carried out according to the plan shown in Table 1. The results of this experiment are shown in the same table.

It is reasonable to use the regression method to process the results of Table 1. The regression equation for quality level versus meat proportion is as follows:

Table 1. Plan for and results of experiments for optimising meat and cod liver ratios

Probe no	Meat (pork) proportion (of net mass), %	MCSCL proportion (of total mass), %	Generalised sensory score, %
1	20	40	93.9 ± 6.4
2	40	20	88.2 ± 7.7
3	30	30	86.1 ± 10.3
4	10	50	88.5 ± 8.5
5	25	35	92.6 ± 7.3

$$q = a \cdot x^3 + b \cdot x^2 + c \cdot x + d, \qquad (3)$$

where $a = 0.0038$; $b = -0.3$; $c = 7.0$; and $d = 45$ – regression coefficients.

Analysis of the regression Eq. (3) shows that the best levels of quality can be found in the case of a meat proportion of 17.3% of the net mass of prepared tinned foods. Moreover, there is a clear trend for a new maximum to appear in which the proportion is above 35% meat content, but tinned foods of such a high meat content would be closer to meat pastes which are outside the scope of the current research.

It is reasonable to not just meat as raw materials, but also fish (in the form of FPI) because fish protein is more widely available on the market, while also being no worse – and often better – than meat protein.

The authors have developed FPI technology from the muscle tissue of blue whiting, which has protein that is full-grade in terms of its quality, meaning that it contains all of the amino acids (both essential and non-essential) that are required for the human organism (Derkach et al., 2017). The experiment has been carried out to determine the optimum composition of tinned paste which is produced from MCSCL with the addition of FPI. The plan for this experiment and the accompanying results are shown in Table 2.

The results of this experiment can be described by the same Eq. as (3), but with different regression coefficients: $a = 0.0084$; $b = -0.443$; $c = 6.05$; and $d = 69.0$.

The maximum generalised sensory score can be found in a 9.26% proportion of FPI, so it is reasonable to include between 9–10% of FPI in the composition.

Table 2. Plan for and results of experiments in optimising FPI and cod liver ratios

Probe no	FPI proportion (of net mass), %	MCSCL proportion (of total mass), %	Generalised sensory score, %
1	2	58	79 ± 10
2	5	55	90 ± 9
3	10	50	93 ± 8
4	20	40	80 ± 18
5	30	30	78 ± 16

Developing tinned food from SCLO

As SCLO is a by-product of the microwave technology that is involved in the production of MCSCL, it is reasonable to develop a complex of technologies for making use of it such as, for example, in tinned foods by enriching them with fatty acids which include PUFA. New groups of compositions in multicomponent tinned foods with SCLO have been developed for this very purpose. One such group includes tinned pastes that are based upon vegetable ingredients (carrot), and SCLO. The one-factor experiment for estimating the maximum acceptable proportion of SCLO in the product has been carried out in order to be able to optimise composition. The plan for and results of this experiment are shown in Table 3.

Table 3. Plan for and results of experiments for optimising SCLO proportions

Probe no	Carrot proportion (of net mass), %	SCLO proportion (of total mass), %	Generalised sensory score, %	Proportion of free liquid in the tin
1	35	35	53 ± 19	10.6
2	40	30	51 ± 25	8.9
3	50	20	58 ± 22	3.5
4	55	15	61 ± 22	1.3
5	60	10	67 ± 13	0.35

Data processing results are shown for the following regression equation for a generalised sensory score (q) versus SCLO proportion (x):

$$q = a + b \cdot x^2 + c \cdot x^3, \qquad (4)$$

where $a = 71.8$; $b = -0.065$; and $c = 0.0014$ – regression coefficients.

The equation adequately describes the generalised sensory score changes; regression coefficients are significant with a confidence level of 0.9 (higher confidence levels are not required for sensory tests as subjective methods).

The regression equation for the proportion of the free liquid part (ω_O) versus SCLO proportion is as follows:

$$\omega_O = d \cdot x^3 + f \cdot x^2 + g \cdot x + h \qquad (5)$$

where $d = -9.7 \cdot 10^{-4}$; $f = 0.0694$; $g = -1.09$; and $h = 5.25$ – regression coefficients.

The equation adequately describes the free liquid part's proportion changes; regression coefficients are significant with a confidence level of 0.9.

Therefore the acceptable quality of the product can be achieved in the case of an SCLO proportion that is no higher than 10%. A more precise choice of SCLO dosage value should be taken by means of objective reasoning. It is obvious that the free liquid part is practically absent if the SCLO proportion is less than 10%.

Characteristics of the finished products

The quality estimation for single and multicomponent tinned foods based on (or with the use of) MCSCL have been carried out. They include:

– 'Blanched cod liver' – single-compound MCSCL-based tinned foods using the technology involved in the processing of natural tinned cod liver;

– 'Liver and carrot paste' – multicomponent minced MCSCL-based tinned foods with the addition of carrot, tomato, and sour-cream sauce;

– 'Liver and mushroom paste' – multicomponent minced MCSCL-based tinned foods with the addition of champignons, carrot, tomato, and sour-cream sauce;

– 'Vegetable and mushroom paste' – multicomponent tinned foods which employ the use of minced cabbage, champignons, carrot, tomato, and sour-cream sauce with the addition of SCLO;

– 'Carrot and mushroom paste' – multicomponent tinned foods which employ the use of minced champignons, carrot, tomato, and sour-cream sauce with the addition of SCLO;

– 'Cod liver and meat paste' – multicomponent minced MCSCL-based tinned foods, with non-fatty pork, tomato, and sour-cream sauce;

– 'Cod liver and protein paste' – multicomponent minced MCSCL-based tinned foods with the addition of FPI, tomato, and sour-cream sauce.

Figs 4–5 show the profiles for the sensory evaluation of the tinned foods in question.

An analysis of the data shown in Fig. 4 shows that tinned foods that are produced using chilled cod liver (reference) are almost the same as tinned foods that are produced using MCSCL, according to characteristics such as oil colour, taste, and aroma. Such characteristics as surface colour, texture, and product state (which are not as important as the previous characteristics) are insignificantly higher for reference.
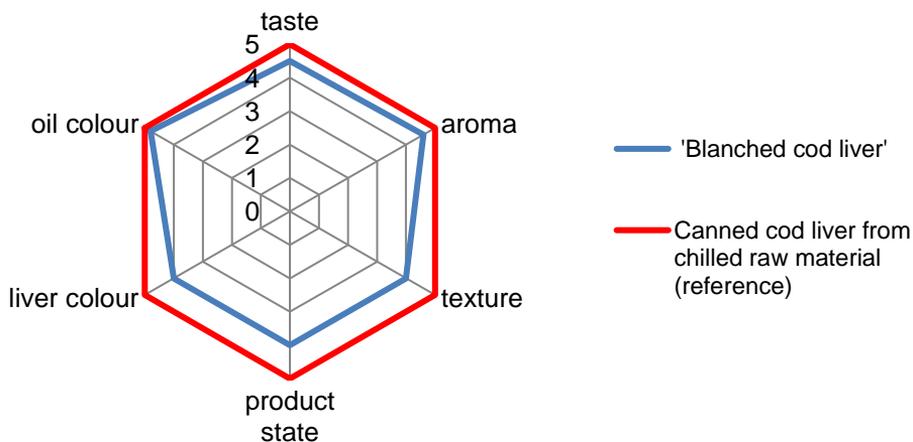

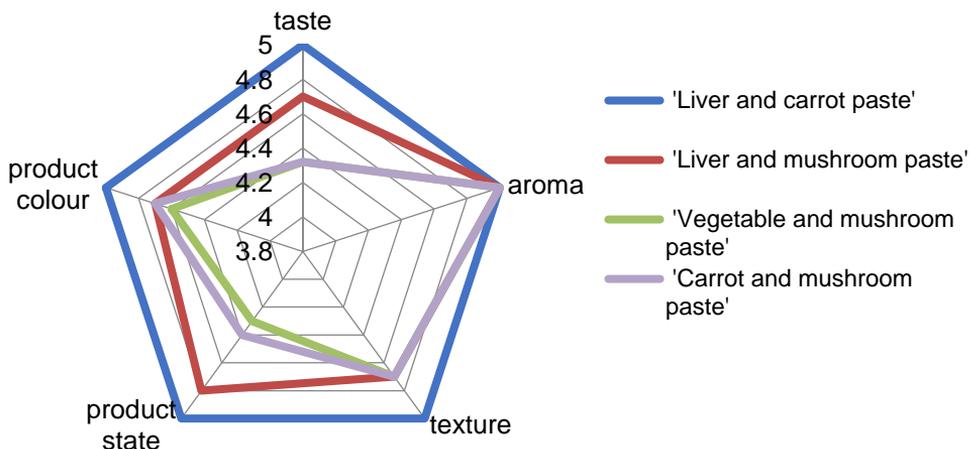**Figure 4.** Comparative sensory evaluation of traditional tinned foods and MCSL-based tinned foods.

Figure 5. Comparative sensory evaluation of multicomponent MCSCL-based tinned foods, and with SCLO added.

When comparing the sensory characteristics of tinned pastes that are produced according to different recipes, it is possible to conclude that 'liver and carrot paste' dominates all other pastes.

Table 4 contains the separate characteristics of the chemical composition of the different tinned foods.

Table 4. Food value for tinned foods that contain MCSCL or SCLO

Tinned food	Content,%		Energy value, kcal
	Lipids	Proteins	
'Blanched cod liver'	63	5.0	587
'Liver and carrot paste'	11.6	4.5	122
'Liver and mushroom paste'	8.5	5.1	97
'Vegetable and mushroom paste'	14.0	6.2	151
'Carrot and mushroom paste'	13.7	5.5	146
'Cod liver and meat paste'	52.8	6.5	501
'Cod liver and protein paste'	56.1	7.4	535

The composition of fatty acids (Table 5) for semi-finished cod liver oil products (for comparison) and those for separate tinned foods has been determined in order to be able to evaluate the biological value of the selected tinned foods.

The results in this table show that tinned foods are rich in ω-3-PUFA, so MCSCL and SCLO can improve the ratios of ω-3:ω-6 in humans (which figures are considered to be increased to at least 1:4). Increasing the proportion of linoleic acid and decreasing the ω-3:ω-6 ratio can be explained by frying the ingredients with vegetable oil.

Physical, chemical, biochemical, and microbiological experiments have shown that tinned foods which are produced using MCSCL and SCLO can be characterised not only by good sensory marks, but also with high food and biological values.

Table 5. The composition of fatty acids

Fatty acid	Content, % from the total of fatty acids			
	SCLO	'Blanched cod liver'	'Vegetable and mushroom paste'	'Liver and mushroom paste'
Saturated, including:	14.65	16.02	16.0	14.47
Lauric	0.02	0.02	0.14	0.03
Tridecanoic	0.15	0.02	0.02	0.01
Myristic	3.06	2.93	3.06	2.98
Pentadecanoic	0.785	0.73	0.71	0.63
Palmitic	7.825	8.82	8.38	7.91
Margarine	0.825	0.86	0.75	0.62
Stearic	2.13	2.64	2.93	2.285
Monounsaturated, including:	54.52	51.26	50.2	53.47
Myristoleic	0.095	0.1	0.12	0.09
Palmitoleic	7.81	7.26	6.6	7.575
Heptadecenoic	0.555	0.6	0.44	0.445
Oleic	23.89	25.3	24.33	23.91
Gadoleic	15.345	12.38	13.04	14.93
Erucic	6.815	5.62	5.67	6.52
PUFA, including	30.83	32.72	33.8	32.06
Hexadecadienoic	0.51	0.38	0.42	0.54
Hexadecatrienoic	0.365	0.27	0.31	0.29
Linoleic	2.4	2.45	10.0	9.17
Linolenic	3.22	3.59	2.73	2.62
Octadecatetraenic	0.25	0.25	0.2	0.17
Eicosadienoic	0.27	0.27	0.21	0.21
Eicosatrienoic	0.675	0.62	0.54	0.54
Arachidonic	0.29	0.31	0.23	0.23
Eicosapentaenoic	9.17	9.81	7.65	7.75
Docosatetraenoic	0.445	0.39	0.37	0.39
Docosapentaenoic	1.075	0.81	0.8	0.82
Docosahexaenoic	12.165	13.57	10.34	9.33
Saturated to PUFA ratio	0.475	0.490	0.473	0.451
PUFA ω-3: ω-6 ratio (estimated)	3.88	4.57	1.47	1.47

CONCLUSIONS

The actuality and necessity of using very valuable raw materials – cod liver with lipids that are rich in ω-3 and ω-6 PUFA – can now be shown to be proven.

The technology involved in processing cod liver using microwave heating has already been developed, which made it possible to protect the quality of the produced semi-finished product in its frozen state over a long period of time.

The technology involved in microwave cooking for cod liver oil has also previously been developed. This technology made it possible to store the frozen MCSCL for a long period of time.

The most acceptable mode involved in microwave treatment of the cod liver has been obtained (the layer need be no thicker than 40mm, cooking time is 2.5 minutes, and specific power is 2,000W kg^{-1}).

The maximum shelf life for frozen MCSCL is recommended to be up to four months according to microbiological tests and lipid quality value changes during storage.

The available assortment of single-component sterilised tinned cod liver is extended by using MCSCL.

The series of new multicomponent functional tinned foods that can be based upon MCSCL and fish oil which is separated during production has been developed. These products contain ω-3 and ω-6 PUFA. Vegetables, mushrooms, lean pork, and FPI were also used in the production of such foodstuffs.

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