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Dietary fibres in preventative meat products

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Abstract: This paper is based on literature and our own studies of high-quality dietary fibres of various types, as well as food materials and products. It provides data on the physiological features, functional and technological properties of dietary fibre, as well as its main uses in food technology. In particular, we assessed the texture of dietary fibre, constructed rheograms for the flow of fibre-water systems, and analysed the histological structure. Our results form a scientific basis for the development of safe meat products of high quality and healthy diets. We established specific structural characteristics, properties, and rheological behaviour of various dietary fibres, as well as their advantages. We found that potato fibres demonstrated greater uniformity in texture and rheology, compared to wheat fibres. Wheat fibres had a clear phase structure (fibre/water), whereas potato fibres showed significant hydrophilic and structuring properties, attributing them to colloidal fibres. The established patterns contribute to the rational selection of dietary fibre to create products with desired properties. In particular, we developed a technology for a restructured poultry product with preventative properties using soluble and insoluble dietary fibres. The paper provides data on the product's safety indicators, nutritional and biological values, as well as functional, technological, microbiological, and other properties. We also conducted microstructural studies to analyse the uniformity of distribution of the curing mixture in the developed meat product. We concluded that using potato and wheat fibres can expand the range of meat products in line with the concepts of rational and healthy nutrition, as well as increase the product's succulence and prevent syneresis and mass loss.

Keywords: Dietary fibre, diet, rheogram, histological structure, food, poultry

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INTRODUCTION

Nutrition is a vital element of human interaction with the environment that has a decisive influence on human health, performance, and resistance to harmful effects of production and environmental factors. A regular diet of nutritious foods containing vital substances is particularly important for maintaining human health and activity in old age.

Nutrition issues are a major physiological and hygienic problem. Studies have shown a recent decrease in the consumption of meat, dairy, and fish products, as well as fresh vegetables and fruits among certain groups of Russian population. Another negative fact is a decline in energy intake from food (91%), especially due to a reduced amount of animal proteins in the diet. Moreover, certain groups consume only 55–60% of the recommended content of vitamins* [1–3].

The importance of enriching foods with various substances for health improvement purposes is specified in the Decree of the RF Government No. 1134-r of June 30, 2012 (amended on February 6, 2014) 'On approving

* MR 2.3.1.2432-08. Normy fiziologicheskikh potrebnostey v ehnergii i pishchevykh veshchestvakh dlya razlichnykh grupp naseleniya Rossiyskoy Federatsii [Methodological Guidelines 2.3.1.2432-08. The norms of physiological requirements for energy and nutrients for various population groups in the Russian Federation]. Moscow: Federal Center for Hygiene and Epidemiology of Rospotrebnadzor; 2009. 36 p.

** Rasporyazhenie Pravitel'stva RF №1134-r ot 30.06.2012 (red. ot 06.02.2014) 'Ob utverzhdenii plana meropriyatiy po realizatsii osnov gosudarstvennoy politiki Rossiyskoy Federatsii v oblasti zdorovogo pitaniya naseleniya na period do 2020 goda' [Decree of the RF Government No. 1134-r of June 30, 2012 (amended on February 6, 2014) 'On approving an action plan to implement the principles of the Russian Federation state policy in the field of healthy nutrition for the period until 2020']. 2012.

an action plan to implement the principles of the Russian Federation state policy in the field of healthy nutrition for the period until 2020'**.

Meat works are forced to use polysaccharide structure-forming agents, such as carob bean gum, carrageenans or alginates to improve food consistency and increase not only the output, but also economic indicators. This raises the price and adds more E numbers on the food labels, which is negatively perceived by the consumer [4].

Current trends in healthy nutrition demonstrate a need for low energy meat products with a minimum fat content, higher protein content, and special substances that improve digestion, absorption, and metabolism [5–7].

Modern scientific aspects of physiology and biochemistry encourage food experts and manufacturers to change requirements for food production. They develop new formulations and adjust the amount of nutrients and fibres in accordance with a person's physiological and professional status, as well as climatic and social living conditions.

Dietary fibres are increasingly used not only in the production of specialised foods, but also products of mass consumption. The reasons for their popularity include improved gastrointestinal motility (according to Ugolev's theory of adequate nutrition), minimum energy value, the ability to bind moisture and fat (taking into account a large amount of refined foods in the diet), structural variety, and safety of use [8, 9].

The daily intake of dietary fibre is 25–35 g. Today, nutritionists recommend increasing this amount to 40–42 g per day. Recent studies have found a decrease in daily fibre intake in many countries. It was revealed that Russian population consumes only 30–35% of the recommended amount of dietary fibre, mostly from wholemeal flour and grain. Even 30 years ago, vegetables and fruits were an integral part of Russian diet. They are immensely rich in cellulose and therefore have a balanced amount of soluble and insoluble fibres [10]. Nutritionists recommend a 3:1 ratio of those, respectively [11].

Numerous studies have proven that a deficiency in dietary fibre causes a risk of developing various diseases, including irritable bowel syndrome, hypomotor colon dyskinesia, intestinal diverticulosis, and even colon and rectal cancer. Annually, about half a million malignant tumours in the large intestine are diagnosed worldwide, 35% of which are rectal cancer. Rectal cancer comes 6th or 7th on the list of all malignant tumours [12, 13].

A connection was established between a consumption of smoked or fried foods and a risk of rectal cancer. Carcinogens (benzopyrene) that form during such types of heat treatment cause point mutations and translocations. As a result, cellular pro-oncogenes are turned into active oncogenes which contribute to the initial synthesis of oncoproteins and the transformation of a healthy cell to a cancerous cell [13]. Scientists believe that dietary fibre, when passing through the gastrointestinal tract, adsorbs water, thereby increasing the amount of faeces. As a result, faeces move faster through the intestines, reducing the risk of colon cancer [14]. In addition, a low energy value of dietary fibre and the feeling of fullness that it induces help people to control their appetite. Ballast substances contribute to the production of insulin, which affects blood sugar.

Comprehensive studies have found that dietary fibre in functional foods affects digestion processes in the gastrointestinal tract, including symbiont digestion. In particular, it improves clinical and metabolic parameters by normalising the functional activity of the intestinal microbiota. Also, it benefits the anthropometric parameters helping to reduce body weight and waist circumference. Therefore, dietary fibre can be used in the treatment and prevention of obesity [15, 16].

Thus, dietary fibre reduces the incidence of atherosclerosis, obesity, diabetes, metabolic syndrome, varicose veins, venous thrombosis of the lower extremities, etc. [17]. In addition, dietary fibre maintains a water-salt balance in the body, contributing to the prevention of gallstone disease, and is a nutritious medium for beneficial intestinal microflora [18, 19].

Until recently, ballast substances contained in vegetables and fruits were considered the main sources of dietary fibre. However, collagen, especially its fractions obtained by various methods, is just as good functionally as its plant analogues. This means that protein hydrolysates and composites can also be regarded as fibrous, anisotropic, three-dimensional food systems [20–22]. In the growing agricultural sector, there is a need for improving the production of hydrolysates and concentrates of various biopolymers (polysaccharides, proteins, etc.).

An important factor is that nanoclusters (for example, in cellulose) are highly likely to preserve various biologically active substances, which ensures their safety in the further cycle of food production [23].

A number of studies have shown that animal analogues of dietary fibres (in particular, modified collagen and ichthys collagen) can be used as a matrix base. For example, a study was conducted to determine the sorption properties of collagen fermentolisate in relation to heavy metals, using Cd^{2+} and Pb^{2+} ions. The study found that the biomodified connective tissue protein showed a similar ability to bind Pb^{2+} ions to that of cellulose, for which the sorption range was 0.10−0.23 mg/g [24]. Thus, hydrolysed forms of collagen are able to bind heavy metal ions in the digestive tract to form insoluble complexes that are excreted from the body without being absorbed. This mechanism can be used in the prevention of heavy metal salt poisoning.

Of scientific interest is also the process of joint sorption of several protein components and bioactive substances. A systematic study of the sequential and joint sorption of several binary protein mixtures and some bioactive substances (for example, ion-exchange components of plant origin such as ascorbic acid or iodine) showed that the binding process was complicated by synergistic phenomena. Such phenomena were promoted by the strong binding of protein to individual components of various nature, which can be determined as the number of fixed ionogenic groups of the sorbent on one protein molecule. A decreased local concentration of ionogenic groups of plant-based bioactive components contributes to the transition to a synergistic mechanism of competitive sorption. Such sorption of bioactive substances on a collagen-based matrix can preserve up to 70% of organic components such as ascorbic acid or iodine that are easily destroyed by heat treatment [25].

We should note that the mechanism of such sorption has not been established yet. However, we know that all proteins have a pronounced ability of non-specific binding to SH groups, the guanidine group of arginine, and other amino acid components. It is possible that the biomodification of connective tissue contributes to the breakdown of peptide chains of collagen. As a result, the previously mentioned functional groups become more accessible for interaction with metals and biologically active substances [26].

Thus, the connective tissue modified by chemical, physical or biological methods is a highly active sorbent for heavy metals and biologically active substances. It therefore has a potential of being used as a functional additive in the production of foods, particularly meat products [24–27].

An important issue in the context of dietary fibre physiological properties is the consumer's attitude to functional components in food production. An online survey among young respondents using Google services demonstrated a positive response to functional ingredients, in particular to dietary fibre, if the necessary information is given on the packaging [28].

However, consumers are concerned about the safety of certain ingredients. According to GRAS, refined wheat, oat, corn, and other dietary fibres are safe to use.

Most studies, both in Russia and abroad, have focused on stabilising systems based on hydrocolloids and composites containing several components, for example, polysaccharide and protein composites, etc. Noteworthily, hydrocolloids can be produced by various methods: chemical, physical, biological, etc [4]. In addition, genetic modification is now used in crop breeding to accelerate the production of target products. However, it is extremely undesirable, especially in terms of consumer demand [28].

The technological aspects of using fibrous food systems or compositions require a study of their rheological properties, including viscosity, emulsifying ability, colloidal and molecular features, as well as hydration characteristics of imported and domestic

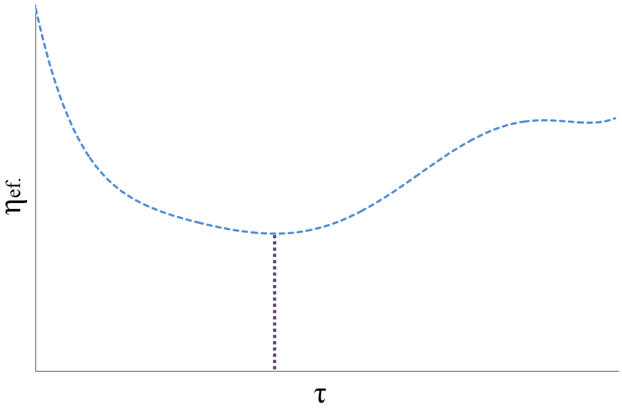


Figure 1 Rheogram for CMC solution

additives for better development of formulations and processes [29, 30].

For example, a solution of carboxymethyl cellulose (CMC) from the group of colloidal fibres is characterised by a thixotropic flow with a decrease in viscosity at constant load and a rather significant increase in effective viscosity after unloading [4], as shown in Fig. 1.

In connection with the above, we aimed to study the rheological and microstructural properties of various types of dietary fibre that contribute to a jelly-like structure with similar mechanical and sensory properties to those of food raw materials, for their further joint use in the development of restructured poultry products.

STUDY OBJECTS AND METHODS

This study used dietary fibres of various SuperCel groups (manufactured by J. Rettenmaier & Soehne GmbH & Co. KG, Germany and supplied by Rettenmaier Rus), namely:

– insoluble: WF 200 R, WF 300 R, WF 400 R, and WF 600 R wheat fibres;
– semi-soluble: KF 200 and KF 500 potato fibres; and
– soluble: psyllium P 95.

Nutritional value indicators were determined as follows:

– moisture mass fraction: according to State Standard R 51479-99***;
– protein mass fraction: on a semi-automatic Tecator Kjeltec System 1002;
– fat mass fraction: according to State Standard 23042-2015****;
– ash mass fraction: according to State Standard R 53642-2009*****; and
– carbohydrates mass fraction: by the computational method.

The digestibility of *in vitro* proteins was examined using the Pokrovsky-Ertanov method and a modified device. The degree of dietary fibre hydration was

*** State Standard R 51479-99. Meat and meat products. Method for determination of moisture content. Moscow: Standartinform; 2010. 4 p.
**** State Standard 23042-2015. Meat and meat products. Methods of fat determination. Moscow: Standartinform; 2016. 9 p.
***** State Standard R 53642-2009. Meat and meat products. Determination of total ash. Moscow: Standartinform; 2010. 8 p.

Table 1 Technological properties of SuperCel fibres

Type of fibre	Grade	Average fibre length, μm	Average fibre thickness, μm	Degree of hydration	Water binding capacity, g water/g	Fat absorption, g fat/g	Bulk weight, g/dm^3
Insoluble: wheat	WF 200 R	250	25	1:8	8.3	6.9	72–98
	WF 300 R	350	25	1:9	9.2	7.3	58–80
	WF 400 R	500	25	1:10	10.5	11	37.5–62.5
	WF 600 R	80	20	1:5	4.2-5.5	3.7	200–240
Semi-soluble: potato	KF 200	200-350	–	1:8	15	–	250–400
	KF 500	400–1000	–	1:8	15	–	80–250
Soluble: psyllium	P95	250	–	1:25	20	–	170

determined visually. The Lipatov Jr. method was used to measure the water holding capacity of meat samples.

Structural and mechanical properties of meat products, namely shear stress and cutting work, were determined on an Instron-1140 testing machine using a Kramer shear press.

Microbiological tests and product safety studies were conducted in accordance with Technical Regulations of the Customs Union 021/2011******, 034/2013*******, and Methodological Guidelines 4.2.2747-10********.

Sensory tests were guided by ISO 11037-2013********; the yield of the finished product was measured by the weight method.

Rheological properties were studied using an RPE-1M Polymer rotary viscometer with a T1-B1 rotor-cylinder sensing system. Microstructural studies of meat samples were guided by State Standard 19496-2013********. They were conducted using an AxioImager A1 light microscope (Carl Zeiss, Germany), an AxioCam MRc 5 video camera, and an AxioVision 4.7.1.0 computer-based image analysis system.

The results were processed using standard methods of variation statistics. The differences were considered significant at a confidence interval of > 0.05.

RESULTS AND DISCUSSION

The technological properties of the dietary fibres under study are shown in Table 1.

According to sensory analysis, wheat and potato fibres showed the most rational properties for use in meat production. In addition, potato fibres had an increased hydrating and swelling ability, contributing to the formation of three-dimensional food products.

This information is relevant to selecting dietary fibre for further use in the production of various foods.

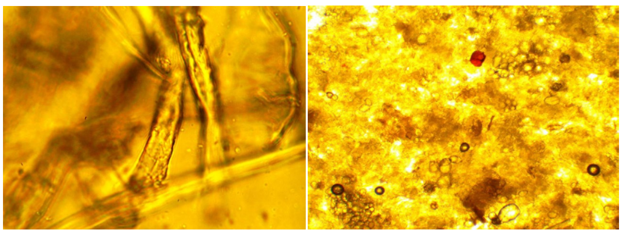
The histological structure of SuperCel wheat and potato fibres of the WF 600 and KF 500 grades, respectively, is shown in Fig. 2.

The analysis (Fig. 2) showed that wheat fibres had a three-dimensional structure characteristic of plant tissues. Under the light microscope, we could clearly see the surface of the fibres: the core, the periphery, and threads with varying degrees of deformation. Observation at different sharpening levels revealed a certain spatial network formed by the wheat fibres.

Potato fibres had a relatively uniform composition with differentiated fragments of cellular structures, round-shaped starch grains of various diameters, and optical density fluctuations over the entire structure of the preparation.

In order to optimise the processes, we then studied the rheological properties of model systems (dietary fibre-water), using the ratios recommended by the manufacturer.

The analysis of the graphs (Fig. 3) showed that WF 600 SuperCel wheat fibres had a more complex rheological behaviour at the initial stage of testing. In our opinion, this was due to the difficulty in rotor spinning at that stage caused by their complex 3D structure and, presumably, adhesion. Initially, the shear rate gradient was 2.7–5.5 s^{-1}.



(a) (б)

Figure 2 Histological structure of SuperCel dietary fibres: (a) WF 600 wheat; (b) KF 500 potato (40 magnification)

****** TR TS 021/2011. Tekhnicheskiy reglament Tamozhennogo soyuza ‘O bezopasnosti pishchevoy produktsii’ [TR CU 021/2011. Technical regulations of the Customs Union ‘On the safety of food products’]. 2011.

******* TR TS 034/2013. Tekhnicheskiy reglament Tamozhennogo soyuza ‘O bezopasnosti myasa i myasnoy produktsii’ [TR CU 034/2013. Technical regulations of the Customs Union ‘On the safety of meat and meat products’]. 2013.

******** MUK 4.2.2747-10. Metody sanitarno-parazitologicheskoy ehkspertizy myasa i myasnoy produktsii, provodili mikrobiologicheskie issledovaniya i izuchali pokazateli bezopasnosti razrabotannykh produktov pitaniya [Methodological Guidelines 4.2.2747-10. ‘Methods of sanitary and parasitological examination of meat and meat products’]. 2011.

******** State Standard ISO 11037-2013. Sensory analysis. Guidelines for sensory assessment of the colour of food products. Moscow: Standartinform; 2014. 16 p.

******** State Standard 19496-2013. Meat and meat products. The method of histological investigation. Moscow: Standartinform; 2014. 10 p.

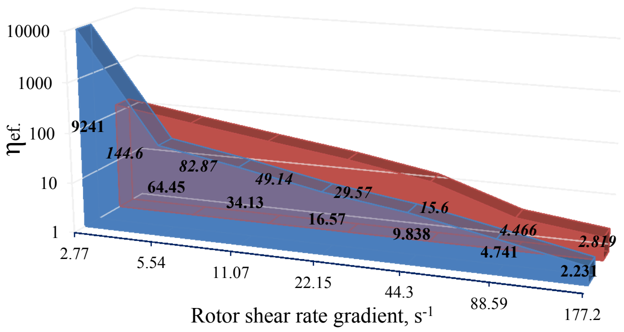


Figure 3 Rheograms for various types of dietary fibre: blue for WF 600 wheat; red for KF 500 potato

Further stages were carried out in the range from 4.2 to 177.2 s^{-1}. In those cases, KF 500 SuperCel potato fibres had a more effective viscosity, expressed in logarithmic coordinates (from 1 to 10000 Pa·s).

The rheograms above can be correlated with typical curves for viscous flow materials that are liquefied by shear. A significant part of food materials (apple pulp, puree-like products, mayonnaise, dairy products, pumping pickles, etc.) are non-Newtonian. It means that their rheological behaviour depends on the shear gradient, and the graph may feature a yield strength. Differentiated on the rheograms, which can be built in logarithmic coordinates, are Newtonian viscosity regions (low shear values), a zone of reduced viscosity as a power function (structural dispersion), and a Newtonian region of high shear [31, 32]. These data are important for predicting the course of production cycles and for food quality control.

The data shown in Fig. 3 suggest that these fibres can be attributed to colloidal structures that are mostly hydrophilic and are able to swell and bind food materials. In addition, due to increased hydration and micelle formation, they form more stable and uniform food masses that can be easily introduced into the formulations of meat products.

Based on the results, we can assume that the KF 500 SuperCel potato fibres correspond to such modified cellulose additives as methyl cellulose and carboxymethyl cellulose in terms of rheological properties and consistency. It means that they can exhibit pseudoplastic and non-thixotropic flow properties. Thus, these potato fibres can form clusters of polymer chains and 3D structures.

Consequently, these data can help us rationalise the processes of mixing, moulding, pressing, and heat treatment, as well as prevent syneresis, layering, and other processes. More stable functional and technological properties can also be used to optimise the stages of packaging and storing semi-finished and finished products (for example, convenience meat products, snacks, etc.).

In connection with the above, of great interest is the use of dietary fibres in the production of various types of meat products, for example, cooked sausages, minced products, pastes, pork products, etc. [33–37]. Taking into account consumers' desire to buy inexpensive high-quality meat products, manufacturers are developing new ways of restructuring meat.

Therefore, our further studies aimed to identify possible uses of dietary fibre in the meat technology, particularly in the development of restructured products from poultry meat.

Pieces of poultry meat, both red and white, were minced in a meat mincer with a hole diameter of 16–25 mm to be used as a meat raw material. Salt and granulated sugar were used as curing ingredients.

Meat raw materials were massaged on a vibrating massager at a rotation speed of 10 min^{-1} for 40 min. The amount of brine was 20% of the initial weight of the material. Further process stages included brining, forming, cooking at 80°C until the product reached 72 ± 2°C in the centre, and air cooling at 4 ± 2°C until the finished product was 8°C in the centre.

The composition of brines is shown in Table 2.

Sensory evaluation is one of the determining factors in assessing the quality of food products (Fig. 4).

As can be seen in Fig. 4, the test sample containing dietary fibres of the selected grades was just as good as the control product in its sensory parameters. The test

Table 2 Brine composition

Ingredients	Ingredient amount, kg per 100 L of brine	
	Control	Test
Water	89.5	84.5
Granulated sugar	0.5	0.5
Salt	10.0	10.0
SuperCel WF 600 wheat fibres	–	1.0
Fucus	–	3.5
SuperCel KF 500 potato fibres	–	0.5
Total:	100	100

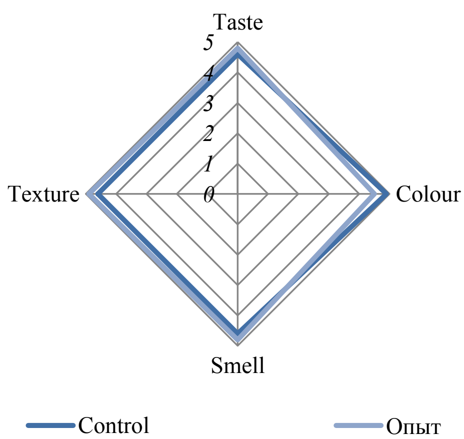


Figure 4 Sensory evaluation of restructured poultry products

Table 3 Safety indicators for restructured poultry products containing dietary fibres

Indicator	Requirements according to			Results
	Technical Regulations of the Customs Union 034	Technical Regulations of the Customs Union 021	Methodological Guidelines	
Microbiological indicators				
Coliforms	not allowed in 0.1 g			not detected
Sulphite-reducing clostridia	not allowed in 0.01 g			not detected
S. aureus	not allowed in 1 g			not detected
E. coli	not allowed in 1 g			not detected
Pathogenic, incl. salmonella	not allowed in 25 g			not detected
QMA&OAMO, CFU/g	max 1×10^3			not detected
L.monocytogenes	not allowed in 25 g			not detected
Content of toxic elements, mg/kg, max				
Lead mass fraction	0.5			< 0.001
Arsenic mass fraction	0.1			< 0.001
Cadmium mass fraction	0.05			< 0.0001
Mercury mass fraction	0.05			< 0.0001

sample's consistency received the highest rating from the panelists.

Microbiological tests and safety indicators analysis can be used to establish the degree of product safety. Safe products do not contain pathogenic or conditionally pathogenic microorganisms and do not exceed the maximum permissible concentration of toxic elements, pesticides, mycotoxins, antibiotics, hormones, and radionuclides. We found that the test sample met the requirements of the Methodological Guidelines and Technical Regulations of the Customs Union 034 and 021 (Table 3).

With regard to strength characteristics, we concluded that introducing dietary fibre into the brine for massaging the test sample contributed to an increase in shear stress and cutting work, compared to the control (Fig. 5). It improved the consistency of the finished product and its sensory characteristics (Fig. 4).

The meat products containing dietary fibre had a lower mass loss during heat treatment and higher water-holding capacity and yield, compared to the control sample (Table 4).

Table 5 shows the influence of dietary fibre on the indicators of biological and energy value of the meat products.

The total energy value of the test sample decreased by 8% due to a reduced fat content. We believe that the decrease in the mass fraction of fat was caused by the formation of a capsule of dietary fibre around fat droplets, which prevented the extraction of the lipid component during its determination.

The digestibility of *in vitro* proteins in the test sample was 10% lower than in the control. This was due to the presence of ballast substances in the restructured poultry product that are not digested by enzymes of the gastrointestinal tract.

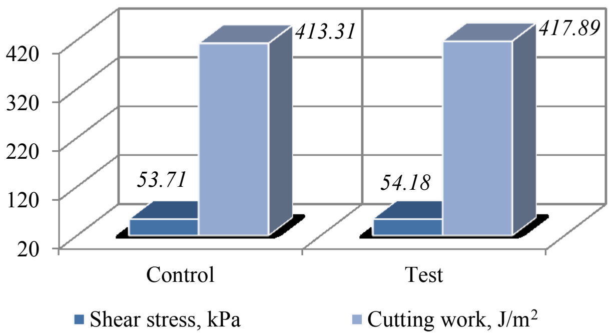


Figure 5 Structural and mechanical properties of restructured poultry products

Table 4 Functional and technological properties of restructured poultry products

Samples	Yield, %	Thermal loss, %	Moisture, %	Water-holding capacity, % to total moisture
Control	83.8	14.7 ± 0.8	72.5 ± 2.3	79.1 ± 2.1
Test	87.3	9.3 ± 0.7	74.1 ± 2.4	87.2 ± 2.0

Table 5 Nutritional indicators of restructured poultry products

Indicators	Control	Test
Moisture mass fraction, %	66.80 ± 2.32	68.10 ± 2.73
Protein mass fraction, %	16.77 ± 0.49	16.70 ± 0.56
Fat mass fraction, %	13.40 ± 0.37	11.30 ± 0.31
Ash mass fraction, %	3.03 ± 0.09	3.40 ± 0.10
Carbohydrates mass fraction, %	Traces	0.30 ± 0.02
Energy value, kcal/100 g of product	188.40 ± 5.24	170.00 ± 4.86
Digestibility of *in vitro* proteins, mg tyrosine/100 g protein:		
by pepsin	4.84 ± 0.09	4.63 ± 0.09
by trypsin	9.92 ± 0.29	9.83 ± 0.29
Total:	14.76 ± 0.43	14.46 ± 0.43

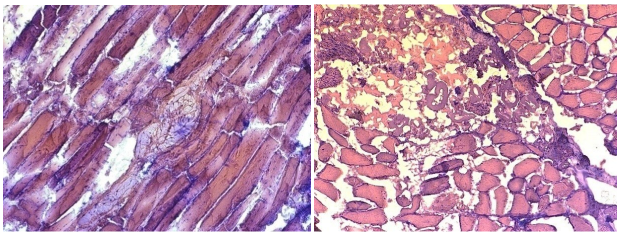


Figure 6 Microstructure of restructured poultry products (10 × magnification)

Figure 6 shows the results of microstructural studies to assess the uniformity of distribution of the curing mixture in the finished products.

The analysis of histological preparations did not reveal any significant differences between the control and the test samples. Their microstructure showed the presence of exclusively muscle tissue with a few fragments of adipose and connective tissue that make up the muscular skeleton. We also found some components of endomysium, coarse fibrous interlayers of perimysium, and a small amount of fat cells. Noteworthily, cell membranes of muscle and connective tissue retained their integrity outside the fragmentation zone. A distinctive feature of the test sample's microstructure was a local presence of dietary fibre fragments and an increased amount of muscle tissue decomposition products.

CONCLUSION

We established specific structural characteristics, properties, and rheological behaviour of various dietary fibres. We found that potato fibres demonstrated greater uniformity in texture and rheology, compared to wheat fibres.

Wheat fibres had a clear phase structure (fibre/water), whereas potato fibres showed significant hydrophilic and structuring properties, attributing them to colloidal fibres.

Comprehensive studies revealed that a combined use of wheat and potato fibres in massage brines contributed to the production of restructured poultry products with good functional and technological properties. It also increased meat succulence and prevented liquefaction, syneresis, volume loss, etc.

Using potato and wheat fibres can help producers to expand the range of meat products in line with the concepts of rational and healthy nutrition, i.e. preventative products.

Our experimental material can become a basis for further research aiming to create combined dietary fibre complexes that can be used in the production of biologically active dietary supplements and specialised meat products.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Kudryashov LS, Kolesnikov VA, Molotilin YuI, Artem′ev AI, Lisitsyn AB, Malikova VI. Pishchevye sveklovichnye volokna i vozmozhnost′ ikh ispol′zovaniya v myasnoy promyshlennosti [Dietary beet fibres and a possibility of their use in the meat industry]. All about the meat. 2001;(3):6–8. (In Russ.).
2. Litvinova EV. Spetsializirovannaya pishchevaya produktsiya - put′ k sokhraneniyu zdorov′ya natsii [Specialised food products as a way to preserve national health]. Meat Technology. 2018;187(7):58–64. (In Russ.).
3. Nikityuk DB. Sposob diagnostiki obespechennosti organizma cheloveka pishchevymi voloknami [A method for measuring the sufficiency of dietary fibre in the human body]. Moscow: Federal Research Centre for Nutrition and Biotechnology; 2016. 25 p. (In Russ.).
4. Imeson A. Food Stabilisers, Thickeners and Gelling Agents. Wiley-Blackwell; 2010. 372 p.
5. Kodentsova VM, Vrzhesinskaya OA, Risnik DV, Nikityuk DB, Tutelyan VA. Micronutrient status of population of the Russian Federation and possibility of its correction. State of the problem. Problems of Nutrition. 2017;86(4):113–124. (In Russ.). DOI: https://doi.org/10.24411/0042-8833-2017-00067.
6. Tutel′yan VA. Vashe zdorov′e – v vashikh rukakh [Your health is in your hands]. Food processing industry. 2005;(4): 6–8. (In Russ.).
7. Prosekov AY, Ivanova SA. Food security: The challenge of the present. Geoforum. 2018;91:73–77. DOI: https://doi.org/10.1016/j.geoforum.2018.02.030.
8. Ugolev AM. Teoriya adekvatnogo pitaniya i trofologiya [The theory of adequate nutrition and trophology]. St. Petersburg: Nauka; 1991. 272 p. (In Russ.).
9. Khyoling A, Volkov VV. Proteiny iz vtorichnogo syr′ya – innovatsionnye komponenty v ehkologichnom promyshlennom proizvodstve [Proteins from recycled materials – innovative components in green industrial production]. KSTU News. 2015;38:83–92. (In Russ.).
10. Nordlund E, Lille M, Silventoinen P, Nygren H, Seppanen-Laakso T, Mikkelson A, et al. Plant cells as food – A concept taking shape. Food Research International. 2018;107:297–305. DOI: https://doi.org/10.1016/j.foodres.2018.02.045.

11. Branavets IN. Dietary fibers - an important part of a balanced healthy diet. Meditsinskie novosti [Medical news]. 2015;10:46–48. (In Russ.).

12. Zlokachestvennye opukholi v pryamoy kishke [Malignant tumours in the rectum] [Internet]. [cited 2019 Jun 15]. Available from: http://enterolog.ru/tolstaya-kishka/pryamaya/rak.

13. Khismatullina ZN. Osobennosti ehtapov khimicheskogo, fizicheskogo i virusnogo kantserogeneza [The stages of chemical, physical and viral carcinogenesis]. Bulletin of the Technological University. 2013;16(7):198–202. (In Russ.).

14. Philpott H, Nandurkar S, Lubel J, Gibson PR. Food, fibre, bile acids and the pelvic floor: An integrated low risk low cost approach to managing irritable bowel syndrome. World Journal of Gastroenterology. 2015;21(40):11379–11386. DOI: https://doi.org/10.3748/wjg.v21.i40.11379.

15. Kurmangulov AA, Dorodneva EF, Troshina IA, Petrova YuA, Golubeva TI. Effects of inclusion of dietary fibers in the composition of the diet in obesity. Obesity and metabolism. 2018;15(2):35–39. (In Russ.). DOI: https://doi.org/10.14341/omet8785.

16. Borodina SV, Gapparova KM, Zainudiniv ZM, Grigorian ON. Genetic predictors of obesity development. Obesity and metabolism. 2016;13(2):7–13. (In Russ.). DOI: https://doi.org/10.14341/omet201627-13.

17. Sokolova EV, Bogdanovich LN, Ivanova TB, Byankina AO, Kryzhanovskiy SP, Yermak IM. Effect of carrageenan food supplement on patients with cardiovascular disease results in normalization of lipid profile and moderate modulation of immunity system markers. PharmaNutrition. 2014;2(2):33–37. DOI: https://doi.org/10.1016/j.phanu.2014.02.001.

18. Tutel′yan VA, Baygarin EK, Pogozheva AV. Pishchevye volokna: gigienicheskaya kharakteristika i otsenka ehffektivnosti [Dietary fibre: hygienic characteristics and evaluation of effectiveness]. Moscow: SvR-Argus; 2012. 243 p. (In Russ.).

19. Vaynshteyn SG, Masik AM. Pishchevye volokna i usvoyaemost′ nutrientov [Dietary fibre and nutrient absorption]. Problems of Nutrition. 1984;3:6–12. (In Russ.).

20. Prosekov A, Babich O, Dyshlyuk L, Noskova S, Suhih S. A Study of Polyfunctional Properties of Biologically Active Peptides. Research Journal of Pharmaceutical Biological and Chemical Sciences. 2016;7(4):2391–2400.

21. Lavelli V, Proserpio C, Gallotti F, Laureati M, Pagliarini E. Circular reuse of bio-resources: the role of *Pleurotus* spp. in the development of functional foods. Food & Function. 2018;9(3):1353–1372. DOI: https://doi.org/10.1039/c7fo01747b.

22. Tumenova G, Zhakupova G, Suleimenova Z, Nurimkhan G, Toxanbayeva B. Utilization of poultry skin as one of the components for emulsion-based products. Journal of engineering and applied sciences. 2016;11(6):1370–1373.

23. Chen SQ, Lopez-Sanchez P, Wang DJ, Mikkelsen D, Gidley MJ. Mechanical properties of bacterial cellulose synthesised by diverse strains of the genus *Komagataeibacter*. Food Hydrocolloids. 2018;81:87–95. DOI: https://doi.org/10.1016/j.foodhyd.2018.02.031.

24. Kiykova AS, Antipova LV, Storublyovtsev SA. Gidrolizovannyy kollagen – analog pishchevykh volokon zhivotnogo proiskhozhdeniya [Hydrolysed collagen – an analogue of animal-based dietary fibre]. Advances in current natural sciences. 2011;7:118–119. (In Russ.).

25. Titov EI, Litvinova EV, Kidyaev SN, Artemeva IO. Collagen matrix as a way of preservation of minor components in food products. All about the meat. 2019;1:40–43. (In Russ.). DOI: https:doi.org/10.21323/2071-2499-2019-1-40-43.

26. Yugay AV, Boytsova TM. To the question of multifunctional use of a collagen received from skin of fish. Fundamental research. 2015;2(4):704–707. (In Russ.).

27. Gorlov IF, Titov EI, Semenov GV, Slozhenkina MI, Sokolov AY, Omarov RS, et al. Collagen from porcine skin: a method of extraction and structural properties. International Journal of Food Properties. 2018;21(1):1031–1042. DOI: https://doi.org/10.1080/10942912.2018.1466324.

28. Sokolov AYu, Shishkina DI, Pchelkina VA. Development of meat products with wheat fiber for food industry. Herald of Ryazan State Agrotechnological University Named after P.A. Kostychev. 2018;40(4):172–178. (In Russ.).

29. MakKenna BM. Struktura i tekstura pishchevykh produktov. Produkty ehmul′sionnoy prirody [Texture in food. Semi-solid foods]. St. Petersburg: Professiya; 2008. 488 p. (In Russ.).

30. Musienko IV. Stabiliziruyushchie sistemy na osnove gidrokolloidov. Kamed′ guara, ksantana [Hydrocolloid-based stabilising systems. Guar and xanthan gum]. Meat Industry. 2003;3:26–38. (In Russ.).

31. Moreira JB, Lim LT, Zavareze ED, Dias ARG, Costa JAV, de Morais MG. Antioxidant ultrafine fibers developed with microalga compounds using a free surface electrospinning. Food Hydrocolloids. 2019;93:131–136. DOI: https://doi.org/10.1016/j.foodhyd.2019.02.015.

32. Zhu QM, Lu HQ, Zhu JY, Zhang M, Yin LJ. Development and characterization of pickering emulsion stabilized by zein/corn fiber gum (CFG) complex colloidal particles. Food Hydrocolloids. 2019;91:204–213. DOI: https://doi.org/10.1016/j.foodhyd.2019.01.029
33. Zabashta AG, Basov VO, Pismenskaya VN. Use of structure-forming components in the technology of ham products. Meat Industry. 2016;8:36–39. (In Russ.).
34. Kudryashov LS, Kupriyanov VA, Scherbakov IT, Krylova VB, Gustova TV. The impact of the cooked sausage enriched with lactulose and food fibers on the morphofunctional condition of the mucous membrane of the large intestine and microbiota (microbiocenosis) in rats. Theory and Practice of Meat Processing. 2018;3(1):4–15. (In Russ.). DOI: https://doi.org/10.21323/2414-438X-2018-3-1-4-15.
35. Antipova LV, Voronkova IuV. Food fibers of the domestic production for the meat-processing industry. Proceedings of the Voronezh State University of Engineering Technologies. 2014;2(60):95–98. (In Russ.).
36. Rechkina EA, Gubanenko GA, Mashanov AI. Prospects of dietary fiberuse in food production. The Bulletin of KrasGAU. 2016;112(1):91–97. (In Russ.).
37. Hvilya SI, Gabaraev AA, Pchelkina VA. Structural features of wheat fiber for meat products. Food Processing: Techniques and Technology. 2013;29(2):71–75. (In Russ.).

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