THE QUALITY CHARACTERISTICS OF SAUSAGE PREPARED FROM DIFFERENT RATIOS OF FISH AND DUCK MEAT

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ABSTRACT

The article aims to determine the effect of combining duck meat (*Anas platyrhynchos*) and freshwater fish (*Hypophthalmichthys molitrix*) on the quality (nutritional value, functional and technological properties, sensory attributes) of meat-containing semi-smoked sausages. The optimal version of the recipe with the highest quality indicators of semi-smoked meat sausages with duck meat and freshwater aquaculture was determined. It was found that the protein content of meat-containing, semi-smoked sausages with different ratios of duck and fish meat was 17.90% – 21.34% higher than that of the analog. A sample containing 50% duck and 30% fish has an ideal protein: fat ratio of 1:1. The following high functional properties of model minced experimental semi-smoked sausages were established: up to 72.75% moisture, water binding capacity of up to 71.47%, and water holding capacity of up to 60.60%. A comparative analysis of the rheological properties of minced meat showed that increasing the proportion of duck meat in minced meat modelling systems improves the strength of the system and increases shear stress. The addition of fish raw materials improves the elasticity of meat-containing systems. The optimal ratio of duck and fish is 50:30 for plastic and easily minced mince system. Combining duck meat with raw fish increases the stability of the emulsion to 74.8%. Analysis of the sensory parameters of the experimental sausages confirmed that the best ratio of duck to freshwater fish is 50:30.

Keywords: fish; duck; combination; smoked; sausage

INTRODUCTION

Semi-smoked sausage is a popular meat product made from different types of raw materials: pork, beef, chicken, etc. **(Sălăgean et al., 2012; Drachuk et al., 2018)**.

The production of meat-containing semi-smoked sausages, in which the mass fraction of raw meat is not more than 60%, is topical today in Ukraine. Due to the requirements for meat-containing sausages, meat ingredients are more widely used in recipes in combination with protein fillers **(Strashynskiy et al., 2016)**.

Duck meat is valued by consumers for its dense muscular structure, which determines its high functional and technological properties, pronounced taste, and nutritional value **(Qiao et al., 2017; Bozhko et al., 2020)**. Duck meat is in great demand both in Ukraine and around the world **(Biswas, Banerjee and Bhattacharyya, 2019)**. Thus, products made from duck meat have high-quality characteristics and consumer attractiveness.

On the other hand, it is possible to introduce into the recipe of meat-containing semi-smoked sausages muscle tissue of food raw materials from freshwater aquaculture as a source of high-quality protein with appropriate functional properties **(Tischenko, Bozhko and Pasichnyi, 2016; Lago et al., 2017; Nawaz et al., 2019)**.

Given the fact that duck and fish meat differ from traditional types of meat in structure and physicochemical properties, it is important to select recipe components rationally to ensure the quality characteristics of the new range of semi-smoked meat-containing first- and second-grade sausages using these raw materials **(Bozhko et al., 2020; Ramadhan, Huda and Ahmad, 2014)**.

The authors have proven the effectiveness of the combination of duck meat and freshwater aquaculture meat **(Bozhko et al., 2018a; Bozhko, Pasichniy and Bordunova, 2016)**. Replacing pork with duck meat in boiled sausage recipes allows the product to be balanced in terms of protein and fat and increases the functional and technological performance and cooking yield. Through the use of fish meat in sausage technology as a structural component of the minced meat system, its water-binding capacity can be increased. The content of salt-soluble myofibrillar proteins with high hygroscopicity is between 75% and 80% of total freshwater fish protein. This causes high juiciness and cooking yield of products from fish raw materials.

Meat-containing semi-finished products with the meat of different types of freshwater aquaculture have been developed **(Bozhko et al., 2018b)**. It is determined that

when combining Peking duck and freshwater fish (*Carassius gibelio*) as part of frozen chopped meat-containing semi-finished products, it is possible to produce high-quality products.

The analysis of functional-technological and organoleptic indicators confirmed an increase in water binding capacity to 81.54%, in the water holding capacity to 76.47%, in emulsion capacity to 98.0%, and in emulsion stability to 69.49%. The developed semi-finished products of the combined composition had high organoleptic characteristics and were safe in terms of microbiological parameters **(Bozhko et al., 2018b)**.

Thus, prospects for the development of new products require further study of the combination of waterfowl and freshwater aquaculture as the ingredients in meat-containing semi-smoked sausages.

Scientific hypothesis

This project was carried out to determine the effect of a duck meat (*Anas platyrhynchos*) and freshwater fish (*Hypophthalmichthys molitrix*) combination on the quality (physicochemical and sensory properties) of meat-containing semi-smoked sausages. We are expecting to determine the optimal recipe with the highest quality for semi-smoked sausages containing duck meat and freshwater aquaculture due to the optimal ratio.

MATERIAL AND METHODOLOGY

Semi smoked sausage preparation

Three different ratios of duck *(Anas platyrhynchos)* and fish *(Hypophthalmichthys molitrix)* were used in this research, where sample 1 = 30:50, sample 2 = 40:40, and sample 3 = 50:30. Other used ingredients were pork fat – 10%, soya bean protein isolate – 4%, hemp protein – 6%, salt 2.3 – 2.8%, black pepper 0.1%, sodium nitrite – sample 1 – 0.003%, 2 – 0.004%, 3 – 0.005%, nutmeg – 0.05% and fresh garlic – 0.2%. The control (analog) was semi-smoked meat containing sausage with the following proportions of ingredients: duck 40%, pork fat 15%, pork heart 20%, soya bean protein isolate 5%, dry whey 5%, fibre 5%, and chicken skin 10%.

Meat, fish, pork heart, and chicken skin were mixed into a mixer cutter (Philipps, Germany). Soya bean protein isolate was hydrated in a 4:1 water: isolate ratio for 15 min. Minced ingredients were mixed for 8 min. The forcemeat was stuffed into the casings. The sausages were settled at a temperature of 4 – 8 °C for 2 hours, then dried in an oven at a temperature of 90 ±10 °C for 60 minutes. Sausages were cooked for 40 minutes at a temperature of 80 ±5 °C, cooled and smoked at a temperature of 43 ±7 °C for 5 hours, and dried at a temperature of 10 °C for 2 days.

Raw Protein Measurement

Protein measurements were performed using the Kjeldahl method **(ISO 937, 1978)**. 5 g of homogeneous fillet with 20 mL of concentrated sulfuric acid and 8 g of catalysts were placed in a special container and then heated at 350 °C for 30 min. After mineralization, the sample was quantitatively transferred to a solution of NaOH at a concentration of 33%, sealed, and distilled off with the steam. The resulting steam distillate was transferred to a container containing several drops of the

Tashiro indicator. The titration was performed with a solution of 0.01N sulfuric acid.

Fat Measurement

Total fat was measured by the Soxhlet method **(ISO 1443, 1973)**. 4 g of the dried sample in a paper cartridge was placed in an extraction flask of a Soxhlet apparatus. Petroleum ether with a boiling point of 45 °C was used for the extraction. After multiple extractions, the weight of the test cartridge to constant weight was determined. The difference between the initial and final weight shows the percentage of fat.

Ash Measurement

Ash content was determined by ashing samples overnight at 520 °C in a muffle furnace (Germany).

Definition of the energy value

Energy value was calculated by the Atwater general factor system. The average values of energy are expressed as the number of calories per 1 gram of the macronutrient. The Atwater general factor system includes energy values of 4 kcal per gram (kcal.g^{-1}) (17 kJ.g^{-1}) for protein, 4 kcal.g^{-1} for carbohydrates, and 9 kcal.g^{-1} (37 kJ.g^{-1}) for fat **(FAO, 2003)**.

pH measurement

The pH of the mincemeat was measured using a Partabell digital pH meter pcd650. Samples were prepared to measure pH based on the standard method **(Pasichnyi, 2013)**, and 10 g of minced meat in 100 mL of water were mixed.

Moisture analysis

Moisture was determined by the method of drying **(ISO 1442, 1997)**. 5 g of the sample was placed in a container, dried for 1 hour at 150 °C.

Methods of measuring functional indicators

WBC (water binding capacity) of minced meat was determined by the pressing method **(Pasichnyi, 2013)**. WBC_a is the water-binding capacity to the moisture of the sample; WBC_m is the water-binding capacity to the mass of the sample. WHC (water holding capacity) of minced meat was defined as the difference between the mass fraction of moisture in the minced meat and the amount of moisture released during the heat treatment. The following procedure was used to determine the emulsifying capacity (EC). The stability of the emulsion was determined by heating at 80 °C for 30 min. and cooling with water for 15 min followed by centrifugation and measuring the ratio of the emulsion layers **(Pasichnyi, 2013)**.

Definition of rheological indicators

Rheological indices of minced systems were determined using a rotational viscometer. RV-8m viscometer was used with a corrugated rotor (2 mm corrugation step) with an inner cylinder (Rc) of 0.605 cm, and an outer rotor radius of Rn – 1.9 cm, the length of the rotor was equal to 8 cm. on a scale using a stopwatch. The processing of the

obtained results was performed according to the method **(Pasichnyi, 2013)**.

Statistical analysis

The statistical analysis data were produced by Microsoft excel and Statistica 15. All experiments were carried out in triplicate and the results reported are the results of those replicate determinations with standard deviations. The Student t-test was used for the statistical analysis of the obtained results. Data are presented as mean ±standard deviation of the mean (SDM). The smallest acceptable difference for probes from the one sample was pointed at 5%. Probes with more differences were not considered. We selected the value of reliability as $p < 0.05$.

RESULTS AND DISCUSSION

The data obtained for the nutritional value of semi-smoked sausages are presented in Table 1.

It was found that the sausages had a high protein content, which ranged from 20.47 to 19.89 g.100g^{-1} of product, which was 17.90% – 21.34% higher compared with the analog (control). This was due to the inclusion of protein ingredients such as duck meat, silver carp, soy isolate, and hemp protein in the recipe. Due to the use of high-protein components in the technology, it was possible to reduce the mass fraction of fat in sausages. Thus, in the analog, the fat content was 31.03 g.100g^{-1}, which is on average 75% higher than in the experimental samples. The fat content in the combined sausages ranged from 14.42 to 20.98 g.100g^{-1}, which significantly affected the energy value of products. The caloric content of the experimental samples decreased relative to the control by 51% on average. According to physiological norms, the ratio of protein and fat in the human diet should be 1:1 **(Trumbo et al., 2002)**. According to the present research, a similar content of protein and fat was obtained in a sample of 50% duck and 30% fish. The set values meet the requirements for commercial smoked sausages.

The problem of protein deficiency in diets remains unresolved **(WHO, 2004)**. This is especially true for countries with low economic development **(Eshetie, 2017)**. After all, the diets of their inhabitants mainly consist of vegetables and cereals. Adequate protein intake is crucial for health and development **(Elmadfa and Meyer, 2017; Santarpia, Contaldo, and Pasanisi, 2017; Brandhorst and Longo, 2019)**. As a rule, animal protein, including that of fish, is of higher quality for human consumption due to its amino acid composition and good digestibility **(Cieślik et al., 2017; Khalili Tilami and Sampels, 2017)**. Meat-containing semi-smoked sausages with duck and freshwater fish will supplement the human diet with a high-quality, easily digestible protein.

Proteins play a major role in the formation of functional and technological properties of forcemeat systems **(Strashynskiy et al., 2016; Kang et al., 2016)**. The introduction of freshwater aquaculture proteins into the meat-containing system and their combination with duck muscle tissue and vegetable proteins allow model forcemeat systems with a high level of hydration to be obtained. Duck meat proteins have high functional properties, in particular the ability to bind and retain water

in minced meat systems **(Adzitey, 2012; Ismail et al., 2010)**.

The results of the study of functional and technological properties of model minced meat systems with different ratios of duck and freshwater fish are presented in Table 2.

Analysis of the data in Table 2 shows that the amount of moisture in the experimental samples ranges from 71.00% to 72.75%. The high moisture content of minced meat is due to the high moisture-binding capacity of the systems. The results of physicochemical properties are within the normal range of previously reported experimental smoked sausages **(Bozhko et al., 2018c)**.

The WHC of minced meat systems is 58.44% – 60.60%, which is 5.05% – 8.93% higher than in the control. Due to the balancing of the ingredient composition, the pH value of the experimental samples decreased by 14.70% – 16.54%, which helped to shift the pH from the isoelectric point of muscle and fish proteins and increase their ability to attach water molecules. Due to the processes of hydration, the WBC$_a$ of experimental samples was in the range of 69.60% – 71.47%, which confirms the high ability of model meat and fish systems to retain moisture in the structure of the forcemeat **(Fennema, 1990)**.

In the technology of sausage production, an important and basic operation of the technological process is the preparation of minced meat with a strong structure and the highest water-binding capacity. It is known that the strength of the forcemeat structure is due to the number of proteins that can pass from cellular structures into a continuous phase and form a dispersion medium and affect the structural and mechanical properties of products **(Smith, 2001; Bouton, Harris and Ratcliff, 1981)**.

Analysis of structural and mechanical parameters of the combined minced meat (Table 3) proves that changing the ratio of the same ingredients in the recipe makes it possible to directly regulate the rheological properties, thereby affecting product quality increasing the content of fish raw material to 50% in the formulation of sample 1 reduced the shear stress by 35.5% compared with the control sample and by 11.5% and 18.8%, respectively, according to samples 2 and 3. The forcemeat of all test samples was more elastic in comparison with the control. The results are within the normal range of commercial smoked sausages.

Increasing the proportion of duck meat in minced meat modeling systems enhanced the strength of the system and, accordingly, increased the shear stress.

Also, as the content of dense duck meat increased, the plasticity of the forcemeat decreased. Thus, the minced meat with the highest plasticity had a fish content of 50% and a duck meat content of 30% – 25.9 ±0.38 cm^2.g^{-1}, while in the sample with a duck content of 50% and 30% fish meat, this indicator was 21.6 ±0.37 cm^2.g^{-1}. That is, for a plastic and easy-to-form system, the optimal ratio of duck to fish is 50:30.

An important role in the production of a juicy sausage is played by the emulsifying properties of the minced dispersed system **(Tian et al., 2019; Santhi, Kalaikannan and Sureshkumar, 2017)**. The data in Figure 1 shows the effect of the ratio of duck to fish in minced smoked sausages on the emulsifying capacity (EC) and the stability of the emulsion (SE).

Figure 1 Samples of semi-smoked meat containing sausages with different ratio of duck and fish. Note: Ratio of duck and fish: A – 30:50; B – 40:40; C – 50:30
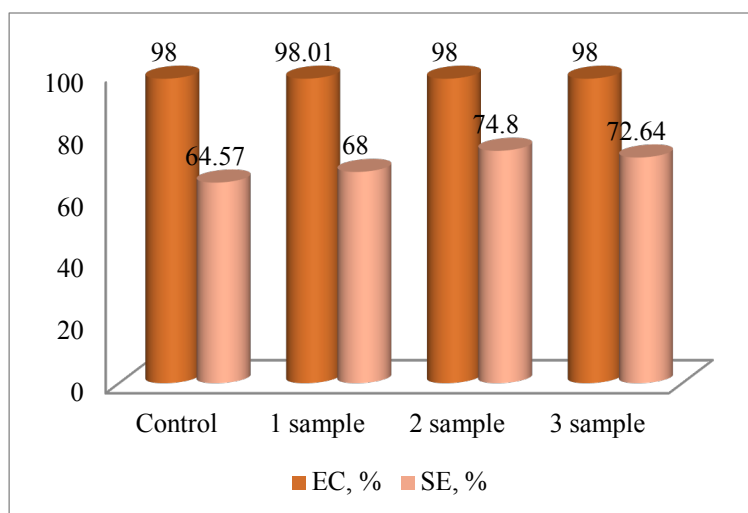

Figure 2 Analysis of emulsifying properties of forcemeat with different ratios of duck to fish.

Table 1 Nutritional value of combined minced meat semi-smoked sausages.

Parameter	Control	Sample 1	Sample 2	Sample 3
Protein, g.100g^{-1}	16.87 ±0.85	20.47 ±0.23	20.18 ±0.54	19.89 ±0.54
Fat, g.100g^{-1}	31.03 ±0.13	14.42 ±0.09	17.70 ±0.09	20.98 ±63
Ash, g.100g^{-1}	0.98 ±0.05	1.51 ±0.02	1.30 ±0.04	1.10 ±0.01
Energy value, kcal	364	212	241	269

Table 2 Functional and technological properties of combined minced meat of semi-smoked sausages.

Sample	Moisture,%	WBC$_a$,%	WBC$_m$,%	WHC,%	pH
Analog (Control)	70.51 ±0.31	69.34 ±0.60	98.34 ±0.85	55.63 ±0.05	7.62 ±0.03
1	72.75 ±2.20	71.47 ±1.64	97.46 ±2.16	58.44 ±0.36	6.50 ±0.37
2	71.00 ±3.60	69.60 ±1.45	97.35 ±2.31	60.60 ±0.96	6.40 ±0.10
3	71.80 ±0.36	70.17 ±2.17	98.66 ±3.01	60.50 ±0.27	6.36 ±0.55

Table 3 Structural and mechanical properties of combined minced meat of semi-smoked sausages.

Samples	Shear stress, Pa	Plasticity, cm^2/g	Effective viscosity, Pa × s
Analog (Control)	1407 ±23.7	20.5 ±0.16	817 ±17.3
1	1038 ±19.1	25.9 ±0.38	579 ±21.9
2	1157 ±20.1	23.7 ±0.52	691 ±27.5
3	1234 ±21.9	21.6 ±0.37	684 ±24.1

Table 4 The effect of the duck meat and fish ratio on the organoleptic characteristics of semi-smoked meat containing sausages.

Sample	Appearance	Colour	Flavor	Texture	Taste	Juiciness	The total score, points
Control	4.7 ±0.05	4.7 ±0.05	4.8 ±0.08	4.6 ±0.03	4.5 ±0.04	4.5 ±0.01	4.6 ±0.12
1	3.1 ±0.03	3.3 ±0.06	3.1 ±0.05	2.8 ±0.04	3.1 ±0.02	4.0 ±0.03	3.2 ±0.11
2	3.6 ±0.04	3.5 ±0.03	3.6 ±0.02	3.5 ±0.01	3.4 ±0.02	3.8 ±0.05	3.6 ±0.09
3	4.7 ±0.04	4.6 ±0.04	4.5 ±0.01	4.3 ±0.02	4.6 ±0.03	4.7 ±0.02	4.5 ±0.11

Analysis of the data in Figure 2 shows that the emulsifying properties of minced meat with different ratios of duck meat and freshwater fish meat were almost at the same level. This confirms the data of **Kornyenko and Ghuseva (2018)** regarding the high ability of fish proteins to retain fat in the emulsion state. Water-soluble and salt-soluble fractions of fish muscle proteins promote the formation of a solvate shell on the surface of fat capsules and prevent their adhesion **(Huang et al., 2018; Santana, Huda and Yang, 2015)**.

When studying the stability of the emulsion under the influence of heat treatment, it was found that with the increase in the proportion of duck meat in the sausage recipe, the stability of the emulsion increased. In the sample with a ratio of 50% duck meat to 30% fish meat, the CE was 72.64 ±1.25%, which is 12.5% greater than the control. According to EC and SE indicators, minced fish is close to minced duck meat **(Huda, Putra and Ahmad, 2011)**. The emulsifying ability of minced poultry meat is 75%, and the stability of the emulsion is about 70% **(Strashynskiy et al., 2016; Yancheva, Dromenko and Grinchenko, 2017)**; thus, the combination of this raw material with multicomponent functional mixtures based on plant and animal proteins and food additives, i.e. fillers **(Pasichniy et al., 2015)** will effectively develop meat products with a combined composition of raw materials.

The data for organoleptic quality indicators, namely appearance and color, aroma, texture, taste and juiciness, and overall acceptability of meat-containing semi-smoked sausages with different ratios of duck and freshwater fish, were assessed on a five-point scale by nine semi-qualified experts. The results are shown in Table 4. The evaluation results showed a significant difference in appearance and color, flavor juiciness, texture, and total evaluation between control and experimental samples containing duck and fish meat in all three ratios. The data indicated that the addition of duck and fish had a significant effect on the sensory attributes of sausages.

Freshwater aquaculture is not a traditional ingredient in meat products, one of the reasons being the inherent odor of fish products. Therefore, when combining poultry and fish, it is important to maintain the optimal ratio in terms of organoleptic characteristics.

Among the samples, the highest score on all indicators was given to sample number 3, with a ratio of duck: fish 50:30. Higher color intensities are due to the higher content of duck meat, which has a dark color. A similar effect was observed **(Biswas, Chakraborty and Sarkar, 2006)** in the study of patties with duck and broiler chicken meat. The consistency of the sausages improved with the increase in the proportion of duck meat. When duck meat was combined with the meat of broiler chickens, this effect was not observed. In contrast, the consistency deteriorated, as found by **Huda et al. (2010)**. However, in other studies, no difference was observed **(Kumar et al., 2015)**.

CONCLUSION

It was found that the protein content of meat-containing semi-smoked sausages with different ratios of duck and fish meat was 17.90% – 21.34% higher than the analog.
A sample containing 50% duck and 30% fish has an ideal protein: fat ratio of 1:1. High properties of model minced experimental semi-smoked sausages were established: moisture content of up to 72.75%, a WBC_a of up to 71.47%, and a water holding capacity of up to 60.60%.

A comparative analysis of the rheological properties of minced meat showed that increasing the proportion of duck meat in minced meat model systems increases the strength of the system and, accordingly, the growth of shear stress. Furthermore, the addition of fish improves the elasticity of experimental forcemeat systems. The optimal ratio of duck and fish meat for a plastic and easy formatted minced meat system is 50:30.

The combination of duck meat with fish raw materials helps to increase the stability of the emulsion to 74.8%. Analysis of the sensory attributes of experimental sausages confirmed that the best ratio of duck meat and freshwater fish in the recipe is 50:30.

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