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Oksana Chepurna,
Oksana Shtonda,
Iryna Osypenkova,
Yuliia Kurylenko

DETERMINATION OF THE DEPENDENCE OF THE FATTY ACID COMPOSITION OF BOILED-SMOKED SAUSAGES WITH THE ADDITION OF VEGETABLE RAW MATERIALS

The object of research is boiled-smoked sausages with the addition of vegetable raw materials, which can ensure the production of high-quality products with low cost and maximum yield.

One of the ways to solve this problem is to combine traditional and non-traditional resources, with preference given to additives of vegetable origin. When developing technologies for the production of new types of boiled-smoked sausages, part of the main raw material of animal origin is replaced by vegetable raw materials, thus obtaining a composite product. The authors used brewer's grain flour as a vegetable raw material. Brewer's grain is a valuable by-product in brewing, which is obtained after filtering the wort in the process of brewing beer.

Due to the need for a balanced diet, the study of fat is reduced not only to determining its mass content, but also to analyzing the fatty acid composition, nutritional, biological value and other indicators. Products containing plant raw materials have an improved fatty acid composition, which characterizes the nutritional and biological value of fats. In order to study the fatty acid composition, samples of boiled-smoked sausages were made from beef, pork, nitrite salt, sugar, black and allspice pepper, nutmeg and brewer's grain flour. Partial replacement of meat with brewer's grain flour in an amount of 2–6 % increases the biological value of the product by increasing essential fatty acids. Compared with the control sample, the following results were obtained: the amount of monounsaturated fatty acids increased by 6.8 % (sample 1), polyunsaturated fatty acids – by 39.3 % (sample 3). Regarding the amount of omega-3 fatty acids, the indicator increased in the 1st and 2nd samples, respectively, by 35.6 % and 8 %, while omega-6 increased in the 3rd sample by 45.2 % and expand the range of high-quality and lower-cost sausage products.

The created sausage products, with the addition of brewer's grain flour, allow solving the issue of recycling brewery waste. This is due to the fact that the rational use of resources and the principles of zero waste are the basis for increasing production efficiency, which allows for a comprehensive solution to the problem of resource supply of the economy and environmental protection.

Keywords: *boiled-smoked sausages, brewer's grain, saturated fatty acids, mono- and polyunsaturated fatty acids.*

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1. Introduction

Due to the martial law in Ukraine, there is a sharp reduction in the livestock population, so the pressing issue in the meat processing industry is to expand the raw material base through the use of plant raw materials. This allows to create additional resources, expand the range and increase the biological value of meat products.

With the development of scientific research on the biological value of boiled-smoked sausages, an important indicator is the fatty acid composition of raw materials.

The article [1] determined that the fatty acids of pork meat products have the following composition: monounsaturated 41–59 %, saturated 30–45 %, polyunsaturated 9–18 %. It is also noted that the proportion of individual fatty acids affects not only the biological value, but also the organoleptic indicators and shelf life of meat products. Saturated fatty acids have a higher melting point than unsaturated fats, but their excessive amount increases cholesterol levels, which is associated with cardiovascular disease and other chronic diseases [2]. The fatty acid composition of animal fats has a different degree of digestibility. It is believed that the lower the melting point, the higher its digestibility. For example, pork fat is digested by the human body by 96–98 %, beef fat – 80–90 % [3]. Saturated fatty acids are necessary for energy production, and are also involved in the construction of cells. However, excessive consumption of saturated fatty acids can lead to weight gain, increased cholesterol levels in the body, heart disease and even some types of cancer. If saturated fatty acids are not consumed, the body can synthesize them from other foods. However, this is an additional burden on the body, and saturated fatty acids are needed in small quantities [4]. Unsaturated fats are better absorbed by the body, but their high proportion in fat can worsen the oxidative stability of products [5] determining the biological value in meat snacks with the

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addition of honey, propolis extract and bee pollen. It was established [6] that in the experimental samples a decrease in saturated fatty acids was observed, while the amount of polyunsaturated fats increased slightly.

To improve the fatty acid composition, the article [7] developed a technology for semi-smoked sausages with the addition of lentil flour in an amount of 1–2 % to the total amount of meat raw materials. It was determined that with an increase in the concentration of the plant ingredient, the amount of saturated fatty acids decreased. In [8], the value of essential fatty acids in chicken meat products with the addition of rice flour was presented. The results showed that saturated fatty acids decreased by almost 3 times, and polyunsaturated fats increased by 7 times.

Particular attention is paid to the use of food industry waste as a secondary raw material. One of such promising areas is the use of brewing grains, which is a valuable source of proteins, fats and carbohydrates [9]. Modern scientific research is focused on the use of grains in the meat processing industry [10].

It has been studied that brewer's grains have high antioxidant properties, which are associated with the total content of phenols. The main classes of phenolic compounds present in the grains include hydroxycinnamic acids, which are hydroxy derivatives of cinnamic acid, formed by the phenylpropanoid pathway. Thus, the addition of brewery's grains to meat products, in particular boiled-smoked sausages, contributes to the enhancement of antioxidant activity by slowing down oxidation processes [11].

The scientific aim is to analyze the fatty acid composition of boiled-smoked sausages with the addition of plant raw materials to increase biological value.

The practical aim is to expand the raw material base of meat processing production, save meat resources, increase the range of sausage products, and utilize brewery waste.

2. Materials and Methods

The research was conducted in the laboratory of the Department of Analytical Research and Food Quality of the Institute of Food Resources of the National Academy of Agrarian Sciences of Ukraine (Kyiv, Ukraine).

For the research, samples of boiled-smoked sausages with the addition of brewery's grain flour were used, 2 % of the mass of raw materials, 2–4 % and 3–6 % were added to 1 sample.

Boiled-smoked sausages were produced using the following raw materials: beef, pork, nitrite salt, sugar, black and allspice pepper, nutmeg. The technological process included preliminary preparation of raw materials, chopping, mixing minced meat with the addition of brewer's grain flour, forming loaves, settling, cooking, smoking, drying. The control sample was prepared without the addition of brewery's grain flour.

The determination of the fatty acid composition was carried out in accordance with DSTU EN ISO 12966–4:2019 "Animal and vegetable fats and oils. Gas chromatography of fatty acid methyl esters. Part 4. Determination by capillary gas chromatography". Chromatographic analysis of fatty acids was performed on a Crystal 2000 gas chromatograph.

The obtained research results were processed using the built-in functions of Microsoft Excel 365.

3. Results and Discussion

Fats play an important role in human nutrition: they are sources of energy, supply the body with a complex of essential substances that are not synthesized in the human body and whose physiological significance is very high (fat-soluble vitamins, polyunsaturated fatty acids). In addition, fats perform taste, plastic, and protective functions.

Fat in meat is mainly represented by triglycerides, which include saturated and unsaturated fatty acids. The results of the study of saturated fatty acids in experimental samples according to different recipes of boiled-smoked sausages are given in Table 1.

Table 1

Saturated fatty acids, %

Fatty acid	Control, %	Sample 1	Sample 2	Sample 3
Butyric C4	0.019±0.000	0.026±0.001	0.014±0.000	–
Capric C6	0.009±0.000	0.027±0.001	0.017±0.000	0.003±0.000
Caprylic C8	0.011±0.000	0.014±0.000	0.01±0.000	0.011±0.000
Capric C10:0	0.085±0.003	0.087±0.003	0.087±0.003	0.092±0.003
Undecanoic C11:0	0.006±0.000	0.006±0.000	0.002±0.000	0.002±0.000
Lauric C12:0	0.183±0.011	0.179±0.011	0.147±0.009	0.161±0.010
Myristic C14:0	3.553±0.114	4.079±0.130	3.365±0.108	3.022±0.096
Pantadexaronic C15:0	0.621±0.017	0.755±0.020	0.728±0.020	0.495±0.013
Palmitic C16:0	25.718±0.267	27.208±0.277	27.217±0.286	25.972±0.266
Margarine C17:0	1.044±0.015	1.222±0.018	1.236±0.018	0.892±0.013
Stearic C18:0	14.072±0.226	13.019±0.212	15.275±0.244	14.23±0.237

Considering the data in Table 1, it can be concluded that the samples with brewer's grain flour contained approximately the same amount of saturated fatty acids compared to the control. The most abundant was palmitic acid 25.7–27.2 % and stearic acid – 13.019–15.275 %. Their main biological role is energetic. For example: complete oxidation of 1 molecule of palmitic acid in the human body leads to the formation of 130 ATP molecules. The overall equation for the oxidation of palmitic acid in mitochondria [12]:

$$C_{15}H_{31}COOH+23O_2+130ATP+130P_H \rightarrow$$
$$\rightarrow 16CO_2+16H_2O+130ATP.$$

Regarding low-molecular-weight saturated acids of butyric C4, caproic C6 and caprylic C8, which can affect the sensory properties of sausage products, their amount decreases slightly.

When determining the biological value of fats, the presence and quantitative content of the "triad" of essential (essential) fatty acids – linoleic, linolenic, arachidonic – is of great importance. These acids are vital substances that have vitamin activity. The mixture of these acids is called vitamin F.

Linoleic acid (cis-9, cis-12-octadiethylene acid):

$$CH_3-(CH_2)_4-CH=CH-CH_2-CH=(CH)_7COOH.$$

Linolenic acid (cis-9, cis-12, cis-15–octatrienoic acid):

$$CH_3-CH_2-CH=CH-CH_2-CH=$$
$$=CH-CH_2-CH-(CH)_7COOH.$$

Arachidonic acid (5,8,11,14-eicosatetraenoic acid):

$$CH_3-(CH_2)_4-CH=CH-CH_2-CH=$$
$$=CH-CH_2-CH=CH-(CH)_3COOH.$$

It is believed that a complete food should contain 0.1 % arachidonic or 1 % linoleic and linolenic acids, since there is an assumption that arachidonic acid is synthesized in the human liver from linoleic acid (Fig. 1) [12].

Currently, unsaturated fatty acids are divided into omega classes, which are designated depending on the position of the double bond closest to the methyl or ω-carbon. Accordingly, monounsaturated fatty acids – oleic and oleinopalmetinic are defined as ω-9 and ω-7, polyunsaturated – linoleic, arachidonic and γ-linolenic – ω-6, polyunsaturated – α-linolenic, docosahexaenoic and eicosapentaenoic – ω-3. ω-9 is considered necessary for the human body, but unlike ω-3 and ω-6, it can be synthesized by the body independently. The functions of fatty acids are given in Table 2.

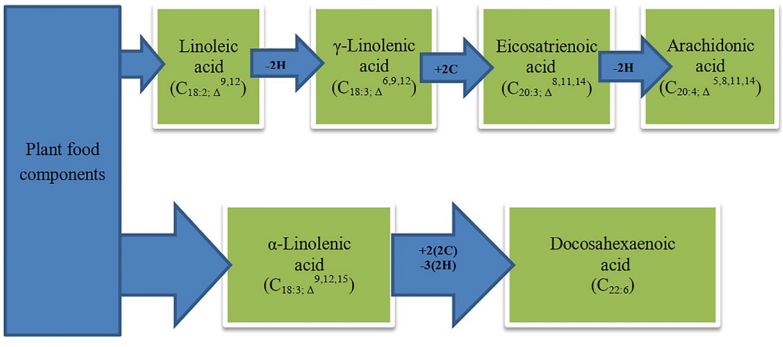

Fig. 1. Metabolic map of the biosynthesis of unsaturated fatty acids by the enzyme systems of the human body

Table 2

Functions of fatty acids

Fatty acids	ω-3: α-linolenic, docosahexaenoic, eicosapentaenoic	ω-6: linoleic arachidonic γ-linolenic	ω-9: oleic
Functions	Important for cardiovascular health by lowering cholesterol levels. Has anti-inflammatory properties, supports the immune system, regulates hormonal levels, stimulates tissue regeneration processes, are strong antioxidants	Play a role in regulating general processes, participate in the formation of cell membranes. Contribute to lowering blood sugar levels, increase the protection of the stomach lining, slow down skin aging processes	Affects blood cholesterol levels, provides energy, participates in the formation of cell membranes. Strengthens the body's protective functions. Normalizes the body's metabolism and promotes the synthesis of hormones

Note: developed based on data [13]

The quantitative characteristics of unsaturated fatty acids are presented in Table 3.

Among polyunsaturated fatty acids, linoleic acid (C18:2n6c), which is the precursor of arachidonic acid (C20:4n6), is considered essential. According to the results of the research, it was determined that the largest amount among unsaturated fatty acids was linoleic acid, the proportion of which varied depending on the amount of brewer's grain flour added. In sample 3, its amount increased by 46.7 % compared to the control. An equally important essential fatty acid is linolenic acid (C18:3n3), the amount of which increased in sample 1 by 24 % compared to the control. An increase in linolenic acid contributes to an increase in the content of ω -3 fatty acids, which contributes to a decrease in cholesterol in the human body and an improvement in cardiovascular health [14].

Fig. 2 presents the results of fatty acids in the experimental samples, namely the amounts of: saturated and unsaturated acids, ω-6 and ω-3.

According to the conducted studies, it can be concluded that the content of saturated and unsaturated fatty acids in all samples in relation to the control did not change significantly. As for the amount of monounsaturated fatty acids in samples 3 and 2, the indicators are lower than the control by 2.6 % and 7.2 %, and in 1 it increased by 6.8 %. The value of the amount of polyunsaturated fatty acids is significantly higher in sample 3 – by 39.3 %. As for the amount of omega-3 fatty acids, the indicator increased in samples 1 and 2, respectively, by 35.6 % and 8 %, while omega-6 increased in sample 3 by 45.2 %.

Taking into account the FAO recommendations, the indicators of biological effectiveness of fats of boiled-smoked sausages were determined, which are given in Table 4.

The nutritional value of fat is usually assessed using the ω-6/ω-3 ratio. According to FAO, there are no rational recommendations for the ω-6/ω-3 ratio, only recommended ones. However, recently there has been an increase in the consumption of ω-6 fatty acids, while ω-3 fatty acids have decreased, which has led to a significant increase in the ω-6/ω-3 ratio to 20:1 or even higher. Such an increase contributes to the spread of atherosclerosis, obesity and diabetes [16]. Based on the tabular data in the experimental samples, the biological value corresponds to the hypothetical ideal fat.

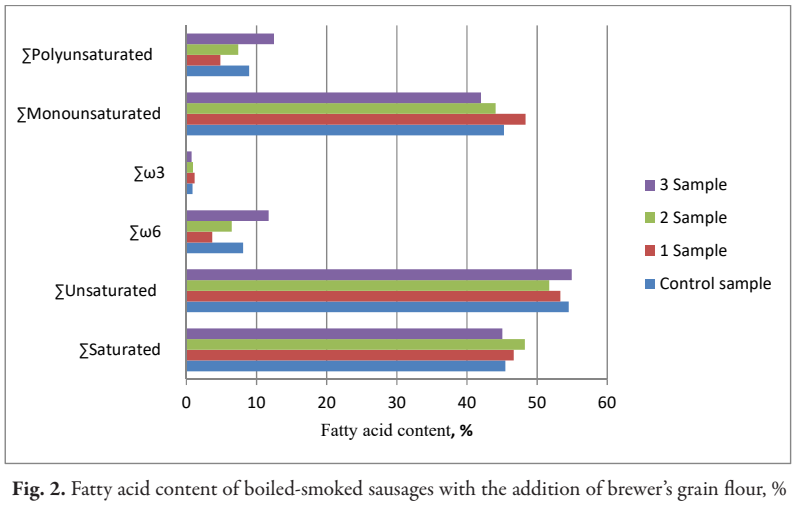

Fig. 2. Fatty acid content of boiled-smoked sausages with the addition of brewer's grain flour, %

Table 3

Unsaturated fatty acids, %

Fatty acid	Control, %	Sample 1	Sample 2	Sample 3
ω-3				
Linolenic C18:3n3	0.865±0.020	1.073±0.022	0.801±0.016	0.544±0.011
Eicosapentaenoic C20:5n3	0.000±0.000	0.001±0.000	0.002±0.000	0.004±0,001
Cys-4,7,10,13,16,19-Docosahexaenoic C22:6n3	0.002±0.000	0.006±0.000	0.000±0.000	0.002±0.000
ω-6				
Linoleic C18:2n6t	0.055±0.001	0.114±0.002	0.043±0.001	0.024±0.000
C18:2n6s	7.836±0.128	3.388±0.055	6.207±0.102	11.496±0.187
Arachidonic C20:4n6	0.025±0.003	0.044±0.006	0.053±0.007	0.038±0.005
ω-9				
Oleic C18:1n9t	2.472±0.102	2.397±0.099	2.638±0.109	1.402±0.058
C18:1n9s	36.41±0.464	36.947±0.478	35.26±0.445	35.082±0.451
Erucic C22:1n9	0.147±0.001	0.035±0.000	0.063±0.001	0.129±0.001

Based on the above, it can be stated that boiled-smoked sausages with the addition of brewery's grains have a high biological value and will have a positive effect on the human body when consumed.

The organoleptic quality indicators of a meat product include appearance, consistency, smell and taste. A description of the main indicators of a meat product is presented in Table 5 [17].

When determining the sensory quality of cooked-smoked sausage samples, each expert individually assessed the intensity of all indicators on a 5-point scale:

0 – no sign;
1 – only recognizable or felt;
2 – fairly clear intensity;
3 – moderate intensity;
4 – strong intensity;
5 – very strong intensity.

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Table 4

Biological efficiency indicators of fats of cooked and smoked sausages

Name	PUFA:MUFA:UFA	PUFA:UFA	Linoleic (18:2):Oleic (18:1)	Linoleic (18:2):Linoleic (18:3)	ω6:ω3
Hypothetically ideal fat	1:1:1	0.2–0.4	>0.25	>0.7	10:1 (4:1)
Control sample	1:1:1.2	0.2	0.22	9.06	9.1:1
Sample 1	1:1:1.2	0.1	0.1	3.16	3.3:1
Sample 2	1:0.9:1.1	0.2	0.2	7.75	7.9:1
Sample 3	1:0.9:1.2	0.3	0.33	21.13	11.6:1

Table 5

Description of the main indicators of the meat product

Indicators	Characteristics
Appearance (in product section)	
Moisture	Visual perception of moisture released
Porosity	Visual perception of small voids
Layering	Visual perception of concentric circles that disrupt the uniformity
Inclusions	Visual perception of any inclusions that disrupt the uniformity of the structure (including pieces of raw meat, connective tissue, etc.)
Red color intensity	The strength of the red color or "amount of red color", which varies in the range from light to dark
Consistency	
Density	The effort required to deform the product (tactilely – between the cutlery (finger) and the surface of the plate, in the oral cavity between the molars)
Juiciness	The amount of moisture released by the product
Stickiness	The effort required to overcome the force of gravity between the product surface and the teeth
Fatness	The quantitative sense of fat, perceived by touch
Taste	
Meaty	Sense associated with the presence of meat in a sausage product
Sweet taste	Taste caused by various spices and substitutes
Salty taste	Taste caused by sodium chloride
Smokedness	Sense associated with the perception of smoke or smoking liquid
Nutmeg	Sense associated with the perception of spice – nutmeg
Spicy	Sense associated with the perception of a complex of spices – cardamom and nutmeg
Glutamine	Complex sense of the perception of flavor saturation
By-product	Sense associated with the perception of thermally processed offal
Cardamom	Sense associated with the perception of spice – cardamom
Spice extracts	Sense associated with the perception of a complex of spices – pepper, cardamom and nutmeg, with a characteristic burning sense in the oral cavity
Milk	Sense associated with the perception of milk or cream
Animal protein	Sense of cooked connective tissue (pork) or beef hide) after heat treatment
Sour	Senses in the oral cavity caused by most organic and inorganic acids
Tart	Senses in the oral cavity caused by contraction of mucous surfaces and arising from the influence of chemicals such as phosphates, tannins, etc.
Alkaline	Sense associated with the presence of soap solution in the oral cavity a nd arising from the influence of chemicals such as phosphates, sodium bicarbonate, etc.
Salty	Perceptions in the oral cavity caused by fat oxidation products
Odor	
Spice extracts	Sense associated with short-term intense perception of a complex of cardamom and nutmeg
Meaty	Sense associated with the presence of meat in a sausage product
Smoked	Sense associated with the perception of smoke or smoking liquid
Nutmeg	Sense associated with the perception of spice – nutmeg
Spicy	Sense associated with the perception of a complex of spices – a mixture of cardamom and nutmeg
By-product	Sense associated with the perception of thermally processed offal

The results were entered into tasting sheets and profiles of appearance, consistency, smell, and taste were constructed based on the results obtained (Fig. 3).

In appearance, all samples, including the control, had a smooth, clean, dry surface and received the maximum number of points. Sample 2 had a more delicate consistency. In terms of taste, all samples had a meaty taste with a pronounced taste of spices, namely pepper and nutmeg. Sample 1 was distinguished by more pleasant taste characteristics and received the highest score, in sample 3 a sweetish aftertaste was felt, which is due to the high concentration of brewery's grain flour. In terms of smell, all samples received a high score. A sensation was observed that is associated with the presence of meat in the sausage product, smoke and nutmeg.

Considering the above, it can be concluded that replacing part of the meat raw materials with brewery's grain flour has a positive effect on the organoleptic indicators of boiled-smoked sausage.

Practical significance. The use of plant raw materials allows to increase the range of sausage products, expand the raw material base of meat processing production, while achieving savings in meat resources and partially solving the issue of recycling brewery waste.

The limitation of research is that the accuracy and reliability of the results depend on the climatic conditions of barley cultivation and its variety, the type of malt and the technological mode of its processing.

The influence of martial law conditions. Turning off the light during martial law conditions affected the duration of the research.

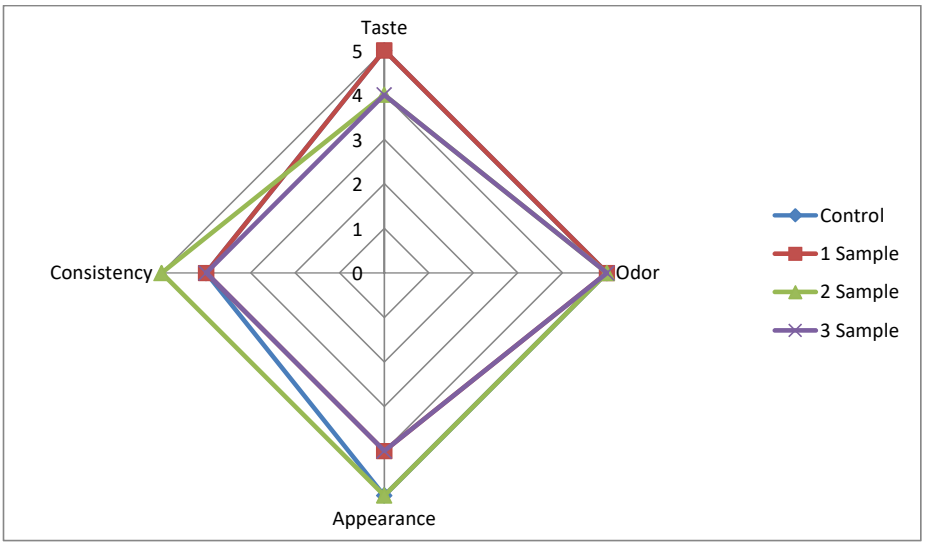

Fig. 3. Organoleptic profiles of boiled-smoked sausages with the addition of brewery's grain flour

The prospects for further research are to study the amino acid composition and safety of boiled-smoked sausages with the addition of brewery's grain flour.

4. Conclusions

The fatty acid composition of cooked-smoked sausage with the addition of brewer's grain flour was studied by capillary gas chromatography. It was found that this plant additive increases the biological value of the product by increasing essential fatty acids. Compared with the control sample, the following results were obtained: the amount of monounsaturated fatty acids increased by 6.8 % (sample 1), polyunsaturated fatty acids – by 39.3 % (sample 3). Regarding the amount of omega-3 fatty acids, the indicator increased in samples 1 and 2, respectively, by 35.6 % and 8 %, while omega-6 increased in sample 3 by 45.2 %.

This is explained by the fact that vegetable raw materials in the composition of fats contain more unsaturated fatty acids than meat raw materials. The organoleptic evaluation of the samples was evaluated according to the following indicators: taste, smell, consistency and appearance on the cut, each of which was evaluated on a five-point scale. With a maximum score of 20 points, the samples received the following results: control – 19 points, first – 18, second – 19 and third – 17.

The results obtained can be useful both theoretically, since the fatty acid composition of boiled-smoked sausage with the addition of brewer's grain flour was studied for the first time, and in practical terms: replacing meat raw materials, expanding the range of sausage products and using brewing waste as secondary raw materials.

Conflict of interest

The authors declare that they have no conflict of interest regarding this study, including financial, personal, authorship or other, which could affect the study and its results presented in this article.

Financing

The study was conducted without financial support.

Data availability

The manuscript has no linked data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies in creating the presented work.

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✉***Oksana Chepurna,*** *PhD Student, Department of Meat, Fish and Seafood, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine, e-mail: va88877@ukr.net, ORCID: https://orcid.org/0000-0003-1498-8745*

Oksana Shtonda, *PhD, Associate Professor, Department of Meat, Fish and Seafood, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0002-7085-6133*

Iryna Osypenkova, *PhD, Associate Professor, Department of Food Technology, Cherkasy State Technological University, Cherkasy, Ukraine, ORCID: https://orcid.org/0000-0001-6585-9359*

Yuliia Kurylenko, *Senior Lecturer, Department of Food Technology, Cherkasy State Technological University, Cherkasy, Ukraine, ORCID: https://orcid.org/0000-0001-6083-2122*

✉*Corresponding author*