Chapter 11

Interrelation of Functional Properties of Protein Products from Wheat with the Composition and Physicochemical Characteristics of Their Proteins

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http://dx.doi.org/10.5772/intechopen.75803

Abstract

The results of studies of the correlation relationship between the functional properties of dry wheat gluten, protein concentrates from wheat bran and their granulometric fractions with the features of the chemical composition, and the physicochemical properties of their proteins are presented. Granulometric fractions of bran were obtained from grinding process systems with different particle sizes. The correlation interrelation between the functional properties of protein products (solubility, water binding capacity, fat-binding capacity, and foaming capacity) with a mass fraction of components, fractional amino acid composition, the number of thiol metabolism groups (–S-S– and –SH) and the aggregation capacity of whole gluten proteins, its fractions (gliadin, glutenin) and products from wheat bran. The obtained information is expedient for using when modifying the properties of wheat protein products with the purpose of expanding the directions of their use.

Keywords: protein products from wheat, chemical composition, functional properties, physicochemical characteristics of proteins, interrelation

1. Introduction

Cereals crops on a global scale are the largest (or most spread) sources of proteins. Among them, wheat occupies an important place, the world production of which has increased from 450 million tons in 1981–750 million tons at present. Wheat is the only type of grain crop

from which spare proteins in the dry wheat gluten (DWG) form were extracted industrially, intended as a protein ingredient to improve the baking properties of flour and meat substitution in sausage products. In time of processing of wheat grains on DWG forms bran, which is additionally a source of valuable food protein. Therefore, this chapter is devoted to the results of a study of the physicochemical properties of DWG proteins and protein concentrates from wheat bran for the purpose of applying the information obtained for practical purposes to improve and regulate the functional properties of protein ingredients in the development of food formulas.

Functional properties of protein products are understood as physicochemical indicators that determine the behavior of proteins in the production of food products, providing the necessary structure, and consumer properties [1]. The indicators characterize the parameters of products, some of which are substituted or supplemented with protein in the technological processes of food production. The functional properties of protein products are evaluated both in numerical values and in profiles of dependencies on various technological factors (temperature, pH, processing time, etc.) [2–5]. This approach to the evaluation of properties is reflected in the term "techno-functional," which includes the features of the reactivity of proteins in the technological processes of production and storage of food systems. Functional properties for concrete food systems are usually evaluated on model recipes, and then compared with the properties of traditional or known protein products. The presence of hydrophilic and hydrophobic groups in one chain ensures the interaction of proteins with water, lipids, carbohydrates, other compounds and leads to the formation of stable emulsions, foams, gels, and so on. In solutions proteins can perform a dispersing and suspending roles, it's able to cling to solid particles and by that forming cementing structures. The presence of polar and nonpolar, charged and uncharged groups in one polymer chain allows proteins to interact with different types of compounds and, thereby, influence the quality of food products.

The most important functional properties of protein products are hydration, fat-binding capacity, foam ability, stability of emulsions, foam stability (FS), gel-forming ability, adhesion, rheological properties (viscosity, elasticity), ability to spin and texturing [1, 6, 7]. The values of the functional properties of protein products always determine the directions of their use in the production of food products as technological or nutritional ingredients, but not always these properties satisfy the requirements of the consumer; therefore, in the chemistry of dietary protein, there is a direction devoted to regulating the quality indices of vegetable protein products by various modification processes [8–12].

It is known that the functional properties of protein products depend on the chemical nature of the raw materials (wheat, rye, soybean, etc.), methods of isolation, processing, and technological regimes of food production (pH, temperature, recipe, etc.) [13–14]. When analyzing the nature of vegetable proteins, food recipes' designers limit themselves, as a rule, to a statement of facts showing how a particular kind of raw material affects the functional properties but does not study the molecular basis that conditions these properties. In the practice of using protein products, at best, technological factors affecting their functional properties (temperature, pH, electrolytes, etc.) are taken into account, whereas the characteristics of the chemical,

biochemical composition, and physicochemical properties of the polypeptides themselves are practically not are considered. Despite the fact that, for example, dry wheat gluten (DWG) is widely used in the production of bread as an improver or filler [15–19], the areas of its use can be expanded by modifying the functional properties.

The choice of DWG is conditioned not only by the fact that wheat is one of the traditional cultures of many peoples of the world for bread production but also because the increasing volumes of its cultivation are aimed at producers to use it in technologies and other types of food products. In addition, the amount of secondary products of wheat processing in the form of bran is also increasing. Taking into account the functional properties on the basis of DWG, we have developed special mixtures for the production of oil cakes and protein-containing biscuits [20], based on the gel-forming and foaming ability—marshmallows with the replacement of egg protein on DWG [21], based on enzymatically hydrolyzed DWG-bread with increased content protein from amaranth (20–25%) for diabetics (unpublished data). However, the processes of modifying the functional properties of protein products from wheat, the prophylactic and dietary properties of products from them, can be more effective if one has more information about the structural features and properties of their proteins, as it is known for proteins from other cultures [22–24] that additional studies are needed on the characteristics of the composition and properties of protein products from wheat, are the following facts. Thus, it is known that soluble proteins have a greater set of functional properties than poorly soluble proteins. They have little change in viscosity, gelatinization, but they have a high ability to stabilize suspensions, emulsions, and foams. However, there are proteins that do not fall under these patterns. So DWG proteins, despite their low solubility in water (1–3%), form structured gels that withstand heating, freezing, and drying. Therefore, they are used to prepare protein fibers as a binding agent in the production of film membranes, meat analogs, and non-food products [25, 26].

Another example is protein flour made from wheat bran. Having relatively low solubility values (10–20%), it has a high fat-emulsifying ability (FEA) and foaming capacity (FC): 72–97% and 74–100%, respectively [2, 3]. It is possible to increase the solubility of proteins to 25–100% by heating to 40–90°C, changing the ionic strength of the system or pH [3], but it is difficult to predict the final result of solubility control, as well as other functional properties, because it will often have a "one-time" nature and do not provide, as a rule, a stable forecasting of the quality of finished products. Hence, in order to predict stable results of the modification of the quality of protein products, the purpose of the present study was to study the composition and physicochemical properties of DWG proteins and products from wheat bran and to establish a correlation relationship between the results and the basic functional properties of the ingredients.

2. Materials and methods

2.1. Materials

As protein products, two samples of dry wheat gluten were used from LLC "BM" (Kazakhstan) and "Royal Ingredients Group BV" (the Netherlands), as well as concentrates from wheat

bran and their fractions obtained according to the technology developed by us [27]. To study the amino acid composition of proteins, three samples of wheat gluten were used, which were manually washed from the flour of a typical "strong" sort of grain Saratov 29 (spring), typically "weak"—Akmolinka 1 (spring) and typically medium Gorkovskaya 52 (winter). The crude gluten was dried on a lyophilic plant, it was regenerated by washing in tap water for 15 min and the deformation index on the IDG-1 instrument was determined. Regenerated gluten in the first grade of grain was characterized as slightly elongated, "strong," with an indicator of the device of 58 units, in the second—tensile, "normal" with an indicator of 70 equipment units, the third—as very extensible and "weak" with an indicator of 100 equipment units.

Protein concentrates from wheat bran were obtained from various systems of the technological process of JSC "Moscow Combine of Bread Products," the quality of grain and bran was in accordance with the requirements of standards. The bran was combined, sieved through a sieve of different diameters, and granulometric fractions with a particle size of more than 1000, 670, 195, and less than 195 μm were obtained.

To compare the results of the relationship between functional properties and physicochemical parameters for proteins from wheat and protein products from another type of raw material, soy concentrate, soy isolate Supro 760 from "Soloe" Supro (USA), soy isolate ArdexF ADM (USA), concentrates from amaranth and grain of rye, obtained by our methods [28, 29].

2.2. Determination of chemical composition

Indicators of the chemical composition of protein products were determined by the methods of state standards of the Russian Federation and generally accepted methods. The mass fraction of moisture was determined in accordance with GOST 13586.5-85; ash content—GOST 10847-74; mass fraction of fat—according to the method of Soxhlet in the apparatus of the firm "Buchi"—GOST 29033-91, the mass fraction of protein—in the automated Kjeldahl system of the firm "Buchi"—GOST 10846-91, fiber—according to Gennesberg and Shtoman—GOST 31675-2012. Carbohydrates were calculated as the difference between 100% and the sum of the mass fraction of protein, fat, ash, and fiber.

2.3. Determination of the amino acid composition of proteins

A liquid chromatograph from Hitachi (Japan) was used in a mode with a sulfonated styrene-divinylbenzene copolymer and a step gradient of sodium citrate buffer solutions with increasing pH and molarity. The data were processed in an online system "MultiChrome 1.52" for Windows 98. A sample of 3–5 mg sample was placed in a glass ampoule, 300 μl of a mixture of concentrated hydrochloric acid and trifluoroacetic acid (2, 1) with 0.1% 2-mercaptoethanol was added. The sample was frozen in liquid nitrogen, evacuated and hydrolyzed at 155°C for 1 h. The hydrolyzable mixture was evaporated on a rotary evaporator (Centrivap Concentrator Labconco, USA). To the residue, 0.1N HCl was added and centrifuged for 5 min at 800 g on a Microfuge 22R centrifuge (Beckman-Coulter, USA).

2.4. Determination of the fractional composition of proteins

1 g of the protein product, weighed to within 0.001 g, was placed in a centrifuge tube, 10 cm^3 of a 0.5 mol/dm^3 NaCl solution was added, shaken for 1 h and centrifuged for 15 min at 8000 g. The centrifugate was drained, 10 cm^3 of cold distilled water was added to the precipitates, thoroughly mixed, and centrifuged again. The combined centrifuges were taken as albumins and globulins. To extract the gliadin proteins, 20 cm^3 of 70% ethanol was added to the precipitates, shaken at 180–200 rpm for 1 h and left overnight at room temperature. The next day the sample was shaken for 30 min and centrifuged at 8000 g for 15 min. The centrifugate (gliadin) was drained, 20 cm^3 of 0.1 mol/dm^3 acetic acid was added to the precipitates and again shaken for 1 h. The suspension was centrifuged under the same conditions. The extraction procedure was repeated one more time. The combined solutions of proteins soluble in acetic acid were considered to be soluble glutenin. To isolate insoluble glutenin to the precipitates, 20 cm^3 of AUC included 0.1 N acidic acid, 6M urea, and cetyl three methyl ammonium bromide solvent (pH 4.1) were added [24]; the tubes were shaken for 1 h and centrifuged. The extraction operation was repeated once more, after which the centrifuges were combined and the protein content of Kjeldahl was determined therein. The protein precipitate was designated as an insoluble protein. The amount of each fraction was expressed as the percentage of soluble and insoluble protein from the total amount of protein in the sample.

2.5. Determination of the functional properties of protein products

Functional properties of DWG samples, protein products from wheat bran, amaranth, rye, and soybean were determined by the methods described in [30].

2.6. The content of thiol exchange groups

The content of disulfide bonds and sulfhydryl groups in protein preparations from wheat bran was analyzed by the Ellman method in Bogdanov's modification [31].

2.7. Determination of the constant of the final stage of protein aggregation

To determine the aggregating properties of proteins, a sample of the product 1.0 g with an accuracy of ±0.001g was suspended in 10 cm^3 of a 0.05 mole/ dm^3 solution of CH_3COOH for 1 h on a mechanical shaker. The solution was then centrifuged for 15 min at 3000 g, the centrifugate was filtered and the Lowry protein was determined in the filtrate. The solution was diluted with 0.05 mol/dm^3 acetic acid to a concentration of 0.02% protein. To 1.3 cm^3 of the protein solution, 1.3 cm^3 of 0.2 mol/dm^3 phosphate buffer containing 2 mol/dm^3 NaCl (pH 5.6) was added to the spectrophotometer cuvette. Then, after 10 min at a wavelength of 350 nm, the optical density (turbidity) of the solution was measured. The constant of the final stage of aggregation (τ_{10}/C) was calculated as the ratio of turbidity (τ) to protein concentration (C) [32].

Analyses were carried out in 3–5 replicates, the results were represented as arithmetic means. To determine the confidence interval of the average arithmetic result, the Student's test was

used at the significance level $p = 0.05$. The statistical processing of the results was carried out with the programs Statistica 6.0 and Mathematica 5.2.

3. Results and discussion

3.1. Dependence of the functional properties of protein products on the chemical composition

To study the relationship between the chemical composition and the functional properties of protein products from wheat, the mass fraction of the main components was determined. It was established that all the products, depending on their belonging to one or another group, contained different amounts of protein, carbohydrates, fat, ash, and fiber (**Table 1**).

The high correlation between the mass fraction of components and the functional properties of protein products from wheat (**Table 2**) was not found, which is confirmed by the calculation of the correlation coefficients (r) for variant pairs for different pairs of indices (**Table 3**). Correlation dependence at the mean level is established only for the mass fraction of protein with FEA, water-binding capacity (WBC), and FC protein products ($r = 0.51 - 0.60$). Correlation coefficients for the mass fraction of the remaining parameters of the chemical composition with fat-binding ability (FBA), foam stability (FS), and protein solubility (PS) are relatively low.

The correlation relationship between the chemical composition of other vegetable protein products (**Table 1**) and their functional properties (**Table 2**) was established at a high level ($r = 0.75 - 0.79$) for the mass fraction of protein with FEA and FC and a relatively low for other indicators ($r = <0.5$).

3.1.1. Effect of amino acid composition on the functional properties of protein products

The interrelation of functional properties with the amino acid composition of proteins was studied on three gluten samples of different quality (strong, good, and weak), three of its fractions (gliadin, soluble, insoluble glutenin), and three protein concentrates from unconventional grains: amaranth, wheat bran, and rye. The results of determining the amino acid composition of gluten and its fractions are given in **Table 4**, and for other protein products in **Table 5**. Based on the data obtained, the sums of polar (lysine, arginine, aspartic, glutamic acid) and nonpolar amino acids (glycine, phenylalanine, alanine, leucine, methionine, isoleucine, valine, and proline), on the ratio of which the surface properties of proteins will depend, hence their functional properties: solubility, foaming, the ability to bind and emulsify fat, and so on (**Tables 4** and **5**). Coefficients of pair correlation, reflecting the interrelation between the amino acid composition and functional properties, are shown in **Table 6**. It is shown that for gluten of different quality (weak, good, and strong), a high positive correlation between the sum of polar amino acids and FBA is detected, high negative with solubility. A high, directly proportional relationship was found for FEA and the sum of nonpolar amino acids ($r = 0.86$).

http://dx.doi.org/10.5772/intechopen.75803

Protein products	Humidity, %	Mass fraction, % on dry substance				
		Protein	Fat	Carbohydrates	Insoluble fibers	Ash
Concentrates from wheat:						
DWG (Kazakhstan)	4.0 ± 004	75.0 ± 0.9	1.0 ± 0.04	22.0 ± 0.6	1.0 ± 0.06	1.0 ± 0.12
DWG (The Netherlands)	5.0 ± 0.10	74.0 ± 0.7	1.0 ± 0.08	23.0 ± 1.0	1.0 ± 0.08	1.0 ± 0.17
Concentrate from wheat bran	5.3 ± 0,05	77.9 ± 2,1	1.3 ± 0.06	14.7 ± 1.0	2.8 ± 0.08	3.3 ± 0.05
Concentrates from wheat bran fractions, N of sieve, d, mcm:						
1,0 > 1000 (descent)	4.1 ± 0.02	72.6 ± 0.21	4.0 ± 0.04	12.8 ± 0.15	4.5 ± 0.03	6.1 ± 0.02
067 670 (descent)	4.7 ± 0.31	69.4 ± 0.32	3.8 ± 0.06	17.4 ± 0.04	3.8 ± 0.01	5.6 ± 0.03
38 195 (descent)	5.1 ± 0.22	72.5 ± 0.51	2.2 ± 0.07	17.3 ± 0.12	3.2 ± 0.06	4.8 ± 0.02
38 <195 (pass)	5.6 ± 0.30	75.7 ± 0.14	1.4 ± 0.02	19.0 ± 0.08	2.1 ± 0.02	1.8 ± 0.05
Protein products from other types of raw materials:						
Soy flour (Belgium)	9.0 ± 0.15	43.0 ± 0.5	14.0 ± 0.7	34.0 ± 0.50	5.0 ± 1.00	4.0 ± 1.00
Soy concentrate (Russia)	4.0 ± 0.13	61.0 ± 1.2	5.0 ± 1.0	26.0 ± 0.25	4.0 ± 0.09	4.0 ± 0.09
Soy Isolate Supro 760	4.0 ± 0.20	92.0 ± 1.5	0.5 ± 0.02	1.5 ± 0.80	3.0 ± 0.08	3.0 ± 0.05
Soy isolate Ardex F	4.0 ± 0.40	91.0 ± 1.1	0.5 ± 0.01	2.0 ± 0.40	3,0 ± 0,05	3.5 ± 0.08
Amaranth concentrate	8.0 ± 0.20	71.6 ± 1.4	1.0 ± 0.08	20.0 ± 1.1	3.0 ± 0.20	4.4 ± 0.10
Concentrate from rye grains	6.2 ± 0.13	75.5 ± 2.0	1.3 ± 0.04	17.8 ± 0.09	2.6 ± 0.05	2.8 ± 0.08

Table 1. Chemical composition of protein products from plant material.

For the gliadin fraction, the regularities in the relationship between the sum of polar amino acids and FBA and solubility are similar to those of the whole gluten complex, and additional regularities were revealed for the sum of nonpolar amino acids: the more they were contained in the gliadin, the higher the FC, FS, and FEA gluten (r = 0.70 ± 0, 99). For the sum of nonpolar amino acids in the soluble fraction of glutenin, a high negative correlation with FBA was found, a high positive with solubility and FA. The more the amount of polar amino acids in the fraction was, the lower the values of the FBA, FEA, and FA but higher solubility.

Protein products	PS, % *	WBC, g/g	FBA, g/g	FEA, %	SE, %	FC, %	FS, %
Concentrates from wheat:							
DWG (Kazakhstan)	1.2 ± 0.50	2.39 ± 1.00	2.32 ± 0.25	64 ± 1.6	92 ± 2.5	220 ± 2.8	65 ± 2.0
DWG (The Netherlands)	1.1 ± 0.15	2.27 ± 0.90	1.24 ± 0.50	50 ± 2.0	70 ± 1.6	182 ± 1.9	59 ± 2.0
Concentrate from wheat bran	16.0 ± 0.9	2.90 ± 0.08	4.20 ± 0.5	56 ± 1.3	80 ± 1.2	85 ± 1.3	70 ± 2.0
Concentrates from wheat bran fractions, N of sieve, d, mcm:							
1.0 > 1000 (descent)	13.7 ± 0.6	1.1 ± 0.10	2.4 ± 0.09	95 ± 1.2	90 ± 2.2	132 ± 3.2	75 ± 1.8
067 670 (descent)	21.5 ± 1.1	1.0 ± 0.09	2.4 ± 0.07	89 ± 1.1	85 ± 1.3	130 ± 2.2	74 ± 2.1
38 195 (descent)	26.9 ± 1.6	0.7 ± 0.05	2.8 ± 0.04	72 ± 1.5	79 ± 1.4	129 ± 1.2	65 ± 1.2
38 <195 (pass)	9.8 ± 0.6	0.5 ± 0.06	4.9 ± 0.07	61 ± 2.0	66 ± 2.7	107 ± 1.2	63 ± 1.7
Protein products from other types of raw material:							
Soy flour (Belgium)	45.1 ± 2.0	1.60 ± 0.80	1.20 ± 0.08	49 ± 1.2	47 ± 1.0	80 ± 2.1	60 ± 1.7
Soy concentrate (Russia)	75.3 ± 1.3	7.40 ± 0.35	2.20 ± 0.50	61 ± 0.9	48 ± 0.2	50 ± 2.0	68 ± 1.5
Soy Isolate Supro 760	72.6 ± 1.5	7.90 ± 1.00	1.80 ± 0.05	55 ± 0.5	55 ± 1.2	110 ± 2.5	57 ± 1.2
Soy isolate Ardex F	78.5 ± 2.0	6.00 ± 1.50	1.20 ± 0.08	48 ± 0.9	45 ± 1.0	95 ± 2.0	55 ± 1.2
Amaranth concentrate	46.0 ± 1.0	2.60 ± 0.05	2.60 ± 0.80	57 ± 1.20	54 ± 1.0	200 ± 2.0	65 ± 1.5
Concentrate from rye grains	18.2 ± 1.0	1.80 ± 0.50	2.20 ± 0.90	87 ± 1.5	88 ± 1.1	100 ± 1.5	40 ± 1.6

*PS—protein solubility; WBC—water-binding capacity; FBA—fat-binding ability; FEA—fat-emulsifying ability; SE—stability of the emulsion; FC—foaming capacity; FS—foam stability.

Table 2. Functional properties of protein products.

It was found that the functional properties of gluten are also interrelated with the characteristics of the amino acid composition of insoluble glutenin: the more nonpolar amino acids were FEA. The number of polar amino acids is also directly proportional to the FC values but is inversely proportional to WBC and FBA.

Functional properties	Fraction of total mass, % by dry matter			
	Protein	Carbohydrates	Fat	Insoluble fibers
PS, %	0.44	0.15	0.30	−0.11
WBC, g/g	0.55	0.22	0.13	0.27
FBA, g/g	−0.22	0.41	0.14	0.42
FEA, %	0.60	0.20	0.36	0.32
FC, %	0.51	0.25	0.40	0.18
FS, %	0.23	0.37	0.24	0.28

Table 3. Correlation coefficients (*r*) between functional properties and chemical composition of protein products.

The results of the dependence of the functional properties of the whole complex of dry wheat gluten on the characteristics of the amino acid composition of its proteins were confirmed by data obtained for protein concentrates from amaranth, rye, and wheat bran. It is also shown that the values of Foaming Capacity and Foam Stability are directly proportional to the content of the polar (r = 0.93) and nonpolar (r = 0.68 and 0.85) amino acids, and the values of FEA are inversely proportional to the sum of nonpolar amino acids (r = −0.79).

3.1.2. Effect of the fractional composition of proteins on the functional properties of protein products

The effect of the fractional composition of proteins on the functional properties of protein products was studied using protein products from wheat bran and their granulometric fractions as an example. Protein products obtained from bran fractions with different particle sizes differed both in their functional properties (**Table 7**) and in the fractional composition of their proteins (**Figure 1**). The highest amount of albumins and globulins (44%) had protein products obtained from the bran fraction with a particle size of 195–670 μm, the lowest (32%) protein products from the fraction with a particle size <195 μm.

The highest amount of gluten proteins (gliadin, glutenin) was observed for products isolated from the fraction with a size of <195 μm, the smallest for products from the cut fraction with a particle size> 1000 μm. A large amount of insoluble glutenin (37%) differed products from a large bran fraction (> 1000 μm), a smaller (12%) from a granulometric fraction with a particle size <195 μm. Mathematical processing of the data showed that protein solubility was directly proportional to the sum of albumins and globulins (r = 0.90), FBA—from the amount of both gluten fractions and their sums (r = 0.78–0.90) and the FEA–of the amount of high molecular weight (MM) glutenin and insoluble proteins (r = 0.73–0.78) (**Figure 1**). A high inverse relationship was found for the solubility of wheat bran concentrate proteins on the amount of gliadin and the average negative correlation (r = −0.51–0.69) for WBA on the amount of gliadin and sum insoluble proteins.

Amino acid	Strong DWG				Good DWG				Weak DWG			
	1	2	3	4	1	2	3	4	1	2	3	4
Lysine	2.24	0.70	1.17	2.63	1.57	0.60	1.27	1.74	1.51	0.79	1.21	1.20
Histidine	2.27	1.81	1.47	2.24	1.99	1.70	1.60	1.76	2.04	1.49	1.20	1.67
Arginine	3.62	2.87	2.85	3.96	3.76	2.55	3.62	4.24	3.43	2.51	3.10	3.44
Aspardic acid	3.75	2.84	2.69	4.09	3.17	3.12	2.62	3.89	3.32	2.95	1.99	4.44
Threonine	2.37	2.20	2.73	5.13	5.16	2.24	2.58	3.95	2.55	2.49	2.96	4.40
Serine	4.87	4.12	3.33	4.25	3.05	4.64	4.61	5.23	4.93	3.97	6.08	8.12
Gluetamic acid	40.16	50.86	49.56	33.15	43.59	50.53	44.36	31.88	43.66	50.96	42.06	30.47
Proline	18.19	18.09	17.40	12.08	17.16	20.95	15.44	10.73	19.12	18.73	14.62	8.47
Glycine	3.96	1.89	3.43	5.32	3.66	1.69	3.51	4.37	4.16	1.63	3.55	5.90
Alanine	3.34	2.50	2.53	2.71	3.34	2.27	2.05	2.90	2.89	2.25	1.97	3.19
Valine	4.58	5.15	4.53	3.96	5.08	5.11	3.69	4.56	4.52	4.74	3.58	3.79
Methionine	2.13	1.64	1.78	1.79	1.73	1.48	1.21	1.33	1.91	0.95	1.21	1.59
Cysteine (1/2)	5.43	5.10	5.74	5.10	3.25	2.72	3.91	2.81	1.91	2.84	4.23	2.60
Isoleucine	4.80	5.10	3.65	2.95	4.49	4.84	3.42	3.33	4.42	4.42	3.32	3.26
Leucine	7.84	8.44	7.34	6.82	8.08	7.83	6.34	7.33	7.99	7.15	5.92	6.37
Tyrosine	3.88	3.01	3.53	3.90	3.65	2.87	3.55	3.45	3.48	2.88	3.48	4.62
Fenylalanine	6.76	6.61	5.97	4.06	7.48	7.07	5.25	5.49	7.05	6.68	5.20	2.83
The sum of polar amino acids	49.77	57.27	56.27	43.83	52.09	56.80	50.60	41.75	51.92	57.21	44.05	39.55
The sum of nonpolar amino acids	52.20	49.42	46.63	39.69	51.02	51.27	40.91	40.04	52.06	46.55	39.93	35.4

Note: 1–gluten; 2–gliadin; 3–soluble glutenin; 4–insoluble glutenin.

Table 4. Amino acid composition of wheat gluten of different quality and its fractions, g/100 g of protein.

3.1.3. Effect of the number of thiol exchange groups and the coefficient of the final stage of protein aggregation on the functional properties of protein products

It is known that the covalent (disulfide) and non-covalent (hydrogen, ionic) bonds and hydrophobic interactions play an important role in the structure of vegetable proteins. To identify the participation of these types of interactions in the formation of the functional properties of products from wheat bran, the content of sulfhydryl groups, disulfide bonds, and the aggregating capacity of proteins were determined (**Figure 2**). It was taken into account that the aggregation of proteins in the presence of sodium chloride molecules is carried out with the participation of hydrophobic interactions. It is established that the values

Amino acid	Protein concentrate from:		
	Amaranth	Wheat bran	Rye grains
Lysine	5.43 ± 0.50	6.90 ± 0.40	2.55 ± 0.30
Histidine	3.11 ± 0.25	4.86 ± 0.15	1.58 ± 0.09
Arginine	10.57 ± 1.0	6.21 ± 0.60	3.11 ± 0.10
Aspardic acid	9.51 ± 1.0	8.56 ± 0.50	5.43 ± 1.00
Threonine	3.85 ± 0.25	4.62 ± 0.80	2.37 ± 0.55
Serine	5.40 ± 0.50	6.09 ± 0.80	2.49 ± 0.30
Gluetamic acid	17.88 ± 0.90	14.40 ± 1.1	23.78 ± 1.20
Proline	4.64 ± 0.15	3.77 ± 0.55	9.62 ± 1.00
Glycine	5.57 ± 0.50	6.99 ± 0.90	3.51 ± 0.60
Alanine	4.36 ± 0.20	5.92 ± 0.70	4.07 ± 1.10
Valine	5.17 ± 0.20	5.11 ± 0.50	1.47 ± 0.20
Methionine	4.02 ± 0.3	2.84 ± 0.15	2.13 ± 0.25
Cysteine (1/2)	1.25 ± 0.15	5.10 ± 06	5.43 ± 0.32
Isoleucine	4.63 ± 0.9	3.34 ± 0.62	1.82 ± 0.15
Leucine	7.57 ± 1.05	9.35 ± 1.1	5.60 ± 0.35
Tyrosine	4.61 ± 0.10	5.19 ± 1.0	2.32 ± 0.10
Fenylalanine	10.57 ± 1.5	5.83 ± 1.0	3.96 ± 0.06
The sum of polar amino acids	43.39 ± 1.8	36.07 ± 0.89	34.87 ± 1.12
The sum of nonpolar amino acids	46.53 ± 1.3	43.15 ± 0.67	32.18 ± 1.11

Table 5. Amino acid composition of protein concentrates, g/100 g of protein.

of FC and FEA protein concentrate are interrelated with the content of -SH-groups and -S-S-bonds: the smaller the -S-S bonds and more -SH-groups, the FC and FEA are higher, r = 0.896 and 0.732, respectively.

For FBA, the inverse relationship was observed, the more -S-S bonds in proteins, the indicator, on the contrary, was higher (r = 0.755). For solubility and WBC, there was no significant correlation with the indices of thiol metabolism.

FEA and SE of protein products from wheat bran were positively correlated with the coefficient of the final stage of aggregation of τ10/C proteins, as well as with the number of -SH-groups. Therefore, one can indirectly conclude that the stronger the property of the surface hydrophobicity of proteins, the ability to emulsify fat and the stability of the emulsion in foods is higher. These results are consistent with the number of non-polar amino acids in gluten and wheat gliad, which included amino acids with hydrophobic radicals (**Table 6**).

The sum of amino acids	Functional properties					
	PS, %	WBC, g/g	FBA, g/g	FEA, %	FC, %	FS, %
Wheat gluten and its fractions:						
	Wheat gluten					
Polar	−0. 96	0.54	0.95	−0.78	−0.66	0.22
Nonpolar	0.98	−0.36	−0.76	0.86	−0.11	−0.36
	Gliadin					
Polar	−0.97	—0.20	0.78	−0. 84	0.21	0.21
Nonpolar	−0.21	−0.42	−0.30	0.70	0.79	0.99
	Soluble glutenin					
Polar	0.62	−0.67	−0.85	−0.62	−0.67	0.54
Nonpolar	0.88	0.62	−0.92	−0.39	0.80	0.14
	Insoluble glutenin					
Polar	0.24	−0.98	−0.86	−0.61	0.97	−0.49
Nonpolar	0.10	0.57	−0.52	−0.74	0.95	0.90
Protein concentrates from wheat bran						
Polar	0.15	0.54	−0.17	−0.37	0.93	0.44
Nonpolar	0.06	0.65	0.10	−0.79	0.68	0.85

Table 6. Coefficients of correlation between functional properties protein products and the sum of amino acids.

Raw material	PS, %	FEA, %	SE, %	FBA, g/g	FC, %
Total insoluble fibers	16.0 ± 0.3	89	87	3.6	119
> 1000	13.7 ± 0.2	95	90	2.4	132
670–1000	21.5 ± 0.3	89	85	2.4	130
195–670	26.9 ± 0.5	72	79	2.8	129
< 195	9.30 ± 0.1	61	66	4.9	107

Table 7. Functional properties of protein preparations.

The functional properties of DWG depend on the molecular weight (MM) of the individual electrophoretic components obtained in PAGE. Using the example of native and modified DWG obtained by the limited proteolysis method, we showed that single-chain polypeptides with low (<40 kDa) and medium (40-60 kDa) MM were included in the composition of DWG

http://dx.doi.org/10.5772/intechopen.75803

with increased FC and solubility [30]. In multi-stranded polypeptides, DWG, there were more single-chain peptides with low MW (12–16 kDa) and fewer with medium (27–39 kDa) and high (69–108 kDa) MM.

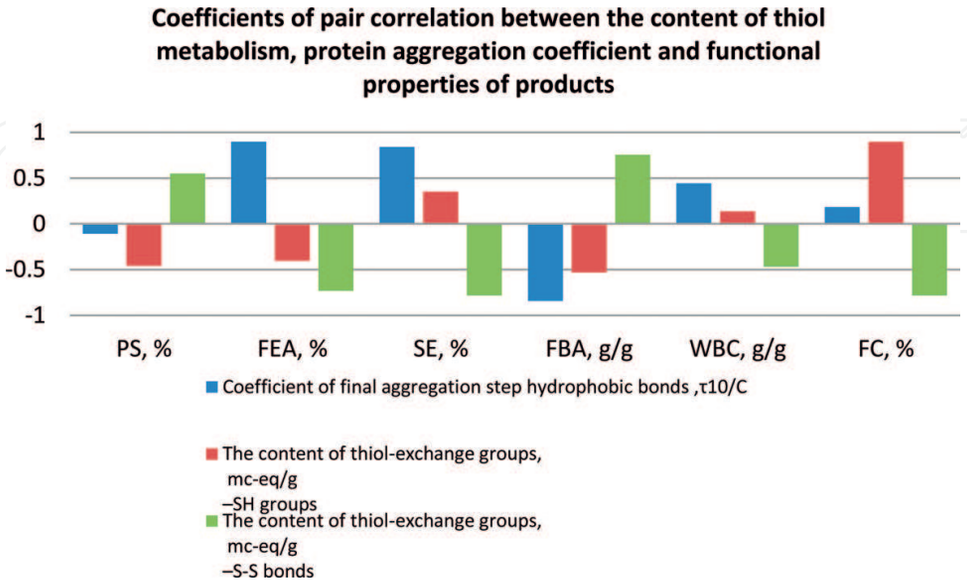

Figure 1. Coefficients of pair correlation between functional properties products and fractional composition of proteins.

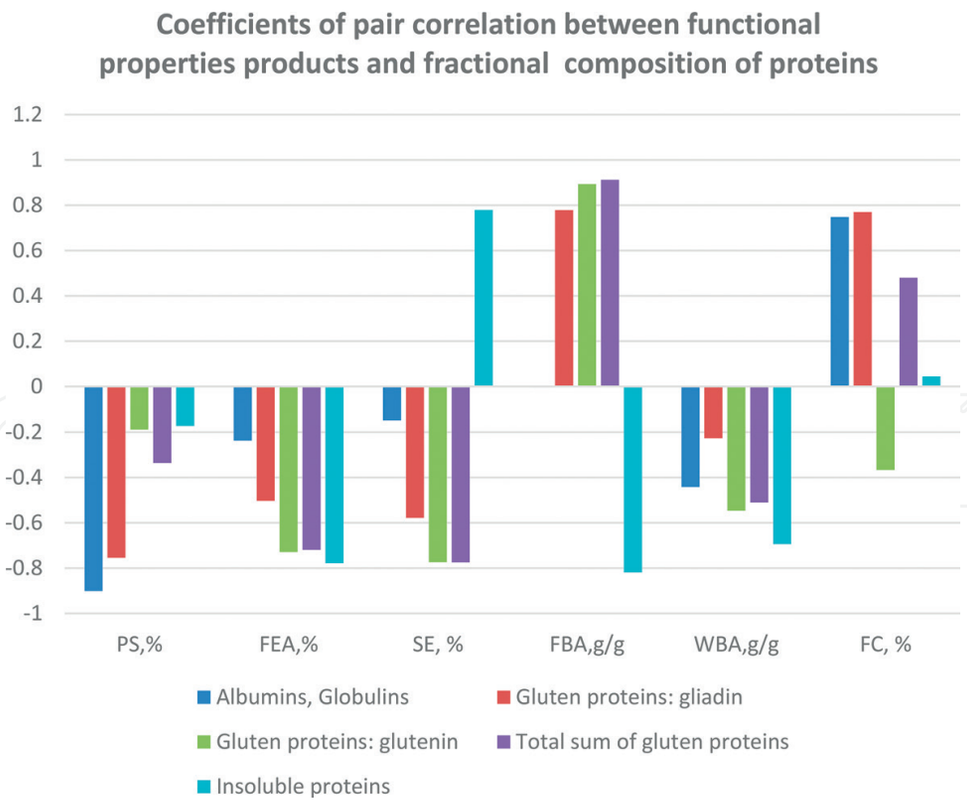

Figure 2. Coefficients of pair correlation between the content of thiol metabolism, protein aggregation coefficient, and functional properties of products.

The revealed regularities of interrelation of functional properties with the component composition were intended for the use of DWG in the production of confectionery products.

4. Conclusion

The results of studies of the chemical composition, physicochemical characteristics of proteins, and functional properties of dry wheat gluten, its components, protein concentrates from wheat bran, and their granulometric fractions have shown that it is advisable to regulate the quality indices of protein products with the aim of improving them and taking into account the revealed regularities. A high correlation positive dependence was established for the solubility of wheat gluten proteins, protein concentrates from wheat bran and their fractions with the amount of albumins and globulins, the sum of nonpolar amino acids (gluten, gliadin, soluble glutenin), and a negative correlation with gliadin gluten. With the indices of thiol metabolism, the relationship between solubility and WBA is not revealed.

For WBC of protein products, the reverse dependence on the sum of the polar amino acids of both fractions of glutenin is typical; for FBA, it is a direct relationship with the sum of gluten proteins and polar amino acids in gliadin and whole gluten and the inverse relationship was observed for the sum of nonpolar amino acids in the alcohol-soluble fraction. The lower the protein aggregation coefficient, hence, the less degree of hydrophobic interactions, less than -SH-groups, but more -S-S-bonds in proteins, the higher the FBA.

FEA positively correlated with the amount of glutenin and insoluble residue in proteins from wheat bran and the sum of nonpolar amino acids in gluten, gliadin. A negative relationship is established for the sum of polar amino acids, as whole gluten, and all its fractions. The higher the degree of hydrophobic interactions in protein products and the less disulfide bonds in them, the ability to emulsify fat and stabilize the emulsion is higher.

The average correlation dependence was revealed for FC and the mass fraction of protein for all types of protein products studied. The FC of gluten proteins positively correlated with the sum of nonpolar amino acids of gliadin, soluble, insoluble glutenin, and polar amino acids of insoluble glutenin. The sum of two kinds of amino acids also positively influenced the FC of other protein products. The higher the mass fraction of albumins, globulins, and gliadin in gluten, the more FC products are. As for FEA protein products from wheat bran, it was found that the higher the content of SH groups and the lower the number of S-S bonds in protein products, the more FC protein products are higher.

Consequently, the main functional properties of the protein products studied from wheat are interrelated with the protein mass fraction, the features of the fractional, amino acid composition of proteins, the number of covalent disulfide bonds, sulfhydryl groups, and non-covalent (hydrophobic) interactions. Thus, in order to predict the high and stable functional properties of protein products from wheat for production or their modification, it is advisable to take into account the patterns of interrelation of these properties with the chemical composition and the physicochemical properties of their proteins.

Conflict of interest

The authors declare no conflict of interest.

Abbreviations

DWG	dry wheat gluten
PS	protein solubility
FBA	fat-binding ability
FC	foaming capacity
WBC	water-binding capacity
ST	stability of emulsion
FS	foam stability
–S-S–	disulfide bonds
–SH	sulfhydryl groups
MM	molecular masses

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References

[1] Tolstoguzov VB. New Forms of Protein Food. M: Agropromizdat. 1987;303

[2] Kolpakova VV, Volkova AE, Nechaev AP. Protein from wheat bran. Functional properties of protein flour: Emulsifying and foaming properties. Izvestiya Vuzov. Food Technology. 1995;**1-2**:34-37

[3] Kolpakova VV, Nechaev AP. Protein from wheat bran. Functional properties of protein flour: Solubility and water binding ability. Izvestiya Vuzov. Food Technology. 1995;**1-2**:31-33

[4] Dorglamud S, Suwannaporn P, Huang T-C, Tester F. Physicochemical properties of protease-treated rice flour. Starch/Stärke. 2013;**65**:613-620. DOI:10.1002/star.201500103

[5] Akintayo ET, Oshodi AA, Esuoso KO. Effects of NaCl, ionic strength and pH on the foaming and gelation of pigeon pea (Cajanus Cajan) protein concentrates. Food Chemistry. 1999;**66**: 51-56. DOI: 10.1016/S0308-8146(98)00155-1

[6] Söderberg J. Functional properties of legume proteins compared to egg proteins and their potential as egg replacers in vegan food. Second cycle, A2E. Uppsala: SLU, Dept. of Food Science. 2013. Available from: https://stud.epsilon.slu.se

[7] Vegetable Protein: New Perspectives/ed. HER. Braudo. Moscow: Pishchepromizdat. 2000;180

[8] Schwenke KD. Structural modification as an instrument for the functionalization of proteins of oilseed and leguminous seeds. In: Braudo EE, editor. Vegetable Protein: New Perspectives/ed. HER. Braudo. Moscow: Pishchepromizdat; 2000. pp. 40-60

[9] Kolpakova VV, Chumikina LV, Vasil'ev AA, Arabova LI, Topunov AF. Wheat gluten proteolysis by enzyme preparations of directional action. International Journal of Agronomy and Agricultural Research (IJAAR). 2014;**5**(2):72-86. ISSN: 2223-7054 (print) 2225-3610 (Online). Available from: http//www.innspub.net

[10] Wang J, Zhao M, Yang X, Jiang Y. Improvement on functional properties of wheat gluten by enzymatic hydrolysis and ultrafiltration. Journal of Cereal Science. 2006;**44**:93-100. DOI: 10.1016/j.jcs.2006.04.002

[11] Zhang H, Claver JP, Li Q, Zhu K, Peng W, Zhou H, Structural modification of wheat gluten by dry heat – enhanced enzymatic hydrolysis. Food Technology and Biotechnology. 2012;**50**:53-58

[12] Popineau Y, Huchet B, Lare B, Berot S. Foaming and emulsifying properties of fractions of gluten peptides obtained by limited enzymatic hydrolysis and ultrafiltration. Journal of Cereal Science. 2002;**35**:327-335. DOI: 10.1006/jcrs.2001.0437

[13] Kolpakova VV, Vanin SV. Influence of hydrocolloids of polysaccharide nature on the foaming properties of protein products. Storage and Processing of Agricultural Raw Materials. 2008;**1**:57-59

[14] Vanin SV, Kolpakova VV. Functional properties of dry wheat gluten of different quality. Izvestiya Vuzov. Food Technology. 2007;**1**:21-24

[15] Toufeili I, Ismail B, Shadarevian S, Baalbaki R, Khatkar BS, Bell AE, Schofield JD. The role of gluten proteins in the baking of Arabic bread. Journal of Cereal Science. 1999;**30**:255-265. DOI: 10.1006/jcrs.1999.0286

[16] Kolpakova V, Yudina T, Vanin S, Lomakin A. Dry wheat gluten is an effective flour improver with short-glutinous gluten. Bread Products. 2007;**2**:50-52

[17] Lazaridou A, Duta D, Papageorgiou M, Belc N, Biliaderis CG. Effects of hydrocolloids on dough rheology and bread quality parameters in gluten free formulations. Journal of Food Engineering. 2007:1033-1047. DOI: 10.1016/j.jfoodeng.2006.03.032

[18] Noorfarahzilah M, Lee JS, Sharifudin MS, Mohd FA, Hasmadi M. Applications of composite flour in development of food products. International Food Research J. 2014;**21**(6):2061-2074

[19] Esteller MS, Pitombo RNM, Lannes SCS. Effect of freeze-dried gluten addition on texture of hamburger buns. Journal of Cereal Science. 2005;**41**:19-21. DOI: 10.1016/j.jcs.2004.08.013

[20] Kolpakova VV, Vanin SV. Method of Biscuit Production. 2008. The Patent of the Russian Federation No 2316968, IPC A 21 D 13/08

[21] Studennikova OU, Kolpakova VV. Method of Zephyr Production. The patent of the Russian Federation No 2432771 IPC A23G3/00

[22] Kinsella JE. Functional properties of proteins: possible relationships between structure and function in foams. Food Chemistry. 1981;**7**:273-288. DOI: 10.1016/0308-8146(81)90033-9

[23] Nakai S. Structure-function relationships of food proteins: with an emphasis on the importance of protein hydrophobicity. Journal of Agricultural and Food Chemistry. 1983;**31**:676-683

[24] Danilenko AN, Dianova VT, Braudo EE, Henning T, Mothes R, Schwenke KD. A novel approach to the evaluation of hydrophobocoty of food proteins. Nahrung. 1998;**44**:179-182

[25] Day L, Augustin MA, Batey IL, Wrigley CW. Wheat-gluten uses and industry needs. Trends in Food Science &Technology. 2006;**17**:82-90. DOI:10.1016/j.tifs.2005.10.003

[26] Guilbert S, Gontard N. Agro-polymers for edible and bodegradable films: Review of agricultural polymeric materials, physical and mechanical characteristics. Innovations in Food Packaging A volume in Food Science and Technology. 2005;**1**:263-276. DOI: 10.1016/B978-012311632-1/50048-6

[27] Kolpakova VV, Zaitseva LV, Osipov EA. Protein from wheat bran: increase in yield and functional properties. Storage and Processing of Agricultural Raw Materials. 2007;**2**: 23-25

[28] Abramov IA, Eliseeva NE, Kolpakova VV, Piskun TI. Amaranth: chemical composition, biochemical properties, processing methods. Storage and processing of agricultural raw materials. 2011;**6**:46-47

[29] Kolpakova VV, Bakhitov TA, Chelnokova EYa, Zaitseva LV. Resource-saving ways of processing grain of rye. Food Technology Izvestiya Vuzov. 2008;**5-6**:49-51

[30] Kolpakova VV, Chumikina LV, Arabova LI, Lukin DN, Topunov AF, Titov EI. Functional technological properties and electrophoretic composition of modified wheat gluten. Foods and Raw Materials. 2016;48-57. DOI: 10.21179/2308-4057-2016-2-48-57

[31] Bogdanov VP, Vukolova GN, Gruzdev LG Vakar AB. Determination of disulfide bonds and sulfhydryl groups in wheat storage proteins biochemistry and microbiology. 1980;**16**(1):127-138

[32] Arakawa T, Yonesawa D. Compositional difference of wheat flour glutens in relation to ther aggregation behaviours. Agricultural and Biological Chemistry. 1975;**39**(11):2123-2128

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