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Nutritive, chemical, and technological properties of liver paté formulated with beef offal, sheep tail fat and liquorice, and ginger root

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ABSTRACT

The present study investigated the incorporation of sheep tail fat, beef heart, kidneys, and herbal ingredients (grounded licorice and ginger root, pumpkin, carrots, and onions) into liver paté formulations. Four types of liver paté were prepared: control sample containing only liver and butter; experimental sample S1 – paté with sheep tail fat (5%), ground dried licorice root (1%), and ginger (2%); experimental sample S2 – paté with sheep tail fat (8%), ground dried licorice root (2%) and ginger (3%); experimental sample S3 – paté with sheep tail fat (10%), ground dried liquorice root (3%) and ginger (4%). Inclusion of the ingredients mentioned above in the paté recipe did not cause significant changes in the mass fraction of table salt and protein (p >0.05) and conversely, significantly increased the moisture content, carbohydrates, fat, and be-ta-carotene in the test sample (p <0.05). The number of amino acids in the experimental samples decreased except for arginine. Among the experimental samples, the highest content of amino acids (18 g/100g) and essential amino acids (8.89 g/100g) was detected in S1. The results of determining the fatty acid composition showed significant changes in the composition of experimental samples compared with the control. The total content of saturated acids in the experimental samples decreased while the content of polyunsaturated and monounsaturated fatty acids increased (p <0.05). Textural characteristics, such as hardness, cohesiveness, and adhesiveness in the test sample, have changed significantly (p <0.05). However, the paste mass's elasticity (springiness) and stickiness were almost the same for the control and experimental samples. The introduction of the ingredients mentioned above in the experimental samples increased the pH and water-binding capacity) values, which suggests an increase in juiciness. The conducted studies have confirmed the prospects for improving the chemical composition without deterioration of the consistency and structure of the finished product.

Keywords: paté, sheep tail fat, heart, kidneys, liquorice root, ginger root

INTRODUCTION

Patés are the most widely used and common type of meat product. Liver patés mainly consist of liver and fat components. Still, they could be diverse on the intended and applied packaging (in sausage casing, in the form of canned food), the use and type of raw materials (with liver, various types of meat and offal, herbs, and natural spices) **[1]**, **[2]**. However, specific features of liver paté, such as the high concentration of fat and low content of antioxidants in the composition, cause their high sensitivity to oxidation of fats **[3]**, **[4]**. In this regard, paté producers use preservatives such as sodium nitrite and synthetic antioxidants (butylhydroxytoluene, butyl hydroxyanisole), and in most cases, their inclusion possesses negative consequences **[5]**. For example, studies conducted by Schulze et al. **[6]** and data from the annual report of the World Health Organization (WHO) **[7]** noted the negative effect of synthetic preservatives used in meat products, as well as high risks to human health from excessive consumption of meat products: high content of certain saturated fatty acids, oxidation of fatty acids during heat treatment, etc. The preservatives mentioned above are causes of several types of cancer, cardiovascular disease, diabetes, and so on. According to **[8]**, preservatives such as nitrite and its derivatives in foods can cause cancer in humans. According to the research results of **[9]**, the use of synthetic antioxidants in meat products can be harmful to the human body. All the factors mentioned above have become the basis for the search for new, safer ways to decrease the oxidation processes in meat products with high-fat content. One of the

possible promising solutions is the use of herbal antioxidant supplements. The main benefit of these additives is their high vitamin, mineral, fiber, and low-fat content **[10]**, **[11]**. It is possible to design the final finished product content knowing the vegetable and animal origin raw material's nutrient content. According to several scientific works, a synergistic effect could be achieved by combining different types of raw materials in the production of meat products **[12]**, **[13]**, **[14]**, **[15]**. These implementations also could solve environmental-food problems. Licorice root is known for its immunomodulatory effects against many diseases. It is used in pharmaceutics to treat respiratory diseases – asthma, pharyngitis, infection, malaria, soothe abdominal pain, peptic ulcers and insomnia **[16]**, **[17]**. The main biologically active component in licorice root is glycyrrhizic acid. In smaller amounts, it contains flavonoids, iso-flavanoids, chalcones, coumarins, triterpenoids, sterols, starch, sucrose and glucose, lignans, amino acids, amines, gum, volatile oils **[18]**, **[19]**. Ginger root is also known in the folk medicine of Asia, especially in Chinese medicine, in the folk medicine of West Africa. It has a positive effect on inflammatory diseases: coughs, colds, and rheumatoid arthritis in stomach diseases: dyspepsia, colic, gastroparesis, etc. **[20]**, **[21]**, **[22]**. The analysis of publications shows that ginger and licorice root is mainly considered by scientists in food products to prolong shelf life **[23]**, **[24]**, **[25]**, **[26]** and to enrich the composition of prepared foods **[27]**, **28]**, **29]**. However, research data on licorice root and ginger in meat products are minimal **[23]**, **[25]**, **[30]**, **[31]**. Due to the growing environmental problems of waste processing in the last decades, the issue of including components such as brains, a combination of the liver of various animals and birds, offal, blood, bones, and other animal by-products into the composition of traditional patés, which has become more relevant in the modern industry **[32]**, **[33]**, **[34]**. Another interest is the use of low-demand by-products, which are sent to animal feed production and are practically not processed for food purposes. However, animal by-products have a high nutritional and biological value **[35]**, **[36]**. Considering that in Kazakhstan, based on its natural and climatic features, sheep breeding has been historically developed, including sheep of indigenous breeds with a different sheep tail fat – a post-slaughter raw material, the processing of which is acute and whose weight reaches up to 40 kg for some breeds. The share of fat-tailed sheep is 70% of the total number of sheep in the Republic of Kazakhstan **[37]**. Their breeding has long been predetermined by climatic and economic conditions, as well as the national traditions of the indigenous population. They are famous for their unsurpassed precocity and adaptability to specific local, often extreme par-atypical environmental conditions in certain regions, where it is practically impossible to conduct other branches of the agricultural sector **[37]**. However, with mass breeding, only meat and skin are in demand and processing. Traditionally, lard and butter are used as fat components in liver paté recipes. Still, in countries with a predominant number of Muslims, this product does not meet demand due to the inclusion of non-halal ingredients. As stated by Unsal et al., there are practically no studies on the beneficial properties of chicken fat as a food ingredient **[38]**. Sheep tail fats are mainly included in the production of fermented Turkish sausages, such as foreign and barbecue sausages, which are prepared from beef, lamb, and goat meat with the addition of sheep tail fat **[39]**, **[40]**, as well as for cooking traditional meat products Gudid and Khabib in Tunisia, Algeria, and Morocco **[41]**. The main obstacle to the use of tail fat in the composition of food products is the presence of a specific taste and smell. We considered the possibility of neutralizing them by frying local types of vegetables (carrots, pumpkins, and onions) on them.

This work aimed to study and evaluate the use of sheep tail fat, beef heart, kidneys, and herbal ingredients (pumpkin, licorice, and ginger root) to replace the liver and butter in the patés partially paté.

Scientific Hypothesis

The scientific hypothesis consists in increasing the nutritional value of meat paté using by-products (liver, heart, kidney) and vegetable raw materials (pumpkin, carrots, onions, ground licorice root, ginger root).

MATERIAL AND METHODOLOGY

Experimental studies were conducted jointly with Nazarbayev University (Nur-Sultan, Republic of Kazakhstan), Kazakh National Agrarian Research University (Almaty, Republic of Kazakh-stan), and Almaty Technological University (Almaty, Republic of Kazakhstan).

Samples

Raw materials: Liver and beef offal (heart and kidney) and sheep tail fat were kindly delivered from the LLP "Aigerim Enterprise" (South Kazakhstan region, Republic of Kazakhstan) immediately after slaughtering. Pumpkin, carrots, onions, ground licorice and ginger root, butter (72.5% fat), and spices were purchased from the local Magnum grocery store (Almaty city, Republic of Kazakhstan).

Paté samples: We have manufactured three kind of paté represents the experimental sample and one control sample.

Chemicals

Potassium hydroxide (Labor Farma Limited Liability Partnership, Kazakhstan). n-hexane (VWR International, France). Sodium Acetate, CH_3COONa (Chemistry and Technology Company, Kazakhstan). Toluene (Labor Farma Limited Liability Partnership, Kazakhstan). Sodium methoxide (Labor Farma Limited Liability Partnership, Kazakhstan). Sulfuric acid, H_2SO_4 (Labor Farma Limited Liability Partnership, Kazakhstan).

Instruments

MX-50 weight moisture meter (LTD A&D Co, Japan). High-performance liquid chromatography SHIMADZU LC-20 Prominence HPLC (Japan). Gas chromatography (GC-Agilent 7890B, Agilent Technologies, Santa-Clara, California, USA). Texture Analyzer (Model Brookfield CT3, AMETEK, Berwyn, PA, USA). pH meter HI 99163 instrument (Hanna Instruments Inc., UK).

Description of the Experiment

Paté preparation technology: Four paté samples were prepared with different sheep fat tail fat contents and plant ingredients. The control paté sample included beef liver and butter, while in the experimental samples, the liver was partially replaced by offal meat (heart, kidney) and plant ingredients. Sheep fat tails partially replaced butter in the experimental samples. So, in the first experimental sample (S1), 21% liver and 8% of butter were replaced by offal meat (8%), sheep tail fat (5%), ground dried liquorice root (1%), and ginger (2%) and vegetables (pumpkin 5%, carrot 4%, onion 4%). In the second experimental sample (S2), 26% of liver and 8% of butter were replaced by offal meat (8%), sheep tail fat (8%), ground dried liquorice root (2%), and ginger (3%) and vegetables (pumpkin 5%, carrot 4%, onion 4%). In the third experimental sample (S3), 30% of liver and 8% of butter were replaced by offal meat (8%), sheep tail fat (10%), ground dried liquorice root (3%), and ginger (4%) and vegetables (pumpkin 5%, carrot 4%, onion 4%) (Table 1). Paté was manufactured in the meat processing workshop at the Kazakh Food Processing and Industry Research Institute. For each formulation, 8 cans of paté were produced. The net weight of one can of paté was 330 g. The technological scheme of paté production is shown in Figure 1. Liver and offal meat were cleaned of skin, blood vessels, bile ducts, and other inclusions. Then soaked in chilled water for 10 – 15 minutes, cut, and blanched in hot water for 15 minutes. Then liver and offal meat were minced in a meat grinder (the diameter of the plate is 2 – 3 mm). Pumpkin, carrots, and onions are peeled, cut, and sautéed in sheep tail fat for 10 – 15 minutes. Liquorice and ginger root was crushed on a grinder (CHANGI, Singapore), and sifted twice through a sieve with a diameter of 1 mm. The ingredients were weighed according to the recipe and then mixed and homogenized on a cutting machine L5-FKM (Voronezh, Russia). After the paste mass was filled into cylindrical tin cans (diameter 72.8 mm, height 95 mm), rolled up with tin lids on a manual seamer MZ04 (Russia), and dyed by sterilization in an autoclave “Malysh Nerzh” (Russia) at a pressure of 0.25 MPa and a sterilization temperature of 117 °C. The finished patés were cooled to ambient temperature and stored at 4 °C until analysis. Obtained meat paté was a homogeneous light brown mass with a smeared consistency and the typical flavour and aroma of meat paté.

Table 1 Control and experimental samples formulation.

Name of raw materials and materials	Control	Experimental sample		
		S1	S2	S3
Main raw material, kg per 100 kg of unsalted raw material				
Blanched beef liver	65	44	39	35
Blanched beef heart	-	5	5	5
Blanched beef kidneys	-	3	3	3
Butter (72.5% fat)	10	2	2	2
Bouillon from cooking beef offal, unfiltered	25	25	25	25
Fat tail fat, melted	-	5	8	10
Sautéed pumpkin	-	5	5	5
Browned carrots	-	4	4	4
Sauteed onion	-	4	4	4
Ground licorice root	-	1	2	3
Ground ginger root	-	2	3	4
Spices and materials, g per 100 kg of raw materials				
Ground black cumin	-	0.16	0.16	0.16
Ground nutmeg	-	0.5	0.5	0.5
Ground turmeric	-	0.16	0.16	0.16
Ground black pepper	0.1	0.1	0.1	0.1
Ground marjoram	-	0.5	0.5	0.5
Salt iodized	0.1	0.1	0.1	0.1

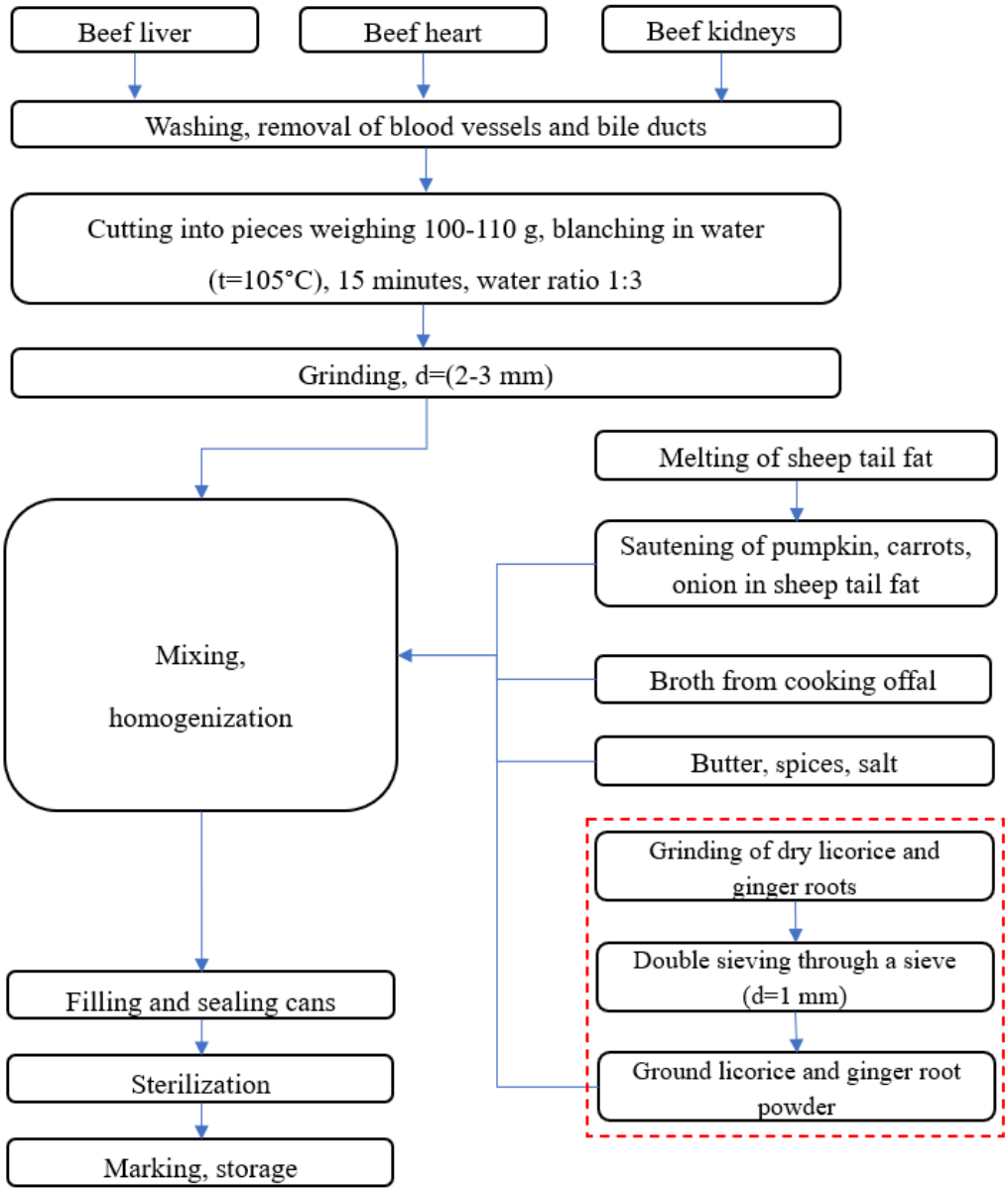

Figure 1 Technological scheme for preparing liver paté.

Laboratory methods

Determination of chemical composition: The moisture content in the meat was determined using an MX-50 weight moisture meter (LTD A&D Co, Japan). All samples for determination of moisture content were weighed in 5 g and evenly distributed inside the instrument cup. The determination of fat, ash, and protein were determined by the methods previously described in **[42]**. The sodium chloride in the paté was determined according to the Volhard method **[43]**. The content of beta-carotene was determined by the method described in **[44]** using beta-carotene standards (Sigma Chemical, USA). Carotenoids were extracted from samples according to the described Yang technique **[45]**. The determination was carried out according to the calibration curves of standard solutions.

Determination of total cholesterol: The total cholesterol content was determined according to the method described in **[46]**. An ethanol solution of potassium hydroxide was added to 2 g of the paté sample from each batch, and then cholesterol was extracted with n-hexane. Then the cholesterol was separated from the rest of the solution, and its content was determined by high-performance liquid chromatography (HPLC).

Determination of amino acid composition: Amino acids were determined using SHIMADZU LC-20 Prominence HPLC (Japan) with fluorimetric and spectrophotometric detectors. We used a chromatographic column 25 cm x 4.6 mm SUPELCO C18, with a diameter of 5 µm (USA), including a pre-column to protect the main column from foreign impurities. The HPLC analysis was based on the method **[33]**. Chromatographic analysis was performed in the eluent gradient mode at a 1.2 mL/min flow rate and a column thermostat temperature of 40 °C. The measurement was carried out on a reverse phase column with fluorimetric and

spectrophotometric detectors at 246 and 260 nm wavelengths using acid hydrolysis and modification of amino acids with a solution of phenylisothiocyanate in isopropanol to obtain phenylthiohydantoines. A 6.0 mm solution of CH_3COONa with a pH of 5.5 (component A), a 1% solution of isopropanol in acetonitrile (component B), and a 6.0 mM solution of CH_3COONa with a pH of 4.05 (component C) were used as the mobile phase. Samples of amino acids produced by Sigma Aldrich (Germany) were used as standards.

Determination of fatty acid composition: The fatty acids were obtained using the protocol described by Bly and Dyer, with a modification proposed by Barros et al. Once the fatty acids were extracted, these compounds were transesterified according to the method described by Dominguez et al. some changes **[46]**. Briefly, 1 mL of toluene was used to dissolve 20 mg of fat before mixing with 2 mL of 0.5 n sodium methoxide solution in a test tube. This mixture was stirred for 10 seconds and kept for 15 minutes at room temperature. After that, 4 mL of 10% was added to the mixture, which was stirred for several seconds, and a methanol solution of H_2SO_4 was added. The mixture was then stirred again for a few seconds after adding 2 mL of saturated sodium bicarbonate solution. Subsequently, fatty acid methyl esters (FAMEs) were separated by adding 1 mL of hexane to a test tube and stirring for 10 seconds. Finally, the vapours were transferred to the appropriate vial.

The vapours were separated and quantified using gas chromatography (GC-Agilent 7890B, Agilent Technologies, Santa-Clara, California, USA) and a PAL RTC-120 autosampler a flame ionization detector (FID). The injection was carried out in the separation mode (1:50) with 1 µL, the injector was maintained at a temperature of 260 °C, and the total flow rate was set to 64.2 mL/min.

Separation was carried out in a capillary column of fused silica SP-2560-100M (inner diameter 0.25 mm, film thickness 0.25 microns; Supelco Inc., Bellefonte, Pennsylvania, USA). The chosen gas carrier was helium, with a 1.2 mL/min flow rate. Pressure at the head of the column was set at 42.135 psi. The chromatography conditions were set as follows: the initial temperature of the furnace was 140 °C (sustained for 4 minutes), the first rise at 5 °C/min to 190 °C, the second rise at 2 °C/min to 210 °C (sustained for 4 minutes), the third rise at a speed of 1 °C/min to 220 °C and the fourth ascent at a speed of 3 °C/min to a final temperature of 235 °C (maintained for 7 minutes). The operating pressure in the FID was set as follows: temperature 260 °C, H2 flow rate 35 mL/min, air 350 mL/min, and recharge flow rate 15 mL/min. The total time of chromatographic analysis was 50 minutes.

MassHunter GC/MS Acquisition B.07.05.2479 software (Agilent Technologies, Santa Clara, California, USA) was used for equipment management and data collection. Data analysis was carried out in the MassHunter Quantitative Analysis B.07.01 software. Authenticated standards (FAME Mix-37 components, docosapentaenoic acid, trans-vaccinoic acid, cisvaccienoic acid, and CLA) were used to identify fatty acid methyl esters by comparing storage times. The results were expressed in g/100g of the total amount of identified fatty acids.

Texture Profile Analysis (TPA): Analysis was performed on a Texture Analyzer (Model Brookfield CT3, AMETEK, Berwyn, PA, USA). The hardness index of the sample was recognized as compression peak loading. For the indicator of cohesiveness, the inclination of the ratio A2/A1 were used. A2 is the zone under compression shock of the second cycle. A1 is the zone under compression shock of the first cycle. If the sample structure was destroyed under the action of the first compression, this ratio was considered equal to zero. If the product's structure was practically not damaged under the influence of compression, this ratio was equal to one. Springiness is an indicator that reflects the ability of the sample to return to its original shape after compression. The adhesiveness value expresses the bonding ability and is calculated as the area under the negative peak when the sensor returns after the first compression. Stickiness (gumminess) was calculated according to the method described in **[47]**. The Brookfield texture analyzer's operation principle is based on measuring the appearance of a stationary tool on a sample, a portable stage (TA-RT-KIT), vertically according to a given velocity law. The device's design consists of a control unit, a measuring head, and a set of interchangeable tools and fixtures. From each batch of paté, a sample of the same size was cut (cubic, 10 mm on each side) and placed in aluminum cylinders. The test was performed in two cycles of sample compression at a speed of 5 mm/s and a sample temperature of 20 – 25 °C, until the samples were compressed to 75% of the initial temperature.

Energy value of paté: The energy value was determined based on the value of the main three nutrients (protein, fat, and carbohydrates) in the product's composition. The energy value of the control and experimental samples were determined according to equation (3):

$$E = 4\,(P+C)+9F \tag{3}$$

Where:

E is an energy cell, kcal/100g; P – protein content, g; F – fat content, g; C – carbohydrate content, g; 4 – protein and carbohydrate calorie index; 9 – fat calorie index.

Water-binding capacity: Water-binding capacity (WBC) was identified by the method proposed by Grau and Hamm using filter paper and a weighted press **[48]**. The weight of the test sample was 0.3 g.

pH determination: The paté's active acidity (pH) patéwas determined by the potentiometric method. The twice ground sample was mixed with distilled water in a ratio of 1:10, followed by stirring on a magnetic stirrer for 30 minutes. The pH was determined using an HI 99163 instrument (Hanna Instruments Inc.).

Sensory analysis. Sensory analysis of samples was carried out according to the Interstate standard GOST 33741-2015 "Canned meat and meat-containing. Methods for determining organoleptic characteristics, net weight and mass fraction of components". Sensory analysis of control and experimental samples of patés was carried out using the profile method. The following indicators were considered: taste, odor, and consistency. In connection with the addition of different components, the following descriptors were selected: taste (sweet, pumpkin, carrot, salty, sharp, spicy, fatty, liver); color (brown-gray, gray); smell (sharp liver, sharp fatty, specific, pronounced); consistency (delicate, smeary, dry, loose, stiff, watery, fibrous). The intensity of each descriptor was evaluated on a scale from 0 to 5 (if no expression of any characteristic was observed, the intensity was evaluated as zero). After statistical processing, the results were obtained, according to which the profiles were designed.

Number of samples analyzed: Three experimental batches of samples (six cans each) and one control batch (six cans each) of patés were analyzed.

Number of repeated analyses: Each study was carried out three times, with the number of samples being twenty-four, which amounted to seventy-two analyses.

Number of experiment replication: The study was repeated three times, with the experimental data processed using mathematical statistics methods.

Statistical Analysis

The experiments were carried out in triplicate. Standard deviation values are given for all measurements. Differences in the measurements of the experimental and control groups were calculated using analysis of variance (one-way ANOVA) using Tukey's test. The measurement value $p < 0.05$ was taken as reliable.

RESULTS AND DISCUSSION

The chemical composition of the paté

The moisture content of paté samples is considerably influenced by the incorporation of offal meat, sheep tail fat, and plant ingredients (Table 2). The experimental data obtained differ somewhat from the data of Gonzalez et al. on a decrease in moisture content when adding 3% persimmon flour powder **[9]** and from data from Dominguez et al. on a reduction of moisture content when replacing pork fat with fish oil in liver patés **[49]**.

Table 2 Chemical composition of the control and experimental samples of paté.

Indicator	Control sample	Experimental sample		
		S1	S2	S3
Moisture content, %	60.0 ±1.60^{a}	63.5 ±1.59^{b}	63.5 ±1.59^{c}	64.8 ±1.95^{d}
Mass fraction of protein, %	17.42 ±0.95^{a}	17.01 ±1.02^{a}	16.49 ±1.02^{a}	16.38 ±0.99^{b}
Mass fraction of fat, %	12.53 ±0.01^{a}	12.65 ±0.006^{b}	13.06 ±0.015^{c}	13.08 ±0.012^{c}
Mass fraction of carbohydrates, %	0.71 ±0.01^{a}	0.87 ±0.01^{b}	1.12 ±0.01^{c}	1.25 ±0.02^{d}
Mass fraction of table salt, %	1.3 ±0.03^{a}	1.3 ±0.04^{a}	1.3 ±0.04^{a}	1.3 ±0.02^{a}
ß-carotene, mg/100 g	nd	0.67 ±0.01^{a}	1.02 ±0.02^{b}	1.19 ±0.01^{c}

Note: Indicated values: ± standard deviation calculated from three parallel measurements; nd – not detected; a – d values with different letters inside the graph mean a significant difference between different batches ($p < 0.05$).

The protein content is not significantly changed unless in sample S3, lowering up to 16.38% ($p < 0.05$). These results are consistent with the results of Gonzalez et. al. **[9]** about the absence of the effect of 3% addition of persimmon flour of the "Triumph" and "Rojo Brillante" varieties on the protein content in patés and a significant decrease with an increase in the content of persimmon flour. Sánchez-Zapata et al. **[50]** reported no significant differences in protein content when tiger nut fiber was added in an amount of 5 – 15%.

The mass fraction of table salt for all samples remained the same. The mass fraction of fat and carbohydrates increased in proportion to the increase in the content of additives, and the content of beta-carotene in all experimental samples increased significantly (not detected in control) ($p > 0.05$). These data differ from the results of the fat determination of Gonzalez et al. **[9]**, where the fat content has significantly decreased with a 3% addition

for persimmon flour of the "Rojo Brillante" variety. Still, similar behaviour was reported by Dominguez et al. when replacing pork fat with fish oil in liver patés **[49]**.

Studying the total cholesterol content

The total cholesterol content is significantly decreased (p <0.05) in experimental samples of paté compared with the control sample. Within the experimental samples, the cholesterol content is lowered as the added sheep tail fat increases. The results of determining the cholesterol content are shown in Table 3. Our results are combined with the data obtained by Martins and others with partial re-placement of pork fat with oleogels, where the cholesterol content varied in the range of 19.7 – 24.4 mg/100g **[51]**, but differ from the data of Vargas-Ramella and others on the addition of capsulated olive oil to reindeer meat patés, where the cholesterol content varied between 27.8 – 39.2mg/100g **[52]** and from the data of Dominguez et al. **[49]** when replacing pork fat with fish oil (60.35 – 147.11 mg/100g). These differences are related to the difference in the recipe of patés.

Table 3 The total cholesterol content of the control and experimental paté samples.

Indicator	Control Sample	Experimental sample		
		S1	S2	S3
Total cholesterol, mg/100g	24.4 ±0.97^{a}	22.1 ±0.79^{b}	21.6 ±0.79^{c}	20.3 ±0.56^{d}

Note: Indicated values: ± standard deviation calculated from three parallel measurements; a – d values with different letters inside the graph mean a significant difference between different batches (p <0.05).

Studying the amino acid composition

Replacing the liver in the paté with kidneys, heart and herbal supplements from 21% to 30% significantly reduced the content of all amino acids except arginine. Among the experimental samples, the highest indicator in terms of the total number of amino acids (18 g/100g) and the content of essential amino acids (8.89 g/100g) was shown by samples of S1 with 26% liver replacement in the formulation (plant additives (9%), beef heart (5%), kidneys (3%) licorice root powder (1%), ginger root powder (2%) (Figure 2, 3). The results of the amino acid composition of the batch of patés are presented in Table 4.

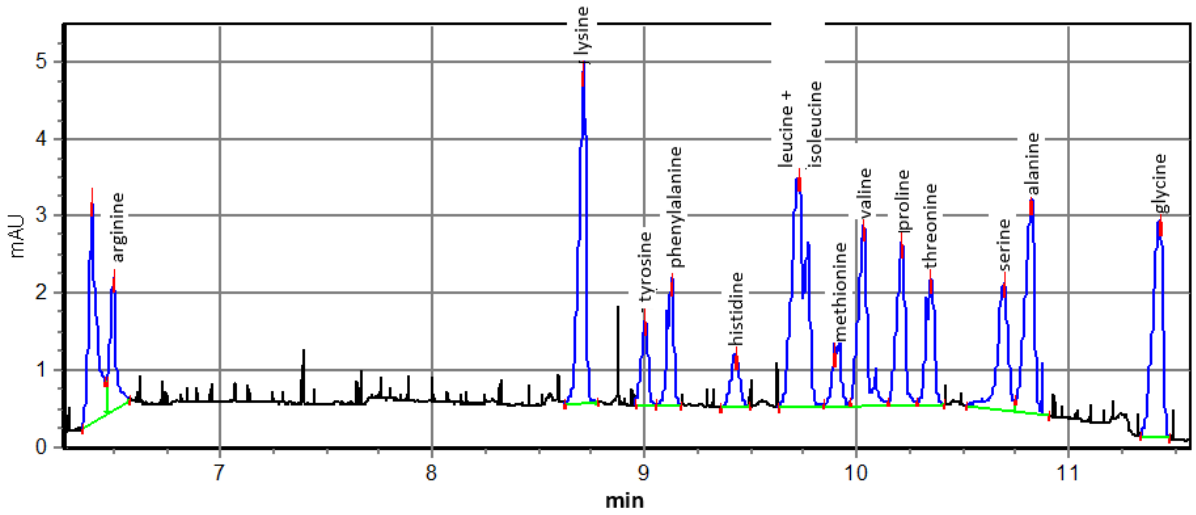

Figure 2 Amino acid composition of control paté sample.

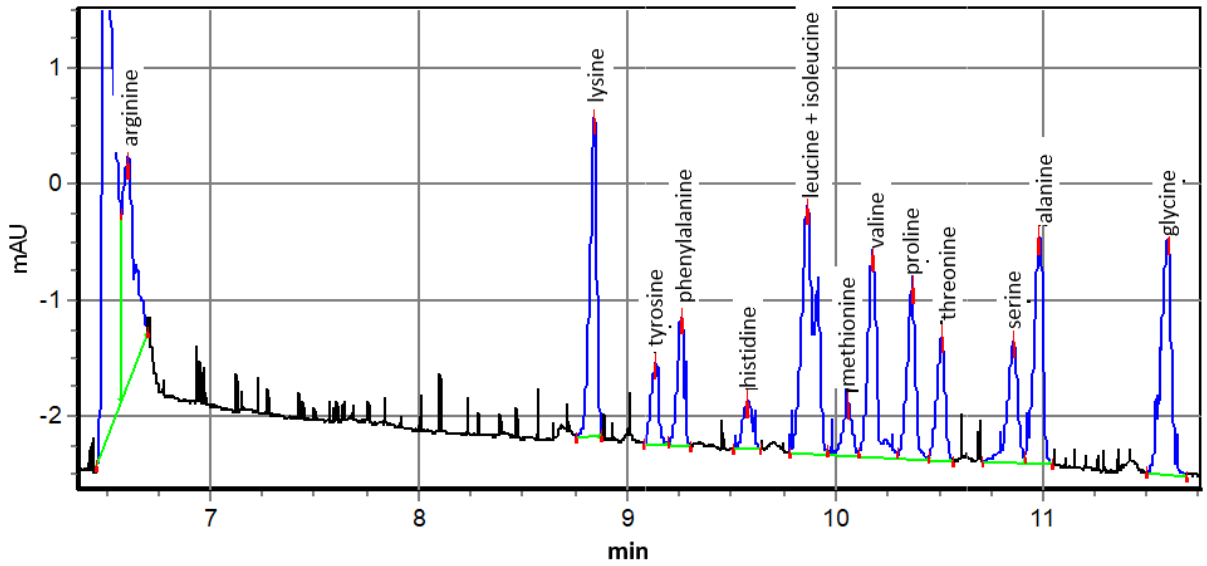

Figure 3 Amino acid composition of experimental paté sample S2.

Table 4 Amino acid composition of control and experimental paté samples (g/100g).

Indicator	Control	Experimental sample		
		S1	S2	S3
Essential Amino acids				
Threonine	1.26 ±0.50^{a}	1.13 ±0.29^{a}	0.87 ±0.35^{b}	0.79 ±0.26^{b}
Lysine	2.15 ±0.73^{a}	2.01 ±0.59^{a}	1.38 ±0.47^{b}	1.25 ±0.34^{b}
Phenylalanine	1.57 ±0.47^{a}	1.43 ±0.36^{a}	1.13 ±0.34^{b}	1.09 ±0.28^{b}
Leucine+isoleucine	2.29 ±0.59^{a}	1.78 ±0.20^{b}	1.56 ±0.41^{c}	1.42 ±0.19^{d}
Methionine	0.90 ±0.30^{a}	0.65 ±0.22^{b}	0.56 ±0.19^{bc}	0.49 ±0.10^{c}
Valine	2.11 ±0.84^{a}	1.89 ±0.74^{b}	1.51 ±0.61^{c}	1.40 ±0.45^{c}
Total essential amino acids	19.3 ±1.51^{a}	8.89 ±0.73^{b}	7.01 ±0.49^{c}	6.44 ±0.75^{c}
Nonessential amino acids				
Tyrosine	1.12 ±0.34^{a}	0.96 ±0.44^{b}	0.82 ±0.25^{c}	0.76 ±0.21^{c}
Histidine	0.81 ±0.40^{a}	0.76 ±0.30^{a}	0.56 ±0.28^{b}	0.45 ±0.14^{b}
Proline	1.61 ±0.42^{a}	1.28 ±0.36^{a}	1.13 ±0.29^{b}	1.09 ±0.20^{b}
Arginine	1.93 ±0.015^{a}	2.56 ±0.79^{b}	3.81 ±1.52^{c}	3.99 ±0.35^{c}
Serine	1.39 ±0.36^{a}	1.06 ±0.29^{b}	0.82 ±0.21^{c}	0.73 ±0.13^{c}
Alanine	1.70 ±0.44^{a}	1.35 ±0.34^{b}	1.13 ±0.29^{c}	1.04 ±0.36^{c}
Glycine	1.43 ±0.49^{a}	1.14 ±0.28^{b}	1.08 ±0.37^{b}	0.98 ±0.28^{c}
Total nonessential amino acids	9.99 ±0.78^{a}	9.11 ±0.65^{b}	9.35 ±0.45^{c}	9.04 ±0.74^{b}
Total amino acids	29.29 ±0.93^{a}	18 ±1.64^{b}	16.36 ±0.95^{c}	15.48 ±1.52^{b}

Studying the fatty acid composition

Changing the composition of the paté, especially replacing butter with sheep tail fat, significantly affected all measured fatty acids, both saturated and unsaturated, except for thymnodonic and erucic acids. All experimental samples of paté showed a significant decrease in the amount of all saturated fatty acids (except stearic acid) in proportion to the increase in the content of sheep tail fat, ground liquorice root, and ginger, and a simultaneous increase in the sum of monounsaturated and polyunsaturated fatty acids. The results of the determination of the fatty acid composition are presented in Table 5.

Table 5 Fatty acid composition of control and experimental paté samples (%).

Fatty acid name	Control sample, % weight	Experimental sample, % weight		
		S1	S2	S3
Saturated fatty acids				
Butyric acid	1.91 ±0.02[a]	1.84 ±0.011[b]	1.79 ±0.01[c]	1.64 ±0.015[d]
Caproic acid	76.81 ±0.017[a]	74.65 ±0.0096[b]	72.69 ±0.0082[c]	70.88 ±0.0126[d]
Caprylic acid	0.76 ±0.0208[a]	0.458 ±0.0021[b]	0.333 ±0.0015[c]	0.208 ±0.0011[d]
Capric acid	0.423 ±0.0015[a]	0.326 ±0.001[b]	0.188 ±0.001[c]	0.096 ±0.0015[d]
Undecylic acid	0.12 ±0.0115[a]	0.085 ±0.0015[b]	0.056 ±0.001[c]	0.031 ±0.0015[d]
Stearic acid	10.016 ±0.0015[a]	11.75 ±0.01[b]	13.09 ±0.0153[c]	14.94 ±0.0153[d]
Lauric acid	0.556 ±0.001[a]	0.419 ±0.0015[b]	0.292 ±0.0015[c]	0.158 ±0.0015[d]
Myristic acid	0.034 ±0.001[a]	0.028 ±0.0011[b]	0.014 ±0.0015[c]	0.006 ±0.001[d]
Pentadecanoic acid	0.189 ±0.0011[a]	0.168 ±0.0015[b]	0.147 ±0.0015[c]	0.131 ±0.0015[d]
Palmitic acid	2.229 ±0.001[a]	2.0961 ±0.014[b]	1.9867 ±0.003[c]	1.7495 ±0.027[d]
Total	93.047 ±0.002[a]	91.8201 ±0.009[b]	90.5867 ±0.003[c]	89.8395±0.01[d]
Monounsaturated fatty acids				
Palmitoleic acid	0.78 ±0.016[a]	0.65 ±0.009[b]	0.5106 ±0.001[c]	0.39 ±0.0153[d]
Myristoleic acid	0.266 ±0.005[a]	0.213 ±0.005[b]	0.1515 ±0.002[c]	0.101 ±0.003[d]
Oleic acid	3.92 ±0.006[a]	4.98 ±0.1001[b]	6.041 ±0.007[c]	7.015 ±0.007[d]
Nervonic acid	0.0093 ±0.003[a]	0.0081 ±0.001[ab]	0.0062 ±0.001[ab]	0.0041 ±0.001[b]
Erucic acid	0.008 ±0.001[a]	0.008 ±0.001[a]	0.01 ±0.001[a]	0.011 ±0.004[a]
Elaidic acid	0.019 ±0.001[a]	0.024 ±0.002[a]	0.029 ±0.001[ab]	0.033 ±0.001[b]
Total	5.0023 ±0.001[a]	5.8831 ±0.002[b]	6.7483 ±0.002[c]	7.5541 ±0.002[d]
Polyunsaturated fatty acid				
Linoleic acid	0.213 ±0.011[a]	0.698 ±0.004[b]	1.394 ±0.008[c]	1.499 ±0.007[d]
Linolenic acid	0.9734 ±0.001[a]	0.7896 ±0.001[b]	0.4016 ±0.002[c]	0.2356 ±0.001[d]
Timnodonic acid	0.021 ±0.008[a]	0.022 ±0.006[a]	0.025 ±0.008[a]	0.026 ±0.005[a]
Arachidonic acid	0.6297 ±0.0014[a]	0.6827 ±0.001[b]	0.7519 ±0.0019[c]	0.7711 ±0.0018[d]
Cervonic acid	0.108 ±0.009[a]	0.096 ±0.007[ab]	0.084 ±0.010[bc]	0.072 ±0.003[c]
Total	1.9451 ±0.001[a]	2.2883 ±0.001[b]	2.6565 ±0.002[c]	2.6037 ±0.001[d]

Note: Indicated values: ± standard deviation calculated from three parallel measurements; a – d values with different letters inside the graph mean a significant difference between different batches (p <0.05).

The highest content of monounsaturated fatty acids (7.5541%) was showed sample S3, and the highest content of polyunsaturated fatty acids (2.6565%) showed sample S2. The growth of monounsaturated fatty acids is connected mainly with the development of oleic acid content, which increased from 3.92% (78% of total PUFAs) in the control sample to 4.98 – 7.015% in the experimental samples (85 – 93% of total PUFAs). The increase of polyunsaturated fatty acids content is connected with the increase of linoleic acid content from 0.213% (11% of PUFA sum) in the control sample to 0.698 – 1.499% in experimental samples (30 – 58% of PUFA sum) and with the increase of arachidonic acid content from 0.6297% (32% of PUFA sum) in control sample to 0.6827 – 0.7711% in experimental samples (28 – 30% of PUFA sum). The highest content of monounsaturated fatty acids (7.5541%) was showed sample S3, and the highest content of polyunsaturated fatty acids (2.6565%) showed sample S2. The growth of monounsaturated fatty acids is connected mainly with the growth of oleic acid content, which increased from 3.92% (78% of total PUFAs) in the control sample to 4.98 – 7.015% in the experimental samples (85 – 93% of total PUFAs). The increase of polyunsaturated fatty acids content is connected with the increase of linoleic acid content from 0.213% (11% of PUFA sum) in the control sample to 0.698 – 1.499% in experimental samples (30 – 58% of PUFA sum) and with the increase of arachidonic acid content from 0.6297% (32% of PUFA sum) in the control sample to 0.6827 – 0.7711% in experimental samples (28 – 30% of PUFA sum).

Similar results of a decrease in saturated fatty acids and an increase in monounsaturated fatty acids were described in **[53]** when studying burger patties with partial replacement of pork fat with sunflower, olive oil, and avocado oil. However, our data differ from Domínguez et al. **[49]** on replacing pork fat in the paté with fish oil at 50% and 75%. These differences may be related to differences in the fatty acid composition due to the different raw materials used.

Profile texture analysis

The profile analysis results were obtained to compare the structure of samples of the control and experimental batches of paté (table 6). Texture profile analysis is about detecting the simulation of chewing processes in the human mouth by subjecting it to cyclic compression **[54]**, **[55]**.

The experimental samples' values of hardness, cohesiveness, and adhesiveness, expressed as a negative value of the curve in the simulation of chewing, were significantly higher than the control (p <0.05). This, in turn, indicates an increase in the hardness of the consistency, the ability to adhere, and the stickiness of the mass of experimental products. In our study, sample S1 and the control showed approximately the same elasticity (springiness) and stickiness (gumminess) (p >0.05), and its a significant variation in samples S2 and S3. A change in the composition of the paté above a certain value in samples S2 and S3 significantly reduced the required energy for crushing the product's structure before swallowing it in the mouth,.

Table 6 Analysis of the texture profile of the control and test samples of the paté.

Indicators	Control sample	Experimental samples		
		S1	S2	S3
Hardness (kg)	2.09 ±0.08	2.18 ±0.05^{b}	2.35 ±0.11^{c}	2.44 ±0.19^{d}
Adhesiveness (g/s)	- 64.05 ±20.05	-64.75 ±14.10^{b}	- 65.02 ±16.60^{c}	66.15 ±10.12^{d}
Spring force (mm)	0.18 ±0.01	0.20 ±0.01^{a}	0.23 ±0.02^{b}	0.25 ±0.05^{b}
Cohesiveness (g)	0.45 ±0.05	0.59 ±0.04^{b}	0.68 ±0.04^{c}	0.74 ±0.03^{d}
Gumminess (g)	927.10 ±31.25	901 ±27.45^{a}	788.63 ±22.03^{b}	625 ±12.04^{b}

Note: Indicated values: ± standard deviation calculated from three parallel measurements; a – d values with different letters inside the graph mean a significant difference between different batches (p <0.05).

The incorporation of additional ingredients may to some extent affect the structural and mechanical characteristics of the paté. Since the paté is a paste-like homogeneous mixture of various ingredients and with the inclusion of new ingredients, not only textural but also physical–chemical characteristics may change **[56]**, **[57]**, **[58]**.

Studying pH, water-binding capacity, and energy value of paté

The calculation of energy value calculation showed that the prototypes showed a significantly higher caloric content compared to the control (p <0.05). This is due to the test sample's higher fat content (4.22% higher) and carbohydrates (57.75% higher). The water-binding capacity (WBC) of meat products varies depending on the structure of the constituent particles and the size of the constituent particles of the dispersed medium of the product **[59]**, **[60]**. Accordingly, the ability of the paste to bind and retain moisture, including the moisture-binding ability, is affected by factors such as the degree of grinding of ingredients, the content of connective tissue in the product, the salt content, the presence and content of binding mass of ingredients (flour, eggs, etc.), etc. A high value of WBC increases meat products' juiciness, tenderness, appearance, and technological properties **[61]**, **[62]**. In our experience, the WBC of the experimental samples significantly increased with the addition of 8% sheep tail fat, 2% and 3% of ground liquorice and ginger root (S2), and 10% sheep tail fat, 3% and 4% of ground liquorice and ginger (S3) compared with the control sample. The results of the pH determination also showed an increase in proportion to the content of tail fat, ground ginger root, and liquorice compared with the control. Oksukhanova obtained similar results and others **[34]**. When replacing beef tripe and melted horse fat with part of the raw materials in the deer meat paste, an increase in WBC and pH values was observed in the experimental samples.

Table 7 Indicators of pH, WBC, and energy values of the control and experimental samples of paté.

Indicators	Control sample	Experimental sample		
		S1	S2	S3
pH	5.90 ±0.11	5.98 ±0.13^{b}	6.15 ±0.09^{c}	6.18 ±0.07^{d}
WBC, %	67.95 ±0.45	68.02 ±1.30^{a}	68.78 ±0.74^{b}	68.85 ±0.89^{b}
Energetic value, kcal/100g	185.29	185.37	187.98	188.68

Note: Indicated values: ± standard deviation calculated from three parallel measurements; a – d values with different letters inside the graph mean a significant difference between different batches (p <0.05), nd – not detected.

Sensory analysis of paté

Figure 4 shows that the flavour profilogram of the samples is distributed unevenly due to differences in taste characteristics. The control sample has a pronounced liver flavour compared to the experimental samples. The pumpkin and carrot flavour and sweetness are slightly evident and interfere with the taste of sheep fat in the experimental samples. Ginger complements and enriches the taste of paté's paté light spicy flavour due to a large amount of essential oils. The taste of liquorice root is hardly perceptible. Figure 5 shows the sharp liver flavour in the control sample. With the introduction of pumpkin, carrots, and spice flavour additives (cumin, nutmeg, turmeric, black pepper, marjoram), the odours of additives interfere with the smell of sheep fat, are respectively manifested. The profiles to characterize the consistency of the control and experimental samples are shown in Figure 6. The consistency profilograms of control and experimental samples are unevenly distributed. The control sample is drier and stiffer. In the experimental samples with an increasing amount of fat and vegetable ingredients, there is a tendency to a more expressed soft and creamy consistency. As a result of sensory analysis of samples of liver paté visible positive changes in taste, consistency, and odour with the introduction of sheep fat and plant ingredients in the recipe.

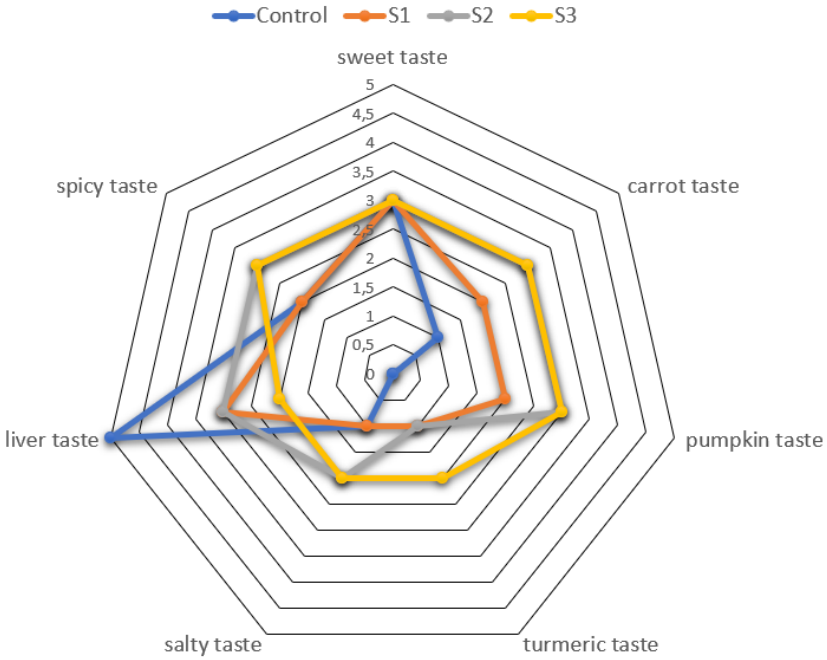

Figure 4 Profiles to characterize the taste sensations of experimental and control samples.

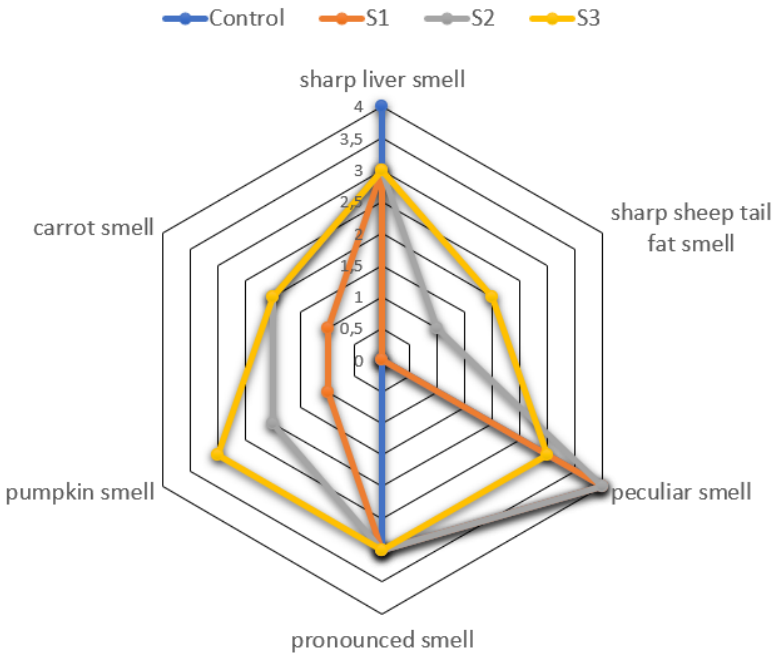

Figure 5 Odor characterization profiles of experimental and control samples.

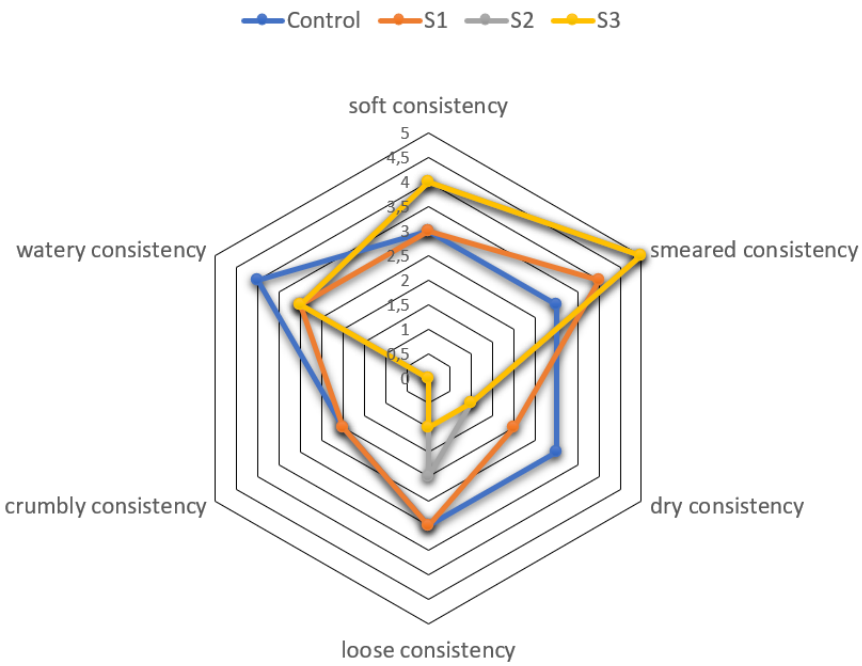

Figure 6 Profiles for consistency characterization of experimental and control samples.

CONCLUSION

Following the principle of minimizing animal slaughter waste, we evaluated the possibility of replacing many ingredients in liver patés with less popular ones: butter with sheep tail fat, liver with beef heart, kidneys, as well as vegetable additives (liquorice root and ginger, pumpkin, carrot, and onion). Including the ingredients mentioned above in the paté recipe did not cause significant changes in the mass fraction of table salt and protein and, conversely, significantly increased the moisture content, carbohydrates, fat, and beta-carotene in the experimental samples (p <0.05). The presence of ß-carotene in the experimental samples is of particular interest, given that in the control sample, this provitamin was not detected at all. The addition of new ingredients in the experimental samples reduced (p <0.05) the amount of amino acids except for arginine and increased the content of fatty acids. Notably, the content of all fatty acids increased significantly (p <0.05) in proportion to the growth of tail fat, ground liquorice root, and ginger. With adding new ingredients of plant and animal origin, hardness, cohesiveness, and adhesiveness have changed significantly (p <0.05). However, stickiness and elasticity (springiness) were almost the same for the control and experimental samples. The introduction of the ingredients mentioned above increased the WBC of the experimental samples, which suggests an increase in the juiciness of the product. A similar effect was found for pH. Sensory analysis showed more expressed soft and creamy consistency in experimental liver pate samples. The use of these ingredients in liver paté demonstrated the possibility of enrichment with ß-carotene, improving the consistency and structure of the product without loss in the quality of the finished product.

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