Composite grain products based on traditional groats with the addition of lentil grits

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Summary

The article deals with the possibility of replacing proteins of animal origin with complete proteins of plant origin. In nutrition, complementarity of proteins in terms of amino acids complementing each other is preferred. One of the methods of balancing essential amino acids is to obtain compositional mixtures from traditional groats and some legumes. Based on the concept of reference protein and the method of balancing scores of limiting essential amino acids, guidance values of the quantities of lentil grits for addition to traditional groats were obtained. The addition of 19–35 % lentil grits allows to obtain mixtures with a high protein content and the protein will be complete. An algorithm was proposed for calculating optimum proportions of two proteins when they are mixed. Described are two methods for obtaining ground large-seeded lentils. Obtaining two-component mixtures implies the comparability of their fractional composition, which allows to synchronize the cooking time. To speed up the cooking process, the lentils were subjected to heat treatment in an infrared stream. The cooking time of lentil groats was evaluated in comparison with the cooking time of traditional groats.

Keywords

lentil; grits; reference protein; amino acid; composite grain products; complete protein; score balancing

To date, development of special foodstuffs as well as products and rations of "functional" and "personalized" nutrition is relevant. The latter is based on the allelic polymorphism of individual "susceptibility genes" associated with fixation of certain food nutrients [1]. Of 20 amino acids contained in proteins, which are required for an active life of humans, 9 are essential amino acids that must be supplied by food. Non-essential amino acids can be synthesized by the human body.

The protein performs the structural function and a number of other vital functions in the body. Supposedly, one should daily consume approximately one gram of protein per kilogram of body weight. However, proteins are different from each other and what is required for the body are not proteins in general but the amino acids that make them up. As early as in the 1970s, experiments on mice demonstrated that when feeding them maize and bean, amino acid imbalance of the protein composition considerably affects their growth [2]. In this context, there emerges the concept of reference (ideal) protein, which establishes the relationship (profile) of essential amino acids in that protein. Fixation of essential amino acids by human body takes place in a certain proportion, in accordance with the profile of a reference (ideal) protein. Nutritional assessment of a protein can be based on comparison of its amino acid composition with a certain reference protein. Periodically this profile is updated to incorporate the latest technological advancements. Tab. 1 presents a number of profiles for an adult that were introduced in various years by the Food and Agricul-

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Tab. 1. Amino-acid composition of reference protein.

Amino acids	Proportion of amino acid [%]	
	FAO (2007) [3]	FAO (2013) [4]
Lysine	4.5	4.8
Methionine + cysteine	2.2	2.3
Isoleucine	3.0	3.0
Leucine	5.9	6.1
Threonine	2.3	2.5
Phenylalanine + Tyrosine	3.8	4.1
Tryptophan	6.0	0.7
Valine	3.9	4.0
Histidine	1.5	1.6

ture Organization (FAO) and the World Health Organization (WHO) [3]. The minimum score of essential amino acids (score of the first limiting essential amino acid) is the main quality indicator of a protein. Subsequently, FAO and WHO have made an adjustment of this indicator, taking into account the digestibility of essential amino acids [4, 5].

Based on the concept of reference (ideal) protein, all proteins can be divided into three groups:

– complete protein, in which the amino acid profile (the ratio of essential amino acids) corresponds to the profile of reference protein (the minimum score of essential amino acids is not less than one);
– incomplete protein, in which at least one of the essential amino acids is absent (the minimum score of essential amino acids is equal or close to zero);
– partial protein, in which all essential amino acids are present, but not in the proper proportion (the minimum score of essential amino acids is less than one).

Amino-acid composition of a reference protein is presented in Tab. 1 referring to an average adult person. However in general, the profile of reference protein should be targeted and vary depending on gender and age of the person, his or her lifestyle, health status and other factors.

If the score of limiting essential amino acids is enough for comparing two proteins, then in the case of comparing two protein products, the situation is somewhat more complex. We shall outline two extreme cases:

– the product contains a lot of protein, but it is incomplete;
– the product contains complete protein, but not enough.

It is obvious that a good protein product should contain enough protein and, besides, this protein should be complete, well digestible. The more such protein, the more valuable the product.

Protein deficiency in the diet, especially of the poorer members of society, has so far remained a problem. Animal products contain complete protein but they are expensive and not enough of them is available for everyone. In this respect, the question is about using effectively the more affordable and available plant proteins.

Cereals are characterized by a low content of lysine, an amino acid responsible for proper functionality of the cardiovascular and immunity systems of the human body [6, 7]. In cereal products, lysine can be complemented by legumes, whose proteins, on the other hand, are characterized by low contents of methionine and cysteine. This approach is used in bakery and pasta production [8, 9].

Functional and pasting properties of yellow maize, soya bean and pumpkin composite flours and sensory attributes of breakfast cereals prepared from the flour formulations were previously studied [10]. The results on functional properties revealed that, water absorption capacity, swelling power and solubility, were in the range of 161.1–269.5 %, 400.0–480.3 % and 6.8–13.4 % respectively. Further, increased pumpkin pulp flour substitution resulted in improvement of functional properties and viscosity. Addition of pumpkin pulp to maize-soya bean blend significantly improved the functional and pasting properties of the flour blends.

It was established that composite flours significantly decrease glucose levels in blood and prevent from heart disease via maintaining good physical properties of arterial walls. Composite flours also cause a decrease in levels of glycosylated lipoproteins, albumins, lipids, cholesterol and also decrease the concentration of glucose in blood [11].

Legume seeds are the traditional source of plant protein. A way to improve the quality of protein, in particular of grain products, is to blend ingredients with complementary proteins. These include, for example, the seeds of traditional groats and legumes, in particular, lentils [12]. Their combination in a mixture with a certain proportion allows to create the compositions with higher contents of protein with the improved amino-acid profile [13].

Usually, lentil seeds are used whole in the cooked state, or they are sprouted and used in salads or other meals, at best, the shell is removed and the cotyledons are separated, as for example in the production of split pea. When producing combined grits, it is desirable that the particles of the components are of comparable sizes. This allows to harmonize the cooking times of composite grits from the mixture of traditional groats and lentils. However, not enough crushed lentils are available on the market, which may be an obstacle to their use in compositions with other whole or crushed cereals. Instant cereals can also be obtained by preliminary high-temperature heat treatment, which partially inactivates anti-nutrients and increases nutritional values of composite grits.

The purpose of this study was to assess the potential of producing crushed lentils and to obtain benchmarking data for the preparation of high-protein composite mixtures from traditional groats (such as oat grits, pot barley, wheat grits, rice grits and wheat groats) and from various varieties of lentils (green, light green, brown, red) with an improved profile of essential amino acids. Another goal was to study the possibility of using lentils heat-treated in an infrared stream to bring the cooking time closer to that of traditional groats.

Scientific hypothesis

Assuming that there is complementarity of lentil proteins with proteins of traditional groats, it is possible to improve the amino acid profile by creating a composite product. In this case, the amino acid profiles of the mixed proteins should be selected in such a way that they complement each other, i.e. they contain different limiting amino acids. Hypothetically, mixtures of crushed lentil grains with traditional groats make it possible to create a composite product with an increased reference protein content and preliminary heat treatment will shorten their cooking time.

MATERIALS AND METHODS

Samples

As the object of the study for obtaining crushed lentils, following lentils were used:

– large green dish-shaped food lentil, of the 2020 harvest, obtained from the Federal Scientific Center for Legumes and Groat Crops (Omsk, Russia);
– calibrated green dish-shaped lentils, medium, light green (Krasnodar territory, Abinsk region, village Kholmskaya, Russia);
– brown lentils (Gori, Gori region, Georgia) harvested in 2020 and obtained from the market in Kutaisi, Georgia;
– red lentils (Gori, Gori region, Georgia) harvested in 2020 and obtained from the market in Kutaisi, Georgia, which were used whole to prepare high-protein composite mixtures without crushing.

At the same time, the initial moisture content of lentils was approximately 8.3 %, 11.0 % and 14.0 % for all varieties separately (Tab. 2). Linear dimensions of lentils were determined using an electronic digital caliper VINCA DCLA-0605, 150 mm. (Neiko Tools, Lu Chu Hsiang, Taiwan). The sample weight was determined using an electronic digital analytical balance SF-400C model (Toms, Qilin, China) with a weighing accuracy of 0.01 g.

Heat treatment

The heat treatment of lentils was carried out on a laboratory device with infrared radiation for “dry” cooking and thermal inactivation of anti-nutrients, consequently, the cooking time of lentils

Tab. 2. Yield rate of produced grits from lentil grain of various moisture content using grinder sieves of various openings diameters.

	Large green lentil						Calibrated green lentil			Brown lentil	
Lentil grain											
Diameter* [mm]	3	3	3	5	5	5	5	5	5	5	5
Moisture content [%]	8.3	11.0	14.0	8.3	11.0	14.0	8.5	11.0	14.0	8.5	14.0
Products	Yield rate of produced grits from lentil grain [%]										
Cereals	62.3	67.7	69.4	61.1	63.1	64.5	59.5	75.5	76.0	69.5	76.8
Cereal No. 1	4.9	7.3	8.4	–	–	–	–	–	–	9.3	21.6
Cereal No. 2	24.0	27.8	30.8	–	–	–	–	–	–	29.1	33.5
Cereal No. 3	24.2	23.5	21.8	–	–	–	–	–	–	26.5	16.2
Semolina	9.3	9.2	8.4	–	–	–	–	–	–	4.7	5.5
Tailings	7.2	8.0	8.5	19.3	17.7	18.8	19.0	8.9	8.1	22.6	7.5
Polished meal	30.1	24.3	22.1	19.6	19.3	16.7	21.5	15.6	15.9	18.5	16.1

Processed lentil grain are 100 %. * – diameter of the openings of grinder sieve.

and activity of antinutrients were minimized. This made it possible to bring the cooking time of lentils closer to that of traditional cereals. The initial moisture content of lentils was determined using an electronic digital meter of grain and seed moisture (moisture meter) VSP-100 (PAtools, Kharkiv, Ukraine). Heat treatment of lentils by infrared radiation was carried out in a QP1 model (Elcer, Odesa, Ukraine) with a panel of halogen quartz emitters (the panel composed of 7 emitters). The dimensions of the panel were 247 mm × 62 mm. The length of the tube was 245 mm, tube step was 8.55 mm, rated power was 1 kW and the emitter temperature was 750–800 °C. Lentils were placed in an oven tray for a fixed time (60 s and 90 s) in the processing zone and heated with infrared rays. The temperature of lentils was determined using an AR360A+ infrared laser thermometer (Simzo, Long, China). The temperature measurement range was from –50 °C to +360 °C and the temperature measurement error was 0.5 °C due to heat loss, which could be taken as insignificant.

Processing

The process of obtaining crushed lentils in the laboratory involved shattering of grain on a laboratory grinder (Bühler, Braunschweig, Germany). The resulting shattered product was preliminarily cleaned of polished meal by sieving and then it was pneumatically separated by removing the shells. The cleaned shattered product was further sieved on the laboratory air separator of grain VSZ (LTK Grainlab, Krasnodar, Russia) with perforated round holes and wire sieves according to GOST 6613-86 standard [14].

Grain processing was carried out according to two technological schemes [15].

In the first case, the crushed grain was separated once and the resulting grains were fractionated once by size, in accordance with grains numbers – a shortened scheme. In the second case, the aspirated flour after the first air separation was sieved and the passing material was air-separated again – a two-stage scheme.

The initial moisture content varied. The processing conditions were kept constant: sweating time was 3 h, impact velocity of the hammer grinder was 17 m·s^{-1}, diameter of the openings of the grinder working sieve was 3.0 mm or 5.0 mm, diameters of the openings of the sizing sieves 1 were 2.5 mm (upper sieve) and 0.63 mm (bottom sieve), air velocity in the pneumatic separator channel was 2.5 m·s^{-1}, diameters of the openings of the sizing sieves 2 were 2.0 mm (upper sieve), 1.5 mm (medium sieve) and 0.67 mm (bottom sieve) [15].

Preparation of composite

Mixtures of traditional groats (oat grits, pot barley, wheat grits, rice grits and wheat groats) with heat-treated and crushed lentils were taken as the objects of analysis of the composite grain products. Mixing the components was carried out in a laboratory paddle mixer, manufactured in the workshop of the All-Russian Research Institute of Grain (Moscow, Russia). Total protein in components and mixtures was determined at various mixing ratios using the Kjeldahl apparatus according to GOST 10846-91 [16]. The additivity of the indicator of the nutrient content of the component when they are mixed was confirmed experimentally. The amino-acid profiles of proteins were taken from the database [17, 18]. The reference protein profile was used in accordance with the FAO/WHO recommendation of 2013 [4] and calculated for mixtures. Since chemical reactions do not occur in mixtures, it is obvious that the additivity is retained for amino acids as well. The amino acid profile and total protein in different batches of groats may vary, but the principle of calculating the balance of essential amino acids does not change.

Calculations were conducted using the methodology of balancing scores of limiting amino acids [13, 19].

Total protein (B) of the mixture was evaluated based on Eq. 1 and reference protein (B_{ref}) using the Eq. 2:

$$B = X(B_1 - B_2) + B_2 \quad (1)$$

$$B_{\mathrm{ref}} = C \times B \quad (2)$$

where C is minimum score of essential amino acids of a mixture, X is the percentage of the first ingredient, B_1 and B_2 are total protein of legumes and cereals, respectively.

Scores of limiting essential amino acids (C_1, C_2) are

$$C_1 = \frac{X(C_{11}B_1 - C_{12}B_2) + C_{12}B_2}{X(B_1 - B_2) + B_2} \quad (3)$$

$$C_2 = \frac{X(C_{21}B_1 - C_{22}B_2) + C_{22}B_2}{X(B_1 - B_2) + B_2} \quad (4)$$

where C_{11} is minimum score of limiting essential amino acids in cereals (lysine), C_{12} is score of the same essential amino acid in legumes, C_{21} is minimum score of limiting essential amino acids in legumes (methionine + cysteine), C_{22} is score of the same essential amino acids in cereals. $X \leq 1$ is the percentage of legumes in a mixture.

When $C_1 = C_2$ (in the case of partial protein), the mixture has the maximum of reference protein at

$$X = \frac{1}{\frac{B_1(C_{11} - C_{21})}{B_2(C_{22} - C_{12})} + 1} \quad 0 < X < 1 \qquad (5)$$

At the points $C_1 = 1$ and $C_2 = 1$, complete protein is obtained. Thus, Eq. 3 and Eq. 4 are followed by two solutions X_1 and X_2, limiting the interval of the percentage of lentils supplement whereby the mixture's protein is complete. If the protein of the mixture is incomplete, then in general there may be no solution at these points and Eq. 5 should be used.

If $C_1 = 1$, from Eq. 3 and Eq. 4, we shall obtain

$$X_1 = \frac{1}{\frac{B_1(1 - C_{11})}{B_2(1 - C_{12})} - 1} \quad 0 < X_1 < 1 \qquad (6)$$

$$X_2 = \frac{1}{\frac{B_1(1 - C_{21})}{B_2(1 - C_{22})} - 1} \quad 0 < X_2 < 1 \qquad (7)$$

As we have already mentioned, in composite mixtures the cooking times of the components should be close to each other. The cooking time of the resulting mixture was determined according to the methodology of GOST 26312.2-84 standard [20].

Cooking properties

Lentil grits were cooked in a boiling water bath. From the centre of the sample of heat-treated grits, 50 g were taken and, with 1 g of cooking salt, were cooked in 125 ml of water. The cooking time was determined using a stopwatch. When cooking for 7 min, 5–6 grains were sampled from the middle of the beaker at a spoon depth, put on a glass, covered with another glass and crushed by placing a weight of 0.5 kg on it. The next samples were taken every 1.0 min until they were cooked. Grits readiness was evaluated by the degree of plastic deformation of grains.

Statistical analysis

To analyse the parameters of the product, statistical analysis of the obtained data was conducted and the reliability of the obtained data was evaluated by T-test, using SPSS Statistics, version 20.0 (IBM, Armonk, New York, USA). To describe the ordered sample, statistical functions of the average arithmetic value and the average standard error were used.

RESULTS AND DISCUSSION

Cereals are used by humans since long from prehistoric times and are rich sources of macro- and micronutrients. They are considered a staple food and provide significant amount of proteins, carbohydrates, vitamin B and minerals. They are also a source of phytochemicals, which impart positive impact on health. Cereals are also a rich source of carbohydrates and present various anti-nutrients [11].

Feyera [21], similarly to our research, argued that convenient and cheap snacks that are consumed by all age group in many countries, can be produced from cereal and legume flour blends. They determined the data on the approximate composition of the protein content, ash, crude fibre and fat content of some cereal-legume based biscuits at various percentage substitution of legumes were determined. It was found that the increase in nutritional value of the biscuits based on cereal and legume blends was associated with the significant quantity of nutrients in legumes [21].

It is widely accepted that to increase the functional and nutritional value of various foods, it is advisable to mix various products. However, insufficient information is available on the perfection of such mixtures regarding proteins and essential amino acids.

To obtain a composite mixture based on traditional groats with the addition of lentil grits, we developed a technology for preparing lentil grits.

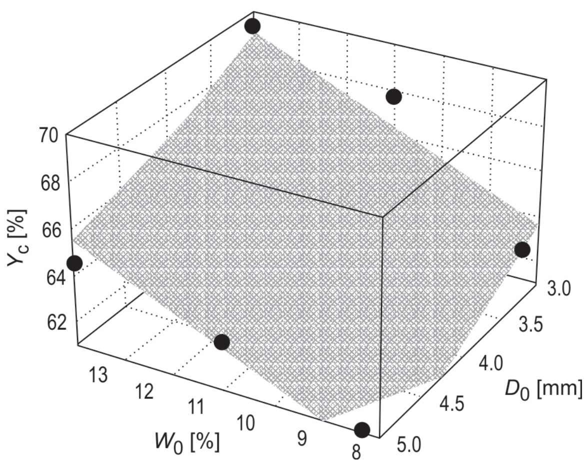

Fig. 1. The dependency of the total amount of produced grits on the moisture content and the diameter of the grinder sieve openings at processing of green dish-shaped lentils.

W_0 – initial moisture content, D_0 – diameter of the grinder sieve openings, Y_c – total amount of produced cereals.

Tab. 3. Yield rate of produced grits from lentil grain using various air velocities and grain tempering times.

	Large green lentil				Calibrated green lentil	Brown lentil
Lentil grain						
Air velocity* [m·s^{-1}]	0.5	0.5	1.7	1.7	0.5	0.5
Moisture content [%]	8.3	11.0	14.0	14.0	11.5	8.5
Grain tempering time [h]	0	3	3	24	0	0
Products	Yield rate of produced grits from lentil grain [%]					
Cereal No. 1	14.5	15.4	20.3	14.4	11.9	9.2
Cereal No. 2	30.5	32.2	32.4	35.1	31.5	30.8
Cereal No. 3	21.7	21.3	16.0	16.4	19.6	27.2
Semolina	4.5	3.2	7.1	7.2	7.4	4.4
All cereals	71.2	72.2	75.7	72.0	69.8	71.6
Husks	9.3	8.6	7.6	9.6	8.7	10.9
Polished meal	19.6	19.2	16.7	17.4	21.5	18.8

Processed lentil grain are 100 %. * – air velocity in the pneumatic separator.

When lentils were processed by a simplified procedure after fractionation of shattered lentil grain, the amount of produced lentil grits depended on the type of lentil grain (Tab. 2). For all grain samples, with an increase in the initial moisture content, an increase in the total amount of produced grits was observed, and the amounts of cereals No. 3 and semolina decreased. The influence of the diameter of the openings of the working sieve of the grinder was also apparent, since an increase in the diameter of the openings led to a decrease in the amount of produced lentil grits. Fig. 1 illustrates the dependency of the total amount of produced lentil grits on the diameter of the grinder sieve openings and the grain moisture content for green dish-shaped lentils. Analysis of the composition of tailings (a mixture of grains and shells) revealed a high content of grains therein. Therefore, a two-stage technological scheme was tested.

Three types of lentils were used in the series of experiments using the two-stage scheme. The initial moisture content, sweating time and the air velocity in the pneumatic separator 2 were varied. Other settings, such as the impact velocity of the hammer grinder, the diameters of the openings of the grinder working sieve, the sizing sieves 1 and 2 as well as the air velocity in the pneumatic separator channel were kept constant. When comparing data from comparable experiments from Tab. 2 and Tab. 3 it can be seen that, when using a two-stage processing scheme, the amount of produced cereals was by 7–9 % higher than using the simplified (one-stage) scheme. Increasing the grain tempering time did not lead to a positive result.

Tab. 4. Scores of cereal protein.

Protein and amino acids	Lentils	Cereals				
		Oat grits	Barley grits	Wheat grits	Rice grits	Millet
Total protein [%]	24.6	16.7	12.5	10.0	6.6	12.0
Reference protein [%]	22.7	9.9	9.7	7.1	5.0	5.3
Amino acids	Scores (dimensionless)					
Lysine	1.49	0.87	0.78	0.71	0.76	0.44
Methionine + Cysteine	0.92	1.86	1.80	1.22	1.91	1.87
Isoleucine	1.42	1.38	1.22	1.37	1.44	1.53
Leucine	1.29	1.25	1.12	1.26	1.36	1.94
Threonine	1.60	1.37	1.36	1.00	1.43	1.40
Phenylalanine + Tyrosine	2.06	2.13	2.08	2.59	2.12	2.22
Tryptophan	1.39	2.11	2.54	1.21	1.77	1.67
Valine	1.32	1.39	1.23	0.83	1.53	1.43

Tab. 4 presents data on total protein, minimum rate (according to data provided by FAO/WHO for 2013 [4]) and the profile of essential amino acids of the composite products from crushed lentils with traditional groats. As can be seen, proteins of lentils and cereal crops are partial but complementary. As an example, Fig. 2 shows the graph of changes in total and reference protein depending on the percentage of lentils in a mixture with barley grits. As shown in Fig. 2, with an increase in the percentage of lentil grits, both total protein and reference protein increase. At point A, score of limiting essential amino acid becomes equal to one. When the proportion of lentil grits is greater than 19 % (point A), all protein (14 %) becomes complete until the point of its proportion at point B. At point B (85 % of lentil grits, total protein 22 %), protein of the mixture becomes partial again. The graphs for other compositions behaved similarly.

Tab. 5 shows the results of calculating the range of the percentage of lentil grits ($X_1 - X_2$) and the protein percentage corresponding to point A (Fig. 2) for various combinations of grain products. To calculate the percentage of lentil grits and the protein percentage (denominator) for various combinations of grain products, a program was developed in a mathematical package MathCad (Mathsoft, Cambridge, Massachusetts, USA), in particular, MathCad 15 [22]. The obtained magnitudes of the percentage of lentil grits and reference protein in the mixtures with traditional groats are only indicative, because calculations are based on statistical averages. Their improvement would be possible if experimental data on total protein and limiting essential amino acids in specific grains, cereals or flour lots are available.

Previously, composite weaning foods were developed using cereals, malted legumes and vegetable powders, which were then analysed regarding nutrients, functional properties and sensory attributes [23]. Selected legumes (green gram and lentil) were germinated, dried and dehulled. The results of analysis showed the following range of constituents per 100 g of formulations on dry weight basis: protein 18.1–18.9 g, fat 0.78–1.36 g, iron 5.09–6.53 mg, calcium 265–310 mg.

Cassava, rice and banana flours were used individually to replace wheat flour in cereal-legume-based composite flours [24]. Replacing wheat flour with rice flour significantly improved protein, fat, potassium and phosphorus content in samples. The findings showed that nutritional properties and aflatoxin content of composite flours can be improved by replacement with local crops.

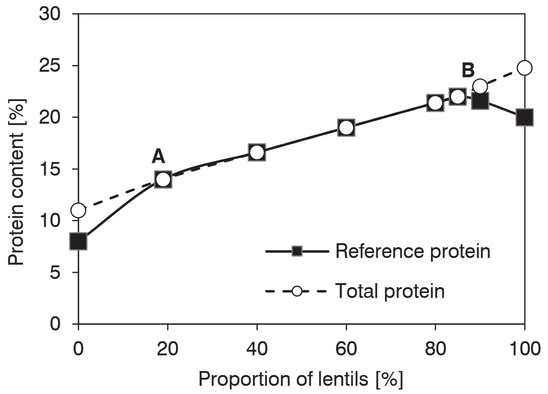

Fig. 2. Impact of lentil grits in a mixture with barley grits on total and reference proteins.

Point A – proportion of lentils (19 %) at which the composite protein becomes complete, point B – the proportion of lentils (85 %) at which the composite protein again becomes incomplete.

Tab. 5. Ranges of the proportion of lentils and the protein content for various combinations of grain products.

	Proportion of lentils [%]		Complete protein [%]	
	A	B	A	B
Oat	12.0	85.7	13.7	22.3
Barley	18.9	84.9	14.7	22.2
Wheat	19.6	55.0	12.7	17.1
Rice	12.0	77.1	8.7	20.0
Millet	34.3	84.2	15.4	21.9

A – the calculating range of the percentage of lentil corresponding to point A (Fig. 2) grits for various combinations of grain products, B – the protein percentage corresponding to point B (Fig. 2) for various combinations of grain products.

Tab. 6. Cooking time of red lentil and grits from brown and green lentils.

	Lentils	Heat treatment [s]	Moisture content [%]	Cooking time [min]
1	Red, whole	0	13.0	12.0
2	Red, whole	60	12.9	10.1
3	Red, whole	90	12.7	8.9
4	Brown, whole	0	13.8	36.0
5	Brown, grits	0	13.8	14.5
6	Brown, grits	60	13.6	12.5
7	Brown, grits	90	13.4	10.2
8	Green, whole	0	13.6	31.5
9	Green, grits	0	13.6	12.6
10	Green, grits	60	13.3	10.8
11	Green, grits	90	13.0	9.4

Cooking time for traditional cereals is 8–12 min.

Tab. 6 shows the results of determining cooking time of various varieties of lentils. As shown in this table, the cooking time for red lentil grains was 9–12 min, for green lentil grits 9.4–12.6 min and for brown lentil grits 10.2–14.5 min, while the cooking time of whole grains of green and brown lentils was 31.5–36.0 min. It is known from trading networks that the cooking time of traditional groats under consideration ranges from 8 min to 12 min, which is comparable to the cooking time of thermally processed crushed grains of large lentils. These data demonstrate that lentil grits can be used for preparation of composite mixtures with traditional groats leading to a product containing complete protein.

CONCLUSION

Production of various grits from lentils is possible on the basis of a traditional flour-grinding cereal equipment involving hammer crusher, pneumatic separator, sieving equipment and magnetic separator.

The technological properties of dish-shaped large lentils of various varieties may differ. The use of a two-stage technological scheme allows to slightly increase the total amount of produced cereals, however, it requires additional investment and must be economically justified in specific production conditions. The addition of lentil grits to traditional groats allows to significantly increase both the total protein content and its quality (score of limiting amino acid) in such compositions. The lentil grits content over 19–35 % provides complete protein in the mixture with traditional groats.

The accuracy of calculating the percentage of grains depends on the accuracy of the initial content of total protein and the limiting essential amino acids in the ingredients of the mixture, and can be improved if experimental data are available in further studies.

Preliminary heat treatment of lentil beans in an infrared stream and crushing them into groats was shown to reduce the cooking time by an average of 2.88-fold (from 36.0 min to 12.5 min). This showed that it is possible to use grits from large or red whole lentils in combination with traditional groats for the production of cereal mixtures. Such mixtures of cereals are supposed to be used in retail trade, in public catering, sanatoriums, in hospitals, in the army, in penitentiary institutions and in the production of composite grain products with high protein content.

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