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Received: 6.9.2023
Revised: 21.9.2023
Accepted: 17.10.2023
Published: 27.10.2023

Slovak Journal of Food Sciences

Potravinarstvo Slovak Journal of Food Sciences
vol. 17, 2023, p. 816-832
https://doi.org/10.5219/1916
ISSN: 1337-0960 online
www.potravinarstvo.com

The use of protein-carbohydrate composition of okara, chickpea flour and whey protein in the technology of minced meat cutlets

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ABSTRACT

Kazakhstan's market for producing minced meat semi-finished products is not sufficiently developed. At the same time, the demand for products of the "economy" segment is growing. Providing balanced recipes for semi-finished meat products, with a rational combination of raw materials of animal and vegetable origin, is a significant problem. Chopped meat cutlets with high nutritional and low energy value have been developed, which are not inferior in functional and technological properties and sensory characteristics to traditional products. Pork and wheat bread were excluded from the recipes, with a replacement for lamb or broiler chicken meat in combination with a protein-carbohydrate composition (PCC) of the composition: soy minced okara – chickpea flour – whey protein concentrate (WPC 80) in a ratio of 9:5:10, at 1:3 hydration. The rational share of the introduction of PCC into the recipe of cutlets was 25% for minced beef – the meat of broiler chickens and 20% for minced beef – lamb. The studied samples of PCC, control minced meat with pork and bread, and two modified minced meat recipes for cutlets have similar values of the mass ratio of water fractions at three stages of dehydration during heat treatment. PCC particles are evenly distributed between the muscle fibers in minced meat. It has been shown that the developed PCC can serve as a substitute for minced meat not only in terms of the balance of the amino acid composition of the total protein but also in terms of the percentage of moisture with different forms of communication with the product, influencing the microstructure and consistency of raw semi-finished products of the combined composition, the consistency and juiciness of fried cutlets. According to the developed recipes, the mass fraction of protein in cutlets increased from 13.8 to 19.1-19.8%; fat decreased from 12.6 to 9.5-9.7%.

Keywords: semi-finished meat product, functional and technological properties, beef, nutritional value

INTRODUCTION

Kazakhstan's market to produce minced meat semi-finished products needs to be sufficiently developed, although at present, in the Republic of Kazakhstan, it is possible to note a significant increase in the volume of consumption of frozen and chilled semi-finished products. First, this is due to the employment of the population and the accelerated dynamics of modern life. At the same time, the demand for "economy" segment products is growing to a greater extent **[1]**.

Providing balanced recipes for semi-finished meat products, with a rational combination of raw materials of animal and vegetable origin, is an important problem. The reasons for the inclusion of vegetable raw materials in the recipes of meat products include WHO recommendations on the advisability of reducing the share of red meat and products of its processing as a risk factor for oncological diseases of the digestive system and a decrease in immunity in the context of the COVID-19 pandemic **[2]**, **[3]**, positive the influence of plant materials in combination with animals on metabolic processes in the human body **[4]**, a rich set of nutrients and biologically active compounds in the composition of various types of plant materials: chia and quinoa seeds **[5]**, bioactivated seeds of legumes – chickpeas, lupins, mung beans **[2]**, lupine flour, amaranth cake **[4]**, cedar cake **[6]**, pumpkin seeds **[7]**.

A promising type of secondary raw material for the complex enrichment of meat products with dietary fibres, macro- and microelements, vitamins, and isoflavones that act as natural antioxidants is soy okara, especially against the background of the amino acid profile of soy protein, which contains all the essential amino acids **[8]**. When choosing components for the development of a protein-carbohydrate composition, we considered data on the amino acid composition of chickpea flour **[9]**, as well as the possibility of enriching products and diets using whey processing products, in particular, in the form of whey protein concentrate WPC-80 **[10]**.

We have developed a protein-carbohydrate composition of the composition: minced soy okara – chickpea flour – whey protein concentrate (WPC 80) in a ratio of 9:5:10 for use in the production of chopped semi-finished meat products in the form of a hydrated mixture **[11]**. The specific index of amino-acid content balance (IACB) was used to optimise the PCC composition. IACB was designated (U_A) and was calculated using the formula **[12]**:

$$U_A = \sqrt[n]{\prod_{j=1}^{n}\left(\frac{A_j}{A_{ej}}\right)}$$

Where:
A_j is the weight ratio of the j^{th} *amino-acid* in the product, mg%; A_{ej} is the weight ratio of the j^{th} *amino-acid* equal to the required daily intake of this amino-acid, mg%; n is the number of essential amino acids in the product.

According to the calculated data, PCC and various types of meat and vegetable raw materials according to ISAS can be arranged in the following descending row: WPC- 80 >PCC >minced beef >minced lamb >minced chicken> chickpea flour> okara (Figure 1).

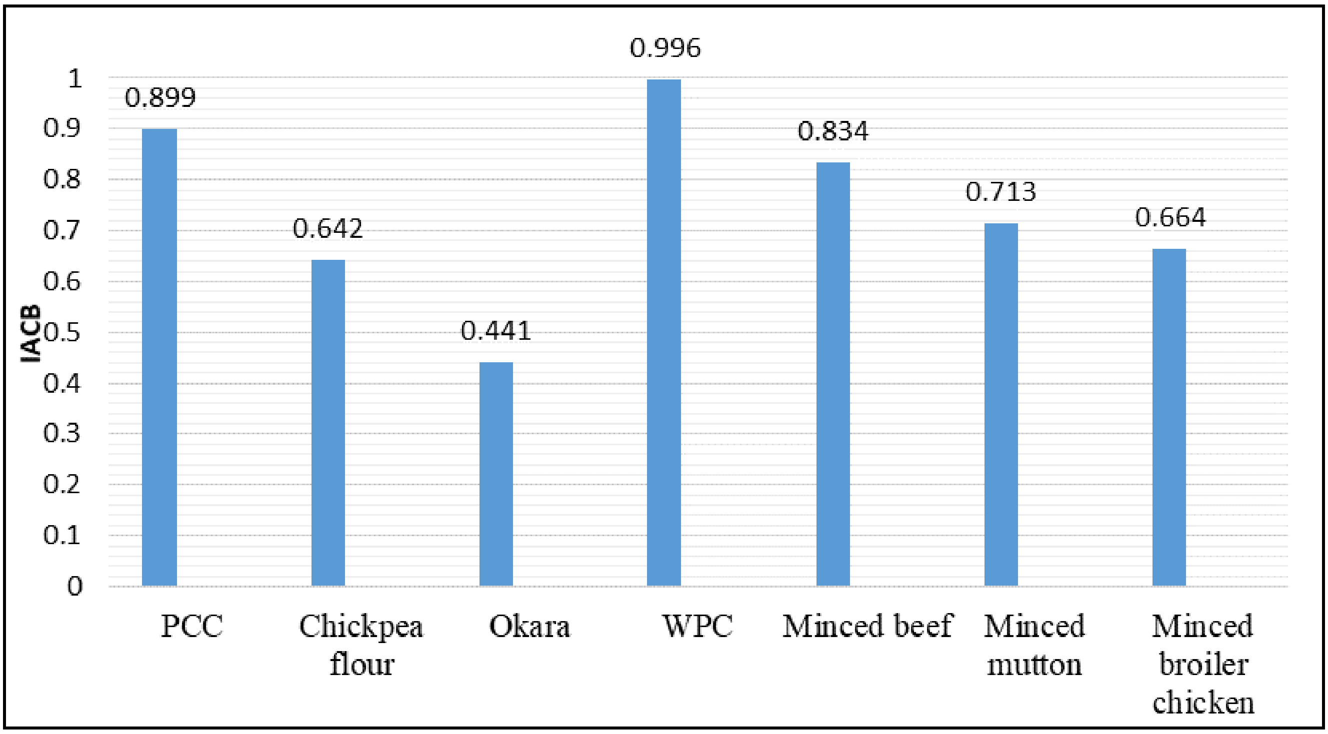


Figure 1 Partial index of the balance of various food systems, calculated according to the method **[12]**.

However, for the technology of semi-finished meat products, important: criteria for the applicability of PCC as prescription components is the ability to bind and retain moisture and fat during heat treatment, both alone and in combination with meat components. For the Republic of Kazakhstan, in addition to beef, the relevant types of meat raw materials for inclusion in the recipes of semi-finished products are lamb and broiler chicken meat, including in combination with beef.

The work aims to develop minced meat cutlets with high nutritional and reduced energy value, not inferior in functional and technological properties and sensory characteristics to traditional products of this assortment group, without the use of pork and the traditional carbohydrate component – wheat bread, due to PCC with soy okara, chickpea flour, whey protein concentrate.

Work tasks:

- study of the influence of PCC on the functional and technological properties of minced meat for semi-finished products;
- development of modified recipes for semi-finished meat products using PCC based on minced meat composition: beef - broiler chicken meat; beef – lamb;
- comparative assessment of hydration characteristics and microstructure of the developed minced meat for cutlets;
- assessment of cutlets' nutritional and energy value obtained according to modified recipes.

Scientific hypothesis

We assume that the PCC of the composition of soy minced okara – chickpea flour – whey protein concentrate (WPC 80) in a ratio of 9:5:10 can serve as a substitute for minced meat not only in terms of the balance of the amino acid composition of the total protein but also in terms of the ratio of free and bound moisture, the effect on the microstructure and consistency of raw semi-finished products combined composition. We expect a reduction in the mass fraction of fat while maintaining the high juiciness and tenderness of the cutlets after heat processing.

MATERIAL AND METHODOLOGY

Samples

Protein-carbohydrate composition (PCC). For the manufacture of PCC, the following raw materials were used: soy minced okara (Standards of organization 81952917-001-2013); whole grain chickpea flour (Standards of organization 12396977-004-2015); whey protein concentrate WPC-80 (Standards of organization All-Russian Research Institute of Butter-and-Cheese Making VNIIMS 045-2019).

Minced meat for cutlets and ready-to-eat fried cutlets. For the manufacture of cutlets, the following raw materials were used: pork cutlet meat (ECE/TRADE/369:2006); beef cutlet meat (ECE/TRADE/326:2004); lamb cutlet meat; broiler chicken meat (E/]ECE/TRADE/355).

The following ingredients were used as components of cutlet recipes: wheat bread, fresh onion according to [E/ECE/]TRADE/WP.7/GE.1/2001/10 |; edible salt according to (CODEX STAN 150-1985); ground black pepper according to (ISO 959-1:1998;) drinking water according to (ISO 19458:2006). The recipes for samples of semi-finished products are presented in Table 1.

Chemicals

Technical formalin GOST 1625-89, grade FM, the highest grade (Chemical Industrial Reagent LLP, Shymkent, Kazakhstan).

Ethyl alcohol rectified from food raw materials (manufacturer: "DOSFARM LLP", Kazakhstan).

Homogenized paraffin medium HISTOMIX (manufacturer: BioVitrum, Russia).

Hematoxylin regression and eosin alcohol staining kit "MEDIX" (manufacturer: Russia). Fir balsam (manufacturer: Russia).

Instruments

The amount of free and bound moisture in the samples was determined by a STA 449 F3 Jupiter synchronous thermal analysis instrument with a sample holder (DSC/TG) type S in an aluminium crucible with a pierced lid (an empty aluminium crucible with a perforated lid was used as a reference); nitrogen class 5.0 (active gas flow rate 50 ml/min, protective gas flow rate 20 ml/min). Software: NETZSCHProteus – Thermal Analysis. Heating program: heating from 25 °C to 200 °C at 2 °C/min. The results were presented in the form of TG and DTG curves and processed according to the method **[13]** to obtain data on the kinetics of dehydration.

Samples were cut on microtome «Hospitex diagnostics». The obtained preparations were studied using a Biolam P1U4 microscope under 3.2-40 objective lenses with an overall magnification of 400×.

Laboratory Methods

Laboratory studies of raw materials were carried out based on JSC "Almaty Technological University" (Almaty, Kazakhstan) and in the laboratory of the Center for Collective Use "Control and Management of Energy Efficient Projects" of the Voronezh State University of Engineering Technologies.

The functional and technological properties of minced meat were determined by standard methods **[14]**.

Moisture-binding capacity (MB C) was determined by pressing a minced meat sample under a load of 1 kg and then calculating the difference in masses before and after pressing and the area of the wet spot, determined by a planimeter according to the Grau and Hamm method. In the modification of Volovinsky and Kelman and expressed in % of the total mass of moisture in the product.

Table 1 Recipes of control and experimental samples of chopped semi-finished products.

Raw materials	The norm for cutlets with a share of replacing meat raw materials with PCC						
	Contr. [15]	**Exp. No. 1 15% PCC**	**Exp. No. 2 20% PCC**	**Exp. No. 3 25% PCC**	**Exp. No. 4 15% PCC**	**Exp. No. 5 20% PCC**	**Exp. No. 6 25% PCC**
Unsalted raw materials, kg/per 100kg							
Meat cutlet beef with the content of connective and adipose tissue 15%	54.0	51	46	41	51	46	41
Cutlet pork meat with a mass fraction of adipose tissue 30%	10.0	-	-	-	-	-	-
Cutlet lamb meat	-	-	-	-	10	10	10
Meat of broiler chickens of manual deboning	-	10	10	10	-	-	-
Wheat bread	12.0	-	-	-	-	-	-
Breadcrumbs	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Fresh peeled chopped onion	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Drinking water	18.0	18.0	18.0	18.0	18.0	18.0	18.0
PCC	-	15	20	25	15	20	25
Total	100	100	100	100	100	100	100
Materials and spices, g/100kg							
Food salt	900	900	900	900	900	900	900
Ground allspice	100	100	100	100	100	100	100

Note: Contr. – Control, Exp. – Experiment, PCC – protein-carbohydrate composition.

The samples' free and bound moisture amount was determined by differential scanning calorimetry (DSC) and thermogravimetry (TG). DSC is based on recording the thermal effects of transformations occurring in the test sample under conditions of programmed temperature exposure. Thermogravimetry makes it possible to establish the changes occurring in the product, including the loss of mass while increasing the temperature **[13]**. Software: NETZSCHProteus – Thermal Analysis. Heating program: heating from 25 °C to 200 °C at 2 °C/min. The data obtained were presented in the form of TG and DTG curves.

The microstructure of raw minced meat was determined by standard histological methods **[14]**, **[16]**. Minced meat samples were fixed in 10% neutral buffered (pH 7.0) formalin solution to determine microstructural features, followed by dehydration in alcohols and pouring into Histomix homogenized paraffin medium. To analyze the microstructure of the samples, sections were prepared with a thickness of 2-3 µm according to the generally accepted method, followed by staining with hematoxylin-eosin.

An organoleptic evaluation of minced meat semi-finished products was carried out. It was carried out on a 9-point hedonic scale, per ISO 8586-1 (1993) and ISO 8586-2 (2008), evaluated by a commission of 15 people. The commission included the staff of the department and students of the Almaty Technological University.

The mass fraction of moisture, protein, fat, carbohydrates, and ash in finished semi-finished products was determined according to standard methods **[14]**, and the energy value was determined by calculation.

Description of the experiment

Sample preparation: For the preparation of PCC, soy minced okara, chickpea flour, and whey protein concentrate WPC-80 were weighed, dosed in a ratio of 9:5:10, mixed to a homogeneous mass and hydrated in a ratio of 1:3 for 30 minutes at a temperature of 12 ±2 °C.

For the preparation of minced meat, chilled pork cutlet meat with a mass fraction of adipose tissue of 30%, beef cutlet meat with a mass fraction of connective and adipose tissue of 15%, lamb cutlet meat with a mass fraction of adipose tissue of 10%, meat of hand-boned broiler chickens were used. Meat raw materials were ground on a spinning top with a diameter of 2-3 mm grid holes. The raw meat was dosed according to the recipe (see Table 1), and prepared hydrated non-meat components were introduced: wheat bread in the case of a control sample, hydrated PCC in an amount of 15, 20 or 25% in the case of prototypes. Salt was used in dry form after sieving. Sliced bread was soaked in cold water and then crushed on a spinning top with a diameter of 2-3 mm grid holes. Breadcrumbs were previously sifted. Forming and breading of cutlets were carried out manually. The formed cutlets were fried until they reached culinary readiness.

Number of samples analyzed: One PCC sample, one control sample and six experimental samples of minced meat for cutlets with PCC in a dosage of 15 to 25%, one control sample of fried cutlets of culinary readiness and six experimental samples were analyzed

Number of repeated analyses: All measurements of instrument readings were performed two times.

Number of experiment replication: The number of repetitions of each experiment to determine one value was three times.

Design of the experiment: In the first stage, the functional technological properties of the control and test samples of minced meat for cutlets were determined, and the appearance of the semi-finished products before and after heat treatment and the consistency of the finished cutlets were evaluated. For the second stage, two modified recipes of semi-finished products were chosen: one with the replacement of pork and bread with broiler chicken meat and PCC, and the second with a replacement with lamb and PCC. For four samples (PCC, one control and two modified recipes of semi-finished products), the dependence of the conversion of PCC and cutlet masses on temperature was determined; the kinetics of dehydration of these samples, the mass ratio of water fractions according to the stages of dehydration. Then, the features of the microstructure of raw minced meat, the features of the chemical composition, the energy value, and the organoleptic characteristics of cutlets after heat treatment were determined.

Statistical Analysis

Statistical processing was performed in Microsoft Excel 2016 and Statistica 12.0 (USA). The accuracy of the obtained experimental data was determined by the Student's t-test with a confidence probability of no more than 0.05 with the number of parallel determinations of at least 3.

RESULTS AND DISCUSSION

In the technology of meat semi-finished products with additives of plant and animal origin, which are protein-carbohydrate complexes, an important role is played by the water-binding capacity, moisture-retaining capacity and fat-retaining capacity of minced meat **[17]**. Table 2 presents the results of determining the WBC, MRC and FRC of the control and experimental samples of minced meat. Full recipes for control and test samples of minced meat are listed in Table 1.

Table 2 Influence of the PCC dosage on the functional and technological properties of minced meat.

Sample	Mass fraction PCC, %	WBC, %	MRC, %	FRC, %
Control	0	60.81 ±0.29	85.18 ±0.38	50.47 ±0.22
Exp. 1	15	63.52 ±0.28	87.14 ±0.38	52.20 ±0.21
Exp. 2	20	62.23 ±0.24	86.55 ±0.37	51.65 ±0.23
Exp. 3	25	65.05 ±0.25	90.93 ±0.39	54.96 ±0.20
Exp. 4	15	60.24 ±0.26	85.88 ±0.38	51.62 ±0.23
Exp. 5	20	65.15 ±0.23	88.51 ±0.37	55.13 ±0.21
Exp. 6	25	61.18 ±0.29	82.05 ±0.39	49.79 ±0.20

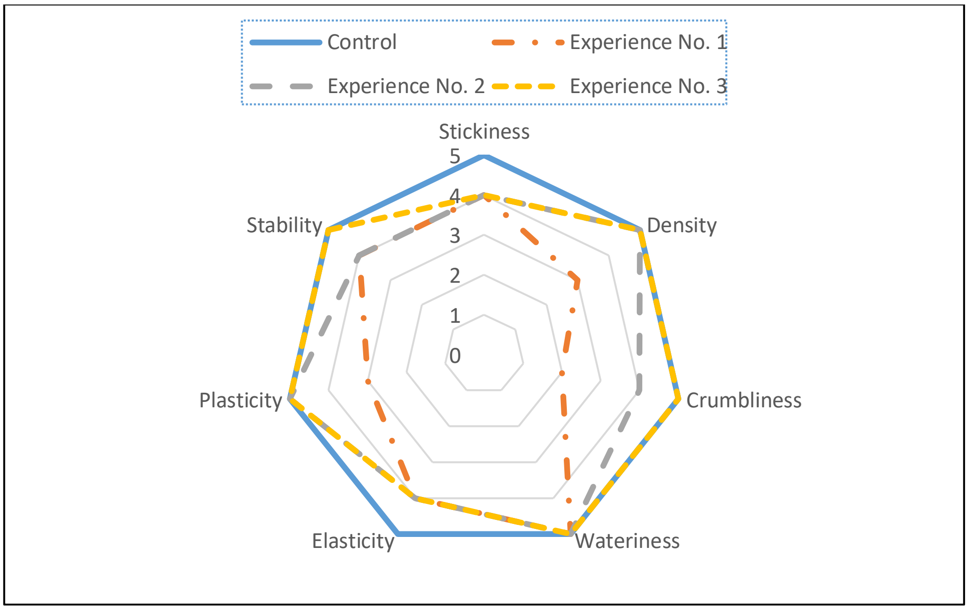
Note: Exp. – Experiment, PCC – protein-carbohydrate composition, WBC – water-binding capacity, MRC – moisture-retaining capacity, FRC – fat-retaining capacity

Water-holding capacity is characterised by water adsorption with the participation of hydrophilic amino acid residues, and fat-retaining capacity is characterized by fat adsorption due to hydrophobic residues. At low humidity, hydrophilic groups, interacting with water molecules, form a monomolecular layer **[17]**. In this regard, it is advisable to use PCC in a pre-hydrated form **[18]**. Okara, which we used as a PCC component, has a great potential for forming water-absorbing, water-binding, and fat-retaining properties of various food systems **[19]**. Polysaccharides represented by cellulose, hemicellulose, and lignin play an important role in forming a complex of functional and technological properties of soy okara **[20]**. This factor plays an important role in ensuring the dietary properties of products with its use, including for gero-dietary nutrition and the expansion of meat-based products, which is relevant for the Republic of Kazakhstan **[21]**, **[22]**. In addition, the okara carbohydrate complex can be positioned as dietary fibers that positively affect meat systems' functional and technological properties **[23]**. The protein-carbohydrate complex of chickpea flour also contributes to forming the functional and technological properties of PCC and minced meat with its use **[4]**. The effectiveness of using chickpea flour instead of beef to improve the consumer and protective properties of minced meat semi-finished products has been confirmed **[24]**. At the same time, the optimal dose of the inclusion of chickpea flour in the recipe of minced meat semi-finished products from beef indicated in **[24]** is consistent with the dosage of chickpea flour added to the recipes of similar semi-finished products when combining beef with poultry meat or lamb. Protein's high water retention capacity in meat products increases yield, extends shelf life, and improves texture **[17]**. An additional effect in forming the functional and technological properties of PCC and minced meat with its use is achieved due to WPC-80, which consists mainly of whey proteins **[25]**. The study of the influence of PCC on the functional and technological properties of recipe compositions of cutlets showed that the best indicators of functional and technological properties are recipe No. 3 (beef + poultry meat + 25% PCC) and recipe No. 5 (beef + lamb + 20% PCC).

Introducing a protein-carbohydrate composition into minced meat leads to the stabilization of meat coagulation structures, as was shown by combining a meat food system with buckwheat **[26]**. A strong, elastic, heat-resistant membrane is formed that protects fat globules and does not lead to any change even when heated **[27]**. A further increase in the amount of the protein-carbohydrate composition to 25% leads to a slight decrease in the values of the WBC, MRC, and FRC indicators relative to the maximum, and therefore, an increase in the mass fraction of PCC to increase these indicators is inappropriate **[28]**. As a result, we can conclude that creating a recipe for minced semi-finished meat products using a protein-carbohydrate composition of 20% makes it possible to obtain a product with high functional and technological properties **[29]**. In addition to functional and technological properties, the organoleptic characteristics of semi-finished products were evaluated: appearance before and after heat treatment, as well as consistency, since the organoleptic assessment of the consistency of cutlets is an important criterion when choosing the ratio of components in the recipe **[30]**. Sensory evaluation plays an important role in the consumer's acceptance of PCC in semi-finished meat products, other meat products, as well as vegetable analogues of meat **[31]**. The consistency of cutlets was assessed according to a previously developed scoring scale, taking into account the recommendations **[32]**. The profilograms of the consistency of the samples corresponding to the scoring are shown in Figure 2. As shown in Figure 2, prototypes No. 2 and No. 6 received the lowest scores in terms of crumbling, elasticity and density. The ratings of prototypes No. 3 and No. 5 almost completely coincide with the ratings of the control sample. Such consistency indicators received the highest marks for these samples as density, water content, elasticity, plasticity, and dimensional stability **[33]**. It has been established that the inclusion of PCC in minced meat in an amount of 20-25% for different samples makes it possible to obtain semi-finished products with high organoleptic characteristics due to the high water-holding capacity of PCC, which includes soy minced okara. The products are juicy, retain their shape well, and are characterized by a non-crushed texture **[33]**.

For a comparative assessment of hydration characteristics during heating, four samples were selected at the second stage of research: PCC at hydration 1:3; a control sample of minced meat, and modified recipes for cutlets No. 3 and No. 5. Samples No. 3 and No. 5 were selected based on the totality of the assessment of functional and technological properties and profilograms of the consistency of the samples presented in Figure 3.

Controlled hydration processes play an important role in the technology of food products from raw materials of animal origin **[34]**. It is equally important to know the regularities of the processes of dehydration of raw materials of animal origin and products of their processing under conditions of programmed heating since this allows simulation of key technological processes and simulation of their parameters that affect both the consumer properties of the products produced and the technical and economic indicators of production **[35]**. Thermogravimetry makes it possible to establish the changes occurring in the product, including the loss of mass while increasing the temperature **[36]**.



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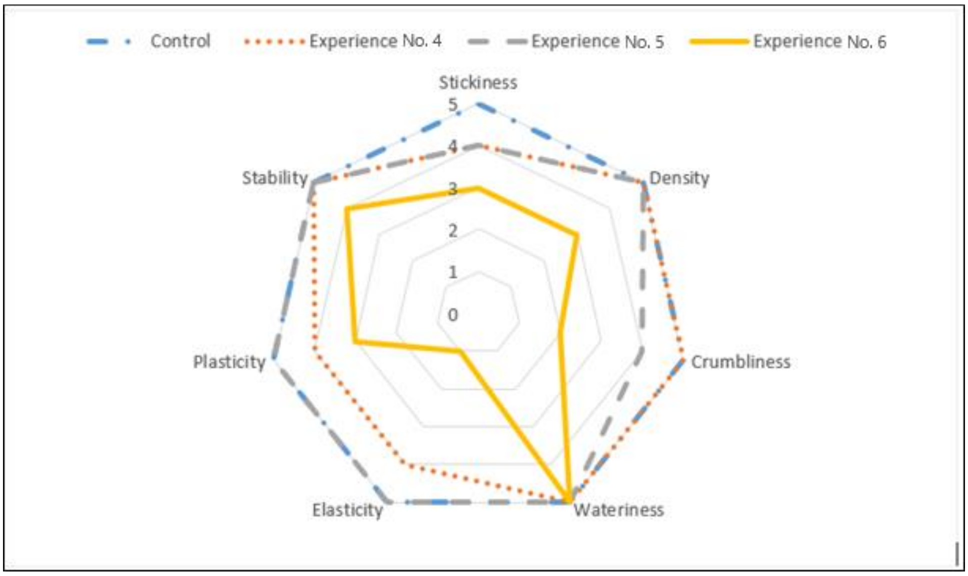
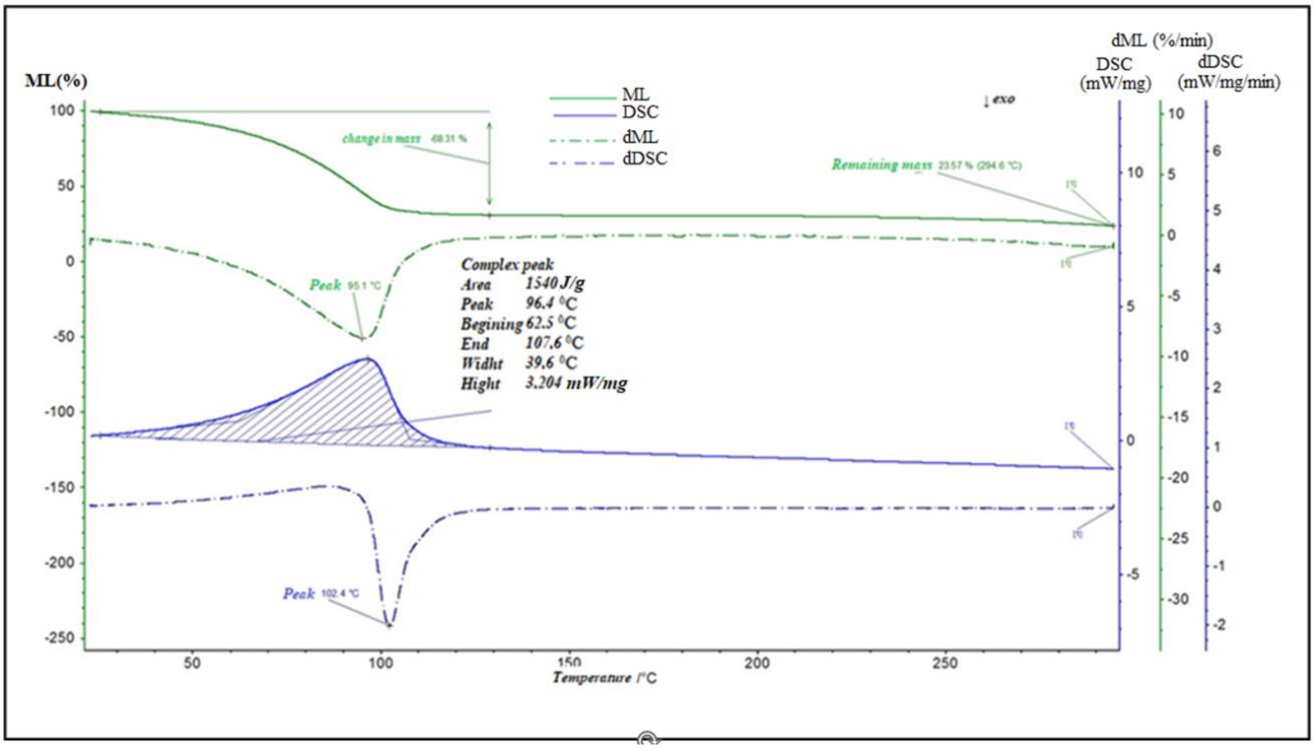


b

Figure 2 Profilograms of the consistency of the control and experimental samples. Note: composition cutlets: a – beef + poultry + PCC; b – beef + lamb + PCC; PCC – protein-carbohydrate composition.

Concentrated mostly in tissue cells, water is in a free and bound state. The mass fraction of water, or rather the ratio of its free and bound forms, is one of the most important characteristics of the product, affecting the structure, consistency and microbiological parameters **[37]**.

The primary information obtained from the synchronous thermal analysis device of the STA 449 F3 Jupiter model is presented in the form of curves of mass loss (ML), the rate of mass loss (dML), differential scanning calorimetry thermoanalytical curve (DSC) i.e. heat flow curve and the rate of change of heat flow curve (dDSC) in Figure 3 and Figure 4.



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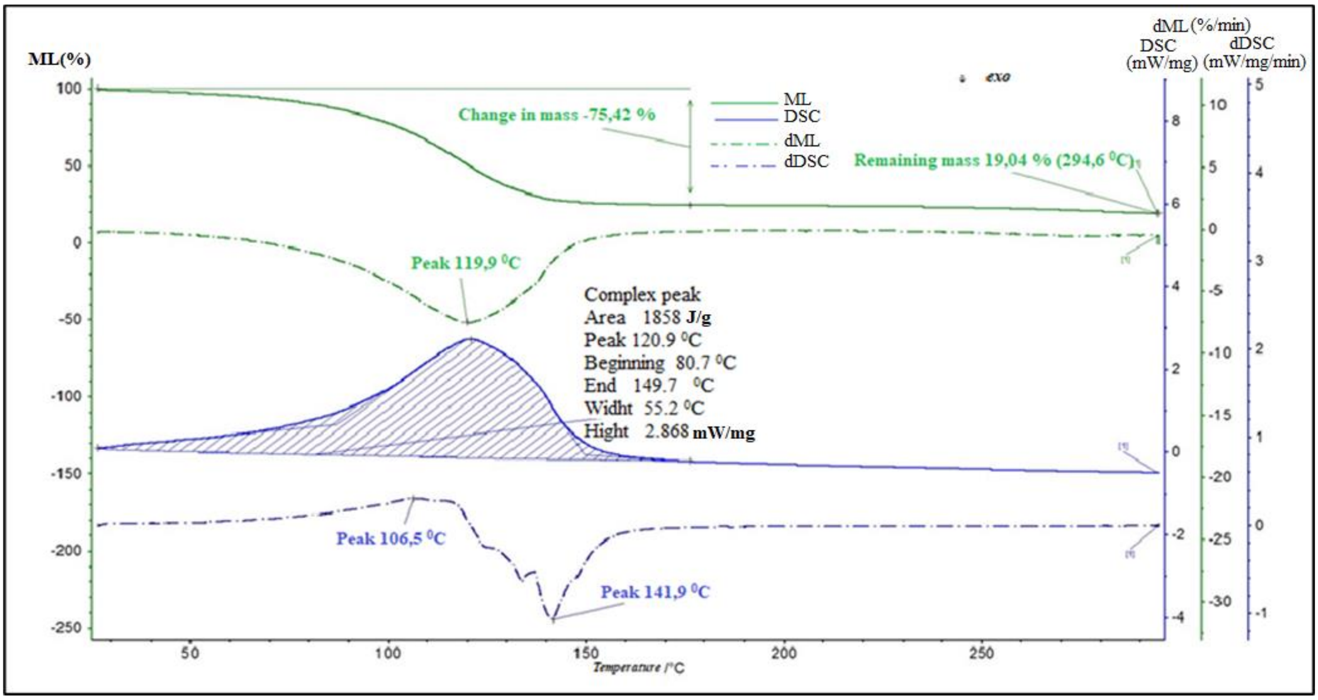


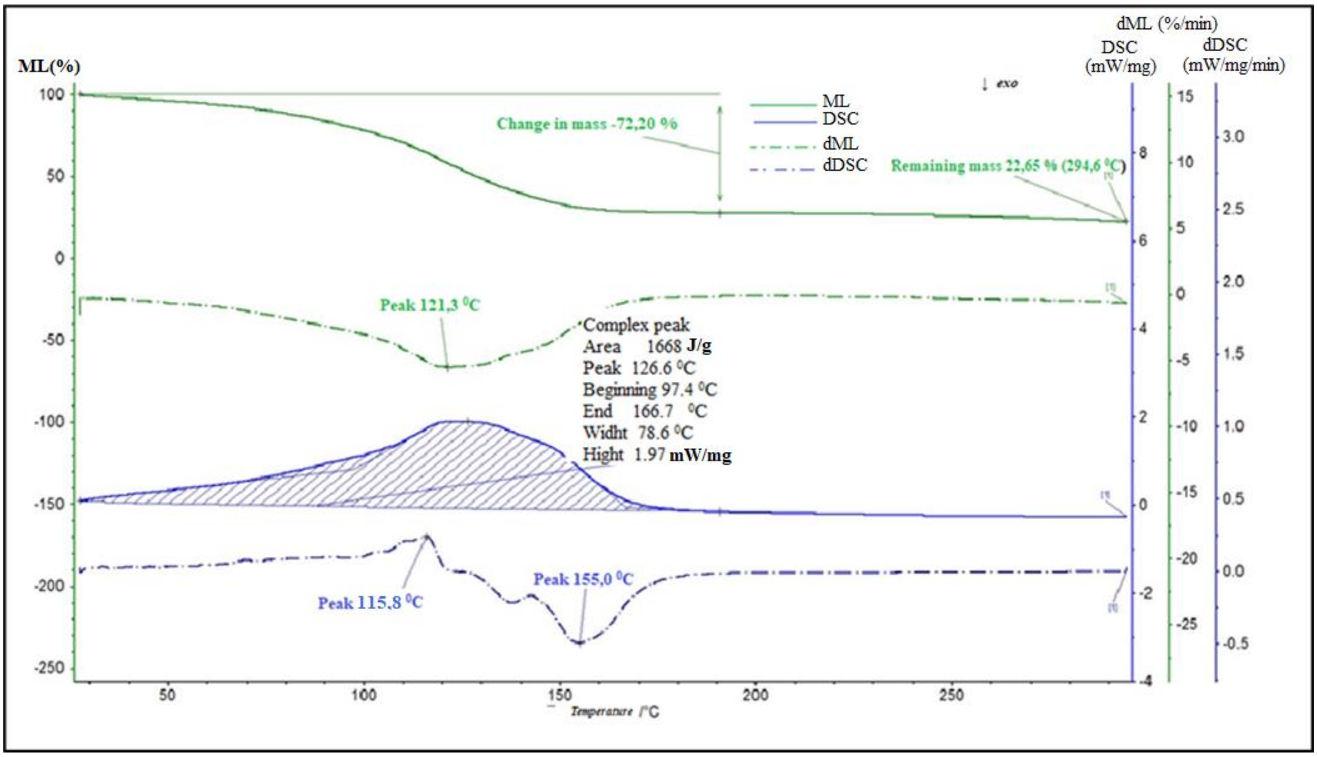
b

Figure 3 Thermograms for samples: a – PCC; b – control (pork cutlets). Note: PCC – protein-carbohydrate composition; ML – mass loss; dML – rate of mass loss; DSC – Differential scanning calorimetry; dDSC – rate of change of heat flow.

The result of the temperature effect exerted on the samples was a monotonous decrease in their mass, a significant loss observed from a temperature of 30 °C and ended at 120 °C. Further temperature effect does not have a significant effect on the weight of the samples.

Following the DSC method for biological objects **[13]**, to quantify kinetically unequal molecules according to the obtained curves, the plot of mass change is converted into the dependence of the degree of substance conversion α on temperature (Figure 6).

The TG curve obtained in α-T coordinates has an S-shaped form, reflecting the complex nature of the interaction of water and dry substances of the samples and suggests differences in the rate of dehydration in different sections of the curve. For a more visual range of dehydration temperatures, a graphical dependence (-logα) on the value of 1000/T is plotted (Figure 7).



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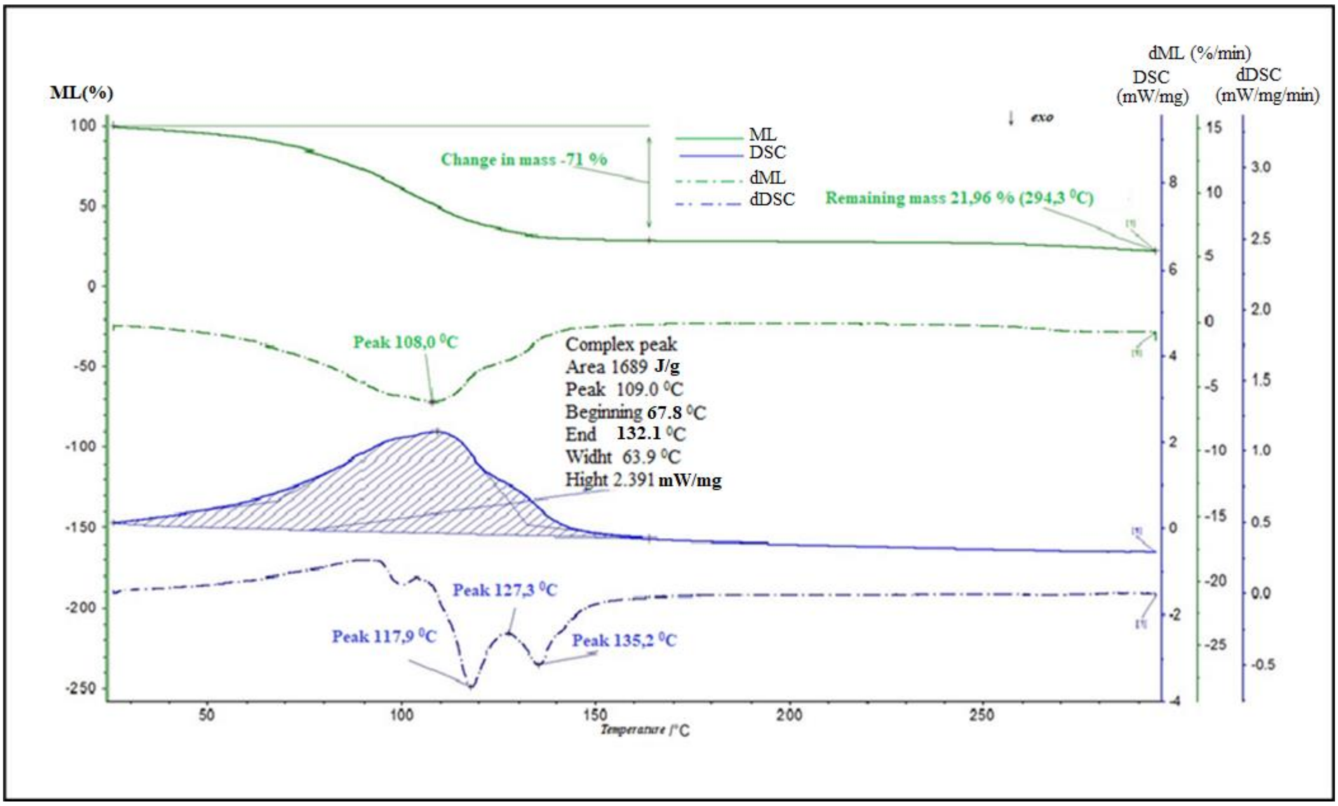

b

Figure 4 Thermograms for samples: a – Expt.3; b – Expt.5. Note: Expt - experiment; ML – mass loss; dML – rate of mass loss; DSC – differential scanning calorimetry (heat flow); dDSC – rate of change of heat flow.

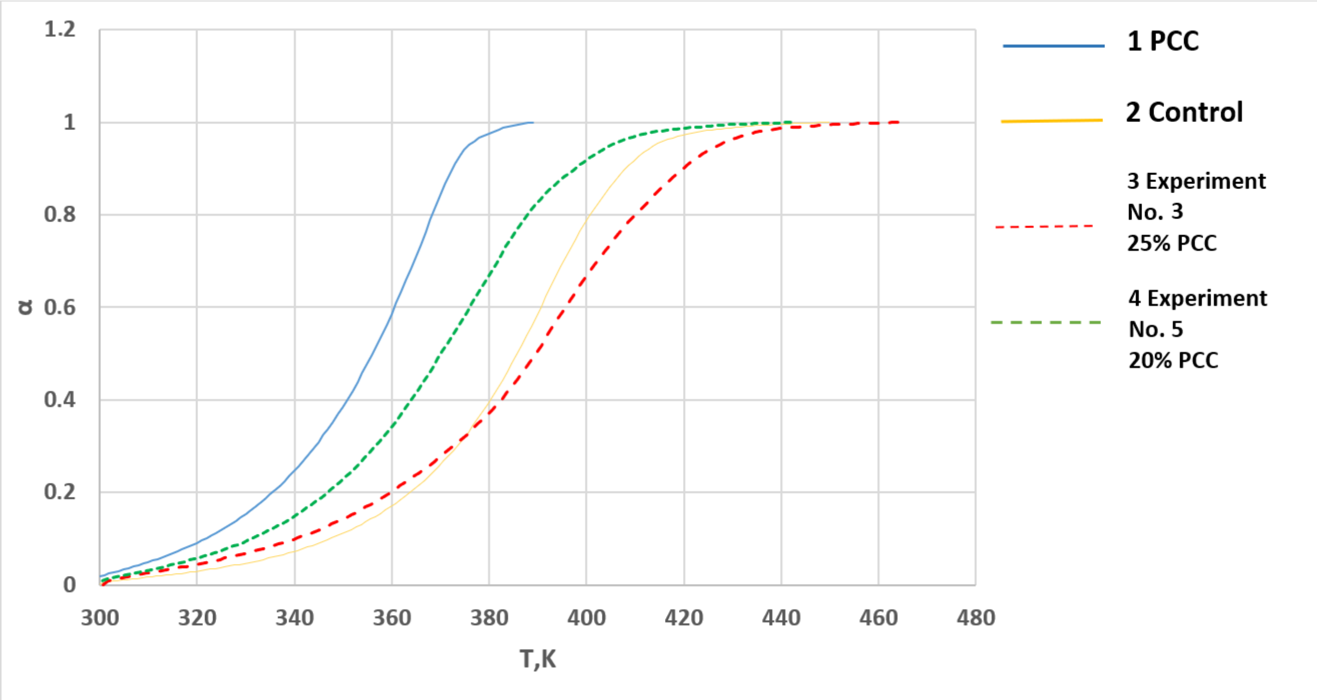

Figure 5 Dependence of substance transformation (α) on temperature (T). Note: PCC – protein-carbohydrate composition.

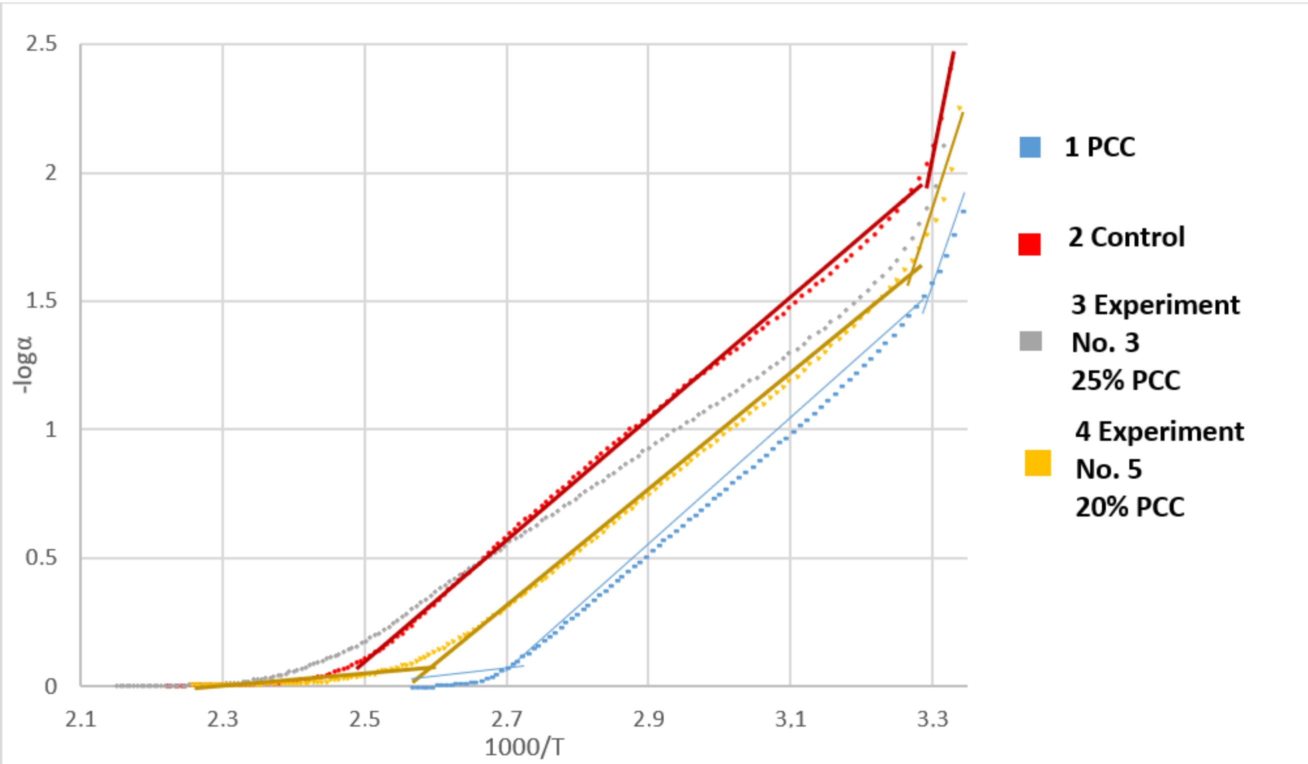

Figure 6 Dependence (-log α) on the value of 1000/T during heating of the studied samples. Note: PCC – protein-carbohydrate composition; α - range of the degree of substance conversion.

In the first section of the curve, heating and release of the first water fraction occurs – water contained in voids and capillaries. In the second section, the removal of the second water fraction begins, and when the first and second fractions are removed, a single pattern is observed.

The moisture removal rate from samples is proportional to the increase in temperature. In the third section, the dehydration rate decreases regardless of the increase in temperature. This demonstrates a significant difference in the binding energy of the third water fraction from the first and second. The removal of the first and second water fractions from samples 1 and 4 (PCC) and the recipe modified with minced lamb is carried out at a lower temperature effect; this is due to the looser spatial structure of the samples.

Table 3 Dehydration kinetics of samples.

Sample	Dehydration stage	Δ T, K	Δ t, °C	Δ α, %	Mass fraction of removed water, %
PCC	I	295-304	22-31	0-3	2.9
	II	304-367	31-94	3-76.2	73.5
	III	367-389	94-116	76.2-100	23.6
Control	I	295-305	22-32	0-1.2	1.3
	II	305-399	32-126	1.2-78.2	76.9
	III	399-450	126-177	78.2-100	21.8
Experiment No. 3	I	300-307	27-34	0-2.2	2.5
	II	307-410	34-137	2.2-80	78.4
	III	410-465	137-192	80-100	24.1
Experiment No. 5	I	298-305	25-32	0-2.2	2.4
	II	305-385	32-112	2.2-76.4	74
	III	385-442	112-169	76.4-100	23.6

Note: PCC – protein-carbohydrate composition; Δ T – temperature range in degrees Kelvin; Δ t – temperature change interval in degrees Celsius; Δ α – substance conversion range

Data on the kinetics of dehydration of the studied samples are presented in Table 3. The information available in the literature and the methods used for evaluation suggest that the first and second water fractions correspond to physically and mechanically bound moisture, which has a low binding energy with the sample, and osmotically bound moisture, respectively **[38]**. In this regard, the evaporation of these fractions is quite active. The third water fraction corresponds to adsorption-bound moisture, as a result of which the partial removal of this fraction proceeds slowly. The presence of simple sugars and disaccharides in the composition of PCC allows, similarly to lactose in the case of UV concentrates of cheese whey, to increase the hydration of proteins through non-covalent interaction with water and protein molecules by hydrogen bonds **[39]**.

Thus, the studied samples (PCC, minced meat semi-finished products with poultry meat, minced meat semi-finished products with lamb) are characterized by close values of the mass ratio of water fractions at three stages of dehydration (Figure 7).

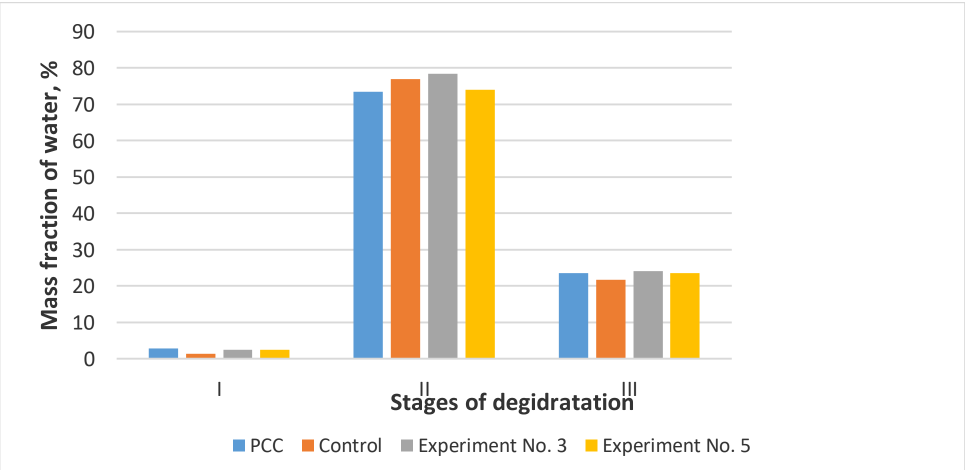

Figure 7 Distribution of removed water by dehydration stages during heating of samples of PCC and minced meat. Note: PCC – protein-carbohydrate composition.

The highest level of energy characteristics of the connection of water fractions with biopolymers of tissue structures of semi-finished products has a sample of chopped meat semi-finished products No. 3 with a recipe modified with poultry meat and PCC. In terms of the mass content of the third fraction, samples No. 3 and 4, prepared according to modified recipes, are superior to the control sample.

At the next stage of the work, a comparative assessment of the microstructure of the combined meat and vegetable minced meat was carried out using protein-carbohydrate raw materials as an objective criterion for assessing the quality of the combined minced meat.

In the control sample of minced meat (Figure 8), scattered muscle particles of various sizes are observed, and connective tissue in different fields of view is visible. The found areas of muscle tissue are fragmented in places, nuclei and transverse striation are absent **[40]**. In some areas, muscle fibers merge into a continuous conglomerate. In the connective tissue, collagen fibers are loosened, partially fragmented.

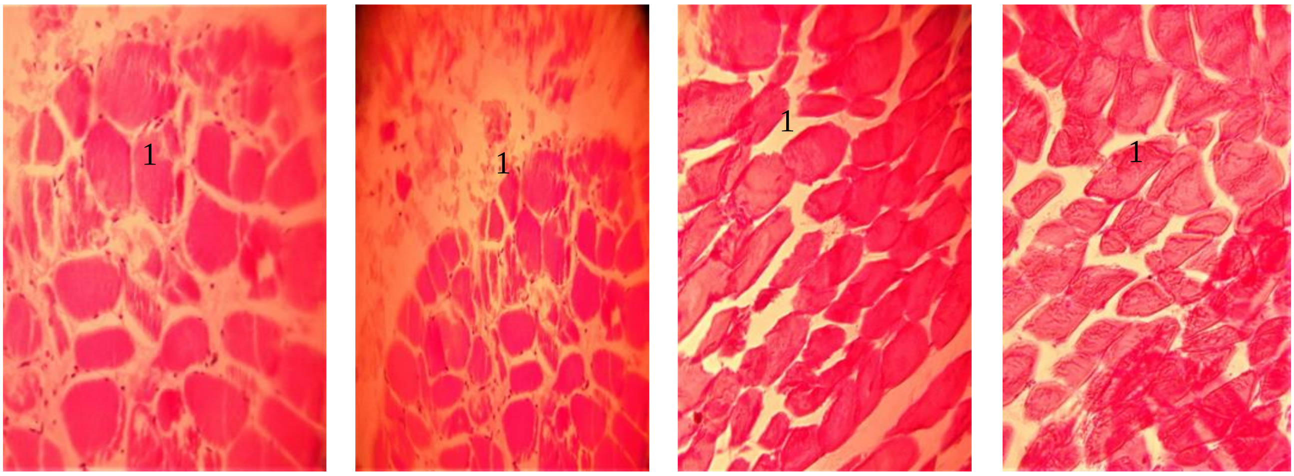

Figure 8 Minced meat (control) histoarchitectonics in different fields of view: 1 – muscle tissue; increased ×400.

The presence of PCC is determined during the visual assessment of histological preparations of minced meat according to modified recipes (Figures 9-10). Okara particles in PCC consist of rounded cells stained in shades of dark pink, surrounded by a narrow, even non-staining lumen.

The particles of the protein-carbohydrate component are evenly distributed between the muscle fibers in minced meat, similarly to the particles of cedar cake **[6]**. The results are consistent with the data of a microscopic study of improved chopped semi-finished meat products through white lupine flour and elecampane root powder **[41]**.

The microstructural characteristics of minced meat systems correlate with other indicators, for example, hydration properties together with the corresponding forms of moisture bonding, which makes it possible to predict the functional and technological properties and behavior of minced meat under conditions corresponding to the technological processing modes in the production of minced meat semi-finished products.

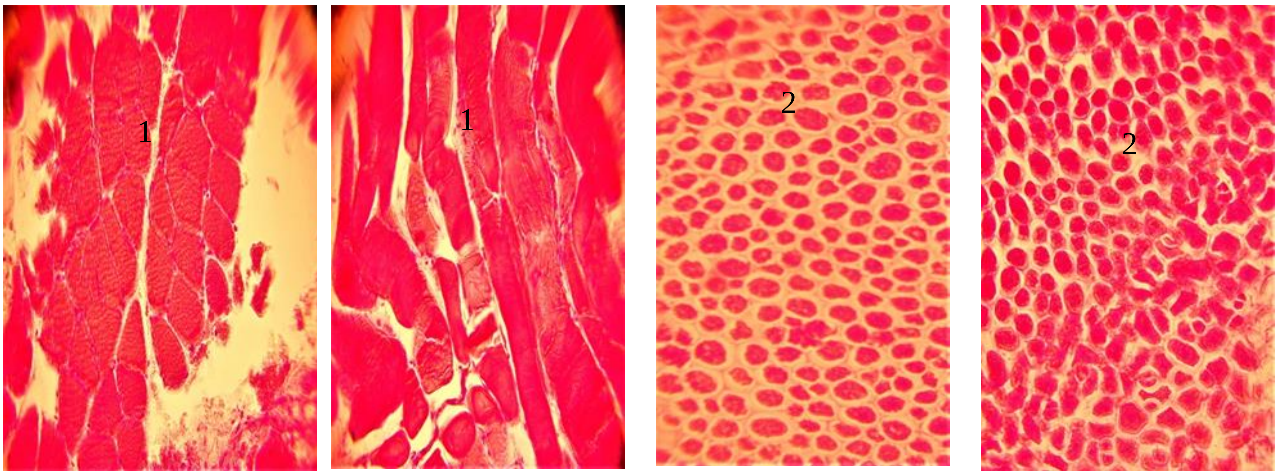

Figure 9 Minced meat histoarchitectonics (beef + lamb + 20% PCC): 1 – muscle tissue, 2 – vegetable protein-carbohydrate component; increased ×400.

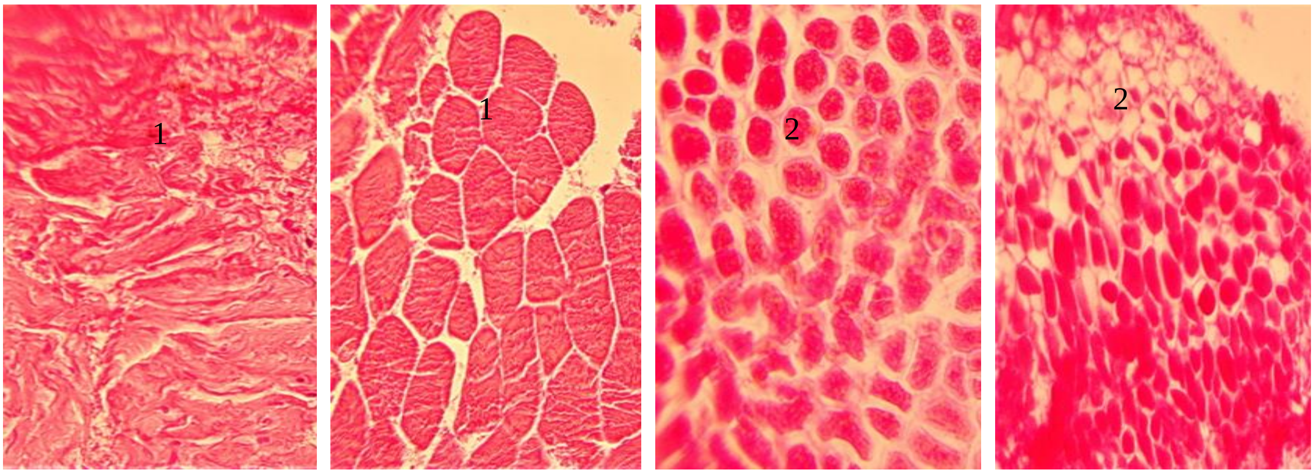

Figure 10 Minced meat histoarchitectonics (beef + broiler meat + 25% PCC): 1 – muscle tissue, 2 – vegetable protein-carbohydrate component; increased ×400.

Products correspond to the traditional organoleptic indicators for chopped cutlets: the shape is rounded-flattened, the surface is evenly covered with breadcrumbs, without torn and broken edges. Minced meat is evenly mixed without visible inclusions of PCC components. Prototypes of cutlets retain moisture well during thermal processing. A comparative assessment of indicators of nutritional and energy value of PCC, as well as semi-finished products obtained according to the control and modified recipes, is presented in Table 4.

Table 4 Indicators of nutritional and energy value of PCC and meat minced semi-finished products.

Sample	Mass fraction, %					Energy value of 100 g of product	
	fat	protein	carbohydrates	water	ash	kcal	kJ
PCC	4.2	38.9	5.5	50.4	0.97	209.3	876.5
Control	12.6	13.8	7.5	66.1	1.5	179.9	753.3
Experiment No. 3	9.5	19.8	2.8	66.92	0.98	175.13	733.29
Experiment No. 5	9.7	19.1	2.5	67.5	1.2	187.84	786.50

Note: PCC – protein-carbohydrate composition.

The sample in experience No. 3 was more juicy than the control sample. The sample in experiment No. 5 also had excellent juiciness, while the experimental samples had a delicate texture and were distinguished by a reduced mass fraction of fat compared to the control: 5,3% less fat in experiment No. 5 and 6% less fat in experiment No. 3.

The results can be used in developing recipe-component solutions for food modules concerning the technology of minced meat semi-finished products, which ensure the preservation of water fractions in the composition of meat products during heat treatment. The expected technical and economic effect is associated with an increase in the degree of use of vegetable raw materials in the production of chopped semi-finished meat products in the main production, an expansion of the range of enriched food products due to natural raw materials, and an increase in the sustainability of the raw material base of meat processing enterprises.

CONCLUSION

It has been established that the protein-carbohydrate composition of the composition: soy minced okara - chickpea flour - whey protein concentrate (WPC 80) in a ratio of 9:5:10, with hydration 1:3, has a positive effect on the functional and technological properties of minced meat for chopped semi-finished products. Modified recipes for cutlets have been developed with the composition, kg per 100 kg: kg/100 kg: beef cutlet meat – 41; meat of hand-boned broiler chickens – 10; PCC – 25; cutlet beef meat – 46; minced lamb – 10; PCC – 20. It has been shown that the developed PCC can serve as a substitute for minced meat not only in terms of the balance of the amino acid composition of the total protein but also in terms of the percentage of moisture with different forms of communication with the product, influencing the microstructure and consistency of raw semi-finished products of the combined composition, the consistency and juiciness of fried cutlets. According to the developed recipes, the mass fraction of protein in cutlets increased from 13.8 to 19.1-19.8%; fat decreased from 12.6 to 9.5-9.7%, with a corresponding decrease in the energy value of products. The development of food modules using protein-carbohydrate compositions as raw materials with a high degree of resource security and potential availability to deterministic groups of consumers needing correction of food rations by amino acid composition, dietary fibers, etc. has a perspective.

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Funds:

This work was not supported by external grants.

Acknowledgments:

The research using the device of simultaneous thermal analysis STA 449 F3 Jupiter was conducted in the common use center laboratory "Control and Management of Energy Efficient Projects" at Federal State Budget Educational Institution of Higher Education «Voronezh State University of Engineering Technologies».

Conflict of Interest:

No potential conflict of interest was reported by the author(s).

Ethical Statement:

This article does not contain any studies that would require an ethical statement.

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