Research of Wheat Fiber with Pumpkin Pectin Plant Additive

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Abstract. The scientific work presents the results of improving the technology of making cooked sausages with the addition of wheat fiber with pumpkin pectin. The advantage of improving the technology of sausages was determined, particularly increasing their quality for the consumer and the prospects of using plant additives to improve their nutritional value. This paper explores the possibility of adding the combined plant additive of wheat fiber and pumpkin pectin to minced meat. A rational grinding mode is 3–4 min to fractions of 500–600 μm was established, which ensured the homogeneity of the plant additive and would contribute to its uniform distribution in minced meat in the cooked sausages production. The influence of the plant additive grinding level on the functional properties was presented, which showed that the best results for water-holding, water-binding, and fat-holding capacity are provided by particles of a size of 600 μm. Rational parameters for preliminary preparation of the plant additive for mixing with the minced meat associated with hydration at hydromodule were determined. This stage of the technological process provides the highest water-holding capacity, and the 1:3 ratio of the plant additive to refined oil provides a high fat-holding capacity. The solution to this problem improves the biological value and therapeutic and preventive properties of cooked sausages.

Keywords: Fat-holding capacity · Grinding · Hydromodule · Plant additive · Water-binding capacity · Water-holding capacity · Water resource

1 Introduction

Nowadays, a promising direction in providing the population with high-quality food products of increased nutritional and biological value is the combination of raw materials of plant and animal origin, considering adequate human needs according to the modern nutritional requirements [1]. Innovative approaches to solving the nutrition problem consist of creating products with an increased nutritional value which is one of the priority areas for solving problems highlighted in the concept of the state policy in product quality management [2].

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The socio-economic problem of the shortage, high cost, and low quality of food, including meat products in Ukraine, is particularly critical. Recently, there have been specific changes in people's lives: a significant decrease in physical activity, a change in healthy eating habits, and consumers' needs. Considering this, some of the previously declared features of sausages do not correspond to the current demand, for example, high-calorie content, which does not attract but requires adjustment instead.

2 Literature Review

The analysis of scientific literature has determined the main directions of modern technologies for the production of cooked sausages. First of all, these technologies replace meat raw materials with food additives and ingredients. Thus, a technology for the production of cooked sausages has been developed, which differs from the traditional one that at the stage of preparation of minced meat, 1–2% of a multifunctional additive is added to the cutter based on animal protein, alginate, carrageenan, and guar gum [3].

Scientists pay special attention to balancing the amino acid composition of the proteins. There is a specific deficiency of three amino acids - tryptophan, methionine, and lysine in the diet of a significant number of people in the world. This deficiency limits the absorption of proteins from food and is explained, mainly, by the predominant consumption of plant-based food [4].

In Ukraine, there are meat and vegetable raw materials for manufacturing combined products. Sausages are essential products in the population's diet. Their production is the most common meat and other animal products processing in the meat industry [5]. Development of the new generation products by combining plant and animal raw materials with a therapeutic and preventive effect is of particular importance. Plant-based ingredients can protect the human body from the harmful effects of the environment, prevent the formation of diseased cells, and prevent diabetes as they reduce blood sugar levels [6]. Such products are cooked sausage products, combining plant and animal raw materials. By the way, such a combination makes it possible to reduce the cost of final products and produce a high-quality and nutritious product that will be tasty and healthy in terms of overall nutrients and energy value [7].

However, many issues remain unresolved. In Ukraine, the market for cooked sausages with high biological value is minimal. At the same time, the industry produces wheat fiber with pumpkin pectin, which can be used in cooked sausages to produce more balanced products in terms of essential nutrients [8].

Dietary fiber's positive role in cereals and vegetables' cell walls, which significantly affects digestion and excretion of harmful toxic substances, salts of heavy metals, and radionuclides, is well-known [9, 10]. The low-calorie content of the cereals and vegetables is also an additional argument for their use in high-calorie meat products [11]. There are raw materials for the production of wheat fiber with pumpkin pectin in Ukraine. Therefore, the purpose of the work was to study this complex additive for inclusion in the recipe of cooked sausages [12, 13].

3 Research Methodology

The experimental part of the work was performed in the laboratory of the technology departments of meat, fish and seafood, processes and equipment for processing agricultural products and microbiology, virology and biotechnology of the National University of Life and Environmental Sciences Ukraine, the Institute of Biochemistry. OV Paladin, in the Ukrainian laboratory of quality and safety of agricultural products, in the production conditions of PE "Zlagoda-Lutsk", Rivne region, Boromel village.

The raw materials and materials used in the research complied with the current regulations in Ukraine in terms of quality and safety, approved for use by the Ministry of Health of Ukraine. The following raw materials were used for research:

- lean beef I grade - muscle tissue with a mass fraction of connective and adipose tissue, not more than 6% – DSTU 6030: 2008. State standard of Ukraine. Meat. Beef and veal in carcasses, carcasses and quarters;
- lean pork semi-fat - muscle tissue with a mass fraction of adipose tissue from 50% to 85% - DSTU 7158: 2010. State standard of Ukraine. Meat. Pork in carcasses and half-carcasses;
- wheat fiber with pumpkin pectin TU U 15.8-2783308472-005: 2010. Technical conditions of Ukraine. Biologically active additive "Wheat fiber with pumpkin pectin" in the composition: 20.0% - pumpkin pectin, 80.0% – a crushed shell of wheat grain;
- multi-component minced meat, which includes lean semi-fat pork, beef, and grade, plant additive PKZPG in different ratios (3%, 5%, 7%, respectively);
- ready cooked sausage with vegetable additive.

The experimental studies included three stages. At the first stage, a study of physicochemical parameters of PFWPP (pectin fiber with pumpkin pectin) supplement, the amino acid composition of its proteins, mineral and vitamin composition. Based on the obtained indicators, the energy value and coefficients were calculated: protein, protein-water, fat-water, food saturation, potential biological value, the difference of amino acid SKORu [14, 15], utilitarianism of amino acid composition of protein; an indicator of excess content and index of essential amino acids.

The safety of raw materials was assessed by microbiological parameters, the content of heavy metals, pesticides (insecticides, pesticides, herbicides), the content of mycotoxin "patulin" and radionuclides.

At the second stage, the development and substantiation of the technology of cooked sausages were carried out, which included:

- determining the features of the preliminary preparation of vegetable additives for the introduction of cooked sausages into the minced meat system, and the time of grinding to a homogeneous state;
- study of the hydraulic module and the ratio of crushed vegetable additives before the formation of cooked sausages;
- substantiation of the prescription composition of cooked sausages with the addition of PFWPP and the method of its introduction into the minced meat;

- assessment of structural-mechanical and organoleptic indicators of cooked sausages using vegetable additive PFWPP and changes in these indicators during storage.

The third stage of research included the characterization of ready-cooked sausages by organoleptic, physicochemical, biochemical, microbiological, and rheological parameters. The kinetics of changes in organoleptic and microbiological parameters of cooked sausages during storage at a temperature from 0 °C to + 6 °C for up to 10 days of storage in a polyamide shell were studied. The shelf life of sausages was set based on the research. The work aimed to study the plant supplement of wheat fiber with pumpkin pectin and replace it with a certain amount of meat to enrich the nutrients in ready-made sausages.

4 Results

The study of combining a dry plant additive into the model minced meat showed the inexpediency of its use in this form because the proper structure of the cooked sausage did not occur.

Dry wheat fiber's shape and particle size with pumpkin pectin have a heterogeneous composition. By shape, the particles are divided into three groups: arrow-shaped, rod-shaped, and spherical. By size, we found particles with sizes of 1000–700 μm, 600–500 μm, and 400–100 μm (Fig. 1).

№1 №2 №3

Fig. 1. Shapes of wheat fiber with pumpkin pectin.

The fractional composition of wheat fiber with pumpkin pectin is presented in Table 1.

The analysis of these data shows that the particles of 600–500 μm have the largest mass fraction of wheat fiber with pumpkin pectin (45%), particles of 400–100 μm have the smallest mass fraction (15%), and particles of 1000–700 μm have the mass fraction of 40%.

The technological process of preparing a plant additive is associated with the influence of various factors on the components of wheat fiber with pumpkin pectin (mechanical grinding, classification by particle size, temperature, solvent, and hydromodule). Adding the dry plant additive to the meat grinding system did not produce a positive

Table 1. Research results of wheat fiber's particles fractional composition characteristics with pumpkin pectin.

№ grist	Size, μm	Mass fraction, % of the total mass
1	1000–700	35 ± 1.5
2	600–500	45 ± 3.8
3	400–100	15 ± 2.4

result. The heterogeneity of the size and shape of the plant additive did not provide a satisfactory consistency of the cooked sausage. Thus, it was necessary to determine the degree of grinding of wheat fiber with pumpkin pectin to a uniform state and particle size.

A meat shop universal drive PM-1.1 with a replaceable grinding mechanism was used to fine grind wheat fiber with pumpkin pectin. The degree of grinding (grist size) of the wheat fiber with pumpkin pectin depends on the plant additive's strength, hardness, ultrastructure, and the time of grinding (Fig. 2).

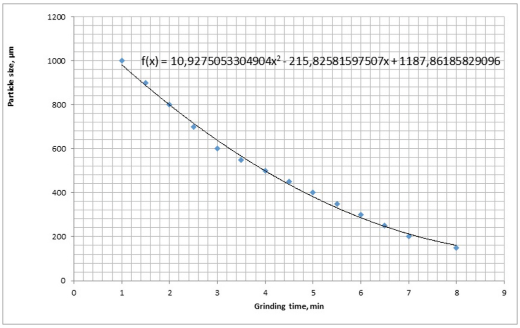

Fig. 2. Dependence of the grinding degree of the wheat fiber with pumpkin pectin on time.

Studies have shown that after 3–4 min of grinding wheat fiber with pumpkin pectin has a homogeneous structure with a grain size of 500–600 μm. The longer grinding time of wheat fiber with pumpkin pectin leads to its transformation into a sticky flour state. High homogenization of the additive results in the adhesive interaction of its particles, and a technological problem of the separation of individual fractions arises. The resulting crushed mixture of plant additive was sieved on a sieve with a magnetic metal contamination trap. As a result, the obtained plant additive looked like a uniform color powder of free-flowing consistency with pleasant taste and smell.

During the manufacture of cooked sausages, there are properties that, to a greater extent, provide organoleptic and structural properties of these products. Such properties include indicators of water-binding, water-holding, and fat-holding. Previous research has shown that one factor affecting these functional properties is the grinding degree of plant additives. The results of studies on the dependence of the functional parameters of wheat fiber with pumpkin pectin on the degree of its grinding are presented in Table 2.

Table 2. The influence of the grinding degree of wheat fiber with pumpkin pectin on functional properties.

Additive particle size, μm	Functional parameters		
	Water-holding, %	Water-binding, %	Fat-holding, g
1000	30.62 ± 2,1	16.10 ± 1,8	2.01 ± 0.5
800	40.41 ± 1,9	18.23 ± 1,5	2.12 ± 0.1
600	45.24 ± 2,5	20.44 ± 1,7	2.51 ± 0.3
400	39.32 ± 1,7	17.21 ± 0,9	2.03 ± 0.2
200	35.14 ± 1,3	16.32 ± 2,4	1.95 ± 0.4
100	28.51 ± 2,1	14.35 ± 1,3	1.72 ± 0.2

The results of studies indicate that particles with a size of 600 μm have the largest water-holding, water-binding, and fat-holding capacities.

According to the literature, many dry plant additives are added into the meat-grinding system as water suspensions because plant additives have a high-water absorption capacity [16]. However, this characteristic for each additive is unique and depends on many factors. Adding dry, ground to 600 μm wheat fiber with pumpkin pectin to the minced meat did not result in homogeneous consistency; the signs of plant additives were visible on the cut of the sausage and were even more noticeable after the heat treatment.

Since the plant additive increases the water-binding capacity of minced meat, the kinetics of this process has been studied.

The water-binding capacity of the plant additive depends on the time of water absorption at different ratios of the additive and water (1 - 1:1; 2 - 1:2, 3 - 1:3, 4 - 1:4, 5 - 1:5) is shown in Fig. 3.

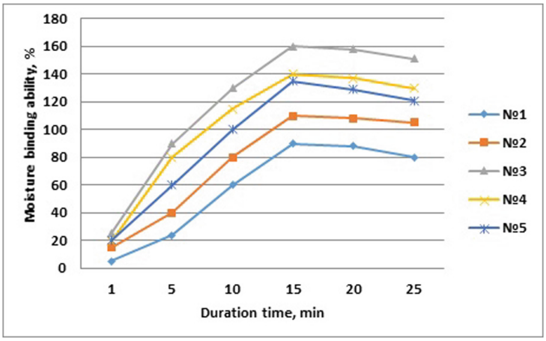

Fig. 3. Wheat fiber with pumpkin pectin water-binding capacity versus the hydromodule and time of keeping in water.

While analyzing the data from Fig. 3, we can see that for all hydromodules the water-binding capacity of the plant supplement grows gradually as time increases up to 15 min. The best water-binding capacity of wheat fiber with pumpkin pectin was reached at hydromodule 3. After keeping the plant additive in water for 15 min, the water-binding capacity decreases at all the hydromodules used in the experiment. An increase in the hydromodule index to 4 and 5 leads to a decrease in the water-binding capacity. Therefore, the best results were obtained at hydromodule 3 and keeping the plant additive in water for 15 min.

The cooked sausages technology uses the cooking temperature up to +80 °C; therefore, it is advisable to determine the influence of this temperature on the water-binding capacity depending on the hydromodule.

The results of the study of the wheat fiber with pumpkin pectin plant additive water-binding capacity at a temperature of +80 °C for different hydromodules are presented in Fig. 4, which shows the most remarkable water-absorbing capacity occurs at hydromodule 3 at a temperature of +16°C. An increase in temperature to 80°C results in an increase of the water-binding capacity for all hydromodules.

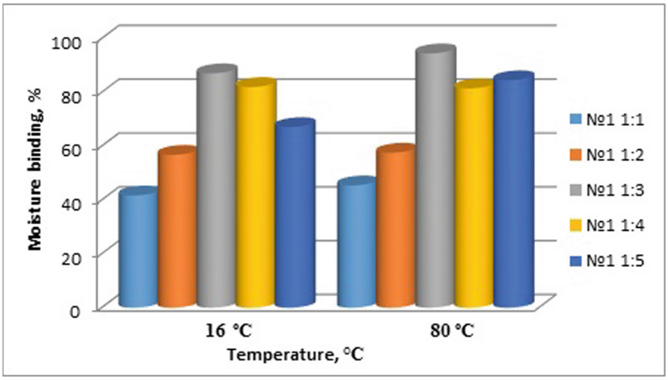

Fig. 4. Dependence of the water-binding capacity of a complex plant additive on temperature.

Therefore, the best water-binding capacity of the plant additive at temperatures from +16 to +80 °C is for hydromodule 3.

It is known that when the various plant additives are used in the technology of cooked sausages, vegetable oils are used to improve the products' functional and technological properties [17].

We have studied the effects of fat-holding capacity at different ratios of plant additive to oils to achieve quality indicators of plant additives to water absorption. When the oil ratio was increased to 4 and 5, the mixture became thin. An increase in temperature to +80 °C leads to an increase in fat-holding capacity for all ratios between plant additive and oil. Therefore, a further increase in the content of refined oil is useless as it leads to a significant deterioration in the functional properties of the plant additive.

We suggest using the 1:2 ratio of plant additive to oil. The 1:2 ratio of additive to oil at +16 °C provides more oil absorption. The binding property of oil is higher at +80 °C due to the binding energy of oil molecules in the plant additive.

The increase in water-binding and fat-holding capacities of plant additives is due to the dry matter content in wheat fiber with pumpkin pectin, which expands in a liquid medium (water, oil) and has better viscosity. Therefore, the highest expansion degree of wheat fiber with pumpkin pectin was observed at +80 °C and above. The high temperature significantly increases the water-binding capacity and fat-holding capacity of the combined plant additive, which should be considered when creating a new recipe and developing the technology for sausages with a plant additive. However, raising the temperature above +80 °C is ineffective because it will contribute to the denaturation of protein substances in the plant additive.

It is essential to consider the rheological properties of the ingredients - effective viscosity and shear stress when creating new recipes for cooked sausages.

Studying these properties enables the technological process of making cooked sausages with specified organoleptic properties. It is known that these properties depend on the chemical composition of hydromodules.

Table 3 presents the data on the chemical composition of wheat fiber with pumpkin pectin at different plant additive to water ratios.

Table 3. The chemical composition of wheat fiber with pumpkin pectin at different plant additive to water ratios.

Plant additive to water ratio	Mass fraction, %				
	Water	Protein	Fat	Ash	Carbohydrates
Control	9.10 ± 1.23	15.01 ± 2.1	3.43 ± 0.41	4.31 ± 0.02	65.80 ± 2.46
1:1	18.21 ± 1.33	13.29 ± 1.75	3.03 ± 0.09	3.9 ± 0.25	58.26 ± 2.33
1:2	27.31 ± 0.58	11.92 ± 1.21	2.72 ± 0.82	3.42 ± 0.84	52.27 ± 3.45
1:3	36.41 ± 1.55	10.55 ± 0.92	2.41 ± 0.43	3.03 ± 0.09	46.29 ± 2.85
1:4	45.51 ± 1.78	9.19 ± 0.87	2.40 ± 0.51	2.64 ± 0.89	40.30 ± 3.35
1:5	54.61 ± 1.85	7.82 ± 1.31	1.78 ± 0.43	2.25 ± 0.85	34.31 ± 2.36

It is found that the increase in moisture leads to a corresponding decrease in dry matter content (i.e., protein from 15.01 to 7.82%, fat - from 3.0 to 1.78%, ash - from 4.31 to 2.25%, and carbohydrates - from 65.80 to 34.31%) while changing the hydromodule from 1 to 5. The change in the chemical composition will result in a change in functional and technological properties. Therefore, a study of the dependence of the effective viscosity shear force on the ratio of plant additives to water was conducted.

It was established that the hydration of the combined plant additive was insufficient, and the additive was dry at hydromodule 1 and 2; the additive had a dense consistency which was suitable for combining with minced meat for the cooked sausages at hydromodule 3; with an increase of the hydromodule to more than 4, a liquid consistency of the additive was formed, resulting in a decrease in the effective viscosity value. Under these conditions, hydration occurs due to the action of water dipoles on the molecules of the peptide groups of the main chains (between which there are hydrogen bonds [18]).

Therefore, the optimal result was obtained at the hydromodule 3, which helped improve the plant additive's viscosity and consistency.

It has been determined that a compact coagulation system's structural and mechanical properties are changed depending on the proportion of the dispersion medium in the system and the presence or absence of a stabilizing component [19]. At low shear stresses, they act like elastic bodies. At high stresses, they get the ability to flow. When the shear stress is higher than the conditional yield point, the conditionally plastic body can irreversible deformations and a relatively slow flow with a high constant viscosity. When the shear stress is above the conditional yield point, the destruction of the body structure in the flow begins, accompanied by a significant drop in viscosity [20].

It can be concluded from Fig. 3 that the complex plant additive has a high effective viscosity due to the high water-binding capacity at specific parameters of the hydromodule. The structural and mechanical properties of the plant additive can be attributed to compact solid coagulation structures.

5 Conclusions

The fractional composition of the additive wheat fiber with pumpkin pectin was studied, the largest mass fraction of which was the particles with sizes 600–500 μm (45%), the smallest – particles with sizes 400–100 μm (15%), and the rest – particles with sizes 1000–700 μm.

The influence of the plant additive grinding degree on the functional indicators is presented, which shows that the particles with a size of 600 μm have the best indicators of water-holding, water-binding, and fat-holding capacities.

The rational mode of preliminary preparation of plant additive for combining with minced meat, which is the hydration at hydromodule 3, is determined. This stage of the technological process provides the highest water-holding capacity, and the 1:3 ratio of plant additive to refined oil provides a high rate of fat-holding.

The benefit of improving the technology of sausages has been determined, particularly increasing their consumer qualities and the prospects of using plant additives to improve their nutritional value.

It is proved that wheat fiber with pumpkin pectin has all the necessary properties to be recommended as the plant additive in the technology of cooked sausages to improve the functional, technological, and organoleptic properties.

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