Foods and Raw Materials, 2020, vol. 8, no. 2
E-ISSN 2310-9599
ISSN 2308-4057

Research Article
Open Access

Check for updates

DOI: http://doi.org/10.21603/2308-4057-2020-2-362-368
Available online at http://jfrm.ru/en

Identification of total aromas of plant protein sources

Luydmila V. Antipova, Tatiana A. Kuchmenko, Anastasiya A. Osmachkina*, Natalia A. Osipova

Voronezh State University of Engineering Technologies, Voronezh, Russia

* e-mail: antipova.L54@yandex.ru

Received June 15, 2017; Accepted in revised form September 30, 2017; Published August 25, 2020

Abstract:
Introduction. Due to the deficit and high cost of complete animal protein, the search and analysis of alternative sources is an actual scientific trend. Lentils is a good alternative to animal protein, but the pronounced bean smell and taste limit its full or partial use in food production. The aim of the work was to determine the total aromas of lentils when germinated to eliminate the bean taste and smell.
Study objects and methods. The object of the study was brown lentil beans germinated under laboratory conditions. Samples of the equilibrium gas phase formed over samples of wet and sprouted beans were investigated. The analysis of total aromas was carried out on a laboratory odor analyzer MAG-8 ("electronic nose") by the method of piezoelectric quartz micro-weighing with an array of sensors.
Results and discussion. The study results showed qualitative and quantitative differences in the equilibrium gas phase over samples of wet and germinated grain. The quantitative analysis showed that the content of volatile compounds over sprouted grain is 12% less than over wet. The qualitative composition of the samples of wet and sprouted grain differed by 60%, which confirmed the influence of germination on the composition of the equilibrium gas phase and the possibility of eliminating bean odor. Testing showed that the use of pre-processed lentil grains allows to replace up to 50% of raw meat in minced products (minced food, chopped food) without changing the smell of the products.
Conclusion. According to the results obtained, preliminary processing of lentils by germination will allow using this bean culture as an alternative source of animal protein to expand the range, and improve the quality of meat and dairy products.

Keywords: Lentils, germination, amino acid composition, biological value, total flavors, total analytic signal, the equilibrium gas phase

Funding: The authors are grateful to the administration of Voronezh State University of Engineering Technologies (VSUET) for the opportunity to carry out the study in specialized laboratories.

Please cite this article in press as: Antipova LV, Kuchmenko TA, Osmachkina AA, Osipova NA. Identification of total aromas of plant protein sources. Foods and Raw Materials. 2020;8(2):362–368. DOI: http://doi.org/10.21603/2308-4057-2020-2-362-368.

INTRODUCTION

The lack of animal protein resources on the planet arose a long time ago, and a global protein deficit in human nutrition continues to grow. According to some experts, for example, over next 20 years, the shortage of meat will remain one of the global problems of mankind.

At the same time, in foreign and domestic technologies of obtaining food products, there is a positive experience in the complete or partial replacement of expensive and difficultly reproducible animal protein resources with vegetable ones, including meat and dairy products [1–3].

The use of alternative sources of protein allows manufacturers to simultaneously solve economic and technological problems, such as reducing production costs, stabilizing and improving the quality of meat systems, increasing product yield, etc.

Currently, a consumer begins to find benefits of consuming products with alternative sources of protein, namely a lower cost and the ability to provide themselves with healthy food in the required amount.

The experience of using vegetable proteins on an industrial scale is mainly associated with imported soy [4]. However, at the moment, during the unfolding of measures to implement the provisions of the Food Security Doctrine, either ensuring healthy nutrition, or the development of domestic technologies, and rejection of imports become relevant. Russian scientists have

Table 1 Digestive enzyme inhibitors in legumes

Soybean		Lentils	
Inhibitors	Their action	Inhibitors	Their action
1. Protease inhibitors	Binding trypsin and chymotrypsin, which are secreted by the animal's pancreas, thereby reducing the efficiency of digestion of feed.	1. Trypsin inhibitor	Inhibiting the activity of trypsin, which is synthesized by the pancreas in the form of zymogen, activated in the duodenum 12, and catalyzes the hydrolysis of proteins and peptides. Trypsin is involved in the activation of many digestive enzymes through a limited proteolysis mechanism.
2. Urease Inhibitors	Suppressing urease activity, thereby reducing urea hydrolysis with ammonia formation, and neutralizing its toxic effect on the body.		
3. Lipoxygenase inhibitors	Inhibiting the activity of lipoxeginase involved in the enzymatic rancidity of fats during storage with the formation of aldehydes and ketones, which give an unpleasant smell and taste.		

proved the benefits of legume proteins traditionally grown in Russia (Saratov, Samara, Orenburg and Penza regions and Altai Krai), the potential of which can be significantly increased by pre-germination [1].

Among alternative sources of protein, legumes occupy priority positions in terms of protein quantity and quality. That is why they are preferred when creating, for example, meat food systems [5, 6]. Among them, lentils, known for its healing properties, should be distinguished. By the quantity and quality of amino acids, the lentil protein is closest to the first grade beef protein. Compared to other legumes, lentils have a more balanced amino acid composition, containing an increased amount of valuable vitamins, macro-, microelements (including iodine), and less oligosaccharides that cause intestinal flatulence.

Lentils is one of few cultures containing only one digestive enzyme inhibitor that acts on trypsin (Table 1).

Lentils have good botanical properties, develop and fruit well in Central Russia (Chernozemye, Volga region).

The choice of lentils as an object of the study is justified by the results of chemical analysis obtained by Howell, according to which this culture has a number of obvious advantages compared to other legumes [9]. However, the test results achieved in the conditions of the "Kalacheevsky" meat factory showed the limited use of lentils even in small quantities (5–8%) due to its bean taste and smell. In this regard, germination is of practical interest, not only to improve the balance of the amino acid composition, and to increase the content of micronutrients, but also to assess the possibility of eliminating undesirable sensory properties.

Many researchers confirm that, as a result of germination, a decrease in the oligosaccharide fraction is observed (Fig. 1), additional vitamins are synthesized, increasing the total nutritional and biological value of the product [10–17]. However, the information concerning change in organoleptic properties is extremely insufficient, and ungeneralized [13–16]. Lentil products (flour, concentrate, isolate) combine well and replace food systems of animal origin (meat, dairy).

Our previous results proved that germinating significantly improved the biological value of raw materials, namely the content of proteins, vitamins, and minerals. The amount of amino acids increased by a factor of 1.5–2 (Fig. 1).

The amino acid composition of the protein becomes more balanced, with the score close to the score of the reference protein (Fig. 2). A significant increase in lysine and tryptophan, the most valuable amino acids, can be mentioned. Lysine is a deficient amino acid, which, combined with vitamins, strengthens the immune system, promotes calcium absorption from the intestine, as well as contributes to cellular protein and bone tissue formation. Tryptophan is involved in the serotonin (the hormone of happiness) formation; mood, sleep quality, level of pain threshold and susceptibility to various irritants and inflammations depend on its concentration.

An increase in the content of minerals and vitamins, as well as a decrease in the number of oligosaccharides,

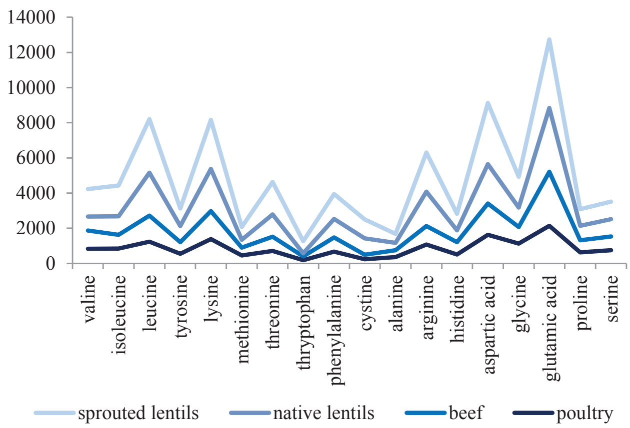


Figure 1 Amino acid composition of lentil grains, beef and poultry meat

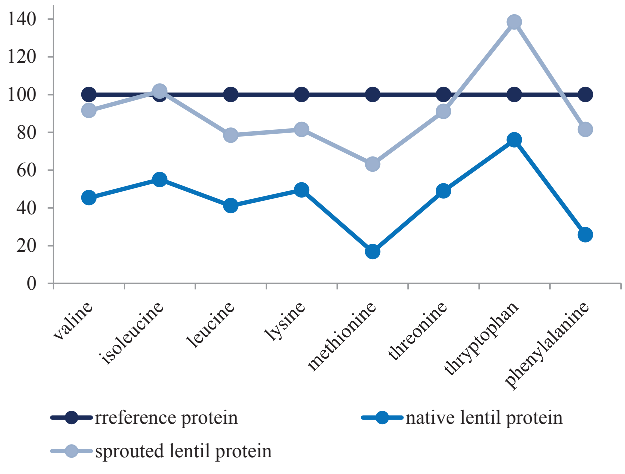


Figure 2 Effect of germination on lentil amino acid score

an anti-nutritional factor of legumes, were also noted (Table 2).

Identification of total aromas by sensory methods, taking into account the nutritional value of lentils, is especially important. All these indicators belong to food chemistry, the most important section in the study of food products, providing important information in the selection of raw materials, and it also means for a consumer a better applicability of the product in a food system [17, 18]. The information obtained will allow us to construct a product with properties (chemical composition, appearance, taste, and smell) close to those of meat.

The aim of the study was to assess the total aromas of lentils during germination, to eliminate extraneous odor by partial or complete replacement of animal proteins in food systems of animal origin.

STUDY OBJECTS AND METHODS

The object of study was brown lentil beans (State Standard 7066-77[1]) germinated in laboratory conditions at Voronezh State University of Engineering Technologies.

Grains of untreated lentils were germinated at 21–23°C for 3–4 days, preventing their complete drying out.

The general chemical composition of sprouted lentils is presented in Table 2, and the amino acid composition of proteins in Fig. 1. It can be seen from the data that germinated lentil grains have significant advantages in the content of the most important nutrients.

The study of total aromas was carried out on a MAG-8 laboratory (experimental) odor analyzer (Fig. 3) with the electronic nose methodology, by the method of piezoelectric quartz weighing with an array of sensors [20–22]. We analyzed three samples: wet grain, germinated grain and water.

The sensor array consisted of eight sensors based on BAW-type piezoelectric quartz resonators with an oscillation frequency of 10.0 MHz and with diverse film sorbents on electrodes.

Coatings are selected in accordance with the test objective (possible emission from samples of various organic compounds):

Sensor 1 – Multilayer Carbon Nanotubes, MCNT;
Sensor 2 – Polyethylene glycol succinate, PEGS;
Sensor 3 – Polyethylene glycolsebacinate, PEGSb;
Sensor 4 – Polyethylene Glycol Adipate, PEGA;
Sensor 5 – Polyethylene glycol-2000, PEG-2000;
Sensor 6 – Dicyclohexane-18-Crown-6, DCH18C6;
Sensor 7 – Twin-40, Tween;
Sensor 8 – Polyethylene Glycolphthalate, PEGP.

Grain samples were placed in glass tubes (10 g in each), tightly closed, kept at room temperature (20 ± 1°C) for at least 20 min to saturate the equilibrium gas phase over the samples. Then, we determined moisture content, which amounted to 51.2%. 3 cm^3 of the equilibrium gas phase was taken through a membrane with individual syringes and introduced into the detection cell. The background of the array of sensors was from 15 to 30 Hz·s. The measurement time was 60 s, the mode for recording sensor responses was uniform with a step of 1 s, the optimal algorithm for presenting

Table 2 Effect of germination on chemical composition of lentil seeds

Indicators	Content in 100 g of product	
	Before germination	After germination
Proteins, g	26.15	29.56
Fat, g	1.2	1.1
Carbohydrates, g	53.7	41.06
including glucose	8.45	13.64
Oligosaccharides:		
raffinose	0.9	0.5
stachyose	2.7	2.1
verbascose	1.4	0.8
Starch	33.8	24.12
Cellulose	3.65	3.04
Ash	3.65	3.31
Moisture	12.33	18.1
Minerals, mg		
calcium	84.23	84.62
phosphorus	401.16	400.3
magnesium	78.9	76.3
iron	12.06	12.32
sodium	56.12	55.91
potassium	659.18	659.51
Vitamins, mg		
B1	0.5	0.78
B2	0.21	0.48
PP	1.8	2.21
C	–	0.04
β-carotene	0.03	0.08

[1] State Standard 7066-77. Lentil for human consumption (plate-shaped). Requirements for state purchases and deliveries. Moscow: Izdatel'stvo standartov; 2003. 8 p.

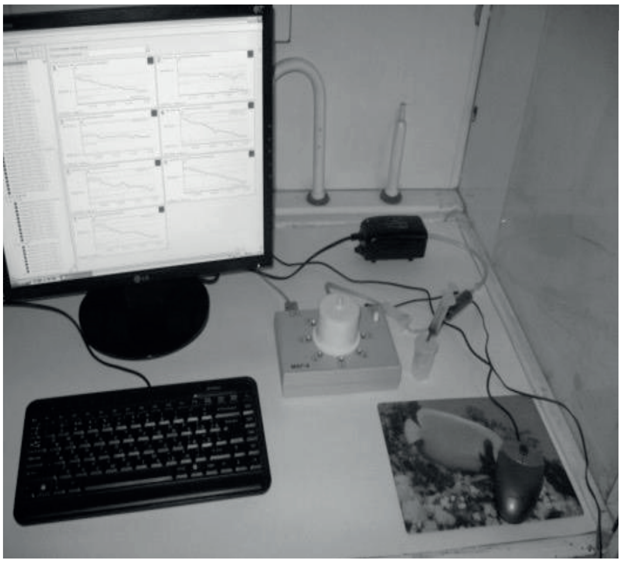


Figure 3 A general view of the workplace with the MAG-8 analyzer

responses was based on the maximum responses of individual sensors. The measurement error was 10%.

The total analytical signal is generated by using the integrated signal processing algorithm of eight sensors in the form of a "visual imprint". To determine the total composition of sample smell, we used the full "visual imprints" of the peaks (the largest responses of eight sensors), constructed from the maximum responses of the sensors in the equilibrium gas phase of the samples during the measurement time (no more than 1 min). The similarity and difference in the composition of the volatile odor fraction over the analyzed samples was established [20]. Slight differences in the composition of the gas mixture were established by comparing the kinetic "visual imprints" constructed from the responses of all the sensors recorded at different times over the entire measurement interval. The nature of the components mixture is more apparent in such analytical signals. Both types of signals, as well as the area of the figures are calculated automatically in the instrument software.

The following criteria for assessing differences in the smell of the analyzed samples are selected:

A qualitative characteristic – the form of a "visual imprint" with characteristic distributions along the response axes, was determined by the set of compounds in the equilibrium gas phase.

Quantitative characteristics:

1) The total area of the full "visual imprint" (SΣ, Hz·s) was used to estimate the total intensity of the aroma proportional to the concentration of volatile substances, including water. This parameter was constructed from all signals of all sensors for the full measurement time;

2) The maximum signal of sensors with the most active or specific sorbent films (ΔFmax, Hz) was applied to assess the content of individual classes of organic compounds in the EGP by the normalization method [21, 22];

3) The identification parameter (Aij) was used to identify individual classes of compounds in a mixture. This parameter was calculated from the signals of the sensors in the analyzed samples and for standard compounds.

Sensor responses were recorded, processed and compared in the software of the MAG Soft analyzer.

RESULTS AND DISCUSSION

In the course of experimental studies (Table 3), the total content of volatile compounds in the EGP was found to correlate with the total analytical signal of the "electronic nose" – the area of the "visual imprint" of the response peaks.

Insignificant differences were found in the total odor intensity over samples of wet and germinated grains, however, the contribution to the total sorption response of different classes of compounds is not equal. To establish differences in the composition (qualitative and quantitative) of the volatile odor fraction, we analyzed the total content of readily volatile components in the equilibrium gas phase over the samples (Fig. 4).

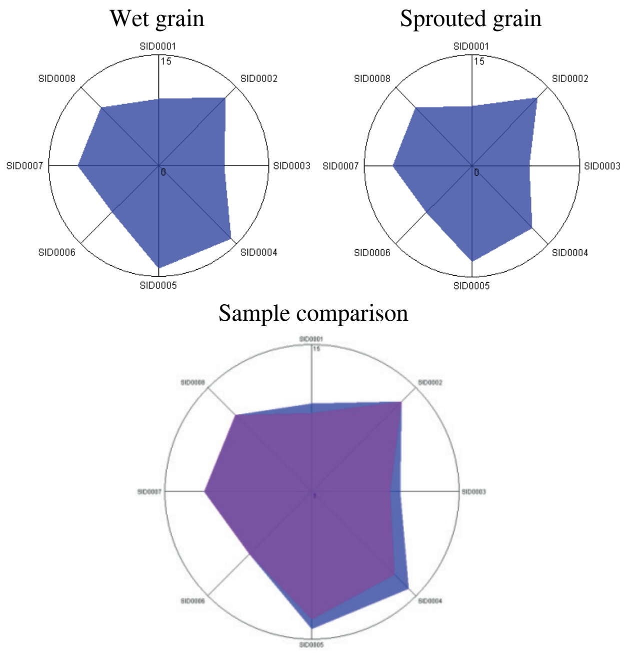
The shape of the "visual imprint" of the sensor responses in the array showed insignificant differences in the chemical composition of the equilibrium gas phase over samples of wet and germinated grain. The content of volatile compounds in the equilibrium gas phase over germinated grain was less by 12% than over wet grain.

Additionally, we noted the change in the quantitative composition of the odor above the samples according to the relative content of the main classes of volatile compounds, evaluated by the normalization method (Table 4).

Table 3 "Visual imprint" area of the sensor signals (S1-S8) in the equilibrium gas medium above the samples

Samples	S1-MCNT	S2-PEGS	S3-PEGSb	S4-PEGA	S5-PEG-2000	S6-DCH18 C6	S7-Tween	S8-PEGP	S_{sum}, Hz·s
Wet grain	9	13	9	14	14	9	11	11	353
Germinated grain	8	13	8	12	13	9	11	11	312
Water	18	21	15	24	23	17	21	22	1135

MCNTs – multilayer carbon nanotubes, PEGS – polyethylene glycol succinate, PEGSb – polyethylene glycol sebacinate, PEGA – polyethylene glycol adipate, PEG-2000 – polyethylene glycol, DCH18C6 – dicyclohexane-18-Crown-6, Tween – Twin 40, PEGP – polyethylene glycolphthalate



Imprint Area:
basic measurement 353.91,
compared measurement 312.89
Absolute area difference: 41.01,
Relative area difference: 11.59%.

Figure 4 "Visual prints" of the maximum sensor signals in the equilibrium gas phase above the samples. The rotary axis indicates the numbers of the sensors in the array (experimental part), and the vertical – the responses of the sensors at a particular point in time (ΔFmax, Hz)

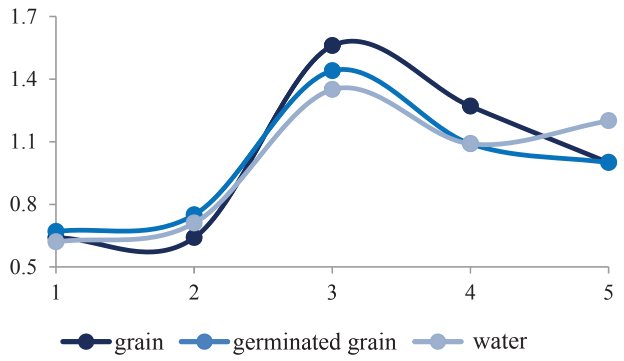


Figure 5 Spectra of identification parameters for grain and water. The X-axis indicates the numbers of identification parameters, the Y-axis indicates their values

After germination, a decrease in the intensity of aroma was noted in the universal indicator, as well as in the "O-containing", "alcohols, ketones, amines" and "alcohols, ketones, water" indicators.

Alcohols are the most commonly found compounds in natural essential oils. As part of essential oils, they do not only add a peculiar aroma, but also contribute to the manifestation of antiseptic activity against bacterial and viral infections, have analgesic, anesthetic and tonic effects, as well as regulate hormonal activity. The absence of toxicity is very important, therefore essential oils with a predominant alcohol content are relatively safe.

Natural essential oils with a high content of ketones can cause side effects: neurotoxicity (negatively affect the functions of the nervous system), embryotropic effect (dangerous during pregnancy), and hepatotropic effect (disrupt liver function).

Some amines are very toxic substances. Inhalation of their fumes and contact with skin are dangerous. Aliphatic amines affect the nervous system, as well as cause violations of the permeability of the walls of blood vessels and cell membranes, liver functions and the development of dystrophy.

We found that grain samples differed in quality composition. For a more visual presentation of the results, a spectrum of identification parameters was constructed (Fig. 5). The compositions of the equilibrium gas phase can be considered identical if the spectra coincide within the error (equal to or greater than 0.1).

Germinated grain contained fewer components in quality composition than wet grain. To establish such differences, the distribution by identification parameters of their absolute differences from water was traced (Fig. 6).

Differences by more than ± 0.1 units are significant and indicate a different composition of compounds in the equilibrium gas phase above the samples. In Fig. 5 the allowable difference interval is marked with black lines.

A significant change in the qualitative composition of the sprouted grain compared to wet grain was

Table 4 Signal ratio of several sensors in the matrix for test samples

Samples	S1-MCNT	S2-PEGS	S3-PEGSb	S4-PEGA	S5-PEG-2000	S6-DCH18 C6	S7-Tween	S8 -PEGP
	Universal sensor	N-containing	Alcohols, ketones, amines	Alcohols, ketones, water	O-containing	Alcohols, acids	Aliphatic acids	Ether
Wet grain	10	14.4	10	15.6	15.6	10	12.2	12.2
Germinated grain	9.4	15.3	9.4	14.1	15.3	10.6	12.9	12.9
water	11.2	13	9.3	14.9	14.3	10.6	13	13.7

MCNT – multilayer carbon nanotubes, PEGS – polyethylene glycol succinate, PEGSb – polyethylene glycol sebacinate, PEGA – polyethylene glycol adipate, PEG-2000 – polyethylene glycol, DCH18C6 – dicyclohexane-18-Crown-6, Tween – Twin, PEGP – polyethyleneglycolphthalate

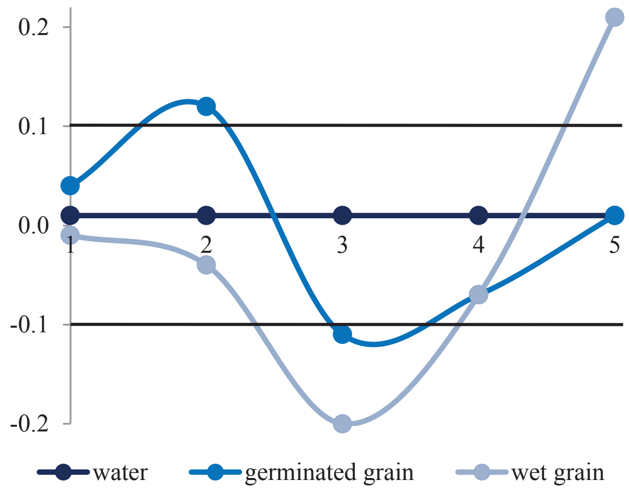


Figure 6 Absolute differences in identification parameters for grain samples compared to water. The X axis is the number of identification parameters

established. Water was also very different from both grain samples, which suggests that not only water vapor, but also other organic volatile compounds were present in the equilibrium gas phase. The qualitative composition of the EGP above wet and germinated samples differed significantly (for selected points – by 60%).

In parallel, an analysis of the sensory characteristics of the grain was carried out. A significant decrease in the sharp smell of legumes after germination was found. This makes it possible to reduce the legume smell, which is a drawback when added to food products, or when traditional raw materials are completely replaced.

CONCLUSION

Testing in laboratory and pilot production conditions showed that the use of pre-processed lentil grains would allow replacing up to 50% of raw meat in minced products (ready-to-cook food, cupats) without changing the smell of the products. Smell is easily masked by spices and food additives. The products possess juiciness and attractive appearance.

The conducted studies opened up new prospects for the creation of meat and vegetable products enriched with biologically active substances, that have the possibility of wider use of domestic raw materials and the development of import-substituting technologies for healthy nutrition products.

Germinated lentils are supposed to be used both as part of meat systems and as an independent ingredient for salads, as well as when creating products that simulate meat for fasting, or when creating enriched extruded products for people who lose weight (bread, bran, etc.).

CONTRIBUTION

L.V. Antipova – 40%, T.A. Kuchmenko – 30%, A.A. Osmachkina – 20%, N.A. Osipova – 10 %.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

REFERENCES

1. Antipova LV, Glotova IA, Astanina VYu, Kilyakova OB. Fiziko-khimicheskie i funktsional′nye svoystva chechevichnoy muki v myasnykh produktakh [Physicochemical and functional properties of lentil flour in meat products]. News of institutes of higher education. Food Technology. 1998;246–247(5–6):11–13. (In Russ.).
2. Pashchenko LP, Zharkova IM. Tekhnologiya khlebobulochnykh izdeliy [Technology of bakery products]. Moscow: KolosS; 2008 398 p. (In Russ.).
3. Samchenko ON. Bobovye kul′tury: perspektivy ispol′zovaniya dlya optimizatsii khimicheskogo sostava myasnykh polufabrikatov [Legumes: Use prospects for optimizing the chemical composition of semi-processed meat products]. Nauka i sovremennost′ [Science and Modernity]. 2014;(28):172–176.
4. Barnes S. The biochemistry, chemistry and physiology of the isoflavones in soybeans and their food products. Lymphatic Research and Biology. 2010;8(1):89–98. DOI: https://doi.org/10.1089/lrb.2009.0030.
5. Antipova LV, Tolpygina IN, Martem′yanova LE. Rasteniya kak istochniki pishchevogo belka: monografiya [Plants as sources of dietary protein: monograph]. Voronezh: Voronezh center for scientific and technical information; 2013. 397 p. (In Russ.).
6. Antipova LV, Tolpygina IN, Martem′yanova LE. Poluchenie i funktsional′no-tekhnologicheskie svoystva pishchevykh rastitel′nykh belkov: monografiya [Obtaining, and functional and technological properties of edible vegetable proteins: monograph]. Voronezh: Voronezh center for scientific and technical information; 2013. 356 p. (In Russ.).
7. Antipova LV, Tolpygina IN, Martemyanova LE. Vegetable proteins texturates for food production. Food Industry. 2014;(2):20–23. (In Russ.).
8. Simonenkova AP. Food fortifier for the dairy industry. Food Processing: Techniques and Technology. 2013;28(1): 41–46. (In Russ.).
9. Howell E. Enzyme nutrition: The food enzyme concept. Avery Publishing Group; 1985. pp. 15–51.

10. Shipard I. How can I grow and use Sprouts as living food? 2005. pp. 37–98.
11. Kazymov SA, Prudnikova TN. Germination influence on amino acids composition of mash beans. News of institutes of higher education. Food Technology. 2012;329–330(5–6):25–26. (In Russ.).
12. Bedford MR. Exogenous enzymes in monogastric nutrition – their current value and future benefits. Animal Feed Science and Technology. 2000;86(1–2):1–13. DOI: https://doi.org/10.1016/S0377-8401(00)00155-3.
13. Dotsenko SM, Bibik IV, Lyubimova OI, Guzhel' YuA. Kinetics of biochemical processes of germination of soybean seeds. Bulletin of KSAU. 2016;112(1):66–74. (In Russ.).
14. Weber AL, Kazydub NG, Fialkov DM, Buyakova AA, Buyakova TA. Development of technology of the sour-milk product with sprouts of haricot grain. Bulletin of Omsk State Agricultural University. 2014;14(2):63–66. (In Russ.).
15. Inyang CU, Zakari UM. Effect of germination and fermentation of pearl millet on proximate, chemical and sensory properties of instant "Fura" – A Nigerian cereal food. Pakistan Journal of Nutrition. 2008;7(1):9–12. DOI: https://doi.org/10.3923/pjn.2008.9.12.
16. Kumar V, Rani A, Goyal L, Dixit AK, Manjaya JG, Dev J, et al. Sucrose and Raffinose Family Oligosaccharides (RFOs) in soybean seeds as influenced by genotype and growing location. Journal of Agricultural and Food Chemistry. 2010;58(8):5081–5085. DOI: https://doi.org/10.1021/jf903141s.
17. Krishtafovich VI, Zhebeleva IA, Kolobov SV. Vliyanie kolichestva soevykh izolyatov na tsvet myasnykh produktov [Influence of the amount of soy isolates on the color of meat products]. News of institutes of higher education. Food Technology. 2004;278(1):18–20. (In Russ.).
18. Statsenko ES. Research of preferences of population at usage of soya products. Far Eastern Agrarian Herald. 2011;18(2):44–46. (In Russ.).
19. Antipova LV, Glotova IA, Rogov IA. Metody issledovaniya myasa i myasnykh produktov [Study methods of meat and meat products]. Moscow: Kolos; 2001. 376 p. (In Russ.).
20. Kuchmenko TA. Khimicheskie sensory na osnove p′ezokvartsevykh mikrovesov [Chemical sensors based on piezoelectric quartz microbalances]. In: Vlasov YuG, editor. Problemy analiticheskoy khimii [Problems of analytical chemistry]. Moscow: Nauka; 2011. pp. 120–195.
21. Okuskhanova EhK, Asenova BK, Igenbaev AK, Rebezov MB. Tendentsii proizvodstva funktsional′nykh myasnykh produktov [Trends in the production of functional meat products]. Universitetskiy kompleks kak regional′nyy tsentr obrazovaniya, nauki i kul′tury: materialy Vserossiyskoy nauchno-metodicheskoy konferentsii [University complex as a regional center of education, science and culture: Proceedings of the All-Russian scientific and methodological conference]; 2014; Orenburg. Orenburg: Orenburg State Universiry; 2014. p. 1273–1278. (In Russ.).
22. Venetsianskiy AS, Mishina OYu. Tekhnologiya proizvodstva funktsional′nykh produktov pitaniya [Production technology of functional food]. Volgograd: Volgograd State Agricultural University; 2014. 80 p. (In Russ.).

ORCID Ids
Anastasiya A. Osmachkina https://orcid.org/0000-0001-6006-221X