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Editors office address:
National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony, Kyiv, Ukraine
E-mail: info@animalscience.com.ua
https://animalscience.com.ua/en

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Influence of different concentrations of taro paste on the sensory characteristics of poultry meat sausages

Shang Feifei[1, 2], Larysa Bal-Prylypko[3*], Tetiana Kryzhska[1], Svitlana Danylenko[3, 4], Duan Zhenhua[2], Tsvitana Korol[5]

[1]Sumy National Agrarian University
40000, 160 Herasym Kondratiev Str., Sumy, Ukraine

[2]Hezhou University
542899, 18 Xihuan Str., Hezhou, China

[3]National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

[4]Institute of Food Resources of NAAS
02000, 4A Yevhen Sverstiuk Str., Kyiv, Ukraine

[5]Institute of Post-Diploma Training of NUFT
03190, 8A Estonska Str., Kyiv, Ukraine

Abstract. Sausage products have a high fat content, which is not the most useful property for a sausage. The purpose of the study is the development of low-fat, nutritionally balanced sausage products. The object of the study was poultry sausages. The subject of research: changes in the quality characteristics of poultry sausage products conditioned by the use of different doses of taro puree, potato starch, and spices. Research methods: physical and chemical properties (moisture, pH, cooking losses, emulsion stability), colour and sensory characteristics of finished products. For the experiment, 500 g of minced poultry meat was prepared (the ratio of duck and chicken meat was 3:2), and 6 experimental groups (D1~D6) to which 0 g, 60 g (12%), 70 g (14%), 80 g (16%), 90 g (18%), 100 g (20%) of taro paste were added, respectively. The optimal amount of taro paste for duck-chicken sausage was determined by analysing sausage pH value, texture, shear stress, cooking loss, emulsion stability, colour, moisture distribution kinetics, and sensory evaluation. It was found that the addition of taro paste changes the structure of the poultry sausage and gives the sausage a unique flavour. Studies have shown that duck-chicken sausage with the addition of 80 g (16%) taro paste had the highest pH. Moisture content, cooking loss, firmness and chewability, and yellowness values were lower ($P<0.05$). Sausage brightness and redness values have been improved. It was found that duck-chicken sausages with 16% taro puree had the best colour, sensory texture and lower cooking losses. The results obtained allow the development of poultry sausage containing plant material and at the same time provide technical support for the use of taro paste in poultry sausage

Keywords: duck-chicken sausage, losses during cooking, quality characteristics, sensory evaluation, emulsion stability

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*Corresponding author

Introduction

Nowadays, there are more and more consumers in the world who prefer quality and safe products, balanced in composition and calories. Since duck and chicken meat are balanced in nutrients, rich in amino acids, and promote digestion and assimilation by the body, the development of sausages from these species is given much attention. Duck meat is a dark type of meat that is not dietary, unlike chicken, contains some of the healthy nutrients, but does not contain as much saturated fat as red meat and takes longer to digest [1]. Taro root is rich in dietary fibre (1.3 g/100 g) and high in protein (3.7 g/100 g). Their content in potato is only 0.75 g/100 g and 2.1 g/100 g respectively. Taro changes the nutritional composition and texture and flavour of poultry sausages.

Given the main trends in the food industry, the use of natural additives and the declared properties of taro paste can be considered a promising area of research. Therefore, the authors of this study focused on this segment, improving technology and expanding the range of duck and chicken sausages. Sausage is widely appreciated because it is rich in flavour, rich in protein, and is convenient to eat. The main raw materials of sausage are pork, beef, etc. It contains more fat, cholesterol and saturated fatty acids, and excessive intake may increase the risk of certain epidemic and chronic diseases [2; 3]. Therefore, adding plant raw materials to sausages to improve the structure of nutrients has become a focus of food researchers around the world. For example, mushrooms, celery, corn, oats, rice flour, crude fibre, etc. are added into sausage. These additives improve the quality of meat products. It has played a good role in increasing the dietary and nutritional properties of the product [3; 4].

The fat content of duck meat is moderate (about 7.5%), higher than in chicken, lower than in pork, and distributed more evenly in the whole body tissue. The fatty acids of duck meat are mainly unsaturated fatty acids and low-carbon saturated fatty acids. Therefore, it has a low melting point (about 35°C) and is easy to digest [5]. In China, duck meat processing has been a weak link for a long time. The duck industry is in the transition period from the segmentation stage to the finishing stage, and the processing level is still very low. C. Kunpeng *et al.* added edible fungi to duck emulsified sausage to improve its quality and nutritional properties. Compared with the results of the control group, the addition of mushrooms, truffles, and pine mushrooms increased the content of unsaturated free fatty acids and free amino acids in duck sausages, increased the umami taste, and at the same time inhibited the degree of fat oxidation [6].

Taro is a perennial crop of *Araceae* stem tubers. It contains low calories, a large amount of dietary fibre, starch, minerals, vitamins, amino acids and other nutrients [7; 8]. It has anti-tumour, anti-oxidation, anti-ageing properties and improves immunity [9-11]. Steamed taro is often served as part of Chinese breakfast. Taro is an alkaline food that can effectively regulate the body's acid-base balance. Therefore, it is a nutrient-rich, low-fat, and high-fibre edible and medicinal plant material. The addition of taro to sausages can change the nutritional content of the sausages and create a special product. X. Guo *et al.* [12] investigated the effect of different amounts of taro puree on the quality of pork balls. The results showed that the sensory evaluation and texture indexes such as hardness and elasticity of pork balls first increased and then decreased with the increase of the amount of taro puree. The addition of puree can change the quality of the pork balls. Therefore, it is very meaningful to develop a new product with duck meat as the main raw material and chicken and taro paste as auxiliary raw materials.

The purpose of this study was to explore the effect of the addition of taro puree, a plant raw material, in poultry sausages on the quality characteristics of sausages, and to provide a research basis for the next stage of product development.

Materials and Methods

Research trials have been completed in 2021 at the Institute of Food Science and Engineering Technology, Hezhou University, China. The Chinese teal's duck meat and chicken breast, taro, potato starch, spices, pepper, salt, Guilin Sanhua rice wine, and compound phosphate were purchased at the Hezhou city agricultural product market in China. Beet red came from the Food Engineering Research Institute of Hezhou University. The taro was washed, peeled, cut into pieces, steamed (30 min), cooled, mashed, and baked (60°C, 5-10 min) to determine the moisture content of 50% and set aside.

Processing of sausage: duck breast meat and chicken breast meat were chopped and mixed, and the ingredients (taro puree, potato starch, spices, ice water etc.) were mixed with minced meat, and the raw materials were put into the sausage casing with filling equipment and divided into sections with cotton thread. The product formula is shown in Table 1.

Table 1. *Duck-chicken sausage recipe with different additions of mashed taro instead of potato starch*

Ingredients (g)	Treatment					
	T1	T2	T3	T4	T5	T6
Duck meat	300	300	300	300	300	300
Chicken breast	200	200	200	200	200	200
Ice water	25	25	25	25	25	25
Onion and ginger Sauce	25	25	25	25	25	25
Rice wine	20	20	20	20		20
Corn starch	75	45	40	35	30	25
Taro puree	0	60	70	80	90	100
Other ingredients	14	14	14	14	14	14

Note: *Other ingredients include 7 g of salt, 1g of complex phosphate, 3 g of complex spices, 2 g of pepper and 1 g of beet red*

Determination of pH value: 5 g of the crushed sample was weighed into a sample tube, 20 mL of distilled water was added and stirred evenly, and placed it at room temperature for 30 min. A pH meter was used to measure the liquid in the middle layer.

Moisture content determination: a rapid moisture analyser was used and the temperature was set to 105°C. A preheated aluminium sample pan was put into the device, 1-2 g of the sample was weighed, and after closing the lid automatic heating was started to evaporate the water, repeated three times.

Cooking loss: the method was described by Jiang Shuai [13]. 35 g of minced meat was weighed into a 50 ml centrifuge tube and centrifuged (3,000 rpm, 5 min) to remove air bubbles in the tube. Then, it was heated in a water bath (75°C, 30 min), and the heated sample was cooled at room temperature for 1 hour, weighed after cooling, and its mass was recorded. The calculation of cooking loss is shown in equation (1):

$$Cooking\ loss\ (\%) = \frac{weight\ of\ raw\ meat\ batters\ (g) - weight\ of\ cooked\ meat\ batters\ (g)}{weight\ of\ raw\ meat\ batters\ (g)} \times 100 \quad (1)$$

Emulsion stability: the liquid lost during cooking (after the tube was centrifuged upside down for 40 minutes) was poured into a glass dish. Moisture loss was the weight of the liquid lost by cooking and drying after heating at 105°C for 16 hours, while fat loss was the mass of the sample remaining after the drying of the liquid lost by cooking [14]. The calculation of water loss and fat loss is shown in equations (2; 3):

$$Moisture\ loss(\%) = \frac{Weight\ of\ Cooking\ liquid - Remaining\ weight\ after\ heating}{Weight\ of\ raw\ meat\ batter} \times 100 \quad (2)$$

$$Fat\ loss(\%) = \frac{weighRemaining\ weight\ after\ heating}{Weight\ of\ raw\ meat\ batter} \times 100 \quad (3)$$

Colour: the sausage was removed from the casing, cooled to room temperature, and cut into 2 cm cylinders, and measured with A CR-400 colorimeter (calibrated with a white plate, L*= +97.83, a*= −0.43, b*= +1.98) using L* (brightness value), a* (redness value) value), b* (yellowness value).

Texture profile analysis: the test method was described by Yi. Chen *et al.* [15] with a slight modification. The sausage was removed from the casing, cut into a cylinder and placed on the TA-XT plus physical property tester for measurement. The test conditions were as follows: the probe was selected as P/5, the rate before the test was 5 mm/s, the test rate was 1 mm/s, test rate was 1 mm/s, the compression ratio was 50%, trigger force was 5 g.

Shear force: the test method was described by J. Song *et al.* [16] with a slight modification. The sausage was removed from the casing and cut it into 2 cm cylinders. The measurement parameters were set as: the probe model was HDP/BSW, and the pre-measurement rate was 2 mm/s, the test rate was 1 mm/s, the post-test rate was 2 mm/s, the measurement distance was 60.0 mm, and the trigger force was 10 g.

Moisture distribution: Low-field nuclear magnetic resonance (LF-NMR) was used to measure the free water, difficult-to-flow water, and bound water in the sausage samples, and the quality characteristics of the samples were analysed according to the relaxation time T2 and the peak area ratio of the three types of water. The main power switch was turned to preheat in advance, then, after turning on the computer host, monitor, and radio frequency, respectively, the standard oil sample was used for calibration. The sausage was cut into a cube, wrapped with plastic wrap, and put into the nuclear magnetic sampling tube to detect the sample relaxation time T2, and CONTIN was used to perform T2 inversion to obtain the corresponding relaxation times (T2b, T21, T22) and amplitudes (A2b, A21, A22) [17; 18].

Sensory evaluation: the sensory evaluation team consisted of 10 graduate students majoring in food science. The sausages were cut into cylinders with a thickness of 1 cm, and the judges scored the sausages in four aspects: colour, flavour, texture, and overall acceptability according to the sensory evaluation standard table, with a full score of 9 points. The sensory evaluation criteria are shown in Table 2 below.

Table 2. *Sensory Evaluation Standard*

Evaluation item	7~9 score	4~6 score	1~3 score
Colour	The colour is rose pink, the lustre is rich, and there is appetite	The colour is light pink purple, the colour is normal, and the appetite is normal	Brownish-yellow colour, dull, no appetite
Flavour	Basically no fishy smell, the taste is suitable, with the fragrance of taro paste	Slight fishy smell, moderate taste, light taro puree fragrance	Strong fishy smell, the taste is too light or too heavy
Texture	Good elasticity, uniform texture, less pores, smoother cut surface	Moderate elasticity, uniform texture, pores, smooth cut surface	Poor elasticity, loose texture, large pores, uneven cut surface
Integrated grade	Accept	General	Not accept

Statistical analysis: The measurement index was repeated 3 times, and the data results were expressed as mean ± standard deviation (X±S). Microsoft Excel 2017 software suite was used to draw charts.

Results and Discussion

The effects of different taro paste additions on the pH, moisture content, cooking loss, and emulsion stability of poultry sausages are shown in Table 3. Compared with the control group T1, the addition of taro paste had a significant effect on the moisture content, pH, cooking loss, and emulsion stability of duck sausage ($P<0.05$). With the increase of the amount of taro paste, the pH value of the sausage first increased and then decreased. When the amount of taro paste was 80 g (T4 group), the pH value of the sausage reached the highest; the moisture content of the sausage first decreased and then increased. When the amount of taro paste was 70 g (T3 group), the moisture content was the lowest, and there was no significant difference with the sausage moisture content of T4 group ($P>0.05$). The cooking loss and emulsion stability of sausage did not change regularly. When the addition amount was 80 g, the cooking loss, water loss, and fat loss reached the lowest value, which was significantly different from the control group ($P<0.05$), which may be related to the water absorption characteristics of dietary fibre in taro puree. When the amount of mashed taro was more than 80 g, the cooking loss of the sausage gradually increased, which indicated that the water retention of the sausage became poor, resulting in a serious loss of the sausage juice. The study by J. Li *et al.* [19] showed that when 10% taro was added to the pork patty, the cooking yield was the highest, and when the addition amount exceeded 10%, the steaming yield of the pork patty decreased. This shows that the addition of taro paste can effectively improve the quality of duck sausage. The T4 group (the addition amount of taro paste is 80 g) has the highest pH value, the lowest cooking loss rate, and the highest emulsification stability ($P<0.05$). The optimum addition amount of taro paste to duck sausage is 80 g.

Table 3. *Effects of different mashed taro instead of potato starch on pH, moisture content, cooking loss and emulsion stability of duck sausage*

Treatments	pH	Moisture content	Cooking loss, %	Water loss, %	Fat loss, %
T1	6.06 ± 0.15^{d}	64.69 ± 0.33^{b}	0.18 ± 0.01^{d}	0.15 ± 0.02^{e}	0.03 ± 0.02^{ab}
T2	6.07 ± 0.15^{cd}	67.20 ± 0.45^{a}	0.17 ± 0.01^{d}	0.16 ± 0.01^{d}	0.01 ± 0.01^{ab}
T3	6.10 ± 0.15^{b}	59.58 ± 0.73^{d}	0.25 ± 0.01^{c}	0.24 ± 0.01^{c}	0.02 ± 0.02^{ab}
T4	6.23 ± 0.15^{a}	60.54 ± 1.14^{d}	0.12 ± 0.01^{e}	0.11 ± 0.00^{f}	0.01 ± 0.01^{b}
T5	6.11 ± 0.10^{b}	62.99 ± 0.17^{c}	0.29 ± 0.00^{b}	0.26 ± 0.01^{b}	0.03 ± 0.01^{ab}
T6	6.09 ± 0.12^{bc}	63.07 ± 0.16^{c}	0.36 ± 0.02^{a}	0.32 ± 0.01^{a}	0.04 ± 0.01^{a}

Colour is an important parameter of sausage. The effect of different taro paste additions on the colour of duck sausage was shown in Table 4. The results showed that L* and a* first increased and then decreased ($P<0.05$), while b* decreased first and then increased ($P<0.05$) with the increase of taro puree. It can be seen from the results that adding 80 g of taro paste (T4 group) can significantly increase the brightness value L* and redness value a* of duck sausage, and reduce the yellowness value b* of sausage, which shows that adding a certain amount of taro paste can significantly increase the brightness of duck sausage. This is conditioned by the decrease in colour brightness caused by the presence of purple fibrous filamentous substances in areca taro [20].

Table 4. *Effect of different taro paste additions on the colour of duck sausage*

Treatments	L*	a*	b*
T1	56.32 ± 0.05^{d}	8.28 ± 0.20^{c}	11.14 ± 0.12^{ab}
T2	60.31 ± 0.14^{c}	10.20 ± 0.11^{b}	11.42 ± 0.24^{ab}
T3	62.59 ± 0.96^{a}	10.32 ± 0.25^{b}	11.66 ± 0.59^{a}
T4	62.46 ± 0.50^{ab}	11.29 ± 0.09^{a}	10.32 ± 0.40^{c}
T5	61.68 ± 0.24^{b}	10.98 ± 0.39^{a}	10.78 ± 0.13^{bc}
T6	59.59 ± 0.41^{c}	10.20 ± 0.29^{b}	11.13 ± 0.40^{ab}

Compared with the control group T1, the addition of taro paste had a significant effect on the hardness, stickiness, and chewiness of duck sausage ($P<0.05$), but had no significant effect on elasticity, cohesion, and recovery ($P<0.05$). The findings obtained by X. Guo *et al.* [12] showed that the addition of taro paste had a great influence on the stickiness and chewiness of taro meatballs, but had no significant change in springiness, hardness, and cohesion. Compared with the control group, the hardness, stickiness, and chewiness of the sausage first decreased and then increased with the increase of the amount of taro paste, while the elasticity, cohesion, and recovery did not change significantly. It shows that the addition of taro paste can effectively reduce the hardness, stickiness, and chewiness of duck sausage. The duck sausage in group T4 (the addition of taro paste is 80 g) is firm and elastic, and has the best texture and taste.

Table 5. *Effects of different taro paste additions on texture properties of duck sausage*

Treatments	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness	Resilience
T1	9,564.08 ± 54.82^{a}	0.92 ± 0.05^{ab}	0.82 ± 0.04^{a}	7,884.15 ± 441.72^{a}	7,222.20 ± 753.52^{a}	0.46 ± 0.03^{a}
T2	7,395.92 ± 68.39^{b}	0.94 ± 0.03^{a}	0.79 ± 0.07^{a}	5,874.45 ± 447.70^{b}	5,515.97 ± 502.21^{b}	0.43 ± 0.04^{a}
T3	7,261.53 ± 54.98^{b}	0.88 ± 0.03^{ab}	0.84 ± 0.04^{a}	6,114.56 ± 286.59^{b}	5,368.97 ± 414.37^{b}	0.45 ± 0.03^{a}
T4	5,284.02 ± 106.95^{e}	0.86 ± 0.02^{b}	0.82 ± 0.04^{a}	4,338.90 ± 215.08^{d}	3,712.84 ± 223.07^{d}	0.44 ± 0.03^{a}
T5	5,522.35 ± 81.03^{d}	0.87 ± 0.03^{ab}	0.81 ± 0.04^{a}	4,453.19 ± 272.37^{d}	3,871.33 ± 303.49^{cd}	0.42 ± 0.03^{a}
T6	6,277.13 ±157.44^{c}	0.91 ± 0.05^{ab}	0.83 ± 0.07^{a}	5,176.56 ± 339.22^{c}	4,719.49 ± 571.30^{bc}	0.42 ± 0.05^{a}

In addition, the shear force value is an important indicator for evaluating the tenderness of meat and meat products, and the smaller the value, the better the tenderness of meat. As can be seen from Figure 1, compared with the control group T1, the shear force of the sausage showed a trend of first decreasing and then increasing with the increase of the amount of mashed taro ($P<0.05$), indicating that the mashed taro can improve the sausage within a certain range of addition, but it will reduce the tenderness of the sausage beyond a certain range. The results showed that with the addition of 80 g of taro puree (T4 group), the shear force of the sausage was the lowest, indicating that adding 80 g of taro puree could make the sausage tenderness the best, which was consistent with the measurement results of texture. The water distribution results of the sausage after adding the taro paste were shown in Figure 2.

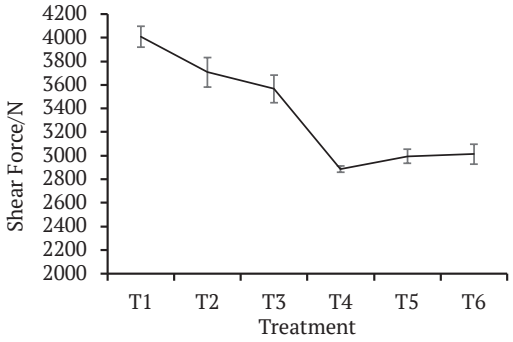

Figure 1. The effect of different taro paste additions on the shear force of sausages

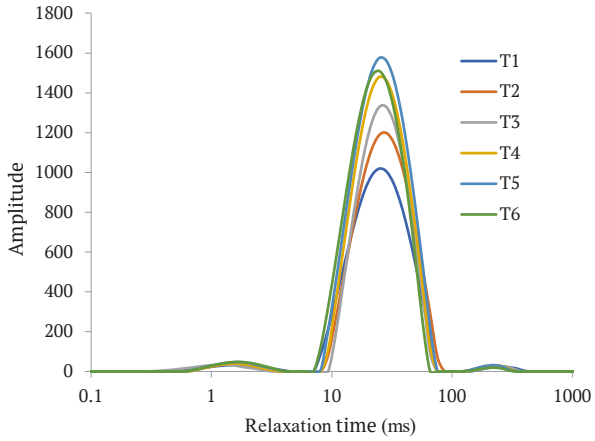

Figure 2. The results of the effect of adding taro paste on the moisture distribution of sausages

It can be seen from Figure 2 that the duck sausage has 3 peaks, and the 3 peaks from left to right are bound water (T2b), difficult-to-flow water (T21), and free water (T22). Compared with the control group T1, different additions of taro paste can change the internal water distribution of the sausage. The bound water relaxation time of the T3 group shifted towards the longer relaxation time, while the bound water relaxation time of the T2, T4, T5, and T6 groups all shifted towards shorter times, among which the T4 group had the shortest relaxation time for bound water, which indicated that the water was tightly bound to the protein and was not easily lost. It can be seen from the peak area of the difficult-to-flow water that the non-flowable water content of the sausage in the experimental group was higher than that in the control group. The content of flowing water was not a significant change in the relaxation time of free water, which indicated that the addition of taro paste changed the bound water and difficult-to-flow

water in the sausage, so that the water in the sausage was tightly combined with the protein. Yi. Chen *et al.* used the pre-emulsion to replace the fat in the frankfurter sausage. The results also showed that the three water relaxation times shifted towards shorter relaxation times, which also showed that the original non-flowing water in the sausage was more closely combined with the protein in the meat [15].

The results of the sensory evaluation of sausages are shown in Table 6.

Table 6. *Effect of taro paste on the sensory evaluation of sausage*

Treatments	Colour	Flavour	Texture	Integrated grade
T1	5.87 ± 0.15^{d}	6.47 ± 0.21^{d}	6.43 ± 0.12^{d}	6.77 ± 0.12^{c}
T2	6.63 ± 0.21^{c}	6.93 ± 0.15^{c}	6.87 ± 0.21^{bc}	7.23 ± 0.21^{b}
T3	6.97 ± 0.15^{b}	7.37 ± 0.12^{b}	7.13 ± 0.15^{b}	7.50 ± 0.20^{b}
T4	7.57 ± 0.21^{a}	8.07 ± 0.21^{a}	7.77 ± 0.25^{a}	8.13 ± 0.15^{a}
T5	7.13 ± 0.15^{b}	7.70 ± 0.20^{b}	7.03 ± 0.15^{b}	7.40 ± 0.20^{b}
T6	7.03 ± 0.21^{b}	7.57 ± 0.21^{b}	6.67 ± 0.21^{cd}	7.23 ± 0.15^{b}

The sensory evaluation of sausage showed a trend of first increasing and then decreasing with the increase of taro puree ($P<0.05$), and the sausage in the experimental group (T4) with the addition of 80 g taro had the highest sensory evaluation score.

When the amount of mashed taro added is low, the flavour of the mashed taro in the sausage is too light, and the fragrance of mashed taro can hardly be felt, with a heavy fishy smell and more pore looseness, decreased elasticity, and more pores. When the amount of taro puree added was 80 g, the taro puree in the sausage had a moderate aroma, less fishy smell, firm texture, better elasticity, and higher overall acceptance. It shows that the moderate amount of taro paste can significantly improve the sensory quality of duck sausage.

Conclusions

Excessive nutrition accelerates the occurrence of cardiovascular and cerebrovascular diseases. Reducing the fat content and improving the nutrient content of food is a research hotspot. The research focus of developing a nutritious sausage product is to add taro, a nutritionally balanced plant material rich in dietary fibre, to duck and chicken sausages. This study paid more attention to the characteristics of sausages while changing the composition of raw meat and increasing dietary fibre to change the nutritional composition.

The effect of different taro paste additions on the quality of duck sausage was investigated, and the duck sausage was evaluated by analysing the sausage pH, texture, shear force, cooking loss, emulsion stability, colour difference, sensory evaluation, and moisture distribution dynamics. It was determined that the optimum addition amount of taro paste was 16% (80 g/500 g poultry) and duck-chicken sausage had the highest pH value, and the moisture content, cooking loss, hardness and chewiness, and yellowness value were significantly reduced ($P<0.05$), the brightness value and redness value of the sausage were improved, and the sausage obtained good colour and taste. The findings can provide reference for the development of new poultry sausage products.

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Вплив різних концентрацій пасти таро на сенсорні характеристики ковбас з м'яса птиці

Шан Фейфей[1,2], Лариса Вацлавівна Баль-Прилипко[3], Тетяна Анатоліївна Крижська[1], Світлана Григорівна Даниленко[3,4], Дуань Чженьхуа[2], Цвітана Олександрівна Король[5]

[1]Сумський національний аграрний університет
40000, вул. Герасима Кондратьєва, 160, м. Суми, Україна

[2]Університет Хечжоу
542899, вул. Сіхуань, 18, м. Хечжоу, Китай

[3]Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

[4]Інститут продовольчих ресурсів НААН
02000, вул. Євгена Сверстюка, 4А, м. Київ, Україна

[5]Інститут післядипломної освіти НУХТ
03190, вул. Естонська, 8А, м. Київ, Україна

Анотація. Ковбасні вироби мають високий вміст жиру, що є шкідливою властивістю ковбаси. Мета роботи – розробка нежирних, поживно збалансованих ковбасних виробів. Об'єктом дослідження були взяті ковбасні вироби з м'яса птиці. Предмет досліджень: зміни якісних характеристики ковбасних виробів з м'яса птиці від використання різних доз пюре таро, картопляного крохмалю, спецій. Методи досліджень: фізико-хімічні властивості (волога, pH, втрати при варінні, стабільність емульсії), колірні та сенсорні характеристики готових продуктів. Для досліду готували фарш з м'яса птиці по 500 г (співвідношення м'яса качки та курки 3:2), і 6 дослідних груп (Д1~Д6) до яких додавали 0 г, 60 г (12 %), 70 г (14 %), 80 г (16 %), 90 г (18 %), 100 г (20 %) пасти таро відповідно. Оптимальна кількість пасти таро до качино-курячої ковбаси була визначена шляхом аналізу значення pH ковбаси, текстури, напруження зсуву, втрати при варінні, стабільності емульсії, кольору, кінетики розподілу вологи та сенсорної оцінки. З'ясовано, що додавання пасти таро змінює структуру ковбаси з птиці та надає ковбасі неповторний аромат. Дослідження показали, що качино-куряча ковбаса з додаванням 80 г (16 %) пасти таро мала найвищий pH. Вміст вологи, втрата при варінні, твердість і жувальна здатність, а також значення жовтизни були нижчі ($P < 0,05$). Значення яскравості та червоності ковбаси було покращено. Обґрунтовано, що сосиски з качино-курячих м'яса з додаванням 16 % пюре таро мали найкращий колір, сенсорну оцінку текстури та менші втрати при варінні. Показано, що отримані результати дослідження дозволяють розробити ковбасу з птиці, що містить рослинний матеріал, і в той же час забезпечити технічну підтримку для застосування пасти таро в ковбасі із м'яса птиці

Ключові слова: качино-куряча ковбаса, втрати за кулінарної обробки, якісні характеристики, сенсорна оцінка, стабільність емульсії

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Influence of the qualitative and quantitative composition of the queen-rearing colony and the number of grafted larvae on the weight of queen bees

Mykola Voinalovych*, Valerii Brovarskiy, Ihor Golovetskyi

National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Abstract. The relevance of the study is conditioned by the practical need to determine the optimal number of grafted larvae in the queen-rearing colony when breeding queen bees. The purpose of the study was to investigate the influence of the qualitative and quantitative composition of bees and brood in the queen-rearing colony on the reception of queen larvae and the weight of reared queen bees. The study was conducted using bees of breed *Apis mellifera sossimai*. To complete the tasks set, control and experimental groups of three bee colonies each were formed. The difference between the control and experimental groups was the different age ratios of bees and the number of open and sealed broods. In each group of colonies, 30, 40, 50, 60 larvae were alternately grafted at a time with an interval of 5 days, the percentage of their reception, the output of queens and their weight were determined by counting the number of larvae that the bees fed and from which the queens came out, and the weight of queens was determined on laboratory scales during the first four hours after leaving the queen cell. A total of 862 queen bees were bred and studied. During the research, it was found that in the colonies of the experimental group, if they were grafted from 30 to 40 larvae, the percentage of their reception was 88.1-86.2%, respectively. Analysing the weight indicators of queens obtained with a given number of grafted larvae, it was found that it was 195.0-197.3 mg, there was no significant difference with the corresponding indicators of the control group. However, with the subsequent loading of queen-rearing colonies in the experimental group with 50 larvae, the percentage of their reception prevailed by 18.2%, and the weight of queens exceeded similar indicators of the control group by 10%. Notably, the average weight of queens in the control group was 176.3 mg, which is 8.7 mg less than the requirements for the weight of infertile queens established by the breed standard. With a further increase in simultaneously grafted larvae in the queen-rearing colony to 60 units, the rate of their admission in the experimental group decreased by 5% and amounted to 80.5%. At the same time, in the control group, larval reception and queen weight decreased to unacceptable levels and amounted to 67.5% and 172.4 mg, respectively. Therefore, by increasing the number of nurse bees and reducing the number of open brood in the queen-rearing colony, better conditions are created for growing high-quality queen bees, which, in turn, allows simultaneously grafting 48% more larvae compared to the conventional method. The results of the study are of practical value for improving the methods of establishing queen-rearing colonies during the artificial breeding of queen bees

Keywords: *Apis mellifera sossimai*, bee brood, larval reception, queen quality, royal jelly, queen larvae

Introduction

Honeybees (*Apis mellifera* L.) are social insects that live in colonies characterised by a cooperative system of brood care, generational overlap, and reproductive distribution of functions. In such an organised biosocial structure, the queen is a fertile female, whose main duty is to lay eggs [1]. In addition, the queen maintains the cohesion of the colony by continuously producing a “bouquet” of pheromones that actively spread in the nest. They prevent worker bees

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*Corresponding author

from replacing the queen and developing their ovaries [2]. The development, productivity, and survival of a bee colony largely depend on the health and physical fitness of its queen and the drones with which it mates [3]. The bee colony is negatively affected if the queen shows any defects or gets sick and stops laying eggs [1; 4]. In addition to pesticides, parasites, and pathogens, queen loss is considered the most important factor leading to the loss of bee colonies worldwide, especially when it occurs outside the active queen breeding season [5]. There are many indicators that can be related to the quality of the queen, which is a result of its genetic origin, development conditions, mating quality, and its habitat, including beekeeper care [6; 7]. The most intuitive are the physical indicators of the queen, such as body weight, which significantly correlates with its morphological measurements and the productivity of the bee colony [8-10]. Weight has also been found to positively correlate with successful queen reception in new colonies [11]. Body weight also positively correlated with the reproductive organs of the queen, such as the ovaries and the number of egg tubes, the diameter of the sperm, and the number of sperm stored [12]. Some researchers [13] have argued that queen body weight may represent an integral measure of size and physiological state. Therefore, it can be considered one of the most informative indicators of the quality of the queen.

The formation of the queen bee's body occurs in the early stages of ontogenesis. It is known that the quality of feeding the brood largely depends on the quality of future queens [14; 15]. Nurse bees under the age of 18 days actively take part in this process. This group of bees has royal jelly, which is necessary for the development of the queen. At the same time, it was found that bees secrete two fractions of royal jelly, so bees of 12 days of age secrete a white fraction of jelly enriched with proteins, and slightly older (17 ± 2) – a transparent one rich in carbohydrates [16]. In the process of feeding queen larvae, the quality of feed is constantly changing, which is determined by the ratio of these fractions [17]. Consequently, the shortage of young bees in the nest of queen-rearing colonies can negatively affect the development of the queen bee brood, and, accordingly, the quality of the resulting queens. There are no recommendations for compliance with certain requirements of the state of the queen-rearing colony and the specifics of its formation in different periods of the queen breeding season.

Given these circumstances, *the purpose of the study* was to investigate the influence of bee age groups and the ratio of brood (open and sealed) in the nests of queen-rearing colonies on the reception of queen larvae and the weight of reared queen bees

Literature Review

The quality of artificially bred queen bees undergoes significant changes during the season. Researchers explain this by the different states of queen-rearing colonies, the amount of feed, weather conditions, etc. [18]. In addition, some researchers have argued that the quality of queen bees depends on the genotype, nutritional factors, growing methods and period, the age of the grafted larvae, and the number of larvae that are grafted into each queen-rearing colony [19]. The number of grafted larvae and their age can be easily regulated by beekeepers who plan to breed queen bees. The optimal number of grafted larvae is the one that allows growing the maximum number of high-quality queen bees. If the number of grafted larvae is greater than optimal, the quality of queen bees begins to decrease [17; 19]. The quality of queens decreases with the increasing age of grafted larvae, and vice versa. Queens grown from one-day-old larvae are known to be heavier than queens grown from two-and three-day-old larvae, just as queens grown from two-day-old larvae are heavier than queens grown from three-day-old larvae [20]. Researchers have found that bees are able to take an active part in the rearing of queen larvae only from the age of five days, and the best results were obtained in the presence of worker bees of 9-12 days of age [21]. Under conditions of older age (13-20 days), bees were raised next to full-fledged queens, transitional forms, and even older nurses – dwarf queens [22]. It has been experimentally found that strong colonies with a large number of nurse bees provide better conditions for growing queen larvae. An approximate sign of the number of young bees can serve as the number of brood in the queen-rearing colony [23].

To obtain high-quality queens, it is important that the age composition of the queen-rearing colony and the presence of open and sealed brood are optimal. The first reports on this issue are found in the study by S.C. Jay [24]. The researcher pointed out that the amount of larval food depends on the general condition of the queen-rearing colony, and especially on the presence of open brood in its nest. The absence of open brood in the queen-rearing colony significantly increases the amount of food for larvae. Consequently, an increase in the number of open brood in the queen-rearing colony leads to a decrease in the intensity of larval feeding. Later, researchers investigated that the amount of royal jelly in the queen cell depends more on the state of the colony (the number of nurse bees, the availability and reserves of food in the nest, honey collection, etc.) than on the presence or absence of open brood [4; 21].

In previous studies, the optimal composition of the queen-rearing colony was determined by the ratio of the age groups of bees (75% of nurse bees and 25% of flying bees) and open to sealed brood (1 to 5) [23]. However, it was important to find out how many grafted larvae such colonies can grow without reducing the quality of the resulting queen bees.

Materials and Methods

The study was conducted on the premises of the Holosiivskyi educational and experimental apiary of the National University of Life and Environmental Sciences of Ukraine in the period from May to July 2022.

A control and experimental group of queen-rearing colonies were developed, which had 10 kilograms of carbohydrate feed each and tightly seeded 12 frames, of which 8 were with brood. The difference between them was the different ratio of working individuals, the number of open and sealed brood. Each group consisted of three bee colonies. The ratio of the age groups of bees and brood remained unchanged (natural for this period of time). Experimental colonies were formed from 75% of young and 25% of flying bees, this ratio of bees was achieved by shifting the hive approximately 1 m relative to its original position, then the intensity of the flight of bees was visually observed, and if

necessary, the hive was shifted to achieve the required ratio of flying bees in it. The general scheme of the method of preparing a queen-rearing colony, considering the age ratio of bees, is shown in Figure 1.

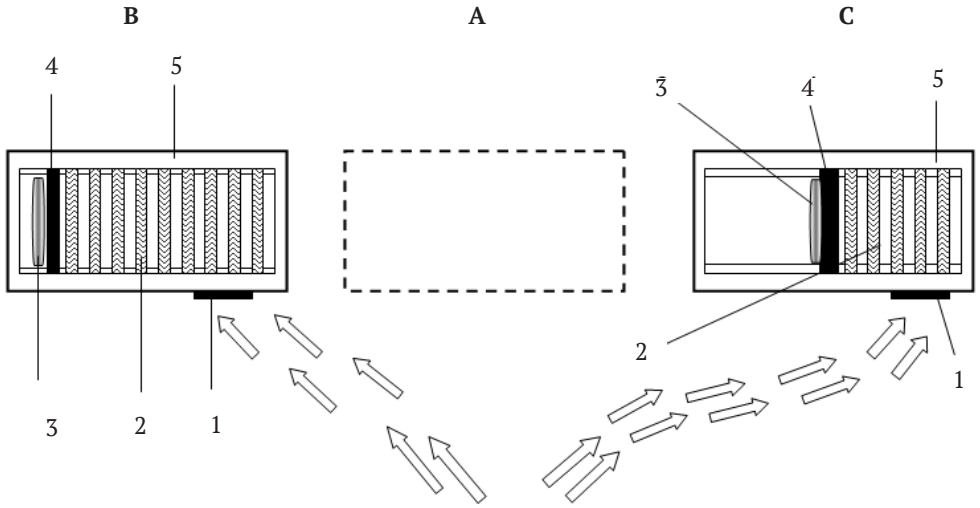

Figure 1. Diagram of moving hives when establishing a queen-rearing colony with the required number of flying bees, (top view): A – location of the bee colony hive before the formation of nucleus and nurse; B – hive of the queen-rearing colony moved to the left after forming a nucleus; C – location of the beehive with nucleus; 1 – hive opening; 2 – honeycomb; 3 – insulation cushion; 4 –partition; 5 – hive body. Arrows indicate the direction of the bees' flight

The ratio of open and sealed brood in the experimental colonies was 1:5, honeycombs with extra open brood were moved to other colonies, and the required amount of sealed brood was taken from donor colonies. In total, there were 7 honeycombs with brood in the colony. Due to the use of the method of shifting the hive of the future queen-rearing colony, some of the flying bees move from its nest to another hive or department with a separate opening, but the nurse bees of the queen larvae remain in the queen-rearing colony. 12 hours before the larvae were grafted for queen rearing, the queen was selected in colonies and a space was left in the middle of the nest for setting up a grafting frame with larvae. Experimental colonies received open brood from donor colonies every 6 days, and after 12 days – sealed to maintain a constant ratio between them. Colonies in the control group were replenished with only two frames of sealed brood after 12 days.

Grafting of larvae was carried out in artificially made wax bowls, which were fixed on the grafting frame in three rows. 24-hours old larvae were taken for grafting. During the research, 30 to 60 larvae were grafted in the queen-rearing colony at intervals of 5 days. Two days after the transfer of larvae, the percentage of their reception by queen-rearing colonies was checked. The quality assessment of infertile queen bees was carried out based on the determination of their weight in the first 4 hours after their exit from the queen cells using WALCOM lb202 laboratory scales. A total of 862 queens were evaluated during the study.

Results and Discussion

The process of establishing a queen-rearing colony is a defining stage in the technology of breeding queen bees. That is why many researchers have tried to determine the optimal way to establish them [21; 22; 24]. However, the vast majority of researchers describe methods that are based on general recommendations for the preparation and establishment of queen-rearing colonies [17; 19]. Based on previous studies, it was found that the best results in growing queens are obtained from queen-rearing colonies formed with a certain ratio between nurse bees and flight bees, as well as open and sealed brood [23].

As a result of the study to determine the optimal number of grafted larvae in queen-rearing colonies, which are formed considering the ratio between the age groups of bees and the number of open and sealed brood (experimental group), it was established (Table 1) that the percentage of larval reception in the 30-piece grafting variant was 88.1%, and no significant difference was found with the colonies of the control group.

Table 1. *Influence of the method of establishing a queen-rearing colony on the reception of larvae and the weight of infertile queen bees, n = 862*

Indicators	Given larvae, units	Groups	
		Experimental	Control
Percentage of larval reception, %	30	88.1 ± 2.65	87.7 ± 2.53
	40	86.2 ± 2.41	81.6 ± 2.34
	50	84.3 ± 1.40***	71.3 ± 0.90
	60	80.5 ± 0.79***	69.7 ± 0.94

Table 1, Continued

Indicators	Given larvae, units	Groups	
		Experimental	Control
Received queens, units	30	26.4 ± 0.66	26.3 ± 0.63
	40	34.4 ± 0.71	32.6 ± 0.71
	50	42.1 ± 0.49***	35.6 ± 0.32
	60	48.3 ± 0.32***	41.8 ± 0.37
Weight of queens, mg	30	197.3 ± 1.14	193.6 ± 0.85
	40	195.0 ± 1.00	185.4 ± 1.06
	50	193.7 ± 1.25***	176.3 ± 1.54
	60	190.3 ± 1.25***	172.4 ± 1.21

Note: *** – *P < 0.001 significantly relative to the control group*

With a further increase in the number of larvae that were grafted in the queen-rearing colony, there was a tendency to gradually decrease the percentage of larval reception. Thus, under the conditions of grafting 40 larvae in the queen-rearing colony, the bees provided 86.2% rearing, which is 5% more than in the control group, and when grafting 50 larvae, the percentage of admission in the colonies of the experimental group was 84.3%, which is 18.2% more compared to the control group. In the case of transmission of 60 larvae to queen growing, the percentage of admission in the experimental group decreased by 5% with the previous variant (50 larvae), but in the control group there was still a significant decrease in the percentage of admission to the level of 65.7%, this, in turn, is 22.5% less compared to the indicators of the experimental group, the difference is highly significant (P<0.001).

As a result of the study, there is a tendency to gradually decrease the percentage of larval reception with an increase in the number of grafted larvae. Thus, when growing queen larvae in the amount of 30 to 40 units by queen-rearing colonies, there was no significant difference in the reception of larvae by the colonies of the control and experimental group, only when 40 to 60 larvae were grafted, there was a predominance of 18-22.5% in the reception of larvae by the colonies of the experimental group. The output of infertile queens also corresponded to this trend.

Queens with the highest weight were obtained under the conditions of grafting 30 larvae in the queen-rearing colony, their average weight was 197.3 mg, which is 2.0% more than the same indicators of the control group. There was no significant difference between these variants compared to the control group. In the future, with an increase in the number of grafted larvae, this indicator gradually decreased, so when 40 larvae were transferred to growing, the weight of infertile queens in the colonies of the experimental group was 195 mg, which is 5.2% more than in the control group. When grafting 50 larvae, the queens of the experimental group had an average weight of 193.7 mg and prevailed in this indicator by 10% over the queens of the control group, which did not meet the breed standard by average weight. With a further increase in the load of queen-rearing colonies with larvae for growing queens, there was a further decrease in the weight of infertile queens received, in particular, in the experimental group it was 190.3 mg, which is 10.4% more compared to the weight of queens received from the colonies of the control group. The difference between the weight of queens raised in queen-rearing colonies with a load of 50 to 60 larvae is significant (p < 0.001).

According to the standard of the Ukrainian steppe bee breed, the weight of infertile queens should be at least 185 mg. These requirements were met by the queens of the control group of colonies under growing conditions from 30 to 40 larvae. At the same time, when establishing queen-rearing colonies, considering the ratio of the age composition of bees, and the ratio of open to sealed brood, it was possible to obtain infertile queens, which even with an increase in grafted larvae to 60 units met the requirements of the standard for this breed of bees, since they had an average body weight of 190.3 mg.

Artificial breeding of bees is a responsible process in which many factors must be considered to achieve the desired result. Thus, the period of the season affects the physiological state of colonies, which, in turn, affects the tendency of bees to raise queens [7]. Since the preparation of the queen-rearing colony is an important technological element in the growing of queen bees, therefore, many researchers put forward similar requirements for the state of the queen-rearing colony, and note that it must be healthy, have a force of at least 12 compartments with bees of different ages, 7-9 honeycombs with different ages of brood, and feed supply at the level of 10-12 kg [17; 18]. The researchers also paid much attention to the investigation of the influence of the general condition of the queen-rearing colony on the quality of the queens received, but the researchers did not give specific ratios for different ages of bees in colonies. When studying the influence of working individuals on the cultivation of brood in a queen-rearing colony, researchers found that the level of feeding of queen larvae depends on the presence of young bees in its composition [4; 21; 22]. However, there are no uniform recommendations among researchers regarding the number of larvae that are transferred for growing to the queen-rearing colony. Some researchers claim that the queen-rearing colony, which is established by the method of complete orphanhood, can be grafted with 60 larvae or more [19], others, on the contrary, prove the opposite, that their number should not exceed 20-30 units [18]. Analysis of the vital activity of bee colonies throughout the spring-summer season showed that even under optimal conditions in the nests of bee colonies, there was no condition that 75% of young bees were in their nests, and the ratio between open and sealed brood was 1:5 [23]. At the same time, in some cases, bee colonies create conditions in their nests that are similar to those

that were in the colonies of experimental groups when conducting these studies. This applies to swarming. Admittedly, swarm queens are characterised by high quality if bees raise them in strong colonies, in the presence of honey collection and favourable weather [6; 7; 10]. Given these conditions, as a result of the conducted research, it was first established that when establishing queen-rearing colonies in the nests of which mainly young bees are concentrated and the share of open brood is reduced, it is possible to increase the number of larvae grafted on queen growing to 60 units. At the same time, the yield of queen bees and their weight is ensured at a high level.

Conclusions

As a result of the conducted studies to determine the optimal number of grafted larvae in the queen-rearing colony, which are established considering the ratio between the age groups of bees and the number of open and sealed brood, it was found that the percentage of larval reception under grafting conditions from 30 to 40 units was 88.1-86.2%, respectively. The average weight of infertile queens obtained within this series of graftings in the experimental group was 195.0-197.3 mg, there was no significant difference with the colonies of the control group. With a further increase in the number of larvae that were grafted in the queen-rearing colony, there was a tendency to significantly decrease the percentage of larval reception. When grafting 50 larvae, the percentage of reception in the experimental group was 84.3%, which is 18.2% more than in the control group, the average weight of queens was 193.7 mg, which is 10% higher than the weight of queens in the control group. When grafting 60 larvae, the percentage of reception in the experimental group decreased by only 5% with the previous variant (50 larvae), but in the control group there was still a significant decrease in the percentage of reception to the level of 65.7%, which is 22.5% less compared to the indicators of the experimental group, the difference is significant ($P < 0.001$).

Thus, it was found out that when establishing a queen-rearing colony, which includes 75% of nurse bees and 25% of flying bees, the ratio of open to sealed brood is 1 to 5 allows increasing the number of grafted larvae by 20 units compared to the conventional method of establishing a queen-rearing colony and bringing it to 60 larvae, their reception is at the level of 80.5%, and the average weight of queens is 190.3 mg, which corresponds to the breed standard.

The results of the study will contribute to improving the methods of establishing queen-rearing colonies during the artificial breeding of queen bees.

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Вплив якісного і кількісного складу сім'ї-вихователькиі та кількості прищеплених личинок на масу бджолиних маток

Микола Володимирович Войналович, Валерій Дмитрович Броварський, Ігор Іванович Головецький

Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Анотація. Актуальність дослідження зумовлена практичною необхідністю визначення оптимальної кількості прищеплених личинок у сім'ї-вихователькиі при виведенні бджолиних маток. Метою даного дослідження було вивчення впливу якісного і кількісного складу бджіл та розплоду в сім'ї-вихователькиі на прийом маточних личинок і масу вирощених бджолиних маток. Дослідження проводили з використанням бджіл раси *Apis mellifera sossimai*. Для виконання поставлених завдань було сформовано контрольну і дослідну групи по три бджолиних сім'ї в кожній. Різниця між контрольною і дослідною групою полягала у різному віковому співвідношенні бджіл та кількості відкритого і запечатаного розплоду. У кожну групу сімей по черзі прищеплювали 30, 40, 50, 60 личинок за один раз з інтервалом 5 діб, визначали відсоток їх прийому, вихід ділових маток та їх масу шляхом підрахунку кількості личинок які бджоли годували, та з яких вийшли матки, визначення маси маток здійснювали на лабораторних вагах впродовж перших чотирьох годин після виходу з маточника. Всього було виведено та досліджено 862 бджолині матки. Під час проведення досліджень з'ясовано, що в сім'ях дослідної групи, за умови прищеплення їм від 30 до 40 личинок, відсоток їх прийому становив 88,1-86,2 % відповідно. Аналізуючи показники маси маток, одержаних за даної кількості прищеплених личинок, встановлено, що вона становила 195,0-197,3 мг, варто відмітити, що вірогідної різниці з відповідними показниками контрольної групи не виявлено. Однак з подальшим навантаженням сімей-вихователькок дослідної групи 50-ма личинками, відсоток їх прийому переважав на 18,2 %, а маса маток на 10 % аналогічні показники контрольної групи. Варто відміти, що середня маса маток у контрольній групі становила 176,3 мг, що на 8,7 мг менше за встановлені стандартом породи вимоги до маси неплідних маток цієї раси. При подальшому збільшенні одночасно прищеплених личинок у сім'ї-вихователькиі до 60 штук, показник їх прийому в дослідній групі знизився на 5 % і становив 80,5 %. В той же час, у контрольній групі прийом личинок та маса маток знизилися до неприйнятних рівнів і становили 67,5 % та 172,4 мг відповідно. Отже за рахунок збільшення чисельності бджіл годувальниць та зменшення кількості відкритого розплоду в сім'ї-вихователькі створюються кращі умови для вирощування якісних бджолиних маток, це в свою чергу дозволяє одночасно прищеплювати на 48 % більше личинок порівняно з традиційним способом. Результати дослідження становлять практичну цінність для удосконалення способів формування сімей-вихователькок при штучному виведенні бджолиних маток

Ключові слова: *Apis mellifera sossimai*, бджолиний розплід, прийом личинок, якість маток, маточне молочко, маточні личинки

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Ichthyofauna of the Bilotserkivskyi lower reservoir on the Ros river

Anton Klymkovetskyi*, Maksym Khalturyn

National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Abstract. The composition of ichthyofauna of Ukraine is changing due to natural processes and the influence of anthropogenic factors in the internal water bodies. Systematic analysis of changes allows controlling these processes and maintaining the diversity of species at a constant level. The purpose of the study was to investigate changes in the composition of the ichthyofauna of the Bilotserkivskyi lower reservoir (Ros River) after the discharge of industrial waste of the Bilotserkivvoda enterprise in 2017 and 2020, which led to the mass death of fish and crayfish. The studies were conducted by catching fish with species identification and a survey of fishermen from November 2016 to October 2020. Additionally, the species composition of fish in this section of the Ros River was considered before the reservoir was created. According to the results of the conducted studies, 24 fish species were identified in 2016, 21 in 2017, and 19 in 2020. Analysing the number of ichthyofauna since the 1960s, it can be concluded that every 10 years the species composition of the ichthyofauna of the Bilotserkivskyi lower reservoir lost about 2-3 species of fish, which is conditioned by the influence of riverbed overlap, industrial activities, uncontrolled and unidentified discharges into the reservoir, etc. After a detailed analysis of the number of ichthyofauna, it was established that by 2016, the following species had disappeared: common dace *Leuciscus leuciscus*, Dnieper chub *P. borysthenicus*, ide *I. idus*, sunbleak *Leucaspius delineatus*, vimba bream *Vimba vimba*, crucian carp *Carassius carassius*, weatherfish *Misgurnus fossilis*, spined loach *Cobitis taenia*; in 2017 – species such as gudgeon *Gobio gobio*, round goby *Neogobius melanostomus*, tubenose goby *Proterorhinus marmoratus*; in 2020 – char, ruffe. Quantitative and qualitative restoration of ichthyofauna is possible at the expense of fish from the Protoka River (Rotok). To continue fishing use, it is necessary to settle fish in the reservoir. The practical significance of this study is to determine the species composition of the ichthyofauna for further use of the reservoir for environmental and fishery purposes

Keywords: inland water bodies, freshwater fish, catch, industrial discharges, ecological fish groups

Introduction

Almost a third of the entire river system of the European steppe zone is located on the territory of Ukraine. The Dniester, Southern Buh, and Dnipro rivers are among the five largest rivers in Europe [1]. Having such a potential of the natural environment, it is relevant to investigate the impact of anthropogenic stress on the environment and maintain ecological balance for the safety of water bodies.

Pollution of internal reservoirs of Ukraine has become threatening. Due to excessive pollution of wastewater, the ability to self-clean aquatic ecosystems also decreases, as a result of which the quantitative and qualitative component of the food supply and fish spawning grounds decreases.

A significant transformation of water bodies (rivers and lakes), which affects the conditions of existence of various representatives of ichthyocenoses that are not able to fully adapt [2] to newly created ecosystems, is reflected in their number [3] and the nature of distribution, which leads to a decrease in the diversity of ichthyofauna with the replacement of long-cyclical species with short-cyclical and

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**Corresponding author*

more plastic ones. In turn, small rivers also play the role of ecological corridors for invading species. The preservation of the natural environment and its species diversity requires constant scientific research and systematic monitoring, especially in small rivers [4].

Ros River basin – is an intensively developed economic complex. Various industries (food, light, and petrochemical) take part in the river catchment area, which have an impact on various components of the aquatic ecosystem. Pollution with heavy metals, petroleum products, and organic substances, disruption of vegetation cover, physical contamination with water erosion products, ingress of pesticides and fertilisers into the water network – all these are the results of harmful industrial activity [5]. The largest wastewater discharges belong to LLC Bilotserkivvoda, which fall on the Bilotserkivskyi lower reservoir; discharges of other subjects have a much smaller impact on the state of the reservoir's biota [6].

The Bilotserkivskyi lower reservoir is the third and last in a series of Bilotserkivskyi reservoirs on the Ros River, located in the city of Bila Tserkva (Figure 1). The dam was built near the village of Shkarivka, designed by the Ukrvodokanalproekt institute and was put into operation in 1971. The main task of the reservoir is to provide water to the private JSC Rosava (formerly the Bilotserkivskyi Tire Factory) [7].

Figure 1. Location of the Bilotserkivskyi lower reservoir on the Ros River

In 2017 and 2020, discharges from the Bilotserkivvoda enterprise occurred, which led to the mass death of fish and crayfish, as a result – reduction of the food base for fish. In the literature on this reservoir, the problem of changes in the composition and abundance of ichthyofauna before and after man-made consequences was quite little mentioned, so it became necessary to analyse the state of the ichthyofauna of the Bilotserkivskyi lower reservoir.

The purpose of the study was to investigate changes in the ichthyofauna of the middle part of the Ros River and after the creation of the Bilotserkivskyi lower reservoir in retrospect and analyse the impact of uncontrolled industrial discharges.

Literature Review

The ichthyofauna of fresh water bodies is affected by a number of factors. The construction of dams during the creation of ponds and reservoirs often has a negative impact on fish biocenoses [8]. Natural features of the riverbed partition are the change of dominant species, in particular, pelagic, herbivorous, and large species with long-distance reproductive migrations are replaced by omnivorous, bentopelagic, and insectivorous species that characterise fish living in a stable environment [9]. In Ukraine, ponds and reservoirs are usually dominated by invasive fish species, most of which are caught during stocking for biological reclamation [10]. Due to the spread of invasive species, changes in hydraulic and temperature conditions reduce or completely displace local fish.

Industrial wastewater pollution plays a key role in the problems of river system biodiversity. Through them, radionuclides, toxic organic and inorganic substances enter the water, in particular, sulphur, asbestos, solvents, polychlorinated biphenyl, lead, mercury, nitrates, phosphates, acids, alkalis, dyes, pesticides, etc. [11]. This leads to a number of changes that affect the flora and fauna of

water bodies. A change in the chemical state of water leads to changes in the ichthyofauna. In particular, it was found that an increase in oxygenation, temperature and number of macrophytes, and the concentration of potassium and a decrease in the concentration of phosphates, Mg and Cl ions creates favourable conditions for such species as crucian carp and tench [12].

In addition to these factors, the number of fish correlates with the area of the basin and the maximum depth of the reservoir and the area of the buffer zone [13]. Due to over-regulation of wastewater flow, water "blooming" is often observed in reservoirs, which causes significant damage to hydrobionts. The qualitative and quantitative composition of the ichthyofauna of natural waters – lakes, rivers, ponds, and reservoirs – is an extremely sensitive indicator of the state and level of anthropogenic load of the studied hydroecosystems. The river network of the Ros River basin is marked by diversity, which is a research perspective, however, the issues of species diversity of ichthyofauna, its qualitative and quantitative composition in various ecological groups have so far been considered only fragmentary, mainly as a result of episodic studies in individual tributaries and specifically on the Ros River, in particular [14-16].

O.I. Surmyi and Z.N. Mavryshcheva [17] investigated the species composition and linear dimensions of fish even before the construction of a reservoir in the Bila Tserkva district (Shkarivske or Bilotserkivskyi lower reservoir). They found 32 species of fish (pike *Esox lucius*, common roach *Rutilus rutilus*, common dace *Leuciscus leuciscus*, chub *Leuciscus cephalus*, Dnieper chub *P. borysthenicus*, ide *I.idus*, rudd *Scardinius erythrophthalmus*, asp *Aspius aspius*, tench *Tinca tinca*, gudgeon *Gobio gobio*, common bleak *Alburnus alburnus*, white bream *Blicca bjoerkna*, common bream *Abramis brama*, vimba bream *Vimba vimba*, Amur bitterling *Rhodeus sericeus*, crucian carp *Carassius carassius*, Prussian carp *Carassius auratus gibelio*, common carp *Cyprinus carpio*, grass carp *Ctenopharyngodon idella*, stone loach *Nemachilus Barbatulus*, weatherfish *Misgurnus fossilis*, spined loach *Cobitis taenia*), and also provided information on the distribution and abundance of these species in the area under study from Bila Tserkva to Shkarivka village. One of the species is the grass carp (*Ctenopharyngodon idella*) – is noted by the authors as acclimatised for breeding in the ponds of the Alexandria arboretum, from where its spawn got into the Ros channel.

As of 2020, the species composition of fish has changed significantly. The study of the fish population of the rivers of the middle Dnipro region, including Ros, indicates the absence of vyrezub, Danube bleak, and lepomis in the catches [18; 19], which were previously mentioned in the studies. During the study on the Protoka River, which is a right tributary of the Bilotserkivskyi lower reservoir, the species composition of fish is characterised by a fairly wide variety. In particular, in 2013 the presence of such species as European bitterling (*Rhodeus amarus*), spined loach (*Cobitis taenia*) and weatherfish (*Misgurnus fossilis*) was noted [20; 21]. In general, the species composition of fish in the Ros River and in some parts of it varies. This is influenced by a number of factors, including anthropogenic loads.

Materials and Methods

The study was conducted from November 2016 to November 2020 at sites within the village of Shkarivka, Bilotserkivskyi district, at the discharge sites of the Rosava tire plant and the upper part of the reservoir near the dam of the Bilotserkivskyi lower reservoir, located on the Ros River between the city of Bila Tserkva and Shkarivka village.

In November 2016, an expedition visit to the reservoir was carried out to collect samples, which was later used for statistical analysis. In May 2017 and 2020, repeated visits were conducted to take ichthyological and hydrobiological samples in connection with the discharges of Bilotserkivvoda [22]. For additional analysis, the species composition of the only tributary of the Bilotserkivskyi lower reservoir, the Rotok River (Protoka), was studied. The study of ichthyofauna was based on the species composition, fish productivity, and other necessary components.

Ichthyological studies were conducted according to generally accepted methods: fish belonging to a certain species by characteristic, specific, individual, external features inherent only in a certain species, and their belonging to an ecological group.

The collection of ichthyological material was carried out by analysing catches from nets, interviewing amateur fishermen, the local population, and materials seized by the inspection from poachers. A 25 m long fry drag net was used to catch young fish. After the analysis, the test material was released back into the reservoir. The description of the species composition of fish and the processing of the material were performed according to the methods described in the determinants of freshwater fish [23; 24]. The findings were compared with the species composition of fish in this part of the Ros River before the creation of the reservoir [17] and after its development [25].

Results and Discussion

In the Ros River, before the creation of the Bilotserkivskyi lower reservoir, 32 species of fish belonging to 8 families were recorded. In the future, there was a significant reduction in the number of species. In particular, there were 20 species from the family Cyprinidae (Table 1) in the 1960s.

Table 1. *Analysis of the composition of the ichthyofauna of the Ros River and the Bilotserkivskyi lower reservoir before and after discharges (family Cyprinidae)*

Types of fish	Ros River, middle part		Bilotserkivskyi lower reservoir (Ros River)		
	1960s [17]	1970s [25]	2016	2017	2020
European carp *(Cyprinus sagrao)*	detected	detected	detected	detected	detected
Prussian carp *Sagassiis auratus gibelio*	detected	detected	detected	detected	detected
Silver carp *Hypophthalmichthys molitrix*	not detected	not detected	detected	detected	detected

Table 1, Continued

Types of fish	Ros River, middle part		Bilotserkivskyi lower reservoir (Ros River)		
	1960s [17]	1970s [25]	2016	2017	2020
Common roach *Rutilus rutilus*	detected	detected	detected	detected	detected
Grass carp *Ctenopharyngodon idella*	detected	detected	detected	detected	detected
White bream *Blicca bjoerkna*	detected	detected	detected	detected	detected
Common bream *Abramis brama*	detected	detected	detected	detected	detected
Common rudd *Scardinius erythrophthalmus*	detected	detected	detected	detected	detected
Common bleak *Leucaspiusde lineatus*	detected	detected	detected	detected	detected
Asp *Aspius aspius*	detected	detected	detected	detected	detected
Gudgeon *Gobio gobio*	detected	detected	detected	not detected	not detected
Bitterling *Rhodeus sericeus*	detected	detected	detected	detected	detected
Tench *Tinca tinca*	detected	detected	detected	detected	detected
Topmouth gudgeon *Pseudorasbora parva*	detected	detected	detected	detected	detected
Common dace *Leuciscus leuciscus*	detected	detected	not detected	not detected	not detected
Dnieper chub *P. borysthenicus*	detected	detected	not detected	not detected	not detected
Ide *I. idus*	detected	detected	not detected	not detected	not detected
Sunbleak *Leucaspius delineatus*	detected	detected	not detected	not detected	not detected
Spirlin *Alburnoides bipunctatus*	detected	detected	not detected	not detected	not detected
Vimba bream *Vimba vimba*	detected	detected	not detected	not detected	not detected
Crucian carp *Carassius carassius*	detected	detected	not detected	not detected	not detected
Total	20	20	14	13	13

The creation of the reservoir did not quickly affect the species composition of fish of this family, and in the 1970s, the species composition of the family Carpinidae remained unchanged. Over a longer period of time, until 2016, the species composition of fish of the family Carpinidae changed significantly. 7 species of fish have disappeared, in particular: common dace, Dnieper chub, ide, sunbleak, spirlin, vimba bream, and crucian carp. However, as a result of artificial fish settlement, the silver carp appeared, which is used to regulate the number of microscopic algae. After uncontrolled industrial discharges into the reservoir's water area, gudgeon disappeared in 2017, which indicates the vulnerability of this species to water pollution.

Predatory fish species belonging to the families *Esocidae, Siluridae,* and *Percidae* were represented in the Ros River and reservoir by only 5 species (Table 2).

Table 2. *Analysis of the composition of the ichthyofauna of the Ros River and the Bilotserkivskyi lower reservoir before and after discharges (families Percidae, Esocidae, and Siluridae)*

Types of fish	Ros River, middle part		Bilotserkivskyi lower reservoir (Ros River)		
	1960s [17]	1970s [25]	2016	2017	2020
Perch *Perca fluviatilis*	detected	detected	detected	detected	detected
Pikerperch *Sander lucioperca*	detected	detected	detected	detected	detected
Ruffe *Acerina cernua*	detected	detected	detected	detected	not detected

Table 2, Continued

Types of fish	Ros River, middle part		Bilotserkivskyi lower reservoir (Ros River)		
	1960s [17]	1970s [25]	2016	2017	2020
Pike *Esox lucius.*	detected	detected	detected	detected	detected
Catfish *Silurus glanis.*	detected	detected	detected	detected	detected
Total	5	5	5	5	4

All these species are well adapted, both in the conditions of a river with a relatively strong current, and in a reservoir. From the 1960s to 2017, the presence of these species did not decrease. Even anthropogenic pollution of the reservoir did not lead to their complete disappearance. However, a repeated case of untreated discharges in 2020 led to the disappearance of ruffes (*Acerina cernua)*, which indicates their greater vulnerability compared to other species.

In the Ros River in the 1960s, there were 8 more species of fish that belonged to the families *Odontobutidae, Nemacheilidae, Cobitidae, Gobiidae* (Table 3).

Table 3. *Analysis of the composition of the ichthyofauna of the Ros River and the Bilotserkivskyi lower reservoir before and after discharges (families Odontobutidae, Nemacheilidae, Cobitidae, Gobiidae)*

Types of fish	Ros River, middle part		Bilotserkivskyi lower reservoir (Ros River)		
	1960s [17]	1970s [25]	2016	2017	2020
Amur sleeper *Perccottus glenii*	detected	detected	detected	detected	detected
Monkey goby *Neogobius fluviatilis*	detected	detected	detected	detected	detected
Round goby Neogobius melanostomus	detected	detected	detected	not detected	not detected
Tubenose goby *Proterorhinus marmoratus*	detected	detected	detected	not detected	not detected
Stone loach *Nemachilus barbatulus*	detected	detected	detected	detected	not detected
Weatherfish *Misgurnus fossilis*	detected	detected	not detected	not detected	not detected
Spined loach *Cobitis taenia*	detected	not detected	not detected	not detected	not detected
Total	7	6	5	3	2

As of 2020, there are only 2 species left, Amur sleeper (*Perccottus glenii*) and the monkey goby (*Neogobius fluviatilis*) from the families *Odontobutidae* and *Gobiidae*, respectively. Immediately after the creation of the reservoir, spined loach (*Cobitis taenia*) and later weatherfish (*Misgurnus fossilis*) have disapeared. Pollution of the reservoir in 2017 led to the disappearance of two species of the family *Gobiidae*, and in 2020 – the stone loach (*Nemachilus barbatulus*) from the family *Nemacheilidae* disappeared.

According to the results of the latest research on the composition and condition of the ichthyofauna of the Bilotserkivskyi lower reservoir before discharges, it can be argued that the most represented is the family *Carpinidae*, which includes 13 species: carp, Prussian carp, silver carp, roach, grass carp, rudd, common bleak, gudgeon, bitterling, tench, and topmouth gudgeon. Less numerous are the families *Percidae* (perch, pikeperch), *Odontobutidae* (Amur sleeper), *Esocidae* (pike), *Siluridae* (wels catfish).

Studies of the actual commercial fish species of the Bilotserkivskyi lower reservoir indicate the presence of carp, Prussian carp, silver carp, perch, rudd, and pikeperch in the reservoir. The quantitative and qualitative composition of the ichthyofauna of the reservoir under study is confirmed by the results of fry netting, in which the same species were found.

The results of the conducted studies of the Bilotserkivskyi lower reservoir in November 2016 allowed calculating the reserves of commercial fish species, which were (tonnes): 22.7: carp – 3.0, herbivores – 5.0, other species – 14.7, including: Prussian carp – 3.7, roach – 1.5, rudd – 0.5, tench – 0.5, pike – 4.0, pikeperch – 1.5, catfish – 1.0, perch – 2.0. The broad-fingered crayfish is also found in the reservoir. The latter's reserves were 2.1 tonnes.

The actual productivity for commercial fish species of the Bilotserkivskyi lower reservoir in November 2016 in general was 319.7 kg/ha, including by species: carp – 42.3 kg/ha, herbivores – 70.4, other species – 207.1 kg/ha, including: Prussian carp – 52.1 kg/ha, roach – 21.1 kg/ha, rudd – 7.0 kg/ha, tench – 7.0, catfish – 14.1 kg/ha, pike – 56.3 kg/ha, pikeperch – 21.1 kg/ha, perch – 28.2 kg/ha. The crayfish productivity was 29.6 kg/ha.

Species composition of the ichthyofauna of the Bilotserkivskyi lower reservoir (Ros River) in May 2017 showed a sharp decrease in the species composition of the ichthyofauna in the reservoir. Fish belonging to 7 families were found. As usual, the most numerous family was

Carpinidae – 7 species (Prussian carp, roach, white bream, bream, common bleak, bitterling, topmouth gudgeon); *Percidae* – 3 species (perch, pikeperch, ruffe), *Gobiidae* – 1 species (monkey goby); *Odontobutidae* – 1 species (Amur sleeper).

In terms of relative abundance, the reservoir was dominated by valuable commercial fish species, namely: bream (14.6%) and pikeperch (27.9%). Among other fish species, European perch, Eurasian ruffe, and monkey goby predominated in number.

The species composition of fish in November 2016 was 19 species, and in May 2017 – only 18 species. The species composition decreased by 1 species.

Analysis of the age composition of fish showed a small number of age groups in the reservoir. Prussian carp had 7 age groups (this order was the largest), bream – 5, and perch – 3 age groups. In all other fish species, namely roach, pikeperch, and white bream, only 2 age groups of non-sexually mature fish are established.

Fish productivity of the Bilotserkivskyi lower reservoir (Ros River) in May 2017 (71 ha) was – 319.7 kg/ha. After the chlorine discharge in May 2017, the fish productivity was only 240-250 kg/ha. That is, it decreased by 70 kg/ha, primarily due to carp and herbivorous fish.

The species composition in 2020 compared to 2016 decreased by 2 species. The study found not only a decrease in the number of species composition of ichthyofauna, but also fish productivity in the reservoir as a whole.

For more than 50 years (1960s-70s – 2020s) as part of the ichthyofauna of the middle part of the Ros River in the Bila Tserkva district has undergone significant qualitative and quantitative changes. This was caused by the results of intensive hydraulic engineering construction at the end of the 20th century, when the transition from a river to a lake (reservoir) type of reservoir took place. This is also the commercial use of the reservoir, which has led to a sharp decrease in the species diversity of the ichthyofauna. The use of the reservoir for water supply has led to an emergency discharge of technological water by the Bilotserkivvoda enterprise, which, in turn, sharply reduced the qualitative and quantitative composition of the fish population of the Bilotserkivskyi lower reservoir (Ros River).

It can be conclude that in 2016 the following species disappeared since the 1960s: common dace *Leuciscus leuciscus*, Dnieper chub *Leuciscus borysthenicus*, ide *I.idus*, sunbleak *Leucaspius delineatus*, vimba bream *Vimba vimba*, crucian carp *Carassius carassius*, weatherfish *Misgurnus fossilis*, spined loach *Cobitis taenia*, in 2017 – gudgeon *Gobio gobio*, round goby *Neogobius melanostomus*, tubenose goby *Proterorhinus marmoratus*, in 2020 – char, ruffe. Every 10 years the species composition of the ichthyofauna of the lower Bilotserkivskyi reservoir lost at least 2-3 species of fish, which is conditioned by the influence of anthropogenic factors, industrial activity, uncontrolled and unidentified discharges into reservoirs.

With further monitoring of the state of the ichthyofauna of the reservoir, the hydrological location of the river is upstream and less subject to anthropogenic pollution, tributaries of the reservoir can serve as a mechanism for restoring the ichthyofauna. According to M.B. Prychepa [20], the species composition of the ichthyofauna consisted of 20 species of fish, which are grouped into 7 orders and 8 families. The following species were found in the catches: *Perca fuviatilis* – perch, *Gumnocephalus cermua* – Eurasian ruffe, *Esox lucius* – pike, *Silurus glanis* – wels catfish, *Rutilus rutilus* – common roach, *Scardinius erychophtalmus* – common rudd, *Abramis brama* – common bream, *Carassius auratus* – goldfish, *Blicca bjoerkna* – white bream, *Tinca tinca* – tench, *Alburnus alburnus* – common bleak, *Cyprinus carpio* – European carp, *Pseudorasbora parva* – topmouth gudgeon, *Hypophthalmichthys molitrix* – silver carp, *Ctenopharyngodon idella* – grass carp, *Gobio gobio* – gudgeon, *Misgurnus fossilis* – weatherfish, *Gasterosteus aculeatus* – three-spined stickleback, *Perccottus glenii* – Amur sleeper, *Neogobius fluviatilis* – monkey goby.

The species composition of the ichthyofauna of the Protoka (Rotok) River exceeded bottom (44.4%) and bottom-swimming fish species (22.4%). A small proportion of natural species in the river's ichthyofauna (16.6%) indicates insufficiently favourable living conditions for these species. It can be noted that the species distribution of ichthyofauna in the Protoka River is strongly influenced by the large number of hydraulic structures in the reservoir. This has a negative effect on fish migration and is unfavourable for fish that react to oxygen dissolved in water [20].

In some sections of the Protoka River, there is no common bleak *Alburnus alburnus*, tench *Blicca bjoerkna*, common roach *Rutilus rutilus* as a result of stopping migration routes by spillway structures, small short-cyclical fish species were observed [24]. It was these species that were characterised by the greatest ecological plasticity and resistance to living conditions [20].

Under conditions of restriction of river sections by hydraulic structures, invasive fish species dominated. At the same time, among the native fish species, a small amount fell on perch *Perca fuviatilis*, weatherfish *Misgurnus fossilis*, and carp *Cyprinus carpio* (the latter came from ponds adjacent to the river). In the Protoka River, phytophilic and psammolithophilic groups of fish were dominant and accounted for 65 and 20%, respectively; zoobenthophages accounted for 50%, predators – 20% [20].

The analysis showed that in the changed areas, namely in areas located within the city limits, the species composition of ichthyofauna on the Protoka River is significantly depleted. However, this has led to an increase in the number of limnophilic and briefly cyclical fish species, in particular goldfish *Carassius auratus*, topmouth gudgeon *Pseudorasbora parva*, and Amur sleeper *Perccottus glenii* [20].

More species diversity of ichthyofauna was recorded in areas above the city of Bila Tserkva, where the following species were found: common roach *Rutilus rutilus*, alburnus, white bream *Blica bjoerkna*, pike *Esox lucius*, tench *Tinca tinca*, common rudd *Scardinius erythrophtalmus*, gudgeon *Gobio gobio,* Eurasian ruffe *Gymnocephalus cernua* [20].

In the mouth of the Protoka River, two more species are added to the ichthyofauna, such as well catfish *Silurus glanis* and monkey goby *Neogobius fluviatilis*. This can be explained by changes in the banks, the preservation of the riverbed, the presence of plants that are adapted to large currents and specific ecological conditions that affect the species composition of the reservoir [20].

During the study in 2018, among the 20 fish species recorded in the Protoka (Rotok) river, only 3 species belong to the undesirable invading species from the Far East. These species were introduced into the water bodies of Ukraine in

the 19th-20th centuries (topmouth gudgeon, goldfish, and Amur sleeper), and to the group of self-settlers who fell into the Dnipro River basin in the second half of the 20th century, this is such a species as the three-spined stickleback [20].

Comparing the species composition of the ichthyofauna of the Bilotserkivskyi lower reservoir and the Protoka River, it can be concluded that no significant species difference was observed, but there are some native species that have not been observed in the reservoir in recent years, such as Loach *Misgurnus fossilis,* Eurasian ruffe *Gymnocephalus cernua* but the value of tributaries, namely estuary sections, lies in their ability to create so-called ecological corridors for the healthy functioning of the hydroecosystem.

Conclusions

Based on the results of research conducted at the Bilotserkivskyi lower reservoir (Ros River) 24 species were identified in 2016, 21 – in 2017, and 19 species – in 2020. Analysing the number of ichthyofauna since the 1960s, it can be concluded that approximately every 10 years the species composition of the ichthyofauna of Bilotserkivskyi lower is reduced by 2.5 species of fish, which is conditioned by the influence of a number of anthropogenic factors, overregulation of the river current, and commercial use of water bodies.

After analysing the number of ichthyofauna since the 1960s, it can be concluded that in 2016 the following species are disappeared: common dace *Leuciscus leuciscus*, Dnieper chub *Leuciscus borysthenicus*, ide *I.idus*, sunbleak *Leucaspius delineatus*, vimba bream *Vimba vimba*, crucian carp *Carassius carassius*, weatherfish *Misgurnus fossilis*, spined loach *Cobitis taenia*, in 2017, such species as gudgeon *Gobio gobio*, round goby *Neogobius melanostomus*, tubenose goby *Proterorhinus marmoratus*, in 2020 – char, ruffe. Restoration of the natural composition of the ichthyofauna of the Bilotserkivskyi lower reservoir is possible due to a tributary – the Protok (Rotok) River. Discharges of pollutants and toxic substances (chlorinated water) by the Bilotserkivvoda enterprise led to the death of fish, crayfish and a decrease in the ichthyofauna and fish feed production.

For the purpose of directed control and restoration of ichthyofauna in conditions of industrial and anthropogenic load on reservoirs, it is necessary to periodically conduct research on the feed base of ichthyofauna and, if necessary, implement a set of measures to improve the development of the feed base and develop a water protection strategy, approaches to solving issues of the revitalisation of reservoirs for the restoration of ichthyofauna.

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Іхтіофауна Білоцерківського нижнього водосховища на річці Рось

Антон Анатолійович Климковецький, Максим Борисович Халтурин

Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Анотація. Внаслідок природних процесів і впливу антропогенних факторів у внутрішніх водоймах України змінюється склад іхтіофауни. Системний аналіз змін дозволяє контролювати ці процеси і підтримувати різноманіття видів на сталому рівні. Метою дослідження було вивчити зміни складу іхтіофауни Білоцерківського нижнього водосховища (р. Рось) після скиду промислових відходів підприємства «Білоцерківводоканал» у 2017 та 2020, що призвело до масової загибелі риби та раків. Дослідження проводились методом вилову риб з ідентифікацією видів та опитуванням рибалок з листопада 2016 по жовтень 2020 років. Додатково враховували видовий склад риб у цій ділянці річки Рось до створення водосховища. За результатами проведених досліджень було виявлено 24 види риб 2016 році, 21 – у 2017 році та 19 – у 2020 році. Аналізуючи чисельність іхтіофауни починаючи з 60-х років XX століття можна зробити висновки, що кожні 10 років видовий склад іхтіофауни Білоцерківського нижнього водосховища втрачав близько 2-3 видів риб, що зумовлено впливом перекриття русла, діяльністю промисловості, неконтрольованих та неідентифікованих скидів у водойму тощо. Після проведеного детального аналізу чисельності іхтіофауни встановили, що до 2016 року зникли такі види: ялець *Leuciscus leuciscus*, бобирець *P. borysthenicus*, в'язь *I. idus*, вівсянка *Leucaspius delineatus*, рибець *Vimba vimba*, карась золотий *Carassius carassius*, в'юн *Misgurnus fossilis*, щипавка *Cobitis taenia*, у 2017 році такі види як пічкур *Gobio gobio*, бичок-кругляк *Neogobius melanostomus*, бичок-рижик *Proterorhinus marmoratus*, у 2020 році – це голець, йорж. Кількісне та якісне відновлення іхтіофауни можливе за рахунок риби із річки Протоки (Роток). Для продовження рибогосподарського використання необхідне зариблення водосховища. Практична цінність цієї роботи полягає у визначенні видового складу іхтіофауни для подальшого використання водойми в природоохоронних і рибогосподарських цілях

Ключові слова: внутрішні водойми, прісноводна риба, вилов, промислові скиди, екологічні групи риб

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Effect of balanced mineral supplements on milk productivity of cows

Yurij Kropyvka[1*], Vitalii Bomko[2], Olena Tytariova[2]

[1]Lviv National University of Veterinary Medicine and Biotechnologies named after S. Z. Gzhytskyi
79010, 50 Pekarska Str., Lviv, Ukraine

[2]Bila Tserkva National Agrarian University
09117, 8/1 Soborna Sq., Bila Tserkva, Ukraine

Abstract. The implementation of the genetic potential of cows is primarily related to the usefulness of providing cows with nutrients, including trace elements, during lactation. Therefore, the purpose of the study was to determine the optimal doses of mineral supplements of zinc (Zn), manganese (Mn), and cobalt (Co) in the diet of dairy cattle by lactation phases and evaluate the economic efficiency of their use. To achieve this goal, a scientific and economic experiment was conducted, for the organisation of which 5 subgroups of cows were formed, 10 individuals each – group 1, which was the control, and 4 experimental groups. According to the experiment design, animals of different groups were fed different amounts of mixed ligand complexes of Zn, Mn, and Co. During the experiment, productivity, dry matter consumption, metabolism, and economic efficiency were evaluated. Based on experimental studies of the use of mineral supplement complexes of Zn, Mn, and Co, in comparison with their sulphate salts, it was found that during the first 100 days of lactation, optimal for highly productive individuals were doses in one kg of dry matter of the feed mixture: Zn – 60.8 mg; Mn – 60.8 mg; Co – 0.78 mg, which were provided by their mixed ligand complexes and which were lower by 20% of the recommended ones and led to an increase in milk productivity of cows by 15%, and profit – by 47%. In the second 100 days of lactation, the best productivity indicators were found in cows that consumed a feed mixture in which the concentration in one kg of dry matter was: Zn – 35 mg, Mn – 35 mg, and Co – 0.4 mg due to the introduction of mixed ligand complexes of trace elements. The advantage of animals in this group over the control group in terms of milk productivity was 18%, in terms of profit – 29%. In the last 100 days of lactation, the best performance indicators were in cows with a dry matter content of Zn – 35 mg, Mn – 35 mg, Co – 0.4 mg per kg of feed mixture. They exceeded the control in terms of milk yield by 9%, and profit – by 42%. Thus, it is proved that highly productive cows require different concentrations of trace elements during lactation. It is proved that due to the introduction of balanced mineral supplements in the diet, the optimal amount of trace elements is less than the use of inorganic compounds, which has a positive effect on the environment by reducing the content of these minerals in manure

Keywords: milk productivity, organic forms of trace elements, profit, lactation phase

Introduction

Feed and feed additives provide highly productive cows with basic nutrients (proteins, lipids, structural and non-structural carbohydrates, and minerals) and biologically active substances (trace elements and vitamins) [1; 2]. Industrial dairy farming in Ukraine over the past three decades increasingly shows a lack of trace elements in the soil-feed-diet and a higher need for them while increasing the milk yield of highly productive cows. Under such circumstances, it is difficult to provide the animal body with the necessary amount of essential trace elements,

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[*]*Corresponding author*

and therefore, for the normal functioning of the body of highly productive cows, an appropriate amount of mineral supplements is required, the ratio of which depends on a number of physiological, economic, and other factors.

The creation of high-performance herds of dairy cattle and the continuation of breeding work in this line encourages a systematic revision of the recommendations for animal nutrition, because ensuring high productivity, reproductive capacity, and preserving the health of cows is impossible only at the expense of natural feed [1-3].

Over the past decade, a number of studies have been conducted in Ukraine and around the world on the feasibility of using organic compounds of trace elements in animal feeding, in particular Zn, Mn, Co, and Cu. Thus, in the available literature, there are reports of an increase in milk productivity [4-6] and milk quality [4; 6; 7] in cows, and an improvement in reproductive function in bulls [8]. In addition to milk productivity, there is also an improvement in the growth of calves [9], pigs [10-12], broiler chickens [13; 14] and rabbits [15] due to the use of chelated forms of trace elements in their feed. The reason for the growing interest of the scientific community in organic compounds is the high degree of their assimilation by the body, which provides animals with the necessary amount of trace elements and reduces the negative impact of their faeces and urine on the environment [3].

Zn is a common element in the body's cells because it is involved in many physiological processes. It is an important component of several metalloenzymes and many transcription factors that control gene expression, so it plays a fundamental role in cell division, development, and differentiation. Zn also plays an important role in stabilising RNA, DNA, and ribosomes as a component of biological membranes; is involved in the production of insulin; has an antioxidant effect; is crucial for maintaining the integrity and barrier function of the skin, and is involved in the immune system. The inability of the body to store Zn necessitates its constant supply with feed [16; 17].

The bioavailability of Zn depends on the source of its entry into the body, the ability to be absorbed and available for storage and use for further processes of digestion, absorption, and metabolism.

Zn from organic sources is usually more readily available to animals than from inorganic compounds. This is conditioned by the mechanism of transition of trace elements from the intestines to the blood of the animal. Thus, microelements from inorganic sources are mainly released from the body through antagonism and the formation of hard-to-reach compounds, while organic microelement compounds (ligands, chelates) are absorbed as amino acids [8; 11; 16]. Microbial fermentation of fibre in the rumen has an additional effect on the bioavailability of trace elements [16].

When Mn is deficient in the feed mixture of dairy cows, the process of fatty acid synthesis is disrupted, skeletal deformity occurs, which is accompanied by animal sterility and abortions, and paralysis occurs in newborn calves. Mn deficiency in the reproductive phase, especially in the dry period, negatively affects the offspring. In cows with insufficient consumption of Mn, due to its lack in the diet, the reproductive capacity of animals may decrease, which may manifest itself in a hidden oestrous cycle, low fertilisation, spontaneous miscarriages in the first months of pregnancy, or possible foetal resorption and frequent gynaecological diseases. At the same time, milk productivity, and often the fat content of milk, decrease [17; 18].

The synthesis of B vitamins depends on the presence of Co in the feed mixture [19; 20]. Excess Co causes the synthesis of a number of vitamin B_{12} analogues, which are physiologically inactive [21]. According to [22], if there is a lack of Co in the feed mixture for the synthesis of cyanocobalamin, which activates the biosynthesis of methionine, Co is consumed by 10% more and accounts for about 13% of its total level, while with its optimal amount – up to 3%. The demand for cobalt is on average 0.10 mg/kg of dry matter of the feed mixture [23].

The purpose of the study is to establish optimal doses of balanced mineral supplements in the feed mixture of highly productive cows by lactation periods and on this basis to substantiate the economic efficiency of using these compounds.

Materials and Methods

In the course of scientific and economic experiments, the effect of balanced mineral additives of Zn, Mn, Co with the addition of Suplex Se against the background of cuprum sulphates and potash iodides with the same type of feeding of dairy cows on the economic efficiency of milk production. To determine the optimal doses of mixed ligand complexes of Zn, Mn, and Co, a scientific and economic experiment was conducted on the premises of the dairy complex of the additional liability company "Terezyne" in the Kyiv Oblast in 2015. The study was carried out in the following sequence: 1) selection was carried out, 20 cows of the Holstein breed; 2) 15 cows of the Ukrainian black and spotted breed were selected; 3) 15 individuals of the Ukrainian red-spotted breed were selected; 4) 5 subgroups of cows of 10 individuals each were formed – 1 control group and 4 experimental groups ((2, 3, 4, and 5).

The experiment was performed on highly productive cows with a milk yield of 7,000-9,000 kg of milk for the previous lactation.

The experiment was conducted by the method of groups of analogues according to the recommendations for experiments in animal husbandry [24]. The actual content of trace elements in the feeds used during the scientific and economic experiment was preliminarily determined; the replacement of Zn, Mn, Co sulphates in the recommended for cows premix P 60-5M (developed by VIT) with their organic forms with the additional introduction of Suplex Se (manufacturer ViloFoss, Denmark) was experimentally substantiated.) Microelements were introduced by step weight mixing with one of the grain components of mixed feed, which was then introduced into the compound feed. Cows of control group 1 were given the recommended cow premix P 60-5M (developed by VIT). In the experimental cows, the sulphate salts of the trace elements Zn, Mn, and Co were replaced with their mixed ligand complexes of different concentrations and additional administration of Suplex Se for all groups. Each group was kept separately, in separate reconstructed premises for loose housing. The animals had free access to fresh clean water around the clock.

During the first 100 days of lactation, advanced feeding was carried out to milk cows and during this period they had the highest productivity. With the onset of new

pregnancy, the productivity of cows gradually decreased. In this regard, different levels of mixed ligand complexes were studied, considering lactation periods, and economic efficiency was determined after each experiment.

Each experiment was divided into two periods – preparatory and accounting. During the preparatory period, the animals consumed a complete feed mixture of the same composition, and during the accounting period, cows were fed in accordance with the research scheme (Table 1). The duration of the preparatory period was 10 days and the accounting period was 100 days. Milk yield for each group was determined by weighing, and for each cow – by control yields every 10 days. In one of the control milk yields, samples were taken once a month to determine fat and protein content (Table 1).

Table 1. *Scheme of scientific and economic experiments*

Group	Number of animals, units	Factor under study
1	2	3
Experiment No. 1. First 100 days of lactation		
Control 1	10	Feed mixture (FM) + $CuSO_4$ + KI. 1 kg of dry matter (DM) contains, mg: Zn – 32.4; Mn – 27.8; Co – 0.27; Se – 0.3; Cu – 12; I – 1.1
Experimental 2	10	FM + $ZnSO_4$, $MnSO_4$, $CoSO_4$, $CuSO_4$ + Suplex Se + KI. 1 kg of DM contains, mg: Zn – 76; Mn – 76; Co – 0.97 mg, Cu – 12, Se – 0.3; I – 1.1
Experimental 3	10	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ + KI. 1 kg of DM contains, mg: Zn – 76; Mn – 76; Co – 0.97; Se – 0.3; Cu – 12; I – 1.1
Experimental 4	10	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ + KI. 1 kg of DM contains, mg: Zn – 60.8; Mn – 60.8; Co – 0.78; Se – 0.3; Cu – 12; I – 1.1
Experimental 5	10	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ + KI. 1 kg of DM contains, mg: Zn – 49; Mn – 49; Co – 0.63; Se – 0.3; Cu – 12; I – 1.1
Experiment No. 2. Second 100 days of lactation		
Control 1	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ + KI. 1 kg of DM contains, mg: Zn – 65; Mn – 65; Co – 0.8; Se – 0.3; Cu – 10; I – 0.9
Experimental 2	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 50; Mn – 50; Co – 0.7; Se – 0.3; Cu – 10; I – 0.9
Experimental 3	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 45; Mn – 45; Co – 0.6; Se – 0.3; Cu – 10; I – 0.9
Experimental 4	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 40; Mn – 40; Co – 0.5; Se – 0.3; Cu – 10; I – 0.9
Experimental 5	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 35; Mn – 35; Co – 0.4; Se – 0.3; Cu – 10; I – 0.9
Experiement No. 3. Last 100 days of lactation		
Control 1	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 50; n – 50; Co – 0.7; Se – 0.3; Cu – 9; I – 0.8
Experimental 2	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 45; Mn – 45; Co – 0.6; Se – 0.3; Cu – 9; I – 0.8
Experimental 3	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 40; Mn – 40; Co – 0.5; Se – 0.3; Cu – 9; I – 0.8
Experimental 4	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se + $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 35; Mn – 35; Co – 0.4; Se – 0.3; Cu – 9; I – 0.8
Experimental 5	9	FM + mixed ligand complexes Zn, Mn, Co + Suplex Se and $CuSO_4$ and KI. 1 kg of DM contains, mg: Zn – 32; Mn – 32; Co – 0.3; Se – 0.3; Cu – 9; I – 0.8

In the course of a scientific and economic experiment, the milk productivity of cows was determined:

– gross milk yield per 1 animal unit – by summing up the daily milk produced from each cow of the group over a certain period of time;

– gross milk yield of basic fat content – by multiplying the amount of milk (in kilograms) by the percentage of fat in it, followed by dividing by the basic fat content of milk (3.4%).

To determine the cost and profitability of milk production, the cost of feed consumed was calculated, which was determined at farm prices, wages and other expenses, considering the actual selling price of 1 metric centner of milk. Since the sale of milk in farms is carried out according to the basic fat content, the actual milk yield was converted to the basic fat content – 3.4%.

Results and Discussion

The economic effect of feeding mixed ligand complexes of Zn, Mn, and Co to dairy cows during the first 100 days of lactation is shown in Table 2.

Table 2. *Economic efficiency of feeding high-performance cows mixed ligand complexes of Zn, Mn, and Co as part of diets during the first 100 days of lactation*

Indicators	Group				
	Control 1	Experimental			
		2	3	4	5
Gross milk yield, kg/cow	3,096	3,400	3,456	3,560	3,416
Gross milk yield of basic fat content, kg/cow	3,369.2	3,710	3,791.4	3,968.4	3,767.7
Total production costs, UAH.	8,423.6	8,776.5	8,780.7	8,845.8	8,658.8
including: sulphates		99.6	–	–	–
mixed ligand complexes	–	–	74.4	56.8	32.4
Profit, UAH	3,705.4	4,579.5	4,868.3	5,440.2	4,905.2

The intake of various sources of Zn, Mn, and Co and the levels of their mixed ligand complexes in the body of experimental cows during the first 100 days of lactation affected the consumption of feed mixture by experimental cows and the intake of more nutrients into their bodies, which was discussed in detail in previous studies. As a result of higher feed consumption by experimental cows, their milk productivity also increased, namely: in the 2nd experimental group – by 304.0 kg; in the 3rd – by 360.0; in the 4th – by 464.0; in the 5th – by 320.0 kg or, respectively, by 9.82%; 11.63%; 14.99%; 10.34%, compared to the control group. This allowed for additional profit in the experimental groups. Thus, the replacement of Zn, Mn, and Co sulphates with their mixed ligand complexes in the 2nd experimental group, which provided the norm in Zn, Mn, and Co, and Zn, Mn, and Co sulphates in the control group by 100%, the additional profit amounted to UAH 874.1 for 80 days of the main experiment period. Meeting the demand for Zn, Mn, and Co by 75% due to their mixed ligand complexes gave an additional profit of UAH 11,621.9, or 31.4%; by 50% – UAH 1,734.8, or 46.8%; and by 25% – UAH 1,199.8, or 32.4%.

Therefore, providing a 50% shortage of Zn, Mn, and Co by their mixed ligand complexes ensures a stable economic effect and is more cost-effective than covering the deficit in Zn, Mn, and Co by 100% due to Zn, Mn, and Co sulphates. The probable reason for this is the orientation of the feeding standards of dairy cows to the results of studies in which inorganic compounds were used as sources of trace elements, the bioavailability of mineral elements of which is 10-15%. The introduction of supplements of organic trace elements into the diet of cows, the bioavailability of trace elements of which is 80-95%, demonstrated that the need of these animals is lower than previously stated.

It is well known that the period of milk production in cows has certain patterns, according to which the cow's lactation is divided into conditional three phases. At the same time, not only the nutritional value of the diet changes, but also its structure [18]. Therefore, it is important to analyse the effectiveness of using feed additives at each stage of changes in productivity, feeding, etc.

The economic efficiency of using Zn, Mn, and Co mixed ligand complexes in feeding dairy cows during the second 100 days of lactation is shown in Table 3.

Table 3. *Economic efficiency of including balanced mineral supplements in the diets of dairy cows during 101-200 days of lactation*

Indicator	Group				
	Control 1	Experimental			
		2	3	4	5
Gross milk yield, kg/cow	3,120	3,302	3,395	3,556	3,685
Gross milk yield of basic fat content, kg/cow	3,413.7	3,632.2	3,701.5	3,922.1	4,064.3
Total production costs, UAH.	8,200.5	8,879.3	8,607.8	8,753.7	8,843.3
including sulphates		–	–	–	–
mixed ligand complexes	135.2	127.5	95.9	63.9	31.8
Profit, UAH	4,771.6	4,923.1	5,457.9	6,150.2	6,601.0

Replacement of Zn, Mn, and Co sulphates with their mixed ligand complexes in the first 100 days of lactation maintains the trend of better productivity in experimental cows in subsequent lactation periods. However, the lowest dose of mixed ligand complex, which was used in the diets of the 5th experimental group, during this period contributed to an increase in milk productivity of natural fat content by 18.1% against the 1st control group; by 11.6% more against the 2nd experimental group, in whose diets due to mixed ligand complexes, the norms of Zn, Mn, and Co were supplemented by 100%; by 9.8% more against the 3rd experimental group, in whose diets the deficiency of Zn, Mn, and Co was replenished by 75%; and by 3.6% more than the 4th experimental group, where the deficit was replenished by

50%. Obviously, this result is associated with a change in the origin of trace element additives, namely, the replacement of inorganic compounds with organic complexes. Better bioavailability of minerals from mixed ligand complexes has led to a decrease in the need of cows for these trace elements, compared to the recommended standards.

As a result, the cost of manufactured products (milk for 100 days) per 1 animal unit in the control group was equal to UAH 12,972.1, in the 2nd – UAH 13,802.4, 3rd – UAH 14,065.7, 4th – UAH 14,903.9, and 5th – UAH 15,444.3. Thus, in the experimental groups it was higher than the control, respectively, by UAH 830.3; 1,093.6; 1,931.8; 2,472.2.

Comparing the profit of the experimental groups fed mixed ligand complexes of Zn, Mn, and Co, the highest profit was in the 5th experimental group – by UAH 1,829.4, or 38.34% more than in the control group; by UAH 1,677.9, or 35.16% compared to the 2nd experimental group; by UAH 1,143.1, or 23.96% compared to the indicators of animals of the 3rd experimental group; by UAH 450.8, or 9.45% – compared to the analogues of the 4th experimental group.

Thus, the use of mixed ligand complexes of trace elements such as Zn, Mn, and Co in feeding highly productive cows during the milk production period, in an amount that eliminates their deficiency by 25%, is the most cost-effective.

During the last 100 days of lactation, feed consumption in experimental cows was better and milk productivity of cows of experimental groups in terms of basic fat content was higher compared to the control group: in the 2nd experimental group – by 58.3 kg, or 2.33 %; in the 3rd – by 57.2 kg, or 2.29 %; in the 4th – by 150.8 kg, or 6.05%; in the 5th – by 224.3 kg, or 8.99 %, which, in turn, increased the economic efficiency of milk production (Table 4).

Table 4. *Economic efficiency of using balanced mineral supplements in feeding dairy cows during 201-300 days of lactation*

Indicator	Group				
	control 1	Experimental			
		2	3	4	5
Gross milk yield, kg/cow	2,320	2,360	2,430	2,540	2,440
Gross milk yield of basic fat content, kg/cow	2,606.6	2,665.4	2,780.2	2,921.0	2,834.7
Cost of milk produced, UAH/animal	9,905.1	10,128.5	10,564.8	11,099.8	10,771.8
Total production costs, UAH	6,763.4	6,861.8	6,812.8	6,624.9	6,492.6
including: sulphates	–	–	–	–	–
mixed ligand complexes	112.3	102.0	76.5	45.6	24.3
Profit, UAH	3,141.7	3,266.7	3,752.0	4,474.9	4,279.2

The difference in gross milk yield and its total sale value between the experimental groups of cows and the control resulted in the highest profit in the experimental cows of the 4th and 5th experimental groups where the required level of Zn, Mn, and Co was provided by their mixed ligand complexes by 50% and 25%, despite slightly increased costs of wages, feed, direct and overhead costs in these groups. In cows of the 2nd and 3rd experimental groups, where the deficiency of Zn, Mn, and Co was covered by their mixed ligand complexes by 100% and 75%, due to its higher cost compared to Zn, Mn, and Co sulphates, despite higher milk yields, the profit was slightly higher than in the control group.

If in the control group the total profit was UAH 3,141.7, then in the 2nd and 3rd experimental groups it was higher by UAH 125.0 and 610.3, or 3.98% and 19.43%, while in the 4th and 5th experimental groups it was higher by UAH 1,333.2 and 1,137.5, or by 42.44% and 36.21%, respectively.

Economic calculations show that during the launch period, it is better not to use trace element preparations in feeding highly productive cows, or to use them in small doses that cover the deficit by 25-50%.

Summarising the results obtained experimentally, it can be argued that the conducted studies are consistent with the data of numerous literature sources that have shown a high level of bioavailability of biometals for the body of dairy cows in general and high-performance cows in particular. Their ability to significantly affect the productivity and physiological state of animals of this group is also proven. Thus, an increase in the average daily milk yield by lactation phases under the condition of using mixed ligand complexes of trace elements was also noted in the studies by other Ukrainian [4] and foreign [5-7] researchers. In particular, the replacement of inorganic salts of trace elements (control group) in feeding dairy cows with their metal-chelate complexes, described in the study by A. Gorchanok *et al.* [4], contributed to an increase in the average daily milk yield of cows compared to the control by 11%. An increase in productivity by 6% with the introduction of chelated compounds of trace elements and a decrease by 4% with an excessive amount of chelates in the diet was recorded by Kholif *et al.* [7]. At the same time, some of these studies [3; 4] contain reports on the economic and environmental feasibility of using organic sources of trace elements in feeding animals, in particular cows. Increasing the productivity of cows with optimal mineral nutrition (dose and source) contributes to greater profit and reduced emissions of heavy metals into the environment with manure, which is used as an organic fertiliser.

Conclusions

To ensure high milk productivity and increase the profitability of milk production, it is recommended to use Zn, Mn, and Co mixed ligand complexes in feeding dairy cows to eliminate the deficiency of these trace elements, considering the lactation phase.

During the first 100 days of lactation, the highest economic effect was achieved by providing dairy cows with

only 50% of the needs for Zn, Mn, and Co, but due to their mixed ligand complexes. It was at this dose that the milk productivity of animals was maximum, and despite the highest indicator of production costs, the profit from the sale of produced milk significantly exceeded both the control indicator and the indicators of analogues of other groups.

A similar trend occurred during the next 100 days of lactation, but the optimal dose of Zn, Mn, and Co mixed ligand complexes was 25% of the recommended requirement.

In the last 100 days of lactation (201-300 days), cows showed the highest level of productivity for the consumption of diets, the amount of Zn, Mn, and Co in which was provided by 50% due to mixed ligand complexes. However, it is possible to reduce the recommended dose to 25%, since the profit indicator is very close to the maximum.

Thus, the findings indicate a positive reaction of the body of dairy cows to the replacement of Zn, Mn, and Co sulphates in their diet with mixed ligand complexes. At the same time, the need for the amount of trace elements is reduced to 50-25%, depending on the lactation phase. Thus, this issue requires further thorough investigation to review the existing feeding standards for dairy cows, which are developed using inorganic compounds of trace elements with low availability.

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Вплив збалансованих мінеральних добавок на молочну продуктивність корів

Юрій Григорович Кропивка[1], Віталій Семенович Бомко[2], Олена Михайлівна Титарьова[2]

[1]Львівський національний університет ветеринарної медицини та біотехнології ім. С. З. Ґжицького
79010, вул. Пекарська, 50, м. Львів, Україна

[2]Білоцерківський національний аграрний університет
09117, площа Соборна, 8/1, м. Біла Церква, Україна

Анотація. Реалізація генетичного потенціалу корів насамперед пов'язана з повноцінністю забезпечення корів поживними речовинами, в тому числі і мікроелементами, за періодами лактації. Тому метою дослідження було встановлення оптимальних доз мінеральних добавок Цинку (Zn), Мангану (Mn) і Кобальту (Co) у раціоні молочного стада за фазами лактації та оцінка економічної ефективностіZn їх застосування. Для досягнення встановленої мети провели науково-господарський дослід, для організації якого сформували 5 підгруп корів по 10 особин в окремій групі – 1 групу, яка була контрольною і 4 дослідні групи. Згідно зі схемою досліду тваринам різних груп згодовували різну кількість змішанолігандних комлексів Zn, Mn і Co. У ході експерименту досліджували продуктивність, споживання сухої речовини, обмін речовин та економічну ефективність. На основі експериментальних досліджень застосування комплексів мінеральних добавок Zn, Mn і Co, в порівнянні із їх сульфатними солями, було встановлено, що упродовж перших 100 днів лактації оптимальними для високопродуктивних особин – дози в одному кг сухої речовини кормової суміші: Zn – 60,8 мг; Mn – 60,8 мг; Co – 0,78 мг, які забезпечувались за рахунок їх змішанолігадних комплексів і які були нижчими на 20 % від рекомендованих і зумовили підвищення молочної продуктивності корів на 15 %, а прибутку – на 47 %. У другі 100 днів лактації найкращі показники продуктивності були в корів, які споживали кормосуміш, в якій концентрація у одному кг сухої речовини була: Zn – 35 мг, Mn – 35 мг і Co – 0,4 мг за рахунок уведення змішанолігандних комплексів мікроелементів. Перевага тварин цієї групи над контрольною за молочною продуктивність становила 18 %, за прибутком – 29 %. В останні 100 днів лактації найкращі результати продуктивності були у корів у одному кг сухої речовини кормової суміші, вміст яких склав Zn – 35 мг; Mn – 35 мг; Co – 0,4 мг. Вони переважали контроль за надоєм молока на 9 %, за прибутком – на 42 %. Таким чином, доведено, що високопродуктивні корови за періодами лактації потребують різної концентрації мікроелементів. Доведено, що за рахунок введення в раціон збалансованих мінеральних добавок оптимальна кількість мікроелементів менша, порівняно з використанням неорганічних сполук, що позитивно впливає на навколишнє середовище шляхом зменшення вмісту цих мінеральних речовин у гною

Ключові слова: молочна продуктивність, органічні форми мікроелементів, прибуток, фаза лактації

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The state of use of fish resources in small reservoirs of the Rivne Oblast

Ilona Parfeniuk[1*], Yuliia Grokhovska[1], Vadym Martseniuk[2]

[1]National University of Water and Environmental Engineering
33028, 11 Soborna Str., Rivne, Ukraine

[2]National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Abstract. Poaching and unregulated amateur fishing have led to impoverishment and, in some places, complete extermination of populations of industrially valuable fish species in Rivne Oblast, so the activities of special commercial fisheries ensure the preservation of fish resources. The purpose of the study is to analyse the state of the water fund of the Rivne Oblast, the use of fish resources of these reservoirs, in particular, the results of the activities of special commercial fisheries, industrial and amateur fishing, and aquatic bioresources. According to the State Agency of land reclamation and fisheries in Rivne Oblast, over the past twenty years, there has been a tendency to reduce the volume of fish caught and introduced into natural and artificial reservoirs. Since 2010, due to low profitability, the activities of fishing organisations have been completely stopped, although previously commercial fishing of aquatic living resources took place on large water bodies, in particular in Rivers (Horyn, Ikva, Styr), lakes (Nobel, Putylivske), reservoirs (Mlynivske, Khrinnytske). Nowadays, the main method of fishing, in addition to the activities of special commercial fisheries, is unorganised amateur fishing. Specialised public organisations of amateur fishermen unite from 8 to 15 thousand amateur fishermen and sportsmen, carry out organised amateur fishing, are engaged in the introduction of fish resources into the water bodies of the region (carp, herbivorous fish, common pike, and silver crucian carp). Carp and crucian carp make up the largest share of fishermen's catches; pike, common perch, silver carp, roach and rudd are less common. The state of fishery management in special commercial fisheries of the Rivne Oblast has not changed over the past 10 years. As of 2021, there were only 11 of them left in the region, working on lease terms; and several private enterprises where commercial fish is grown in full-system and non-system farms. The volume of young fish entering almost all farms has tripled compared to 2015, while the volume of fish caught has slightly increased. Analysis of the state of use of fish resources in small reservoirs is necessary for further rational extraction and restoration of fish resources in small reservoirs of the Rivne Oblast

Keywords: water resources, fisheries, industrial catch, catch volumes, fish introduction, amateur fishing

Introduction

Due to the direct anthropogenic impact, in particular, poaching and unregulated amateur fishing, the fish resources of the Rivne Oblast are under significant threat of impoverishment and, in some places, complete extermination of populations of industrially valuable fish species [1]. One of the ways to preserve and increase them is the introduction of fish into water bodies and the rational use of reserves of industrially valuable species of aquatic living resources [2; 3]. Therefore, the analysis of the results of the activities of special commercial fisheries and the state of amateur fishing are relevant issues for further search for ways to solve the above problems.

Researchers [4-6] investigated the dynamics of catch of hydrobionts by regions and fisheries zones on the territory of Ukraine from 2005 to 2020. It was found that production significantly decreased (up to 70-80%) in

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[*]Corresponding author

almost all regions of Ukraine [7-9]. In 2019, the catches were dominated by carp and herbivorous fish [10]. 134 tonnes of carp were caught in Rivne Oblast. Throughout Ukraine, the smallest share in catches was made up of common pike, grass carp, and wels catfish [11].

The analysis of publications shows that after 2010, amateur sport fishing in inland waters competes with industrial fishing [12] and exerts additional pressure on the ichthyofauna [13]. In European countries, amateur and industrial fishing brings significant profits and facilitates the development of unused fish resources [14; 15]. The organisation of amateur and sport fishing requires knowledge of fish farming, organisational, and economic and legal aspects [16; 17].

Analysis of the possibilities of using inland water bodies of Ukraine for fishery purposes would allow making a correct assessment of the state of fish reserves, determining the volume of fish withdrawal and introduction, and preventing negative environmental and economic consequences.

Thus, a team of researchers [18] reviewed the estuaries of the north-western Black Sea region, where, in particular, the species composition of the ichthyofauna of the studied reservoirs is presented; a strategy for the fisheries use of estuaries of various types in modern conditions was developed [19; 20]. The state of reserves of some commercial fish species of the cascade of Dnipro reservoirs and the possibility of their use for fishery purposes [21; 22], and other large lowland reservoirs of Ukraine [23] are evaluated.

Legal aspects of the protection of aquatic bioresources also require attention [24-26], because the protection of aquatic bioresources in the field of aquaculture does not lose its relevance and prospects for legal improvement [27; 28].

A number of researchers have been studying the state of fish resources in Rivne Oblast over the years, in particular I.V. Hryb, T.M. Kunchyk, V.O. Mosnitskyi, V.K. Bihun, and others [29-31]. In their studies, researchers noted the impoverishment of the ichthyofauna of water bodies in Rivne Oblast, the disappearance of native, industrially valuable fish species [1]. In particular, V.O. Mosnitskyi and T.M. Kunchyk assessed the capacity of the water fund of the Rivne Oblast for fishery use [31]. Researchers also investigated the species composition of the ichthyofauna [1] and the possibilities of preserving fish resources [1; 28; 30].

The water fund of the Rivne Oblast includes a large number of water bodies that are not fully used for fishery purposes, including industrial fishing. Analysis of the state of use of fish resources in small reservoirs would facilitate rational selection of objects of introduction and withdrawal, species and age composition of ichthyofauna, and allow making forecasts regarding the amount of fish withdrawal and introduction into reservoirs.

To investigate the state of use of fish resources in small reservoirs of the Rivne Oblast, it is necessary to analyse the state of the water fund of the Rivne Oblast, industrial and amateur fishing and aquatic bioresources, study the activities of special commercial fisheries.

The purpose of the study is an overview of the state of use of fish resources in Rivne Oblast, in particular, the results of the activities of special commercial fisheries (SCF).

The following tasks were set to achieve the goal: to analyse the state of the water fund of the Rivne Oblast; to analyse the state of industrial and amateur fishing and aquatic bioresources; to study the activities of the SCFs from the standpoint of replenishing fish resources.

The object of research is the state of fish resources in Rivne Oblast (use and replenishment).

The subject of the study is the characteristics of the state of fish resources of the Rivne Oblast based on the results of the SCF's activities.

Materials and Methods

To analyse the state of fisheries, in particular, the use of fish resources in Rivne Oblast, the authors used the annual reports of regulatory authorities, in particular, the Rivne fish protection patrol (territorial fish protection body of the State Agency of land reclamation and fisheries in Rivne Oblast) [32; 33] and the Main department of statistics in Rivne Oblast for 2010-2020 [34]. In addition, data from specialised public organisations of fishermen were used [32]. Data on the catch and stocking of aquatic living resources in special commercial fisheries are analysed and systematised, which are presented in Table 1. Materials on the state and objects of amateur (organised and unorganised) fishing on water bodies of the Rivne Oblast are summarised. Computer programmes (Microsoft Excel) were used to process the reporting data.

Table 1. *Research objects*

Water body number	Location of the reservoir
1	channel pond, Klyntsi village, Dubenskyi district
2	pond, Kolodiivka village, Koretskyi district
3	pond, Kustyn village, Rivnenskyi district
4	pond, Okhmatkiv village, Demydivskyi district
5	channel pond, Varkovychi village, Dubenskyi district
6	channel pond, Yuchyn village, Goshchanskyi district
7	channel pond, Uizdtsi village, Mlynivskyi district
8	channel pond, Mali Dorohostai village, Mlynivskyi district
9	pond, Zabara village, Koretskyi district
10	pond, Derevyane village, Rivnenskyi district
11	pond, Volodymyrets urban-type settlement, Volodymyretskyi district

To monitor the state of stocks, organise rational fishing and regulation, it is necessary to record the relative number and direct accounting of fish stocks [35-37]. Forecasting of annual changes in the stock is mainly carried out by determining the relative number of fish. The method for determining the relative number of fish is based on four initial processes of population dynamics: replenishment, growth, catch, and natural mortality. In addition, the age, size, and species composition of the catch are determined [38; 39].

Results and Discussion

The issues of using and reproducing fish resources in Ukrainian reservoirs have always been relevant. As of 2019, the production of aquatic living resources amounted to 74.7 thousand tonnes (compared to 2013, the catch of fish decreased by 151.1 thousand tonnes or 70%). This is conditioned by the insufficient amount of fish stocking material, the depletion of stocks of commercial fish species, and geopolitical changes in Eastern Ukraine.

In some regions, the total production of aquatic bioresources has increased [40]. Users who received quotas for special use of aquatic bioresources in 2019 extracted 51.5 thousand tonnes of aquatic bioresources, of which 21.3 thousand tonnes were caught in inland waters, which is an increase of 4.2% compared to the previous year. Domestic commercial fishing is carried out in large inland water bodies, mainly in the reservoirs of the Dnipro, estuaries, and in medium-sized natural reservoirs, where the SCF regime is mainly used. Silver carp, bream, roach, white bream, herbivorous fish species, and common pikeperch were mainly caught. In the structure of production of all aquatic bioresources, the share of fish products of aquaculture is only 21.8% of the total volume [4; 5].

The water fund of the Rivne Oblast has a fairly large number of water bodies: 171 rivers (total length – 4,462.0 km), which belong to the Pripyat river basin; 130 lakes (total area – 2,675,722 ha), the most numerous of which are floodplain, but there are also karst lakes (Bile, Ostrivske, etc.); 12 reservoirs (total area – 3,274.07 ha), the largest are Khrinnytske reservoir (total area – 2,046 ha, within the Rivne Oblast 1,610 ha) and Mlynivske reservoir (total area – 440 ha); 1,300 ponds (total area – 10,099.77 ha), most of them are small water bodies – from 10 to 30 hectares [34].

Control over the protection, use, and reproduction of aquatic bioresources at these facilities is carried out by the Department of the State Agency of land reclamation and fisheries in Rivne Oblast [41].

During 2010-2022, commercial fishing of aquatic bioresources was not carried out, as a result of the suspension of the activities of fishing organisations on the water bodies of the region, as it was unprofitable. Until 2010, commercial fishing of fish and aquatic bioresources took place: in the rivers – Horyn, Ikva, Styr; lakes – Nobel, Putylivske; reservoirs – Mlynivske and Khrinnytske [1; 32; 33].

Now specialised public organisations of amateur fishermen in the reservoirs of the region carry out organised amateur fishing. The most numerous of them are the Rivne regional organisation of the Ukrainian Society of Hunters and Fishermen (USHF), the Rivne Regional Federation of Fishing Sports, and the Society of Military Hunters and Fishermen. Since the 2000s, underwater fishing has gained popularity. Fishermen have the opportunity not only to catch fish, but also to observe underwater life, engage in photo hunting. Organisations that unite underwater hunters were created – the spearfishing club Rivenska Sluch and Harpoon. According to various estimates, public organisations unite from 8 to 15 thousand amateur fishermen and athletes [32; 33].

Most often, the objects of unorganised amateur fishing are reservoirs Khrinnytske and Mlynivske, lakes Nobel, Sosno, Omyt, Bile, and rivers Horyn, Styr, Sluch, Ikva, and Pripyat. In the catches of amateur fishermen on the rivers, reservoirs, and ponds of the region, 24 species of fish were found: chub (*Squalius cephalus* L.), ide *Idus idus* L.), silver crucian carp (*Carassius gibelio* Bloch), common crucian carp (*Carassius carassius* L.), common carp (*Cyprinus sargio* L.), common roach (*Rutilus rutilus* L.), common rudd (*Scardinius erythrophthalmus* L.), tench (*Tinca tinca* L.), gudgeon (*Gobio gobio* L.), common bleak (*Alburnus alburnus* L.), white bream (*Blicca bjoerkna* L.), common bream (*Abramis brama* L.), asp (*Aspius aspius* L.), grass carp (*Ctenopharyngodon idella* Valenciennes), white silver carp (*Hypophthalmichthys molitrix* Valenciennes), common pike (*Esox lucius* L.), common perch (*Perca fluviatilis* L.), common pikeperch (*Sander lucioperca* L.), wels catfish (*Silurus glanis* L.), Eurasian ruffe (*Gymnocephalus cernuus* L.), monkey goby (*Neogobius fluviatilis* Pallas), Amur sleeper *Perccottus glenii* Dybowski), European eel (*Anguilla anguilla* L.) (very rarely).

According to public specialised organisations, in 2020, the catch of aquatic bioresources by amateur fishermen amounted to only 16,393 tonnes [35]. The species composition of the caught aquatic bioresources is shown in Figure 1.

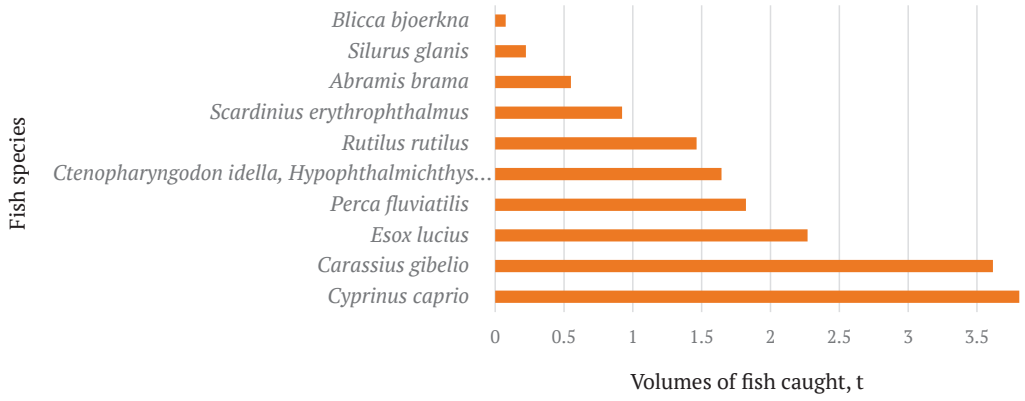

Figure 1. Species composition of aquatic bioresources in the catches of amateur fishermen (2020)

According to the Rivne fish protection patrol, the largest share in fishermen's catches was carp and silver carp – 3.6-3.8 tonnes; less often – such species as pike, common perch, white and mottled silver carp, roach and rudd. The total catch of these fish species was 0.9-2.3 tonnes. Very rarely caught bream, catfish, and white bream, the total catch of these species was only 0.076-0.55 tonnes [32].

In addition to catching fish, public organisations, in particular the Rivne regional organisation of the Ukrainian Society of Hunters and Fishermen, perform settlement of young fish. Thus, in 2019, users of water bodies in the reservoirs of the Rivne Oblast settled two-year-olds of carp, herbivorous fish, and common pike and silver carp (Figure 2).

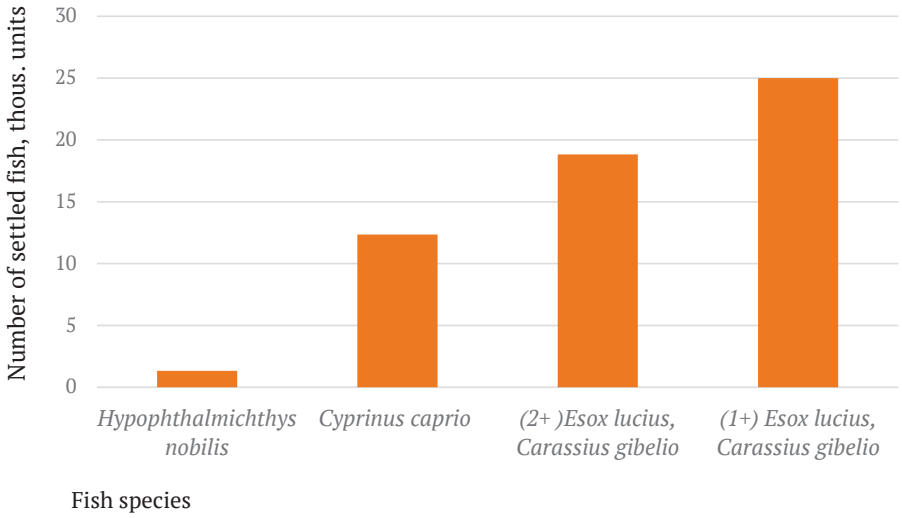

Figure 2. Volumes of the settlement of aquatic bioresources by water body users in 2019

The volume of settlement is relatively insignificant – most of all, two- and three-year-olds of different fish species (pike, silver crucian carp, etc.) are inhabited in the reservoirs of the region – 25 thousand specimens, the least – two-year-olds of the variegated silver carp – 1.33 thousand specimens [32].

Artificial breeding, cultivation, and use of fish and other aquatic bioresources in the SCFs of the Rivne Oblast were carried out by 11 users (the total area of reservoirs used was 204 hectares, most of which were channel ponds). Users start fishing in autumn, in accordance with the technology of growing carp and herbivorous fish of the Far Eastern faunal complex. The planned volume of fish caught in 2020 was 62 tonnes, and in fact, 58 tonnes were caught (that is, 94% of the planned figure). Fish production of reservoirs thus amounted to 285 kg/ha (Figure 3) [32].

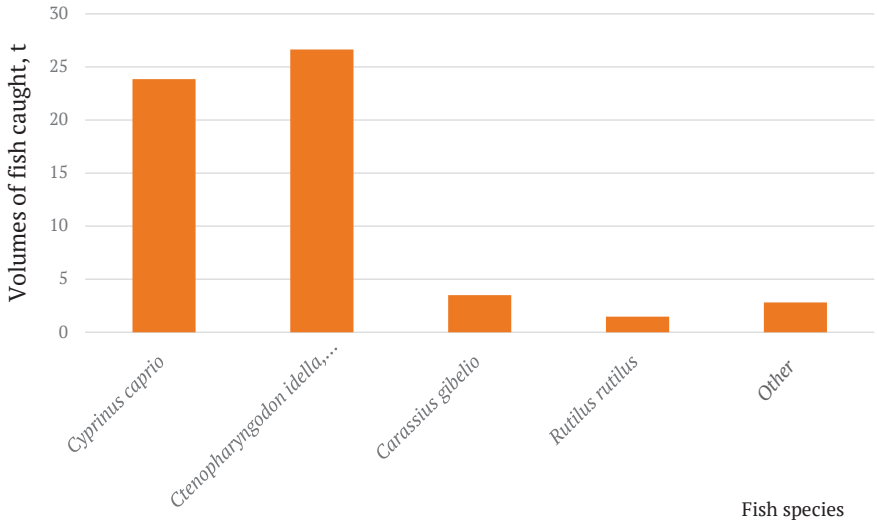

Figure 3. Catch volumes of aquatic bioresources in SCFs of the Rivne Oblast (2020)

Analysing the data on the catch of fish products in SCFs of the Rivne Oblast, it can be noted that most of the herbivorous fish species were caught – 26.6 tonnes; carp fish were 23.8 tonnes; the least amount caught was common roach – 1.5 tonnes [32].

The introduction of fish stocking material can be carried out all year round, but the vast majority of stocking occurs in spring and autumn. In 2020, 97.654 thousand juveniles of various fish species were stocked in the reservoirs of Rivne Oblast (Fig. 4).

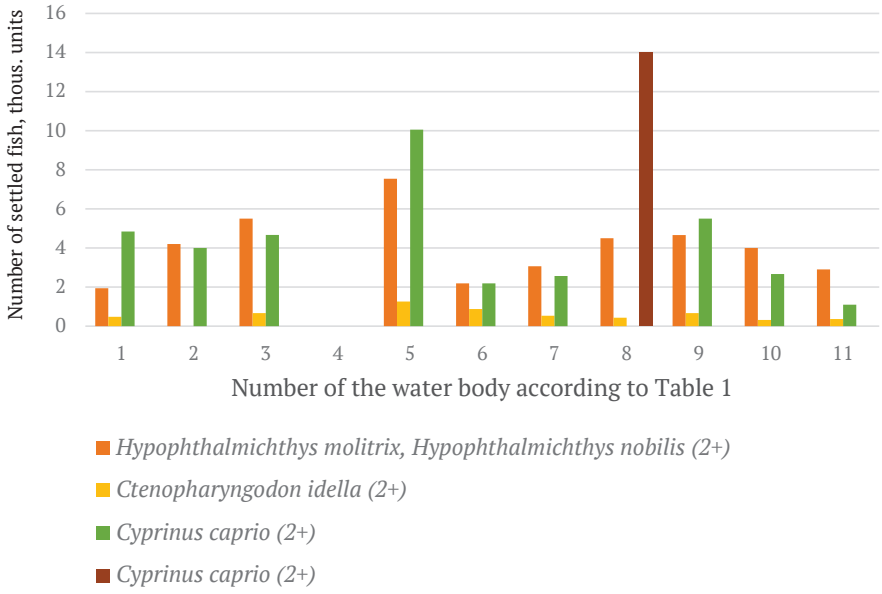

Figure 4. Volumes of settlement of various fish species in SCFs of the Rivne Oblast (2020)

The smallest number of wild fish was made up of two-year-olds of the grass carp – 5,588 thousand specimens; most of all, two-year-olds of silver carp were settled – 40,489 thousand specimens. Analysis of the settlement volumes of the main commercial species of ichthyofauna over a 5-year period showed that all the farms under study are stocked with more herbivorous fish species (grass carp, white and mottled silver carp). According to the reporting data, for five years in almost all farms, the volume of planned stocking coincides with the actual one (Table 2) [32].

Table 2. *Dynamics of fish settlement (thous. units) by users of special commercial fisheries in 2015-2019*

SCF	Years									
	2015		2016		2017		2018		2019	
	plan	fact	plan	fact	plan	fact	plan	fact	plan	fact
1	20.92	20.92	20.92	20.92	20.82	16.01	7.26	7.26	7.26	7.26
2	32.5	30.5	10.83	10.16	10.82	10.82	10.83	10.83	10.83	10.83
3	24.7	24.7	24.7	12.0	24.7	15.0	8.23	4.0	8.7	8.2
4	40.07	–	40.07	–	–	–	–	–	–	–
5	60.32	33.93	56.55	52.78	18.85	9.54	18.85	18.85	18.85	18.85
6	20.02	20.02	17,453	17,453	6.16	2.56	6,158	6,158	6,164	6,164
7	13,993	13,993	15.74	-	15.74	-	5,245	5,245	5,245	5,245
8	21.0	8.0	21.0	21.0	21.0	21.0	21.0	-	7.0	6,985
9	27,933	27,933	28.8	28.8	27.93	27.93	9.59	9.59	18.93	18.93
10	32.5	–	32.5	–	32.5	32.0	10.82	10.82	10.83	10,825
11	13.0	–	13.0	–	12.28	12.28	4.33	4.33	4,365	4,365

According to the reporting data, in 2017-2019, the actual population of commercial fish species mostly coincided with the planned one, except for ponds in Kustyn and Zabara villages. Data on the introduction of aquatic living resources into the channel pond, which is located in Okhmatkiv village has been absent since 2016 [4]. In all farms, there is a tendency to reduce the number of commercial fish species, which is most likely conditioned by difficult economic conditions, in particular, an increase in the cost of fish stocking material. The high cost of grown products creates a high price for consumers, so the demand for live fish is low compared to imported ones. These factors lead to a decrease in the volume of fish population in special commercial fisheries in Rivne Oblast.

Table 3. *Dynamics of fish catch (t) by users of special commercial fisheries in 2010-2019*

2010		2011		2012		2013		2014		2015		2016		2017		2018		2019	
plan	fact	plan	fact	plan	fact	plan	fact	plan	fact	plan	fact	plan	fact	plan	fact	plan	fact	plan	fact
Channel pond, Klyntsi village, Dubenskyi district																			
–	–	5.2	5.2	5.4	–	5.5	5.5	5.6	5.6	5.7	5.7	5.9	5.9	6.0	6.0	6.1	6.1	6.3	6.3
Channel pond, Kolodiivka village, Koretskyi district																			
–	–	–	–	5.1	–	5.3	5.3	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
Channel pond, Kustyn, Rivnenskyi district																			
–	–	–	–	4.4	–	4.7	3.0	5.2	3.1	5.2	2.9	5.4	2.7	5.4	3.6	5.4	5.4	5.4	5.4
Channel pond, Okhmatkiv village, Demydivskyi district																			
–	–	–	–	1.3	–	6.6	6.6	6.9	6.9	7.2	–	7.5	–	–	–	–	–	–	–
Channel pond, Varkovychi village, Dubenskyi district																			
–	–	9.3	9.3	9.3	–	9.4	–	9.4	7.0	9.4	3.3	9.6	5.0	9.6	3.5	9.6	5.2	9.8	6.0
Channel pond, Mali Dorohostai village, Mlynivskyi district																			
11.3	11.3	12.72	–	3.90	3.90	3.95	–	4.10	4.10	4.15	4.15	4.30	4.30	4.40	4.40	4.45	4.45	4.60	4.60
Channel pond, Yuchyn village, Goshchanskyi district																			
–	–	2.86	2.86	3.16	–	3.36	3.36	3.56	3.56	3.76	3.76	3.86	3.86	4.06	–	4.26	4.26	4.46	4.46
Channel pond, Zabara village, Koretskyi district																			
–	–	–	–	6.01	–	6.12	6.12	6.38	6.38	6.38	3.69	6.38	6.38	7.28	5.60	6.38	6.38	6.38	6.38
Channel pond, Derevyane village, Rivnenskyi district																			
–	–	–	–	5.62	–	6.05	6.05	6.30	6.30	6.36	6.36	6.76	6.76	6.76	6.76	6.76	6.76	6.76	6.76
channel pond, Volodymyrets urban-type settlement, Volodymyretskyi district																			
–	–	–	–	8.11	–	8.50	8.50	8.80	8.80	9.10	–	9.10	–	9.10	9.10	9.10	9.10	9.10	9.10
Channel pond, Uizdtsi village, Mlynivskyi district																			
–	–	–	–	–	–	–	–	2.20	–	2.29	2.29	2.38	2.38	2.47	2.47	2.56	2.56	2.65	2.65

According to the reporting data in SCFs, since 2015, the actual catch mostly coincided with the planned one, except for ponds in Varkovychi, Kustyn, and Zabara villages. In the channel pond located in Okhmatkiv village, fishing has not taken place since 2016 [32].

The fishery on the channel pond in Mali Dorohostai village was operating before 2010, while most farms started operating only in 2012 (6 out of 11) and the first catch was carried out in 2013. Analysis of catch dynamics based on the reporting data shows a gradual slight increase in comparison with the first years of operation of special commercial fisheries in Klyntsi and Kustyn villages. On the SCF in Volodymyrets urban-type settlement over the 5-year period, the average catch was 8.92 tonnes [32].

Conclusions

One of the problems of the development of fisheries in Rivne Oblast is low profitability, and as a result, the lack of organised industrial fishing of aquatic living resources. To date, the activities of fishing organisations on the water bodies of the region have been stopped. Thus, fishing is mainly carried out by amateur fishermen. There are several public organisations of amateur fishermen in the region, which unite up to 15 thousand fishermen and sportsmen. The catch of fish according to these public organisations amounted to 16,393 tonnes, but the volume of stocking is insignificant – 25 thousand specimens of annual fish of various species (pike, silver crucian carp, etc.) and 1.33 thousand specimens of two-year-old mottled silver carp.

Fish stocks are replenished in fish farms, mainly by herbivorous fish species and carp. However, in 2016-2019, the volume of moving in almost all farms decreased three times compared to 2015, while the volume of fish caught in SCFs, on the contrary, increased slightly and in recent years the actual catch mainly coincided with the planned one.

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Стан використання рибних ресурсів малих водойм Рівненської області

Ілона Олександрівна Парфенюк[1], Юлія Романівна Гроховська[1], Вадим Петрович Марценюк[2]

[1]Національний університет водного господарства та природокористування
33028, вул. Соборна, 11, м. Рівне, Україна

[2]Національний університет біоресурсів та природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Анотація. Браконьєрство та нерегульоване любительське рибальство призвели до збіднення і, місцями, повного винищення популяцій промислово цінних видів риб у Рівненській області, тому діяльність спеціальних товарних рибних господарств забезпечує збереження запасів рибних ресурсів. Метою дослідження є аналіз стану водного фонду Рівненської області, використання рибних ресурсів даних водойм, зокрема, результатів діяльності спеціальних товарних рибних господарств, промислового та любительського вилову риби і водних біоресурсів. За даними Управління Державного агентства рибного господарства та меліорації у Рівненській області, впродовж останніх двадцяти років спостерігається тенденція до зниження обсягів вилову та вселення риби у природні та штучні водойми. З 2010 року, внаслідок низької рентабельності, повністю припинена діяльність рибодобувних організацій, хоча раніше промисловий вилов водних живих ресурсів відбувався на великих водних об'єктах, зокрема у річках (Горинь, Іква, Стир), озерах (Нобель, Путилівське), водосховищах (Млинівське, Хрінницьке). На сьогодні основним способом рибодобування, крім діяльності спеціальних товарних рибних господарств, є неорганізоване любительське рибальство. Профільні громадські організації рибалок-любителів організації об'єднують від 8 до 15 тисяч рибалок-аматорів та спортсменів, здійснюють організоване любительське рибальство, займаються вселенням рибних ресурсів у водні об'єкти регіону (коропа, рослиноїдних риб, а також щуки звичайної та карася сріблястого). Найбільшу частку в уловах рибалок складають короп та карась сріблястий; рідше трапляються щука, окунь звичайний, товстолобики, плітка та краснопірка. Стан ведення рибогосподарської діяльності у спеціальних товарних рибних господарствах Рівненської області за останні 10 років фактично не зазнав змін. Станом на 2021 рік у регіоні їх лишилось лише 11, що працюють на умовах оренди; та декілька підприємств приватної власності, де здійснюється вирощування товарної риби у повносистемних та неповносистемних господарствах. Обсяги вселення молоді риб майже у всіх господарствах зменшились утричі у порівнянні з 2015 роком, водночас обсяги вилову риби дещо зросли. Аналіз стану використання рибних ресурсів малих водойм необхідний для подальшого раціонального вилучення та відновлення запасів рибних ресурсів малих водойм Рівненської області

Ключові слова: водні ресурси, рибне господарство, промисловий вилов, обсяги вилову, вселення, любительське рибальство

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Effect of concentration of coconut oil with demineralised whey powder on the properties of bean pastes

Igor Stadnyk[1*], Volodymyr Piddubnuy[2], Halyna Karpyk[1], Liudmyla Beiko[1], Khrystyna Kravcheniuk[1]

[1]Ternopil National Technical University named after I. Puliui
46001, 56 Ruska Str., Ternopil, Ukraine

[2]Kyiv National University of Trade and Economics
02156, 19 Kioto Str., Kyiv, Ukraine

Abstract. There is a lack of protein products in the human diet, so balancing the nutritional composition of products remains an urgent task. The purpose of the study is to develop and determine the structural and mechanical characteristics of finishing processed products made from bean paste, demineralised whey powder, and coconut oil for confectionery. The main areas of technological use of confectionery pastes are developed: for applying to the surface of products as a layer; for creating flowers and shaped model products, as a decorative element for flour confectionery products. The study used food-grade white beans of the Mavka variety, demineralised whey powder made from whey with a 90% degree of demineralisation in accordance with TS U 15.5-00413890-089:2014. Rheological properties (resilience, elasticity, plasticity) were determined by a plane-parallel elastoplastometer of Tolstoy modification. The surface characteristics of pastes were studied using a dynamometer connected to a MiG-1.3 measuring device. The adhesive strength was determined by separating the steel plate from the bean paste. Empirical regression equations are obtained by correlation and regression analysis using the MATHCAD-14 software suite. The chemical composition of bean pastes with demineralised whey powder, their organoleptic quality indicators and structural and mechanical properties were determined to optimise the recipe composition to improve the functional and technological properties of confectionery pastes. The positive effect of the mutual use of beans and demineralised whey powder on the structural and mechanical properties of new finishing processed products was established. The improvement of the moulding capacity indicators at the concentration of 10-30% demineralised whey powder and 8% coconut oil in the composition has been proven. The reduction of stickiness in the compositions of bean pastes for modelling shaped products, coating confectionery, and making flowers as decorative confectionery products at a concentration of coconut oil up to 10% was established. Accordingly, the total scores of the developed descriptors were: 2.92 for decorative confectionery, 2.98 for coating confectionery, and 2.95 for modelling shaped products. A change in the colour intensity of bean paste compositions in the case of an increase in the concentration of demineralised whey powder is established, which allows expanding the technological methods of manufacturing shaped products. The developed technology and recipe composition allow obtaining high-quality, high-biological value, and low-calorie finishing processed products for confectionery

Keywords: protein, beans, adhesive strength, rheological properties, optimisation, recipe composition, paste composition

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[*]*Corresponding author*

Introduction

Nowadays, there is a lack of protein products in the human diet. Since protein is a building material for cells, and performs a protective and transport function, supplying oxygen to the tissues of the human body, its lack leads to destructive changes in internal organs, bones, and weakens the immune system. Therefore, an urgent task for researchers and manufacturers is to develop and create products with a balanced nutritional composition. In particular, this applies to confectionery products, because they have a high caloric content and glycaemic index. Especially due to the content of sugar and fat in the recipe, which are of great technological importance in the formation of complex structures. Therefore, measures to develop a rational composition of confectionery products should be aimed at reducing caloric and improving nutritional value [1; 2].

The technological capabilities of the modern confectionery industry allow developing new products with a variety of taste properties, aromas, consistency, and shape. This approach is aimed at attracting the attention of consumers, that is, increasing demand. The creation of bean pastes with a concentration of 12-32% of demineralised whey powder (DWP) and 6% of coconut oil allows expanding the range of their technological properties. Such properties improve the organoleptic parameters of bean pastes and adjust the nutritional value [2]. Promising in this aspect is the influence of bean pastes on the confectionery coating products and modelling of shaped products of the confectionery industry, which were not previously described.

Expanding the raw material base of confectionery production is becoming a promising area for the development of the latest technologies. The use of raw materials rich in protein substances contributes to the expansion of the range of processed products and products with appropriate organoleptic and physicochemical parameters. The choice of components and their combination with each other should consider compatibility and exclude deterioration of consumer properties of products.

To a large extent, the health of a modern person depends on the nature, level, and structure of nutrition. In Ukraine today, there is an excessive consumption of flour confectionery products with low biological value, containing a large amount of sucrose [1]. The researchers [3] note that the high content of sugars in the daily diet of a person leads to a decrease in the sensitivity of the body's cells to it, the level of glucose in the blood increases, that is, conditions are created for the development of diabetes, metabolic processes are disrupted, and excess weight appears. In addition, high-calorie meals with a significant content of easily digestible sugars and fats can cause high cholesterol and weaken the immune system. Fat saturation also affects the incidence of diabetes and obesity in the population. Recipes of many confectionery products contain animal or trans fats. Saturated fats can cause heart and vascular diseases [1; 3]. Therefore, it is relevant to develop the latest health-improving food products with high quality indicators.

Haricot beans are one of the most common leguminous crops, the use of which is based on the balance of its amino acid composition, good digestibility of proteins by the human body, high taste and nutritional qualities of the crop and products from it, and the effectiveness of pricing policy. Due to these properties, they are equated with such legumes as chickpeas, soybeans, peas, lentils, and beans [1]. Beans are traditionally grown on the territory of Ukraine. Due to their high biological value, they are widely used in the food industry, medicine, and cosmetics. Food products from this plant meet the human need for vegetable protein. It is consumed to prevent high cholesterol, heart and vascular diseases, and disorders of fat and protein metabolism [2; 3].

Beans have substances that promote the elimination of radionuclides from the human body [1; 2] and contain up to 32% protein. Beans also contain 41.1 to 54.7% carbohydrates, 2.2-6.6% fibre, 0.43-3.75% fat, and vitamins E, B_1, B_2, B_6, C. They contain a number of minerals – calcium, phosphorus, iron (up to 8%), potassium, sodium, iodine, magnesium, citric acid, and dietary fibre. According to the literature data [4-6], beans are a food product that contains almost all the substances for normal human nutrition. The existing toxic substances phenazine and glycoside are destroyed by heat treatment. Therefore, beans are among the dietary products.

Recent studies [7] have proven the possibility of using sweet bean paste made from boiled beans and sugar, for glueing cakes, pastries, and cookies. This paste is used as a layer for desserts, confectionery sticks, flour products, and for the manufacture of plastic mass in the design of confectionery products with curly decor [7; 8]. Such a processed product has a high biological and nutritional value, but has low organoleptic characteristics due to the specific taste and aroma of beans.

In [8-10], researchers suggest using a combination of DWP and beans of the Mavka variety in the recipe of confectionery paste. Due to the high content of biologically active substances, this combination provides a high nutritional value for finishing processed products.

In their papers, A. Dyakonova [11], M. Riabchenko and K. Ulianchenko [12] prove the expediency of studying the quality and safety of legumes, improving their consumer properties with the prospect of further application.

As evidenced by the experience of Ukrainian and foreign researchers, the use of beans in the production of processed confectionery products was insufficiently investigated. This includes an insufficient investigation of the use of the common Mavka variety of beans in the composition of confectionery pastes.

Based on the above, *the purpose of the study* is to develop and determine the structural and chemical characteristics of finishing bean confectionery pastes made from DWP and coconut oil.

To achieve this goal, it is necessary to consider and solve the following scientific and practical tasks:

– improve functional and technological properties of bean pastes in the composition of Mavka beans, DWP, and coconut oil.

– substantiate the prerequisite for the use of bean pastes for confectionery processed products of increased nutritional value and improved consumer properties;

– establish the feasibility of using DWP and coconut oil for the production of bean pastes;

– investigate the chemical composition of confectionery bean pastes with DWP.

Materials and Methods

The study began in 2019 at the Kyiv National University of Trade and Economics and continued in 2021 with the participation of the Ternopil Ivan Puluj National Technical University.

Materials under study – demineralised whey powder, made from subsurface cheese whey with a 90% degree of demineralisation in accordance with TS U 15.5-00413890-089:2014 [13]; model compositions of bean pastes made from white beans of the Mavka variety with a dosage of DWP of 10-30% and coconut oil – 1-12% per 100 g (Table 1).

Table 1. *Composition of the recipe for model compositions of bean pastes with DWP, per 100 g*

Raw material name	Control	Sample with coconut oil content, %				
		4	6	8	10	12
CC (confectionery coating) paste						
Bean paste processed product	81.0	78.3	76.0	76.5	74.0	74.0
DWP	21.0	18.1	18.0	16.4	16.0	15.0
H_2O (water)	11.0	9.5	11.0	10.1	11.0	11.0
Coconut oil	–	4.2	7.0	8.11	9.0	11.0
DC (decorative confectionery) paste						
Bean paste processed product	89.0	87.6	87.0	87.0	85.0	84.0
DWP	9.0	8.1	7.0	6.0	5.0	4.0
H_2O (water)	6.0	4.5	4.5	4.5	4.5	4.5
Coconut oil	–	3.9	6.0	7.9	10.0	12.0
MSP (modelling of shaped products) paste						
Bean paste processed product	70.0	68.0	67.0	66.0	65.0	64.0
DWP	30.0	28.0	27.0	26.0	25.0	24.0
H_2O (water)	15.0	14.9	14.9	14.9	14.9	14.9
Coconut oil	–	4.0	6.0	8.0	10.0	12.0

Evaluation of the possibility of using paste from white food beans of the Mavka variety with the additives of DWP and coconut oil in the developed recipe formulas is aimed at establishing the rheological, chemical and structural characteristics of their behaviour in a multicomponent system.

The main structural and mechanical properties of pastes with a given range of coconut oil concentrations were determined by the deformation characteristics. The rheological properties of the control and proposed samples were studied on a plane-parallel elastoplastometer of Tolstoy modification [14]. It determines the shear strain related to the thickness of the sample under constant stress. When studying the characteristics of model systems, fixed loads were selected for all variants (65 g), providing a temperature of +6°C and a sample height of 7 mm.

To determine the visco-elastic and visco-plastic properties, the method developed in [14] was used. According to the obtained data, the dependence of the stress action time relative to the strain is graphically displayed. The plastic viscosity of structured systems without destruction, while maintaining constant stresses, was calculated using the equation:

$$ή \cdot 0 = \tau / tg\alpha, \quad (1)$$

where ή·0 – plastic viscosity, PA·s; tgα – the angle of inclination of the linear section of the curve relative to the abscissa axis.

Determination of the aftereffect of elastic viscosity:

$$ήel = \tau / tg\beta, \quad (2)$$

where ήel – elastic viscosity aftereffect, PA·s; tgβ – the angle of inclination of the beginning of the linear section of the curve relative to the abscissa axis.

The surface characteristics of the control and prototype samples were studied with a dynamometer, which was connected to a MiG-1.3 measuring device. It allowed characterising the level of adhesion of the samples under study during their surface contact. The adhesive strength was established using the method of normal separation of the steel plate from the bean paste. The obtained data was statistically processed using the standard Microsoft Office software suite.

Model compositions of finishing processed products were studied according to the developed organoleptic scales. They are based on indicators of appearance, consistency, taste, smell, and moulding ability. Display of the appearance characteristics of colour descriptors provided a range of colours for semi-finished products. The coefficients of weighting by consistency indicator for CC (confectionery coating) are 0.1:0.1:0.7:0.1; MSP (modelling of shaped products) – 0.3:0.2:0.2:0.3; DC (decorative confectionery) – 0.2:0.2:0.3:0.3. Areas of technological use: CC – 0.4:0.2; DC – 0.3:0.3; MSP – 0.2:0.4. The search for the optimal value of the mass fraction of DWP and coconut oil in bean pastes was determined by a multi-factor experiment. Figure 1 shows the order of the research.

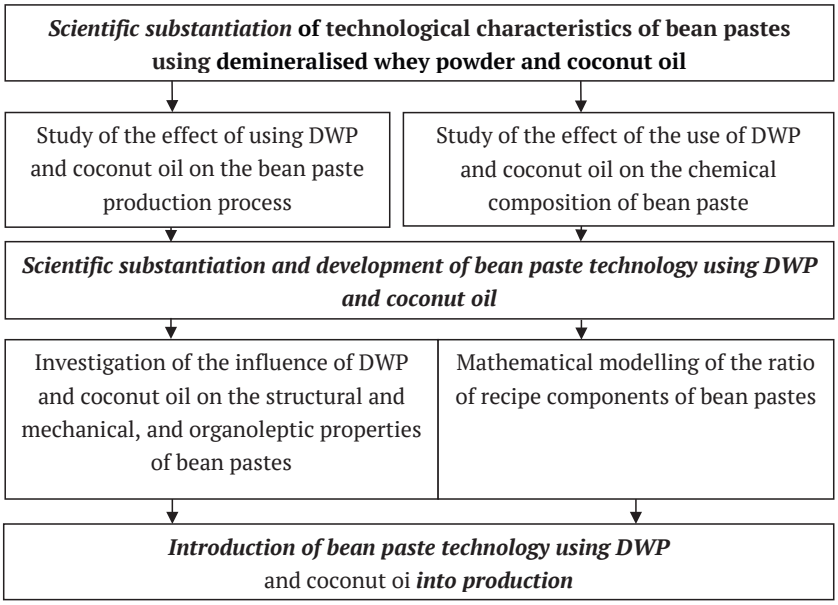

Figure 1. Scheme of the research procedure

The obtained results of the experimental array were statistically processed using correlation and regression analysis using MATHCAD-14 software suite. The obtained empirical regression equations allow qualitatively and quantitatively assessing the characteristics of the selection of matrix components [15; 16].

Defined variable factors: x_1 – coconut oil content, %; x_2 – DWP content, %. According to the design of the experiment, a full factorial experiment of type 21, with two factors, was implemented. Levels and intervals of factor variation (Table 2). The area for determining factors is found (Table 3).

Table 2. *Level and interval of variation of the factor of complex rheological indicator of the consistency of bean pastes with DWP*

Factors	Code designations	Variable intervals	Factor level		
			Main (0)	Upper (+1)	Lower(-1)
Coconut oil content, %	x_1	4	10	20	0
DWP content, %	x_2	5	20	40	0

Table 3. *Complex rheological indicator of the consistency of bean pastes with DWP*

Samples	Value			
	Moulding ability	Strength	Stretchability	Complex indicator
	Y_1	Y_2	Y_3	Y
DC	0.41	0.21	0.39	$Y_{DC} = 0.39Y_1 + 0.22Y_2 + 0.39Y_3$
CC	0.14	0.16	0.69	$Y_{CC} = 0.16Y_1 + 0.16Y_2 + 0.7Y_3$
MSP	0.59	0.26	0.15	$Y_{MSP} = 0.59Y_1 + 0.24Y_2 + 0.14Y_3$

Note: *Y_{CC} – complex rheological indicator of bean paste for CC, points; Y_{MSP} – complex rheological indicator of bean paste for MSP, points; Y_{DC} – complex rheological indicator of bean paste for DC, points*

Using multivariate regression analysis, the response surface is constructed. The defined values of the response functions for the specified rheological parameters are shown in Figures 2, 3.

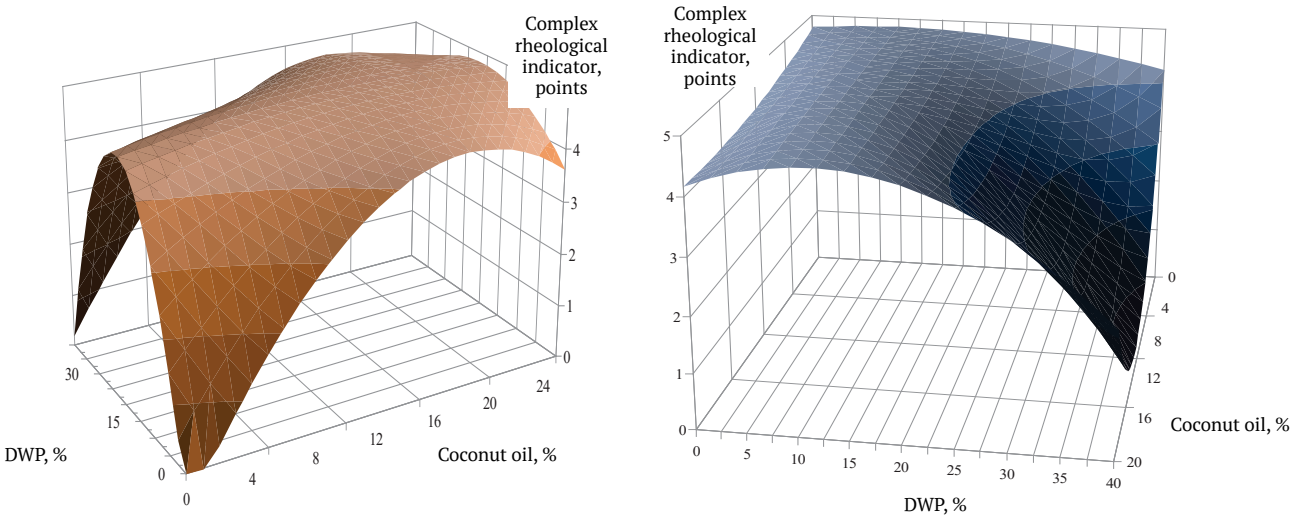

Figure 2. Response surface of the factor space of the complex rheological indicator: A – bean paste for CC; 2 – bean paste for DC

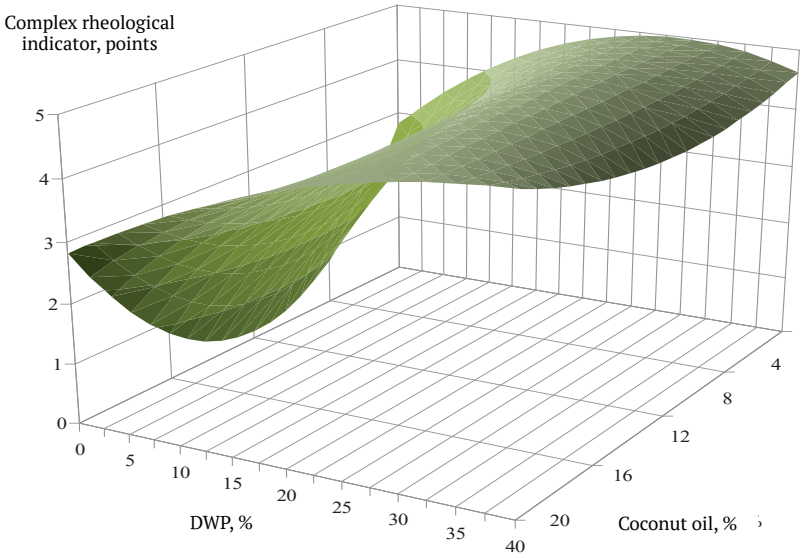

Figure 3. Response surface of the factor complex rheological space indicator for bean paste MSP

The dependences of the complex rheological indicator on the content of coconut oil and DWP are described using the following mathematical models (1-3):

$$Y_{CC} = 3.3\times10^{-5}x_1^2 x_2^2 + 0.00136\, x_1x_2^2 + 0.00121\, x_1^2 x_2 - 0.0106\, x_1^2 - 0.0188\, x_2^2 + 0.4423\, x_1 + 0.6792\, x_2 - 0.9208 \quad (1)$$

$$Y_{DC} = 2.92\times10^{-5}x_1^2 x_2^2 - 0.000515\, x_1x_2^2 - 0.000692\, x_1^2 x_2 + 0.0131\, x_1 x_2 - 0.00091x_2^2 + 0.00841\, x_1 - 0.072\, x_2 + 4.856 \quad (2)$$

$$Y_{MSP} = 3.64\times10^{-5}x_1^2 x_2^2 - 0.002\, x_1x_2^2 - 0.00065\, x_1^2 x_2 + 0.0373\, x_1 x_2 - 0.0287\, x_2^2 + 0.00597\, x_1 - 0.546\, x_2 + 4.917 \quad (3)$$

The obtained data allowed determining the optimal ratio of components of the developed bean pastes (Table 4). It is established that all factors are statistically significant. The greatest statistical value in assessing mutual influence is their use. Based on the data, the optimal ratio of components of the developed bean pastes was determined (Table 4).

Table 4. *Optimisation parameters for recipe components of bean pastes*

Sample indicators	Coconut oil, %			DWP, %		
	Minimum value	Maximum value	Optimal value	Minimum value	Maximum value	Optimal data
CC	9.7	10.2	9.0	19.5	22.6	21.0
DC	9.8	10.13	9.0	10.0	10.8	10.0
MSP	9.7	10.12	9.0	28.9	30.9	31.0

Optimal values are selected by rounding the optimised values within compromise areas to facilitate the dosing of recipe components of bean pastes in a production environment.

Results and Discussion

The results of studies [15; 16] on the organoleptic, and structural and mechanical characteristics of bean pastes allowed determining the zone of rational concentrations of DWP and coconut oil in the developed formulations by a planned experiment.

Clearly, an increase in the concentration of DWP in bean pastes increases the adhesive and cohesive strength, which makes it difficult to work with them. A possible solution to this problem is to use coconut oil, which contains saturated fatty acids – lauric and myristic and a small amount of volatile acids: caprylic and capronic. Therefore, in the production of products made from bean pastes, the selection of the optimal composition of ingredients according to the recipe is an urgent issue.

Some studies [10; 17] were aimed at finding the optimal ratio of structure-forming components of bean taste and aroma. On their basis, harmonious taste and aroma compositions are created. Therefore, the effectiveness of using DWP in the technology of bean paste should be aimed at eliminating the taste and aroma properties of beans with the creation of their harmonious compositions.

The properties of demineralised whey powder (DWP) and its high moisture-binding and moisture-retaining ability in the technology of bean pastes are described in sufficient detail in [18], which allowed taking the data into account in this study. The assistance of DWP in the creation of a stronger structure was also established, which is conditioned by the emergence and development of the spatial framework. Therefore, in the continuous phase of the dispersion medium, stronger hydrogen bonds appear and the frame acquires static shear strength, which gives certain structural and mechanical properties to bean pastes.

It is proved [19] that a different ratio of DWP can be used to regulate these qualitative indicators. It was found [20; 21] that the DWP concentration of 11-31% affects changes in the structural characteristics of bean pastes, improving technological and functional properties. At the same time, this dosage of DWP provides the best rheological characteristics of pastes and, accordingly, gives them optimal moulding ability.

Consequently, the formation of the structure of bean pastes is caused by oppositely directed processes: destruction of the enzymatic cell structure and aggregation of protein particles in the spatial framework due to dehydration of the system. In addition, strong covalent bonds appear, and this is an improvement in the structural and mechanical properties of the paste.

The chemical composition was studied and the protein quality of bean pastes with DWP was evaluated (Tables 5, 6). The protein content is 9.8-10.3%, sucrose is reduced by 1.2 times, which indicates an increase in the quality of protein in the developed pastes. The fat content is 10%. The results of studies of carbohydrate composition reflected a decrease in sucrose, starch, and food fibres by 1.25-1.45 times compared to the control. There was also an increase in the amount of lactose by 11-16% of the total carbohydrate composition.

Table 5. *Chemical composition of bean pastes with DWP*

Indicators	Control	CC	Difference, units	DC	Difference, units	MSP	Difference, units
Protein, %	10.1 ± 0.4	10.2 ± 0.2	0.1	9.8 ± 0.5	-0.3	10.3 ± 0.2	0.2
Fats, %	1.0 ± 0.5	10.9 ± 0.3	9.9	10.9 ± 0.4	9.9	10.9 ± 0.4	9.9
Carbohydrates,%	75.3 ± 0.4	68.6 ± 0.4	-6.7	68.5 ± 0.5	-6.8	68.9 ± 0.2	-6.4
incl. Sucrose, %	51.6 ± 0.1	39.2 ± 0.4	-12.4	44.4 ± 0.5	-7.2	34.1 ± 0.2	-17.5
Lactose, %	–	11.4 ± 0.1	11.4	3.8 ± 0.2	3.8	19.2 ± 0.4	19.2
Starch, %	21.7 ± 0.1	16.5 ± 0.1	-5.2	18.7 ± 0.3	-3.0	14.3 ± 0.3	-7.4
Dietary fibre,%	1.9 ± 0.4	1.5 ± 0.1	-0.4	1.7 ± 0.4	-0.2	1.3 ± 0.1	-0.6
Macronutrients, mg							
Potassium (K)	550.0 ± 0.1	608.5 ± 0.3	58.5	536.5 ± 0.1	13.5	1395 ± 0.1	845.5
Calcium (Ca)	75.0 ± 0.2	283.5 ± 0.3	208.5	140.0 ± 0.2	65.0	524.5 ± 0.5	449.5
Magnesium (Mg)	51.5 ± 0.1	76.6 ± 0.1	25.1	56.8 ± 0.4	5.3	163.4 ± 0.1	111.9
Phosphorus (P)	271.5 ± 0.1	396.8 ± 0.1	125.3	296.9 ± 0.4	-25.4	849.6 ± 0.1	578.1
Microelements, mcg							
Iron (Fe)	2,970.0 ± 0.1	2,656.2 ± 0.1	-313.8	2,687.2 ± 0.2	-282	2,625.0 ± 0.1	-345.0
Iodine (I)	6.1 ± 0.1	14.8 ± 0.5	11.4	8.6 ± 0.1	2.5	20.9 ± 0.2	14.9
Manganese (Mn)	670.0 ± 0.2	510.7 ± 0.1	-159.3	576.7 ± 0.3	-93.3	444.7 ± 0.1	-225.3
Copper (Cu)	290.0 ± 0.1	220.4 ± 0.5	-69.6	249.4 ± 0.3	-40.6	191.4 ± 0.5	-98.6
Molybdenum (Mo)	19.7 ± 0.2	14.9 ± 0.4	-4.7	16.9 ± 0.1	-2.8	13.0 ± 0.5	-6.7
Fluorine (F)	22.0 ± 0.3	16.7 ± 0.1	-5.3	18.9 ± 0.4	-3.1	14.5 ± 0.5	-7.5
Zinc (Zn)	1,605.0 ± 0.5	1,534.8 ± 0.1	-70.2	1,485.3 ± 0.1	-119	1,584.3 ± 0.1	-20.7

Indicators	Control	CC	Difference, units	DC	Difference, units	MSP	Difference, units
Vitamins							
Tocopherol (E), mg	1.92 ± 0.1	1.45 ± 0.2	-0.47	1.65 ± 0.1	-0.27	1.27 ± 0.4	-0.65
Ascorbic acid (C), mg	–	0.75 ± 0.2	0.75	0.25 ± 0.1	0.25	1.25 ± 0.1	1.25
Pyridoxine (B6), mg	0.45 ± 0.2	0.44 ± 0.1	-0.01	0.41 ± 0.1	-0.04	0.45 ± 0.5	–
Cobalamin (B12), mcg	–	0.36 ± 0.1	0.36	0.12 ± 0.3	0.12	1.56 ± 0.5	1.56
Biotin (B7), mcg	–	5.55 ± 0.3	5.55	1.85 ± 0.1	1.85	9.25 ± 0.1	9.25
Niacin (B3,PP), mg	1.05 ± 0.1	0.91 ± 0.4	-0.14	0.94 ± 0.3	-0.11	0.85 ± 0.1	-0.2
Pantothenic acid (B5), mg	0.6 ± 0.4	1.29 ± 0.5	0.69	0.79 ± 0.2	0.19	1.79 ± 0.4	1.19
Riboflavin (B2), mg	0.09 ± 0.4	0.25 ± 0.1	0.19	0.13 ± 0.2	0.04	0.37 ± 0.3	0.28
Thiamine (B1), mg	0.25 ± 0.1	0.22 ± 0.5	-0.03	0.22 ± 0.1	-0.03	0.21 ± 0.1	-0.04
Folacin (B9), mcg	45.0 ± 0.3	35.9 ± 0.3	-9.1	38.3 ± 0.4	-6.7	32.6 ± 0.2	-12.4
Choline (B4), mg	–	15.0 ± 0.1	15.0	5.0 ± 0.5	5.0	25.0 ± 0.2	25.0
Energy value, kcal	331	376	45	372	41	361	30
Glycaemic index	53	49	-4	50	-3	47	-6

Note: *(dry matter content per 100 g), $p \leqslant 0.05$*

Table 6. *Protein quality assessment of bean pastes with DWP*

Essential amino acid	Control		CC		DC		MSP	
	C	ΔAASD	C	ΔAASD	C	ΔAASD	C	ΔAASD
Lysine	205	145	189	132	149	98	161	107
Threonine	118	58	120	63	125	74	132	78
Valine	140	80	132	75	130	79	126	72
Methionine+Cystine	*60	0	*57	0	*51	0	*54	0
Leucine	180	120	164	107	150	99	135	81
Isoleucine	155	95	142	85	135	84	122	68
Tyrosine + Phenylalanine	118	58	108	51	102	51	93	39
Tryptophan	130	70	110	53	120	69	110	56
ΣΔAASD	–	626	–	566	–	554	–	501
AASDF	–	78	–	70	–	69	–	62

Improvement of the vitamin and mineral composition of the developed bean pastes was established. The content of macronutrients increases significantly, in particular, K by 59-846 mg, Ca by 209-450 mg, and P by 126-579 mg. The vitamin composition was supplemented with vitamin C (0.75 – 1.25 mg), B_{12} (0.36 – 1.56 mcg), B_7 (5.55-9.25 mcg), B_4 (15-25 mg), vitamin B_5 increased by 0.69-1.19 mcg, B_2 by 0.19-0.28 mg (Table 5).

The developed bean pastes belong to products with an average GI (glycaemic index), which is 47-50 units, but the energy value increases by 15-20% compared to the control.

As a result of the research, an increase in the colour intensity of model compositions of bean pastes was found with an increase in the concentration of DWP, which approaches a light cream colour and, accordingly, contributes to the disappearance of transparency of the consistency inherent in traditional bean pastes. This allows expanding the areas of their technological use. Thus, the resulting paste becomes suitable for covering confectionery products and modelling of various shapes.

The presence of DWP in the amount of 11-31% in bean pastes increases the saturation of milk taste and smell, and also helps to "mask" the bean taste and aroma. DWP at a concentration of 10-30% creates a harmonious, balanced taste and aroma composition.

The introduction of DWP in the formulation of bean pastes improves their consistency. Increased density and strength indicators while reducing softness optimise the product moulding. However, an increase in the concentration of DWP leads to an increase in stickiness indicators by 10%, which is the main disadvantage.

The results of organoleptic analysis of the developed descriptors indicate that CC pastes have the best indicators. Thus, at an DWP concentration of 20%, the total score is 4.64. For DC paste, the highest overall score is set at a DWP concentration of 30%, but the recommended DWP concentration is 10%. This is substantiated by the optimal score when evaluating appearance indicators, since only bean pastes have a unique transparency, which is optimally preserved only at a DWP concentration of 10%. This typical

transparency allows making flowers from bean paste as a decorative element for finishing confectionery products as realistic as possible. For MSP paste, the best values are observed at a DWP concentration of 30%.

The process of making compositions of bean pastes with demineralised whey powder with the addition of coconut oil is essentially mixing the components. In the process, the formulation mixture undergoes physicochemical transformations and interacts with each other to form various bonds. The mixed mass of the paste belongs to a visco-plastic structured system [20]. Accordingly, the effect of bean pastes with a concentration of DWP and coconut oil in the amount of 4-12% on the adhesive strength indicators was established. The data is summarised in Table 7.

Table 7. *Adhesive strength (wα) of bean paste compositions with DWP and coconut oil*

Designation	Samples with coconut oil concentration, %					
	0	4	6	8	10	12
(ωα), H/m², DWP 21%	65.1	42.1	35.3	27.9	24.2	23.5
Difference, %	–	-22.2	-29.1	-36.4	-43.2	-41.1
(ωα), H/m², DWP 11%	56.3	37.0	31.5	26.2	22.0	22.4
Difference, %	–	-18.6	-24.2	-29.5	-33.6	-33.9
(ωα), H/m², DWP 31%	7.2	55.5	48.0	39.9	26.2	25.1
Difference, %	–	-18.3	-30.8	-25.8	-47.6	-48.7

Note: *($n = 5$, $p \leq 0.05$)*

Table 7 shows that the adhesive strength of bean pastes decreases from 65.1 to 23.5 H/m² at a DWP concentration of 20%, from 56.3 to 22.4 H/m² at a DWP concentration of 11%, and from 73.8 to 25.2 H/m² at a DWP concentration of 31%. The presence of coconut oil reduces the adhesive strength of bean paste with DWP by three times compared to the control sample. The concentration of 11% of coconut oil in the composition of bean pastes with DWP brings the adhesive strength closer to the characteristics of prepared pastes using conventional technologies. The components of the paste have different effects on the deformation characteristics of model compositions. The effect of coconut oil concentration on the deformation characteristics of model compositions of bean pastes with DWP is shown in Table 8.

Table 8. *Deformation characteristics of model compositions of bean pastes with DWP and coconut oil*

Name of the indicator	Designation	0	Samples with coconut oil concentration, %					
			4	6	8	10	12	
Reverse deformation, 10^{-3}	γ_{rev}	CC	340.0	325.7	302.9	301.0	287.1	281.4
		DC	358.6	348.6	337.1	328.6	305.2	291.1
		MSP	334.3	328.1	312.9	305.0	289.1	276.4
Irreversible deformation, 10^{-3}	γ_{irr}	CC DC MSP	13.0	13.0	13.0	13.0	13.0	13.0
Total deformation, 10^{-3}	γ_{total}	CC	352.9	338.6	325.7	319.9	311.0	294.3
		DC	371.4	361.4	350.0	341.4	320.0	300.1
		MSP	347.1	337.1	315.7	312.9	304.2	277.3

Note: *($n = 5$, $p \leq 0.05$)*

Data from the table indicate a gradual decrease in the total deformation by 25-30% relative to the control. The irreversible deformation is stable for all prototypes, regardless of the concentration of DWP and is 12.9 c.u. A decrease was established in the DC deformation index – from 358.6 to 291.1 c.u.; CC – from 340.0 to 281.4 c.u.; MSP – from 334.3 to 276.4 c.u. This trend of change indicates a significant effect of coconut oil on the consistency of bean pastes with DWP.

Based on comparisons of bean paste with marzipan, the strength character is established. Therefore, coconut oil, which has certain crystallisation properties, is a promising component. In general, the experiments described above indicate the feasibility of using coconut oil in bean paste technology. The results of the analysis confirm a decrease in the stickiness of model bean pastes CC, MSP, DC with an increase in the concentration of coconut oil. It also creates conditions for increasing strength and density with a decrease in stretchability indicators.

The results of organoleptic studies showed the best consistency of the compositions of bean pastes with DWP was observed with the 11% concentration of coconut oil. The total score of the developed descriptors was 2.97 for CC, 2.93 for DC, and 2.94 for MSP. Therefore, the impact that is carried out on improving the overall assessment of bean pastes is conditioned primarily by the properties of coconut oil. Evaluating the organoleptic quality indicators of the studied bean pastes, the appearance should be noted,

namely, a unique transparent colour with a light yellow hue, which allows them to be used in the production of decorative elements for finishing confectionery.

Conclusions

Thus, the results of the conducted studies confirmed the prospects of using DWP in the technologies of bean pastes in a concentration of 11-31% and coconut oil in an amount of 10%. The established dosage allows obtaining the desired structural and mechanical properties of finishing processed products in accordance with the area of their technological use. The developed technology of semi-finished products provides high-quality and low-calorie finishing processed products for confectionery.

It has been experimentally confirmed that the developed technologies of semi-finished products with 11-31% DWP in bean pastes significantly improve the mineral and vitamin composition. The balanced chemical composition of bean confectionery pastes based on DWP and coconut oil contributes to the expansion of the range of low-calorie finishing processed products. The nutritional and biological value of the developed bean pastes is experimentally confirmed.

The solution of the research tasks provided the following scientific results:

1. Stabilisation of the rheological characteristics of the bean paste is achieved due to the properties of DWP and coconut oil.

2. Technological basis of the conducted research is an important area for expanding the range of confectionery products. In addition, the proposed recipe composition of processed products improves their organoleptic quality indicators and helps to ensure dietary nutrition conditions.

The prospect of further research is aimed at expanding the investigation of the rheological properties of bean pastes in relation to the use of non-conventional plant raw materials to improve their chemical composition.

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Вплив концентрації кокосової олії із МССД на властивості бобових паст

Ігор Ярославович Стадник[1], Володимир Антонович Піддубний[2], Галина Вікторівна Карпик[1], Людмила Анатолівна Бейко[1], Христина Юріївна Кравченюк[1]

[1]Тернопільський національний технічний університет ім. І. Пулюя
46001, вул. Руська, 56, м. Тернопіль, Україна

[2]Київський національний торговельно-економічний університет
02156, вул. Кіото, 19, м. Київ, Україна

Анотація. В раціоні харчування людини спостерігається нестача білкових продуктів, тому актуальним завданням сьогодення залишається збалансування нутрієнтного складу продуктів. Метою досліджень є розроблення та визначення структурно-механічних характеристик оздоблювального напівфабрикату із пасти бобової, молочної сироватки сухої демінералізованої та кокосової олії для кондитерських виробів. Розроблено основні напрями технологічного використання кондитерських паст: для нанесення на поверхню виробів в якості шару; для розроблення квітів та фігурних модельних виробів, як декоративного елементу для борошняних кондитерських виробів. Використано квасолю білу продовольчого сорту «Мавка», молочну сироватку суху демінералізовану, виготовлену із підсирної сироватки з 90 % ступенем демінералізації відповідно ТУ У 15.5-00413890-089:2014. Реологічні властивості (пружність, еластичність, пластичність) визначали плоскопаралельним еластопластометром Толстого. Поверхневі характеристики паст вивчали динамометром, підключеним до вимірювального приладу MIG-1.3. Адгезійну міцність визначали відривом від бобової пасти пластинки сталевої. Одержано емпіричні рівняння регресії методом кореляційного та регресійного аналізу з використанням програми MathCAD-14. Визначено хімічний склад бобових паст з молочною сироваткою сухою демінералізованою, їх органолептичні показники якості та структурно-механічні властивості з метою оптимізації рецептурного складу для покращення функціонально-технологічних властивостей кондитерських паст. Встановлено позитивний ефект взаємного використання квасолі, молочної сухої сироватки демінералізованої на структурно-механічні властивості нових оздоблювальних напівфабрикатів. Доведено покращення показників формувальної здатності за концентрації 10…30 % молочної сироватки сухої демінералізованої та 8 % кокосової олії в рецептурному складі. Встановлено зменшення липкості у композиціях бобових паст для моделювання фігурних виробів, покриття кондитерських виробів та виготовлення квітів, як декоративних кондитерських виробів, при концентрації олії кокосової до 10 %. Відповідно, загальні бали розроблених дескрипторів становили: 2,92 для декоративних кондитерських виробів, 2,98 для покриття кондитерських виробів та 2,95 для моделювання фігурних виробів. Встановлено зміну інтенсивності забарвлення композицій паст бобових у разі збільшення концентрації молочної сироватки сухої демінералізованої, що дозволяє розширити технологічні прийоми виготовлення фігурних виробів. Розроблена технологія та рецептурний склад дають змогу отримати якісні, з високою біологічною цінністю та низькокалорійні оздоблювальні напівфабрикати для кондитерських виробів.

Ключові слова: білок, квасоля, адгезійна міцність, реологічні властивості, оптимізація, рецептурний склад, композиція паст

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Efficiency of using foamed glass for biofilter of an aquaculture recycling system

Dmytro Sharylo*, Vasyl Kovalenko

National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony Str., Kyiv, Ukraine

Abstract. Modern technologies of cultivation of hydrobionts in recirculating aquaculture systems require significant volumes of biological filters (about 10% of the total volume of the fish farming system), which makes it relevant to search for new fillers that would have a larger specific surface area for colonisation by microorganisms than conventional polymer filling, which would reduce the size of the biofilter and, accordingly, the cost of water and electricity for the production of aquaculture products. The purpose of the study was to evaluate the effectiveness of using highly porous foamed glass as a biofilter filler, compared to conventional floating polymer loading. To achieve this goal, a systematic approach to a particular problem and general scientific research methods were used: experiment, modelling, comparison, analysis, synthesis, and generalisation. The model experiment was conducted in the educational and scientific laboratory of the Centre for Aquatic Bioresources and Aquaculture of the National University of Life and Environmental Sciences of Ukraine. Based on the results of the experiment, it was found that the test material has a significantly higher bio-cleaning potential than polymer loading for biofilters. The maximum concentration of ammonia in the water of the recirculating aquasystem for growing sturgeon fish, which is oxidised by a biofilter with 1 dm^3 of foamed glass as a filler (32 mg/dm^3) during the day, was determined. Calculations of the potential biological load during the cultivation of hydrobionts in the aquasystem were carried out, and it was found that 10 md^3 of this filler maintains an optimal level of nitrogen content when growing sterlet fish planting material with a planting density of 41.6 kg/m^3 or 84.8 kg/m^3 of commercial fish. It is determined that the required volume of the biofilter is reduced by 4.55 times, and the cost of water and energy supply for the operation of the recirculating aquasystem will also be proportionally reduced. Thus, the use of foamed glass as a filler for biofilters of recirculating aquasystems will increase the profitability of fish production at aquaculture enterprises

Keywords: fish farming, sterlet, process water, nitrifying bacteria, TAN oxidation

Introduction

Recirculating aquaculture systems, due to the rational use of water and land resources and a high level of intensification of the technological process, in contrast to pond fish farms, can be placed directly in large settlements, which are the centre of qualified personnel and services, have a developed infrastructure for the supply of raw materials and sales of finished products [1].

Conventional forms of fish farming and animal husbandry are sources of environmental pollution. The bulk of pollutants from growing fish in open aquasystems come together with discharge process water. The water contains the remains of artificial feed, faecal masses, and nitrogen-containing waste from the biochemical processes of fish digestion [1]. The main part of nitrogen (75-85%) is released through the gills of fish in the form of ammonium ions, which in high concentrations is dangerous for hydrobionts and accelerates the processes of eutrophication of water bodies [2]. In addition, in the natural reservoirs of areas where pond aquaculture enterprises are located, there is a risk of biological invasions of foreign species, and the spread of infectious and invasive diseases [3].

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**Corresponding author*

To reduce the impact of aquaculture on the environment, so-called environmentally friendly technologies and production practices are used with the economical use of natural water and land resources and minimal waste in production. One of the forms of such technologies is the cultivation of hydrobionts in recirculating aquasystems [4].

The technology of operation of recirculating aquasystems involves controlling the parameters of the water environment. Systems with a full water regeneration cycle can capture from 96-100% of the resulting pollutants [5], depending on the volume of make-up water passing through the system. For comparison, a system with partial water reuse usually achieves an overall waste collection efficiency of 25-50% [6]. In addition, for the use of "Cornell" round fish tanks with double drainage and microporous filter [7; 8], recirculation systems produce a much smaller and more concentrated flow of waste, the disposal of which is much more efficient than in the operation of conventional pools [9-11].

Thus, systems of partial and fully recirculated water use offer such key advantages over conventional fish farming as the reduction of the need for land and water resources by more than 80% and an increase in the efficiency of waste capture to 80-100%.

To ensure the sustainable functioning of the aquasystem, recirculating aquaculture plants require a large amount of energy resources for the operation of numerous electrical equipment and mechanisms that ensure water circulation and maintain optimal parameters of the quality of the water environment: pumps, climate control and lighting systems, aeration and/or oxygenation devices, control and measuring devices, etc. In addition, the need for water replacement remains at a fairly high level: from 5 to 100% of the system volume per day. Improving the environmental safety of recycling systems and increasing the profitability of aquaculture production is possible by improving the methods of process water regeneration.

One of the objects of improvement is the technology of water purification in biofilters. Researchers from many countries are working on improving the design of biofilters to bring them to certain standards, namely, the impact on the efficiency of removing ammonia by a unit of volume of the biofilter or the specific area of the filler [12-14], study new fillers for biofilters [15-17], carefully investigate the influence of various biotic [18-20] and abiotic factors on the processes of oxidation of nitrogen substances [21-23].

The use of highly porous fillers for biofilters in fish farming has long been unprofitable due to the rapid loss of their main advantage – a high specific area per unit volume, as a result of slagging micropores with biofilm residues. An annual complete replacement of fillers was required, which, given their significantly higher cost compared to polymer fillers, made their use unprofitable. However, the use of the method of reducing highly porous fillers for biofilters with sodium hypochlorite [24] significantly extends their service life, with a complete replacement only after significant mechanical wear of the material, which opens up the potential for using such fillers and requires research on the possibility of their use, drawing up work schemes and determining maximum productivity.

The purpose of the study was to evaluate the effectiveness of using highly porous foamed glass as a filler for the biofilter of a recirculating aquaculture system when rearing young sturgeon fish, compared with conventional floating polymer loading for biofilters.

Materials and Methods

The study was conducted in September-October 2021 in the educational and scientific laboratory of the Department of aquaculture of the Centre for Aquatic Bioresources and Aquaculture of the National University of Life and Environmental Sciences of Ukraine, in two stages: experimental, computational and analytical. At the first stage, the maximum level of saturation with total ammonia nitrogen (TAN) of the process water of the experimental recirculating aquasystem for growing sturgeon fish was determined, which is oxidised in a biofilter with foamed glass during the day. The second stage involved calculations of the potential biological load of young sturgeon fish (using the example of sterlet) and commercial fish of aquasystems with two types of biofilter materials: foamed glass and polymer floating loading.

The material for the research was foamed glass of the JBL MicroMec brand as a filler for the biofilter of the recirculating aquasystem for growing sturgeon (on the example of sterlet).

Research methods are generally accepted in fisheries science: hydrochemical (to establish quantitative parameters of the quality of the aquatic environment), fishery (to calculate the values of the potentially possible load of the recirculating aquasystem with biological material of cultivation objects), and economic (to evaluate the effectiveness of experimental options) [25].

For the experimental stage, 4 model closed water supply installations were designed and installed, each of which consisted of a fish tank (aquarium with a volume of 100 dm^3) and water treatment systems. This system included:

1) mechanical filter – porous foam sponges connected to a circulation pump. The mechanical filter was cleaned manually, daily;

2) biological filter – plastic container with a working volume of 2 dm^3, located at the top of the aquarium and connected to the pump. The filler is in a volume of 1 dm^3, with a usable area of 1,600 m^2/dm^3 (the aerobic zone available for nitrifiers is 10%). The ratio of the volume of biofilter filler to the volume of water in the fish tank was 1 to 100. To supply water to the biofilter, a "MinJang NS F801" pump with a capacity of 1,200 dm^3/h, with an energy consumption of 15 W/h was used.

Aeration of water was carried out using a compressor, with the placement of sprayers both in the fish tank and in the biofilter. To maintain the optimal temperature, "Resun Sunlike 200" aquarium heaters with a power of 200 W/h with a temperature controller were used. The water temperature was maintained in the range of 24.6-25.7°C, optimal for the operation of biofilters. During the experiments, a planned water change was carried out daily.

A preparation containing a culture of nitrifying bacteria was used to start biofiltration processes at the working level. The establishment of biological equilibrium in the systems occurred in the presence of objects of cultivation – sterlet fry (*Acipenser ruthenus Linnaeus*) with an average body weight of 2.5 g/unit according to the planting density of 150 units/ m^2.

After the biological filters reached their operating capacity and equilibrium was established in the systems, the maximum possible amount of ammonium nitrogen that can be oxidised during the day in a biofilter made of 1 dm³ of highly porous foam glass was checked. For this purpose, the systems artificially increased the content of nitrogenous compounds in water by applying a solution of ammonium chloride NH_4Cl, starting at a concentration of 2 mg/dm³. The concentration of ammonia was increased daily: during the first week – by 1, the second – by 2, and the third – by 3 mg/dm³, to the maximum value above which the biofilter no longer performed the main task – oxidation of ammonium compounds.

Before the experiment, young sterlets were removed from aquariums because the concentration of NH_3/NH_4+ in the water was specially raised above the maximum permissible level for the cultivation of sturgeon fish (2 mg/dm³) [1].

The studies included regular monitoring of the main parameters of the quality of the aquatic environment: water temperature, hydrogen index, concentration of oxygen dissolved in water, and content of nitrogenous compounds. The water temperature and the concentration of oxygen dissolved in water were measured according to the methods of quality control of the aquatic environment generally accepted in fish farming, using an AZ-86021 (DO) thermoximeter, the hydrogen index and the concentration of nitrogenous compounds in the water were established using 2010-2021 TM Ptero© ready-made test systems. The duration of the experimental stage of the study was 21 days.

Evaluation of the efficiency of using foamed glass as a filler for the biofilter was carried out using the calculation and analytical method of fisheries science, by predictive determination of the potential volume of fish products grown in an experimental closed water supply installation and comparison of the obtained data with similar indicators for an aquasystem with a biofilter filled with classical plastic floating loading. Generally accepted equations for the design of recirculating aquaculture systems were used for calculations [4].

Results and Discussion

Progress of the experiment to find the maximum permissible concentration of ammonium compounds (based on the average data for 4 experimental closed water supply installations) in an aquasystem with a biofilter containing 1 dm³ of foamed glass as a substrate for nitrifying bacteria is shown in Figure 1.

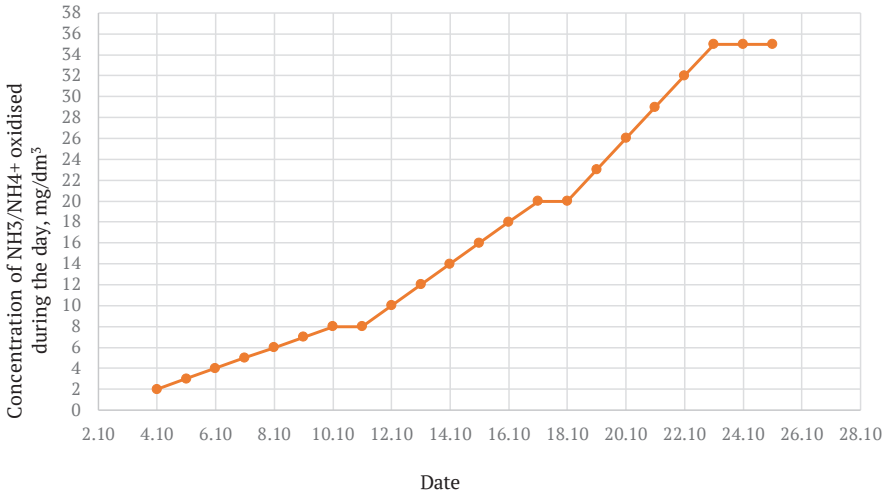

Figure 1. Dynamics of increasing concentration of NH_3/NH_4^+ in water during the experiment

As can be seen from the graph, the maximum concentration of ammonia (32 mg/dm³), in process water with a volume of 100 dm³, which can be oxidised by a biofilter with 1 dm³ of foamed glass during the day was achieved on the 21st day of the experiment.

At the second stage of the study, the potential volume of biological load on the experimental aquasystem was first calculated.

The total ammonia nitrogen (TAN) ions entering the water during fish rearing in closed water supply installations was calculated from the mass of fish feed (Mf) that is applied during the day. The mass of TAN (MTAN) was determined considering the protein content in the feed (Cp, in tenths of a unit), as a nitrogen source, by the equation:

$$M_{TAN} = Mf * Cp * 0.092 \quad (1)$$

Accordingly, knowing the maximum value of $M_{TAN,}$ which nitrifying bacteria can oxidise during the day in a biofilter with 1 dm³ of foamed glass as filler (32 mg/dm³ or 32 g/m³), it is possible to set the amount of feed corresponding to TAN value by the equation:

$$Mf = \frac{M_{TAN}}{Cp*0.092} \quad (2)$$

Aller Silver TM "Aller Aqua" product feed with a protein content of 45%, with a pellet diameter of 3 mm, intended for young sturgeon with an individual weight of 50-200 g, which were kept in experimental systems at the stage of launching biofilters, was taken for the calculation. Therefore, the value of Cp for calculation is 0.45.

As a result of the calculation, it was found that the biofilter filled with 1 dm³ of foamed glass as a substrate for

nitrifying bacteria can provide TAN oxidation, which corresponds to 77.3 g of mixed feed. This amount of feed will provide the daily nutrient requirement for 4.16 kg of sterlet planting material, while the daily feeding rate of this fish is 1.86% of its total weight in a system with a working volume of 100 dm^3. Accordingly, a biofilter filled with foamed glass in a volume of 10 dm^3, will provide biological purification of 1 m^3 process water in which young sterlet with a total weight of 41.6 kg can be kept.

A similar calculation was made for aquasystems that grow commercial sturgeon fish with an individual weight of 0.5 to 2.0 kg/unit on Aller Silwer mixed feed (granule diameter – 8 mm, protein content – 41%), with the recommended daily feeding rate – 1% of fish body weight. It is established that 10 dm^3 of foamed glass in a biofilter can provide biological purification of 1 m^3 of process water for the content of 84.8 kg of commercial sturgeon fish in this volume.

The value of the biological load of commercial sturgeon fish on the aquasystem obtained in the calculations corresponds to scientific data on the maximum permissible biological load of the recirculating aquasystem for sturgeon fish. Thus, according to experimental data, the biomass of commercial sturgeon fish can be increased to 83 kg/m^3, provided that the process water of the recirculation system maintains a sufficient concentration of dissolved oxygen.

By increasing the size of the biofilter and, accordingly, the amount of filler, in the proportion of "biofilter volume: total water volume in the aquasystem", it is theoretically possible to achieve an increase in fish productivity. In this case, the maximum actual value of this indicator will depend on the biological characteristics of the cultivated object and on the ability to meet its requirements for living conditions.

Further calculations concerned the determination of the volume of classical floating polymer loading for a biofilter capable of oxidising 32 g of ammonia in 1 m^3 of process water during the day. Standard capacity of 1 m^2 of the surface of such a substrate, at a water temperature in the range of 21-24°C – 1 g of TAN per day [1]. Therefore, the required surface area of the substrate is 32 m^2. For Helix White 12x12 filler, with a specific substrate surface area of 704 m^2/m^3 which is popular at fish farming enterprises in Ukraine, the loading volume for the biofilter will be 45.5 dm^3. Wholesale price of such filler – 28,500 UAH/m^3, therefore, the cost of purchasing a floating polymer filler for a biofilter will amount to UAH 1,296.75.

To purchase 10 dm^3 of highly porous foamed glass, required for oxidation of 32 g of ammonia per day, at a wholesale price of 246 UAH/dm^3, it is necessary to spend UAH 2,460. However, the operational period for floating polymer loading does not exceed one year, after which a complete replacement of the biofilter filler is required, and the JBL Micromec foam glass is a strong inorganic material that is practically not subject to mechanical wear. The manufacturer of this biofilter filler is JBL GmbH & Co. KG (Germany) guarantees an unlimited period of use of the material.

As evidenced by practice, when using foamed glass as filler for biofilters, there is a need for periodic, once every two months, deep cleaning of the filler pores from outdated biofilm with chemical reagents, in particular, sodium hypochlorite [24]. For the restoration of 1 m^3 of filler, it is necessary to spend 26.3 litres of grade "A" sodium hypochlorite with a concentration of active chlorine of 19%, for a total amount of UAH 733.42. Thus, the cost of cleaning 10 dm^3 of filler 6 times a year will amount to UAH 44.01, which together with the cost of filler will be UAH 2,504.01.

When comparing two types of biofilter filler with a daily ammonia oxidation capacity of 32 g/m^3 according to the indicator of purchase and operation costs (2,504.01 UAH/year – foamed glass, 1,296.75 UAH/year – floating polymer loading), it becomes obvious that the use of foamed glass will pay off in two years. The proposed method of increasing the efficiency of biological treatment of process water in recirculating aquaculture systems allows not only to improve the quality indicators of filtration systems, as proposed in similar studies using new developments of biological fillers [15-17], but also requires a smaller 4.55 times the volume of this filler, compared to the classic one, and, as a result, would require a smaller size and, accordingly, cheaper in the manufacture of biofilters, and would lead to a decrease in the total volume of water in the system and reduce energy costs associated with water circulation and thermoregulation.

Moreover, the use of highly porous fillers as a filler for biofilters does not require the installation of additional specific equipment or the use of consumables to stimulate nitrification processes in comparison with other studies [19; 23]. Separately, there is no need to make significant changes to the design of the biological filter, which is currently most often used in recirculation systems both in Ukraine and in the world, for the use of the proposed fillers, except for a significant reduction in the required volume.

Conclusions

Based on the findings, the following was established:

1. Maximum concentration of TAN that can be oxidised in a 100 dm^3 fish tank by a biofilter filled with 1 dm^3 of foamed glass, is 32 mg/dm^3. This value corresponds to the level of biological load of the aquasystem for young sterlet – 41.6 kg/m^3 and for commercial fish – 84.8 kg/m^3, and does not exceed the technological standards for growing sturgeon fish in recirculating aquaculture systems.

2. The payback period for highly porous foamed glass as a biofilter filler, compared to the classic floating polymer loading, is two years. In addition, due to the smaller size of the biofilter, the cost of water and energy supply to the aquasystem will be reduced.

It is promising to continue research on highly porous foamed glass as a filler for the biofilter of the recirculating aquasystem in the line of increasing the efficiency of using the useful area of the substrate of this material by nitrifying bacteria.

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Ефективність використання спіненого скла для біофільтру рециркуляційної системи аквакультури

Дмитро Юрійович Шарило, Василь Олександрович Коваленко

Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Анотація. Сучасні технології культивування гідробіонтів у рециркуляційних системах аквакультури потребують значних об'ємів біологічних фільтрів (близько 10 % від загального об'єму рибницької системи), що робить актуальним пошук нових наповнювачів, які матимуть більшу, ніж у традиційного полімерного завантаження, питому поверхню для заселення мікроорганізмами, що дозволить зменшити розміри біофільтру і, відповідно, витрати води та електроенергії на виробництво продукції аквакультури. Метою дослідження була оцінка ефективності використання високопористого спіненого скла в якості наповнювача для біофільтру, у порівнянні з традиційним плаваючим полімерним завантаженням. Для досягнення мети використано системний підхід до визначеної проблеми і загально-наукові методи дослідження: експеримент, моделювання, порівняння, аналіз, синтез та узагальнення. Модельний експеримент проведено у навчально-науковій лабораторії Центру водних біоресурсів та аквакультури НУБіП України. На підставі результатів експерименту було встановлено, що досліджуваний матеріал має значно вищий біоочищувальний потенціал, ніж полімерне завантаження для біофільтрів. Визначено максимальну концентрацію аміак-амонію у воді рециркуляційної аквасистеми для вирощування осетрових риб, яку протягом доби окислює біофільтр із 1 дм^3 спіненого скла у якості наповнювача (32 мг/дм^3). Проведено розрахунки потенційно можливого біологічного навантаження при культивуванні гідробіонтів в аквасистемі, та встановлено, що 10 дм^3 зазначеного наповнювача підтримують на оптимальному рівні вміст азотних речовин при вирощувані рибопосадкового матеріалу стерляді за щільністю посадки 41,6 кг/м^3 або 84,8 кг/м^3 товарної риби. Визначено, що необхідний об'єм біофільтра зменшується у 4,55 разів, пропорційно скоротяться й витрати на водо- та енергозабезпечення роботи рециркуляційної аквасистеми. Отже, використання спіненого скла в якості наповнювача для біофільтрів рециркуляційних аквасистем підвищить рентабельність виробництва рибної продукції на підприємствах аквакультури

Ключові слова: рибництво, стерлядь, технологічна вода, бактерії-нітрифікатори, окислення TAN

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Influence of balsamic vinegar on the quality indicators of natural semi-finished pork meat products

Oksana Shtonda*, Viktoriia Kulyk

National University of Life and Environmental Sciences of Ukraine
03041, 15 Heroiv Oborony str., Kyiv, Ukraine

Abstract. Lipid oxidation leads to an unpleasant smell and taste of semi-finished meat, which becomes tougher and less juicy due to the loss of intracellular fluid. The purpose of the study is to determine the effect of fruit and berry components of balsamic vinegar on organoleptic, structural, and mechanical parameters and changes in the pH level of semi-finished meat products. The paper presents the results of the influence of various types of balsamic vinegar on the quality indicators of semi-finished meat products. 5 varieties of balsamic vinegar were used: rowan, blackberry, currant, pomegranate, and grape. At the first stage of the study, the pH value was determined in samples of balsamic vinegar from fruit and berry raw materials. The next stage of the study was to determine the effect of balsamic vinegar on the structural and mechanical parameters, pH and organoleptic characteristics of meat during 7 days of storage of semi-finished pork products, which were injected with 5 types of balsamic vinegar in the amount of 15% to the weight of meat. Meat samples were evaluated by appearance, in-section appearance, taste, colour, consistency, and juiciness. Determination of penetration stress in the samples was carried out by measuring the immersion depth of a standard needle in each marinated meat semi-finished product and the control sample of pork meat. It was confirmed that the use of balsamic vinegar made from rowan, black currant, and pomegranate significantly affects the consistency of meat, making it more tender. When interacting with the components of raw materials, food acids affect the taste and aroma, and partially break down proteins and fats, making meat softer and tastier. It was found that in semi-finished pork meat products under the action of balsamic vinegar as one of the components of the marinade, the pH level decreases, which extends the shelf life and prevents the development of bacteria. Organoleptic characteristics and taste and aroma properties of the semi-finished product were improved and the appearance became more pleasant. The obtained results would allow extending the shelf life, enriching with biologically active substances, and improving the consumer properties of the semi-finished product

Keywords: fruit and berry raw materials, physical and chemical parameters, organoleptic evaluation, penetration stress

Introduction

According to the approved norms of physiological needs of the population of Ukraine in basic nutrients and energy, depending on gender, age, weight, and physical activity coefficient, the daily requirement for protein ranges from 68 g to 117 g for men and from 58 g to 87 g for women, of which 50% are of animal origin [1]. Therefore, it is necessary to create products that can be quickly prepared, and which at the same time will not lose their biological properties and nutritional value [2].

Ukrainian and foreign researchers have established that the use of derivatives of substances that include natural fruits and berries prevents lipid oxidation that leads to loss of product quality, and organoleptic parameters are regulated, such as appearance, colour, taste, smell, and consistency of semi-finished meat products. The goal of improving semi-finished meat products is not only to increase the range, but, above all, to provide the consumer with a product filled with vitamins, biologically active substances, antioxidants, and minerals.

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**Corresponding author*

The needs of the human body for minerals for men are: calcium and phosphorus – 1,200 mg, zinc and iron – 15 mg, magnesium – 400 mg; for women: calcium – 110 mg, phosphorus – 1,200 mg, zinc – 12 mg, iron – 17 mg, magnesium – 500 mg. The required amount of vitamins for men: C – 80 mg, A – 1000 mg, E – 15 mg, B vitamins – from 1.6 mg to 3 mg; for women: C – 70 mg, A – 1,000 mg, E – 15 mg, B vitamins – from 1.3 mg to 3 mg [1]. Therefore, the addition of balsamic vinegar to the marinade for meat semi-finished products due to the mineral and vitamin composition, the presence of micro and macro elements, organic acids, and biologically active substances will not only satisfy the needs of the human body in nutrients.

Lorenzo *et al.* investigated antioxidants from black currant berries, blueberries, blackberries, cranberries, and grapes as a substitute for food additives to inhibit the oxidation of lipids and proteins in meat and meat products, since meat is very susceptible to oxidation [2]. Oxidation can be slowed down by synthetic antioxidants with a phenolic structure. Berries are a good source of phenolic compounds, especially anthocyanins, which can be used as a potential alternative to synthetic supplements. The study suggests that extracts of blueberries, blackberries, cranberries, and grapes can be used as substitutes for synthetic antioxidants in meat products. Their extracts contain polyphenols, antioxidants that have a positive effect on the stabilisation of meat products [2].

Ali Samet Babaoğlu *et al.* evaluated the physicochemical and microbiological properties and sensory parameters of beef patties with an aqueous extract of rowan, blackberries, red currants, and blueberries when stored in the refrigerator for 9 days. Treatment with berry pomace extract significantly reduced the amount of lipid oxidation by-products in the samples. The results show that water extract of chokeberry pomace can be a promising natural preservative among extracts of pomace of various berries to improve oxidative stability and improve the microbiological quality of beef patties when stored in the refrigerator [3].

The purpose of the study is to determine changes in organoleptic characteristics, pH level, structural and mechanical parameters, namely penetration stress of meat semi-finished products, to solve the problems of lipid oxidation, which will increase shelf life and improve consumer characteristics of semi-finished products.

Literature Review

Rowan berries contain sugar (up to 5%), malic, lemon, wine, and succinic acids (2.5%), tannins (0.5%) and pectin (0.5%) substances, sorbitol and sorbose, amino acids, essential oils, potassium, calcium, magnesium, and sodium. The presence of vitamin P (more than 2,500 mg%) provides rowan with the first place among other fruit plants. Rowan berries are also rich in vitamin C (up to 160 mg%) and beta-carotene (up to 5.6 mg%). The preparation of rowan berries reduces the content of fat in the liver and cholesterol in the blood, and powder from rowan berries increases the resistance of blood vessels. In scientific medicine, rowan berries are used as a multivitamin, diuretic, and haemostatic agent [4].

Blackberries are a real storehouse of microelements that are useful for the body. Berries contain glucose, sucrose, and fructose (5.1-13%), organic acids: malic, citric, salicylic, tartaric, etc. (0.5-1.5%), pectin (1.8%), fibre (2-4%), vitamins P, B, E, C, carotene, potassium, salt, manganese, copper, potassium, sodium, calcium, magnesium, phosphorus, iron, etc. [5].

Black currant berries contain various sugars; citric, malic, and succinic acids; pectin, nitrogen, tannins, dyes, and polyphenolic compounds. In terms of vitamin C content, black currant occupies one of the leading positions (about 400 mg%), its content practically does not decrease with proper fruit processing. In addition, berries contain vitamins A and P. Black currant berries are an excellent source of vitamin C, used to produce a variety of concentrates and vitamin C preparations. Currant fruits have a special spicy aroma and sweet and sour taste. The main advantage of fruits is that they are low in enzymes that break down ascorbic acid, so they are a valuable source of vitamins. Ascorbic acid is also stored in frozen berries [6].

Pomegranate has a rich chemical composition, contains manganese, phosphorus, magnesium, potassium, iron, zinc, aluminium, silicon, chromium, nickel, calcium, copper, iodine and other minerals, acids including citric acid, tartaric acid, oxalic acid, and malic acid, vitamins – C, E, B1, B2, B6, B12, P, niacin, folic acid, carbohydrates, protein, fibre, ash, catechins, tannins and colouring agents, flavonoids, amino acids, alkaloids, and oils. Pomegranate has antioxidant, antiseptic, anti-inflammatory, vulnerary, haemostatic, astringent, antihelmintic, and nutritional properties [7].

Pomegranate peel contains the following macro- and microelements: potassium – 18.9 mg/g, calcium – 4.0 mg/g, magnesium – 0.5 mg/g, iron – 0.05 mg/g, manganese – 5.2 mcg/g, copper – 2.5 mcg/g, zinc – 3.8 mcg/g. Pomegranate peel is rich in tannins, anthocyanins, amino acids, vitamins and minerals, which, when used correctly, have a positive effect on the gastrointestinal tract. These substances can treat diseases such as dysentery, diarrhoea, abdominal pain, and increased acidity [8].

Grapes are a highly valuable food product due to the presence of a number of biologically active substances in it, among which vitamins occupy a special place. Their absence in humans causes various pathologies – obesity, cardiovascular, oncogenic, and respiratory diseases. One of the most important and most studied in grape berries is vitamin C (ascorbic acid) [9].

In the study by José M.Lorenzo *et al.*, four natural grape extracts (GRA) with potential antioxidant activity in pork patties were evaluated. During 20 days of storage in packages with a modified atmosphere at 2°C, the pH, colour, lipid oxidation, and microbial spoilage parameters of raw pork patties were studied and compared with a synthetic antioxidant and a control batch. Due to their high polyphenol content, grape extracts were the most effective antioxidants that prevent lipid oxidation and reduce colour degradation. In addition, natural grape extracts resulted in a decrease in the total number of viable cells and lactic acid bacteria, compared to the control [10].

Cranberries – the main active substance of this berry – organic acid, in addition to this acid, it contains quinic, citric, malic, benzoic ascorbic acid; macro- and microelements: Mo, Fe, Mn, I, Cu; flavonoids: anthocyanins, hesperidin, rutin, quercetin; sucrose (0.27-2.8%), sorbitol (2.1-2.3%), fructose (1-9.9%), tannins (0.1-4.9%), pectin

substances, riboflavin, carotene; catechins. Seeds contain fatty oils (16-28.12%), their hydrolysates contain acids: linoleic acid (36%), oleic acid (21%), palmitic acid (5%), stearic acid (1.5%) [6].

The healing properties of viburnum are conditioned by the high content of useful elements, including bioactive substances (tannins, phytoncides, essential compounds, glycosides, anthocyanins, coumarins), sugars, trace elements (magnesium, potassium, zinc, calcium, etc.); organic acids, vitamins (A, C, E, K, P). Tannins contained in the pulp and seeds give the pods astringency. The bitter taste of the fruit is given by the glycoside biburnin, in addition, it improves blood clotting, so viburnum is a remedy for bleeding, and also reduces the risk of diabetes and prevents circulatory diseases. About 30% sugar, but tasteless. Berries have a characteristic sourness due to the content of organic acid (2%). Viburnum berries have the following effect on the human body: they increase the body's defences, promote faster recovery from seasonal colds, relieve swelling, and increase vitality [11].

In berries made from organic acids, succinic, malic, citric, and acetic are most often found. Peshuk & Ishchenko studied the effect of a solution of lactic and orthophosphoric acids in the marinade on the meat properties. The results of studies have shown that when marinating for up to 48 hours, the process of extracting macro and microelements from meat raw materials into the marinade occurs [12]. G.P. Khomych, Yu.G. Nakonechna, L.B. Oliinyk investigated the effect of Chaenomeles juice on the quality of marinated semi-finished products [13]. But the research data needs to be clarified.

Ascorbic acid (AC) is a multifunctional compound that participates in many biochemical processes (synthesis of collagen, catecholamine, bile acids), affects cholesterol metabolism, increases the body's resistance to colds, and has antioxidant properties. Vitamin C is not synthesised in the human body, so it is necessary to constantly get it with food [9].

Ascorbic acid is involved in various biochemical processes in the human body. It is part of the redox system necessary for protein synthesis. This vitamin is involved in the synthesis of collagen, an important component of ligaments that provide mechanical connections to various organs of the tooth, cartilage, bone, and dentin. Ascorbic acid is essential for the proper functioning of nervous tissue, it promotes the absorption of iron in the digestive tract and the subsequent synthesis of haemoglobin, and also supports the active form of vitamin B_9 in the cells of the body necessary for the synthesis of proteins and nucleic acids [14].

Ukrainian researchers V.M. Pasichnyi, & T.R. Mykhavko have proved that the use of an additive based on citrus and pepper extract has the following properties: preservation of the natural red-pink colour of meat products; preservation of organoleptic properties and extend the shelf life; elimination of rancidity; improvement of the product quality; increase in the safety of the product, especially against the following pathogens: *Listeria*, *Listeria monocytogenes* bacteria, *Escherichia coli* H157, and *Clostridium* [15].

Materials and Methods

The study was conducted in the laboratory of the Department of Meat, Fish, and Marine Products of the National University of Life and Environmental Sciences of Ukraine in November 2021. Pork meat of grades 1 and 2, and balsamic vinegar made from rowan, blackberries, grapes, pomegranate, and black currant were investigated Vinegar was added to the samples by injection in an amount of 15% to the portion weight of meat not less than 90 g and not more than 150 g. 6 samples were examined: 5 samples with the addition of balsamic vinegar and 1 control sample without the addition of balsamic vinegar.

To obtain reliable experimental data, all studies were performed at least five times, two repetitions for each experiment. Sampling for sensory and physicochemical parameters and preparation for analysis were carried out in accordance with DSTU 4823.2:2007 [4]. Determination of the main organoleptic properties of natural marinated meat semi-finished products was carried out appearance, in-section appearance, colour, aroma, taste, consistency, and juiciness according to DSTU 4823.2: 2007 Meat products. Organoleptic evaluation of quality indicators. Part 2. General requirements [4].

Organoleptic evaluation was carried out according to the developed five-point scale (Table 1), considering DSTU 2925-94 Product quality. Quality assessment. Terms and definitions [16], where 1 – very bad, 2 – bad, 3 – satisfactory, 4 – good, and 5 – excellent.

Table 1. *Scale of organoleptic evaluation of semi-finished products*

Indicator	Characteristics	Points
Appearance, surface colour	The surface is dry, sticky, with obvious signs of spoilage	1
	The surface is dry, sticky, and unpleasant	2
	The surface is moist, sticky	3
	The surface is moist, slightly sticky	4
	The surface is moist, without stickiness, pleasant colour	5
Muscles in-section appearance	Dry, do not leave stains on filter paper, with signs of spoilage	1
	Dry, leave no stains on filter paper	2
	Barely moist, leave no stains on filter paper	3
	Moist, leave a barely noticeable stain on filter paper	4
	Moist, leave a noticeable stain on filter paper	5

Table 1, Continued

Indicator	Characteristics	Points
Consistency	In-section, the meat is flabby, the hole formed when pressed with a finger not evens out	1
	In-section, the meat is flabby, the hole formed when pressed with a finger evens out slowly	2
	In-section, the meat is less dense, not elastic, the hole formed when pressed with a finger evens out slowly	3
	In-section, the meat is less dense and less elastic, the hole formed when pressed with a finger evens out slowly	4
	In-section, the meat is dense, elastic, the hole formed when pressed with a finger evens out quickly	5
Smell	Sharp, sour, musty, smell of spoiled meat, repulsive	1
	Unpleasant, slightly sour	2
	Neutral, characteristic of this type of meat	3
	Pleasant, too pronounced fruit and berry aroma	4
	Pleasant, with a light fruit and berry aroma	5

Physical and chemical parameters were determined by commonly known methods: the pH of meat was determined by measuring the electrical potential difference between a glass electrode and a comparison electrode placed in a sample of meat or meat products according to DSTU ISO 2917-2001 [17]. Determination of penetration stress in samples consists in measuring the depth of penetration of a standard needle in the test sample. Determination of the needle penetration depth to approximately 330×0.1 mm is performed at a test temperature of 25°C, an applied load of 100 g for 5 seconds on an Ulab 3-31 M penetrometer according to DSTU EN 1426:201X [18].

At the first stage of research, the task was to determine the pH value of a sample of balsamic vinegar of Ukrainian production from fruit and berry raw materials. The pH-150 MI measuring device was used, designed to measure the activity of hydrogen ions, redox potential, and temperature of aqueous solutions, and directly measure meat and meat products. The second stage of research was to determine the effect of balsamic vinegar on the quality indicators of natural semi-finished products. Organoleptic evaluation of the samples was performed on Day 1 and Day 7 of storage. 5 varieties of balsamic vinegar were used: No. 1 – rowan vinegar, No. 2 – blackberry vinegar, No. 3 – currant vinegar, No. 4 – Narsarab (pomegranate) vinegar, No. 5 – grape vinegar, sample No. 6 (control) – pork meat without balsamic vinegar. Each test sample was treated with balsamic vinegar in an amount of 15% by weight of meat. The results were processed using Microsoft Excel.

Results and Discussion

Samples of balsamic vinegar were examined: rowan – No. 1, blackberry – No. 2, black currant – No. 3, pomegranate – No. 4, grape – No. 5 (Fig. 1).

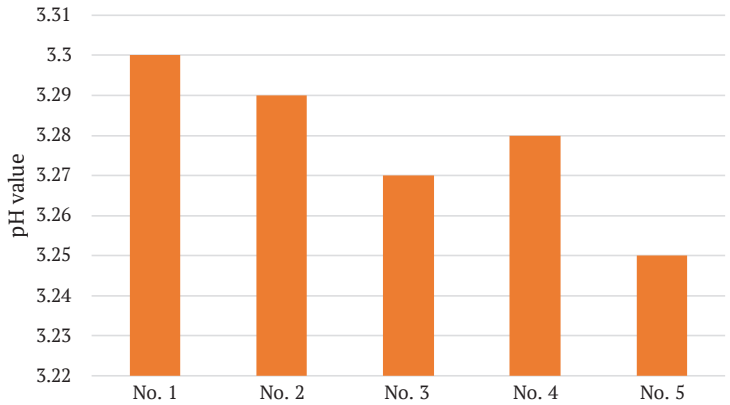

Figure 1. Changes in the pH of balsamic vinegar from fruit and berry raw materials

The pH values of the samples under study were in the range of 3.22-3.3. Such results are associated with the presence of organic acids in the composition of balsamic vinegar. Comparing the obtained indicators with the pH of table vinegar (9%), the latter has a pH value of 2 [19]. The results of the study of the effect of the corresponding samples of balsamic vinegar on the organoleptic evaluation of semi-finished meat products are shown in Table 2.

Table 2. *Organoleptic evaluation of injected semi-finished pork products on Day 7 of storage*

Sample	Indicator			
	Appearance, surface colour	Muscle in-section appearance	Consistency	Smell
No. 1	The skin is moist, without stickiness, red in colour	Wet, leave a barely noticeable stain on the filter paper, red in colour	At the cross-section, the meat pulp is less dense and has poor elasticity, the hole slowly evens out after pressing with a finger (up to 1 min)	Characteristic of this type of meat with a light aroma of rowan
No. 2	The skin is moist, without stickiness, pink in colour with a purple tinge	Wet, leave a barely noticeable stain on the filter paper, dark red in colour	At the cross-section, the meat pulp is less dense and has a flexible elasticity, the hole slowly evens out after pressing with a finger (up to 1 min)	Typical of this type of meat with blackberry aroma
No. 3	The skin is moist, without stickiness, dark red in colour	Wet, leave a barely noticeable stain on the filter paper, dark red in colour	At the cross-section, the meat pulp is less dense and has a flexible elasticity, the hole slowly evens out after pressing with a finger (up to 1 min)	Characteristic of this type of meat with a light aroma of black currant
No. 4	The skin is moist, without stickiness, red in colour	Wet, leave a barely noticeable stain on the filter paper, red in colour	At the cross-section, the meat pulp is less dense and has a flexible elasticity, the hole slowly evens out after pressing with a finger (up to 1 min)	Characteristic of this type of meat with a pleasant hint of pomegranate aroma
No. 5	The skin is moist, without stickiness, purple in colour	Wet, leave a barely noticeable spot on the filter paper, dark red with a purple tinge	At the cross-section, the meat pulp is less dense and has a flexible elasticity, the hole slowly evens out after pressing with a finger (up to 1 min)	Characteristic of this type of meat with a pronounced aroma of grapes
No. 6	The skin is sometimes moist, slightly sticky, darkened, greyish-pink in colour	Wet, leave a barely noticeable spot on the filter paper, dark red with a purple tinge	At the cross-section, the meat pulp is less dense and has a flexible elasticity, the hole slowly evens out after pressing with a finger (up to 2 minutes)	Slightly sour with a hint of mustiness

On Day 1, the condition of all the studied samples corresponded to the indicators of fresh meat, pale pink colour, the muscles on the incision are slightly moist, the colour is characteristic of pork meat, the consistency is dense and elastic, the smell is specific, inherent in this species. Organoleptic evaluation was performed on a five-point scale (Fig. 2).

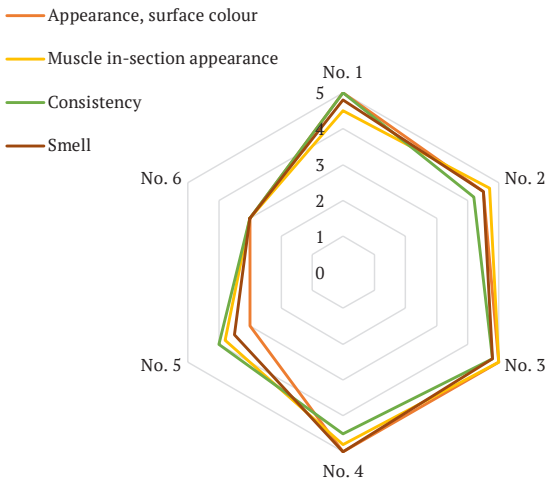

Figure 2. Organoleptic evaluation of semi-finished pork products treated with balsamic vinegar on Day 7 of storage

As a result of the organoleptic evaluation (Fig. 2) of marinated semi-finished pork products, it was found that on Day 7 of storage, samples injected with balsamic vinegar had moist skin, without stickiness, samples No. 1, No. 4 had a red surface colour, sample No. 2 had a pink colour with a purple tint, sample No. 3 had a dark red surface colour, and sample No. 5 had a purple colour. The skin of the control sample is sometimes moist, sticky, darkened, and greyish-pink in colour.

The muscles in-section of the test samples were moist, red to dark red in colour, leaving a barely noticeable spot on the filter paper. The consistency became less dense and less elastic, the hole from pressing with a finger evens out more slowly. The smell of samples injected with

balsamic vinegar is pleasant, characteristic of each type of vinegar, the control sample had a slightly sour smell with a hint of mustiness. As a result of the organoleptic evaluation of marinated semi-finished pork products, the best indicators were observed in samples No. 1, No. 3, and No. 4 treated with balsamic vinegar from rowan, currant, and pomegranate, respectively.

Changes in the pH values of marinated pork meat were studied over 7 days. Resistance of meat to spoilage during storage depending on pH, most bacteria will not develop in an acidic nutrient medium. Below pH 6.2, the development of bacteria slows down, and sufficiently mature meat with low pH is not as sensitive as meat with high pH to the effect of bacterial decomposition. Thus, according to the pH indicator, a conclusion can be drawn about the storage conditions of meat and semi-finished products from it (Fig. 3).

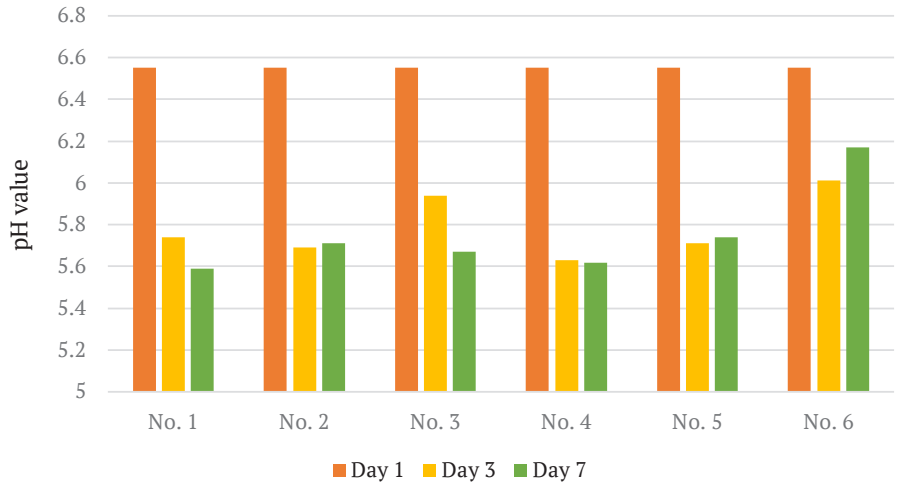

Figure 3. Changes in the pH of injected pork meat during storage

In the control meat sample, the pH value was 6.17, while in the test samples, the PH on Day 3 ranged from 5.63 to 5.94, on Day 7 – from 5.59 to 5.74, which indicates inhibition of bacterial development in samples using balsamic vinegar. Penetration stress studies were performed (Fig. 4) on Day 1 and Day 7 of sample storage.

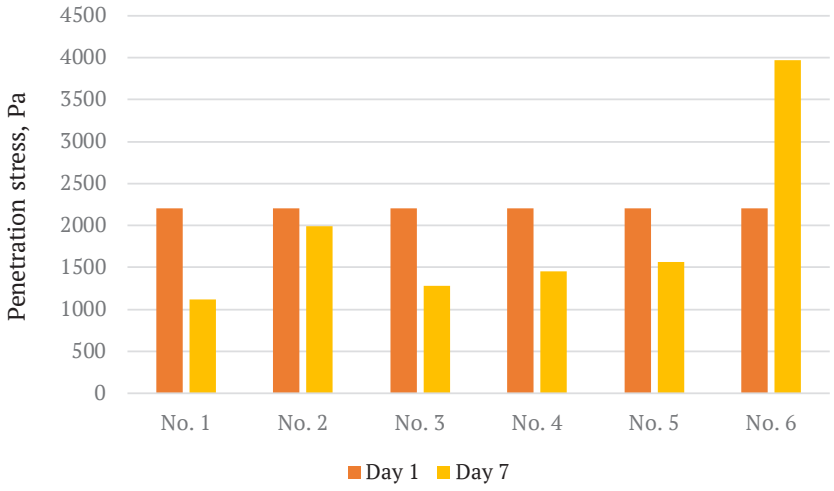

Figure 4. Change in penetration stress of injected pork meat depending on the storage time

It was found that samples injected with balsamic vinegar No. 1 – from rowan, No. 3 – from black currant, No. 4 – from pomegranate, had the softest consistency, samples No. 2 – from blackberries, No. 5 – from grapes had no significant effect, while the control sample became much tougher.

Previous studies have established that the addition of fruit and berry products has a positive effect on the stability of semi-finished meat products due to the presence of polyphenols and antioxidants. It is also proved that fruit and berry components act as natural preservatives, increasing the oxidative resistance of lipids and improving microbial quality during cold storage of semi-finished products. They prevent colour deterioration and reduce the total number of viable cells and lactic acid bacteria. Natural components contribute to the preservation of the natural reddish-pink colour of meat products, their organoleptic properties, and extend the shelf life, eliminate rancidity,

which improves the quality and safety of the product, especially against pathogenic microorganisms. Thus, studies confirm a positive effect on the quality characteristics of semi-finished meat products [2; 6].

Conclusions

Studies have shown that balsamic vinegar has a downward effect on the pH of meat, which prevents the growth of bacteria and spoilage of meat during long-term storage. The use of balsamic vinegar gives a pleasant aroma, helps to soften the consistency of meat, which has a positive effect on organoleptic parameters, taste and aroma properties. As a result of the study, it was found that semi-finished meat products treated with balsamic vinegar from pomegranate, currant and rowan have the best organoleptic characteristics. Due to injection with balsamic vinegar, the semi-finished product is enriched with micro-and macronutrients, vitamins, and biologically active substances that are part of the fruit and berry raw materials from which balsamic vinegar is made, and which are also necessary for the normal functioning of the human body. The results obtained show the feasibility of using balsamic vinegar in the production of semi-finished products.

The possibility of using vinegar in berry and fruit raw materials in meat production is not fully investigated. This area requires the development of methods for these ingredients, the study of their functional properties and mechanisms of interaction with the meat system, and the formulation of recipes for meat products containing ingredients of plant origin, the development of technology and methods for their introduction.

For the production of semi-finished meat products, structural and mechanical properties and pH values are important indicators of raw materials, they directly affect the organoleptic characteristics of the semi-finished product and the finished product. By adjusting these indicators, adding balsamic vinegar to the base of the marinade at the initial stage, it is possible to significantly improve the initial characteristics of raw materials.

Further study is aimed at a more detailed investigation of changes in the indicators of natural semi-finished meat products subjected to marinating with the use of balsamic vinegar.

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Вплив бальзамічного оцту на показники якості м'ясних натуральних напівфабрикатів із свинини

Оксана Анатоліївна Штонда, Вікторія Костянтинівна Кулик

Національний університет біоресурсів і природокористування України
03041, вул. Героїв Оборони, 15, м. Київ, Україна

Анотація. Окислення ліпідів призводить до неприємного запаху та смаку м'ясного напівфабрикату, який стає жорсткішим та менш соковитим у зв'язку із втратою внутрішньоклітинної рідини. Дослідження має на меті визначення впливу фруктово-ягідних складових бальзамічного оцту на органолептичні, структурно-механічні показники та зміни рівня pH м'ясного напівфабрикату. У статті представлено результати впливу різних видів бальзамічного оцту на показники якості м'ясних напівфабрикатів. Використовували 5 різновидів бальзамічного оцту: горобиновий, ожиновий, смородиновий, гранатовий та виноградний. На першому етапі досліджень визначали величину pH у зразках бальзамічного оцту з фруктово-ягідної сировини. Подальшим етапом дослідження було визначення впливу бальзамічного оцту на структурно-механічні показники, pH та органолептичні характеристики м'яса під час 7 днів зберігання напівфабрикатів із м'яса свинини, які ін'єктували 5 видами бальзамічного оцту у кількості 15 % до маси м'яса. Зразки м'яса оцінювали за зовнішнім виглядом, виглядом на розрізі, ароматом, кольором, консистенцією та соковитістю. Визначення пенетраційної напруги в зразках проводили методом вимірюванні глибини занурення стандартної голки в кожному досліджуваному м'ясному маринованого напівфабрикату та контрольному зразку з м'яса свинини. Підтверджено, що використання бальзамічного оцту з горобини, чорної смородини та гранату значно впливають на консистенцію м'яса, роблячи її більш ніжною. Харчові кислоти, при взаємодії з компонентами сировини, впливають на смак і аромат, частково розщеплюють білки і жири, що робить його більш м'яким і смачним. Встановлено, що у м'ясні напівфабрикати зі свинини під дією бальзамічного оцту як одного з компонентів маринаду, знижується рівень pH, що подовжує терміни зберігання та запобігає розвитку бактерій. Органолептичні характеристики та смако-ароматичні властивості напівфабрикату покращуються, зовнішній вигляд стає привабливішим. Отримані результати досліджень дозволять продовжити терміни зберігання, збагатити біологічно-активними речовинами та покращити споживчі властивості напівфабрикату

Ключові слова: фруктово-ягідна сировина, фізико-хімічні показники, органолептична оцінка, пенетраційна напруга

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вул. Героїв Оборони, 15, м. Київ, 03041, Україна
E-mail: info@animalscience.com.ua
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National University of Life and Environmental Sciences of Ukraine
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