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Production of functional macaroni products from soft wheat varieties of the Black Earth region based on aqueous garlic extract

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Abstract:

Macaroni products with dietary and functional properties occupy no more than 1% of the market; therefore, this segment has excellent prospects for growth based on improved macaroni product technology, including modified drying and extraction techniques. Using aqueous garlic extract as a soft-wheat flour dough additive allows the product of macaroni nearly equal in quality to macaroni from hard wheat. Analysis of macaroni from soft wheat shows that aqueous garlic extract with the hydro-modulus 1:25 and 1:50 increases dry macaroni mechanical strength by 18.6-20.9%. The cooking properties of experimental macaroni samples are as follows: unessential increase in cooking time (no more than for 2 minutes); dry substance concentration in cooking medium has increased by 1.93-3.18% and product recovery rate has increased by no more than 10.4% in comparison with reference value. It should be mentioned that dry substance concentration in a cooking medium decreases with the increase of aqueous garlic extract concentration (with hydro-modulus 1:25). Application of aqueous garlic extract renovates the technology to produce macaroni from soft wheat and allows using functional ingredients as additional fortificants that raise the quality of ready products without affecting the gluten.

Keywords: macaroni; soft wheat varieties; gluten; drying; aqueous garlic extract; functional ingredients.

Introduction:

Macaroni production is an impetuously developing branch of the food industry, the basic tasks of which are as follows: raising or maintaining the quality of ready products, enlarging the assortment, and introducing innovative production technologies. These tasks, in turn, are the trends for improvement of existing macaroni production technologies aimed to raise nutritional value and improve gustatory qualities of ready products [1, 2].

Flour products prevail in the Russian consumers' ration. The average per capita consumption of macaroni products is about 6 kg per year, so, macaroni products can be considered as mass-consumption products. This justifies the importance of research work aimed at changing the nutrient content of the main product of the Russians' ration [3, 4].

Traditional macaroni is made from hard wheat flour; they do not boil soft, do not stick together, and have

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a low glycemic index, but in Russia, soft wheat flour prevails, that's why it would be natural to use soft wheat flour. In the Russian Federation, no more than 10% of producers manufacture macaroni from hard wheat flour. Soft wheat flour as raw material for macaroni production is characterized, first of all, by the low quality of ready products, including high cooking properties, untypical color, and high concentration of dry substance in cooking medium [5].

One more problem with using soft wheat flour is that it contains fewer nutritious substances and more starch than hard wheat flour, which raises the macaroni glycemic index.

Research Methodology:

The objects of research were experimental macaroni made from soft wheat flour based on different concentrations of aqueous garlic extract. "Makfa" macaroni made from hard wheat flour served as a reference sample. The basic differences between macaroni from hard wheat flour and macaroni from soft wheat flour include high protein content (more than 11 gr) and low glycemic index.

Theoretical studies of different types of macaroni are based on standard procedures of product quality control and organoleptic assessment.

Flour organoleptic indexes are established by State Standard 27558-87 "Flour and Bran. Methods for determination of color, odor, taste and crunch". The humidity of flour, and dry wheat gluten is established by State Standard 9404-88 "Flour and Bran. Methods of moisture content determination". The acidity of flour is established by State Standard 27493-87 "Flour and Bran. Method for determination of acidity by beaten-up flour and water". The Ash content of flour is established by State Standard 27494-87 "Flour and Bran. Methods for determination of ash content" (burning weighed portions of flour in a muffle furnace). Quantity and quality of gluten are established by State Standard 27839-88 "Wheat flour. Quantity and quality of gluten". Gluten elasticity was estimated by standard methods.

Dough rheologic properties were measured by a capillary viscosimeter (capillary length 30 mm, diameter – 3 mm). The humidity of a test sample and reference sample was taken as 30-31% (average level of dough humidity). The fluidity of macaroni dough is described by the Herschel-Bulkley equation. The fluidity of noodle dough is described by the Herschel-Bulkley equation:

$$\tau = |\pm\tau_0| + \text{К} \cdot \gamma^n$$

where τ – shear stress, mPa;

τ_0 – ultimate shear stress, mPa;

К – consistency ratio;

n – fluidity index.

Coefficients τ_0, К, n were estimated by the graph-analytical method. Macaroni organoleptic, physical-chemical parameters, and cooking properties were estimated according to State Standard P 52377-2005 "Macaroni products. Acceptance rules and methods of quality determination".

The water-absorption ability of flour and plant protein isolates was estimated according to State Standard P 51404-99 "Wheat Flour. Physical characteristics of doughs. Determination of water absorption and rheological properties".

Modified subsidiary technologies included two-stage convection vacuum-impulse drying and vacuum-impulse extraction under low temperatures that exclude denaturation of bioactive substances.

With a certain periodicity, extract samples were taken to estimate the content of dry soluble substances by the refractometric method.

Refractometer ИРФ-454 Б2М calibrated for standard solutions was used. To ensure data reliability, a series of three experiments were conducted in each mode. The data, which deviated considerably from the average values, were excluded.

The ratio of raw material-extragent (hyromodulus) was 1:50, 1:25. Dried garlic flakes were used to achieve maximum extractivity of the resulting solution.

Macaroni antioxidant activity was estimated using the ampere-metric method according to the methodology for estimation of antioxidant content in drinks and food products, biologically active admixtures, and medicinal plant extracts.

Results and discussion:

Sliced garlic drying time did not exceed 120 minutes at the temperature below 60^0C and humidity below 3-4% (Figure 1). The first stage of drying was carried out at the heat-carrying agent temperature of up to 58^0C and heat-carrying agent speed of 2 m/s. Figure 2 shows that the first stage takes 40 minutes and the high-level process of moisture removal by vacuum begins. Over the first 20 minutes, the vacuum stage is short, convection stage is longer because, at the initial stage, moisture evaporates quickly. Then the time of the vacuum stage increases, and the time of the convection stage decreases because a small amount of moisture is easily removed. The parameters of the blow-down are the same at the vacuum stage and the convection stage. At the end of the drying process moisture level does not exceed 3-6%.

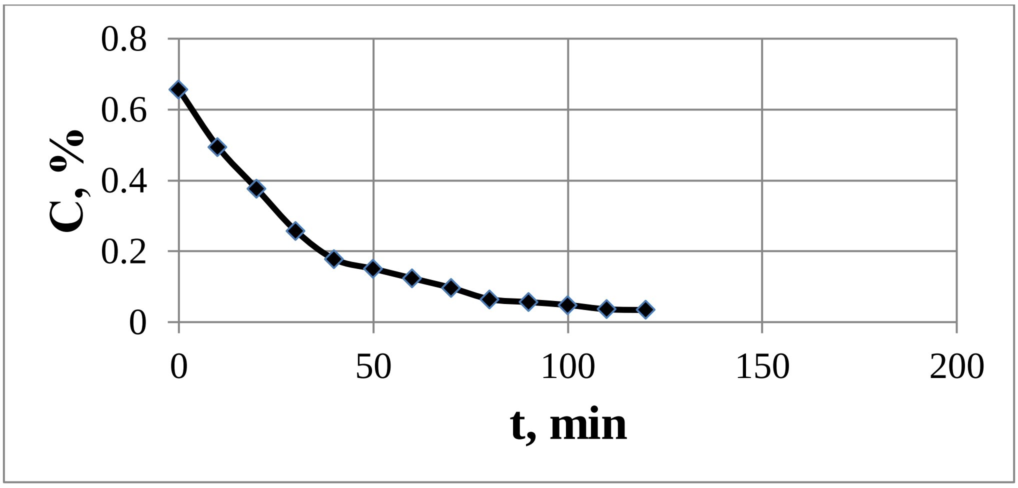

Figure 1 – Rational curve of sliced garlic two-stage convection vacuum-impulse drying

Dry substance concentrations in the extract were recalculated to their concentrations in the liquid using the material balance equation. The process of garlic full extraction with hydromodulus took 55 minutes. A considerable amount of dry water-soluble substances is removed over the first 5 minutes, which is explained by the fact that dry substances in the porous structure of raw material are washed out over the first 25 minutes. Then, with the penetration of extragent into the pores, dry substances extraction occurs due to molecular diffusion, but extraction speed significantly decreases. The dependence of extraction time on hydromodulus value is identified. A two-time increase in hydromodulus value increases extraction time 2.64 times at the temperature of 54-56^0C.

Vacuum extraction allowed intensifying the process. The influence of vacuum on the extraction process can be explained by the fact that the difference in pressure inside and outside the material results in open pores. Dry impulses and vacuum boiling at the temperature of 54-56^{0}C directly stimulate the vacuum extraction process. Low boiling temperature does not influence negatively the properties of extracted substances: useful, biologically active substances and vitamins are preserved [6].

Nowadays vegetable purees or powders are actively used as food additives, which, affecting dough structure, improve its qualitative characteristics: reduce dough adhesion, and increase nutrient content. However, producing such additives requires specific conditions and experts' participation, so it seems hardly possible to use them under the conditions of large-scale production [7].

Recently, vegetable additives have been successfully replaced with ready-mixed aqueous extracts of vegetables, fruits, and species that enrich nutrient content and improve considerably qualitative characteristics and cooking properties of macaroni products [8].

Let's mention protein fortifiers most frequently used in macaroni production: eggs and egg-derived products (melange, dry egg powder, dry egg white), egg powder, lactic whey powder (LWP), corn protein powder (CPP), cultured milk foods (kefir, lactic whey), fish protein concentrate [9]. Dry wheat gluten is often used to raise flour gluten content to a minimum of 28%. Dry wheat gluten allows for raising protein content, improving organoleptic and qualitative characteristics of macaroni products. However, multi-component fortifiers are considered more promising. Hard wheat is grown in small amounts, so hard wheat flour is enriched with gluten acquired from soft wheat flour. To raise the biological value and quality of ready products, the researchers seek to improve the quality of soft wheat flour [6].

However, they fail to suggest an additive influencing the quality of gluten and starch, the key components of macaroni quality. Recently introduced protein additives and fat additives influence the formation of macaroni structure, taste, and color and do not affect gluten properties. Hard wheat starch has a crystalline structure and soft wheat starch is amorphous. Crystallin starch is stable, it stays undestroyed in a grain milling machine, binds with gluten, and forms a solid elastic carcass. Amorphous starch is less stable, porous, and easily destroyed by grinding due to its large size and amorphous structure. Amorphous starch does not bind with weak gluten, during cooking it passes into the cooking medium and causes water turbidity [7].

As it is known, the dough gluten network is formed because of protein coagulation, which presupposes the interaction of additives with the basic dough components.

There are many theoretically justified interpretations of protein interaction with dough components that are based on disperse systems aggregative stability conception, according to which colloid particles with the size of more than 5 micrometers do not participate in coagulation structure formation, consequently, these structures are formed exclusively by gluten proteins.

The process of coagulation structure formation within the dough occurs through contact coagulation leading to agglomerates formation. The coagulation process is due to the introduction of additional proteins in the form of biologically active additives, which can improve gluten structure or change cardinally its properties. To the latter, we refer to vegetable extracts containing protein structures, a vivid representative of which is aqueous garlic extract prepared from dried garlic slices. Airing is required to transform alliin into allicin which possesses powerful antibiotic properties [8].

Polysaccharides contained in many vegetable additives can participate in coagulation structure formation along with flour proteins. This leads to the conclusion that dough is a coagulation structure based on gluten proteins, which bind other dough components (water, starch). Vegetable proteins added into soft wheat flour dough interact with its components improving its structure, which influences directly the quality of ready products [9]. To justify the reasonability of using soft wheat flour in macaroni production an experiment was conducted. Dry garlic extract with the established hydromodulus was added to the dough instead of water. Dry garlic extract with hydromodulus 1:25 and 1:50 was used as a protein additive. With this additive, macaroni from soft wheat flour becomes nearly equal in quality to macaroni from hard wheat flour and water turbidity lowers considerably. Therefore, extract components interact with the dough gluten network improving its stability and elasticity. This conclusion is justified by the fact that during cooking when starch gelatinization occurs, amylose and mechanically damaged starch do not move into the cooking medium, which raises considerably macaroni organoleptic value.

Antioxidant (flavonoid) dihydroquercetin was found in macaroni prepared based on aqueous garlic extract (with hydromodulus 1:50 – 34.6 ml / 100 gr; with hydromodulus 1:25 – 78.7 ml / 100 gr). In "Makfa" macaroni, which served as a reference sample, dihydroquercetin content was equal to 3.5 ml / 100 gr. As it is known, this flavonoid is an essential component of the human diet – it strengthens vascular walls, accelerates metabolism, and fortifies immunity.

Table 1 illustrates the influence of aqueous garlic extract on soft wheat flour properties. Mass concentration of wet gluten decreases insignificantly, no more than 0.35%, which is explained by the fact that extract proteins help to bind moisture. Macaroni dough prepared according to technological parameters has a specific structure, so the replacement of certain receipt components or the addition of new ones inevitably influences rheological properties.

Coefficients estimated by the grapho-analytical method are summarized in Table 2 and represented in Figure 2. Shear stress in experimental dough samples exceeds the reference value by 73.5-100%, consistency coefficient value in experimental dough samples exceeds the reference value by approximately 10-23%, dough viscosity value in experimental dough samples exceeds the reference value by 47.76% and 50.1% correspondingly.

Aqueous garlic extract improves macaroni dough's rheological properties by changing its structure: garlic proteins become elements of wheat dough structure and affect gluten properties, strengthening the gluten network and increasing resistance to pressure. Experimental data testify that aqueous garlic extract improves considerably soft wheat flour dough properties. The elasticity and stability of experimental dough samples are higher in comparison with reference values.

Table 1 – Influence of aqueous garlic extract on soft wheat flour properties

Index	Macaroni samples		
	Reference sample	Garlic extract with hydromodulus 1:25	Garlic extract with hydromodulus 1:50
Mass concentration of wet gluten, %	28.83±0.1	28.62±0.1	28.5±0.1
Mass concentration of dry gluten, %	10.1±0.1	9.97±0.1	9.8±0.1
Elasticity	good		
Gluten ball slackness, mm	8.00	7.00	7.00

Table 2 – Rheological properties of macaroni dough based on aqueous garlic extract

Sample	Index			
	Maximum shear stress, mPa	Consistency coefficient	Flow behaviour index	Effective viscosity, mPa·s, when $\gamma = 3.32 - 4.03\ s^{-1}$
Reference dough sample	0.02	0.22	0.29	0.092
Hydromodulus 1:25	0.035	0.225	0.44	0.0996
Hydromodulus 1:50	0.04	0.245	0.47	0.136

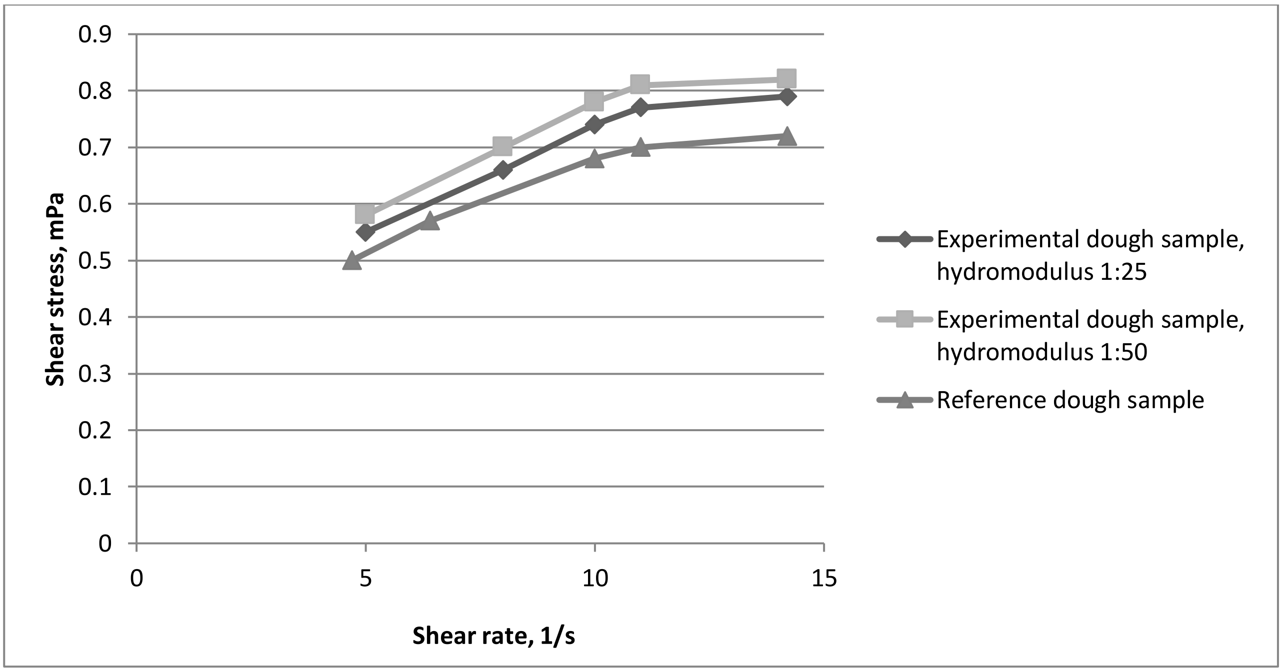

Figure 2 – Flow curves of reference and experimental dough samples

It should be mentioned that soft wheat flour has weak gluten and, consequently, soft wheat flour dough possesses low rheological value, which explains the high concentration of dry substance in the cooking medium.

Let's consider the influence of garlic extract on ready product quality. Macaroni organoleptic evaluation was carried out according to a score scale for quality assessment taking into account importance coefficients. Macaroni dough quality indicators represented in Table 3 serve as the main criterion for the reasonability of using certain additives. Analysis of experimental macaroni samples based on aqueous garlic extract shows that the mechanical strength of ready product increased by 18.6-20.9%. It is represented in Figure 3. Macaroni has a dense consistency and appropriate color; its coarse surface and low friability of rims prevent them from sticking together. The cooking properties of experimental macaroni samples are as follows: unessential increase in cooking time; product recovery rate decreases by an average of 10.5%; dry substance concentration in cooking medium decreases by 1.93-3.18% in comparison with the reference value. Aqueous garlic extract with hydromodulus 1:25 contributes significantly to reducing dry substance concentration.

Experiment results justify the efficiency of aqueous garlic extract with hydromodulus 1:25 as a dough additive.

Analysis of experimental data indicates that aqueous garlic extract influences positively gluten properties and improves macaroni rheological properties and quality.

Table 3 – Influence of aqueous garlic extract on macaroni quality

Indicator	Reference sample	Experimental macaroni samples with hydromodulus	
		1:50	1:25
Humidity, %	8.9±0.1	9.1±0.1	9.0±0.1
Dry macaroni mechanical strength, N	4.3	5.1	5.2
Stickiness	a bit sticky	do not stick together	
Recovery rate	2.1	1.88	1.88
Dry substance concentration in cooking medium, %	9.66±0.1	7.37±0.1	6.48±0.1

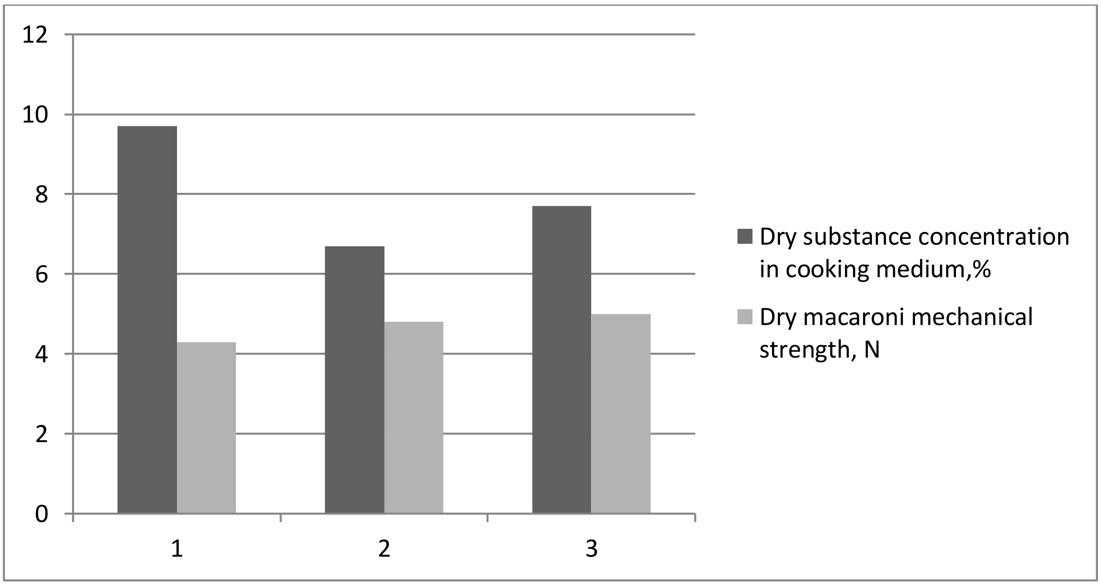

Figure 3 – Cooking properties and mechanical strength of experimental macaroni samples (1 – reference sample; 2 – aqueous garlic extract with hydromodulus 1:25; 3 – aqueous garlic extract with hydromodulus 1:50)

Conclusions:

Experimental macaroni was produced from soft wheat flour based on aqueous garlic extract prepared by specially developed technologies: two-stage convection vacuum-impulse drying and vacuum-impulse extraction. Two-stage convection vacuum-impulse drying allowed for preserving valuable biologically active substances in sliced garlic. The humidity level of 3.4% was achieved for less than 2 hours at the drying temperature of no more than 58^0C. Universal vacuum-impulse extraction allowed getting high-quality extracts of the required concentration (hydromodulus 1:25, 1:50) at a temperature of no more than 54-56^0C. Bioflavonoid content in experimental macaroni samples was estimated by the ampere-metric method. The concentration of antioxidant dihydroquercetin in the reference sample was equal to 3.5 ml / 100 gr; in experimental macaroni samples prepared based on aqueous garlic extract with hydromodulus 1:50 – 34.6 ml / 100 gr; with hydromodulus 1:25 – 78.7 ml / 100 gr. The human daily norm for this flavonoid is a minimum of 25 mg. An organoleptic evaluation of enriched macaroni products was conducted. The analysis testifies that the mechanical strength of experimental macaroni samples has increased by 18.6-20.9%. The cooking properties of experimental macaroni samples are as follows: unessential increase in cooking time; product recovery rate decreases by an average of 10.5%; dry substance concentration in cooking medium decreases by 1.93-3.18% in comparison with the reference value. Experimental data testify that aqueous garlic extract with hydromodulus 1:25 contributes significantly to reducing dry substance concentration.

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