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Study of promising types of legume raw materials for the production of fermented food products

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Abstract. In Russia, a large number of different legumes are grown, such as soybeans, chickpeas, lentils, beans, which are a valuable source of protein. In the context of the global climate agenda and sustainable development goals, the world community has taken the vector of transforming the population's diet towards reducing animal products and increasing the share of products based on plant materials. This paper presents the results of experiments on the fermentation of 8 types of legume raw materials, including soybeans, chickpeas, mung beans, black lentils, green lentils, red lentils, peas, to obtain a food product. An assessment was made of the swelling properties of raw materials, their appearance after swelling, and after fermentation for 24 and 48 hours. An analysis of amine nitrogen indicators before and after fermentation was also carried out. Practical recommendations for the use of the considered raw materials for the food industry are offered.

1 Introduction

Population growth, climate change, rapid urbanization, the Covid-19 pandemic, rising poverty leading to forced changes in food habits and diets, political conflicts are leading to an exacerbation of the global problem of hunger and malnutrition in the world. Residents of developing countries suffer the most from the consequences of these changes. In particular, according to the WPF (World Food Programme), about 50 million people suffer from hunger these days, compared to 27 million people in 2019, and 2 billion people in the world are already experiencing micronutrient deficiencies. According to UN forecasts, by 2080 the number of people suffering from famine and malnutrition will increase by 176 million compared to today. Already, two billion people in the world are deficient in micronutrients [1-3]. This is especially important since the world's human population is expected to grow to 9-10 billion people by 2050.

Thus, changing eating patterns, shifting to healthy and sustainable diets, and fighting hunger and malnutrition are closely connected with the climate agenda and the concept of sustainable development. In particular, Sustainable Development Goal 2 (SDG 2) aims to fight hunger and improve nutrition. According to this goal, a number of states have

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committed to eliminating hunger, malnutrition and ensuring food security by 2030. The above goal partially correlates with SDG 3 in relation to ensuring a healthy lifestyle of the population and promoting well-being for all at all ages and with SDG 12 in terms of developing and implementing sustainable models of production and consumption [1-3].

The term sustainable diets refers to diets that have minimal impact on the environment, while contributing to sustainable food security and improved public health [4].

According to the United Nations Committee on Nutrition (UNNC), the modern human diet is characterized by a significant amount of meat and other animal products consumed. The results of a number of studies indicate the connection of dietary patterns, including excessive consumption of red and processed meat, with an increase in morbidity and obesity, as well as cardiovascular diseases, stroke, cancer, and type 2 diabetes. In contrast, plant-based diets have been adopted to reduce the risk of these factors [4–8]. Today, there are 1.9 billion adults who are overweight or obese. According to the World Health Organization (WHO), 1.4 million people die from cardiovascular diseases in Russia every year. In this regard, ensuring universal access to healthier and more sustainable diets is urgent.

Along with the traditional understanding of hunger, there is the term hidden hunger, which means a chronic deficiency in the diet of any of the dietary microelements and vitamins [7-8, 13]. These deficiencies have negative consequences and affect quality of life, health and life expectancy. The name is due to the fact that deficiency cannot be assessed visually; it correlates with inferiority in terms of the biological value of products. Hidden hunger is just as dangerous as traditional hunger, and both residents of developing and developed countries are at risk.

Micronutrient deficiencies lead to increased morbidity and mortality, decreased productivity, stagnant national development, irreversible impairment of cognitive development in infants and children, and great economic cost and suffering to affected societies.

Due to agricultural systems are the primary source of all micronutrients for all people, changes to agricultural policies and systems are needed to ensure a consistent and adequate supply of all essential nutrients to all people. Additionally, the nutrition and health sectors must turn to agricultural interventions as a core tool in their efforts to eradicate global malnutrition if they are to be sustainable.

Biotechnological advances hold great promise for improving the production of bioavailable micronutrients in agricultural systems that feed the poor. This article examines some of these opportunities and discusses the questions and concerns that should be raised when these technologies are used to improve the micronutrient status of the vast numbers of people who depend on staple food crops for their livelihoods. In addition, important issues related to the bioavailability of micronutrients and plant food factors that influence it are discussed [4].

The importance of enriching people's diets with legumes such as beans, chickpeas, lentils and peas, which are one of the most important sources of plant protein and amino acids for people around the world, as well as a key source of plant protein for the nutrition of farm animals, was emphasized in the initiative of the International United Nations Year of Pulses (United Nations General Assembly, 2014) in the context of providing sufficient bioavailable micronutrients. The World Food Program also emphasizes the role of legumes towards sustainable development and food security.

A wide range of legume crops are grown in Russia, in particular soybeans, which are cultivated on an industrial scale in the Far Eastern Federal District, the Central Black Earth Region and the Krasnodar Region.

In terms of soybean yield, the Kaliningrad region, Adygea and Irkutsk region are leaders, growing 28.3 c/ha, 20.5 c/ha and 19.9 c/ha, respectively.

Thus, the Russian agricultural sector has high potential in soybean production, demonstrating this with a stable annual increase in production and export volumes.

Numerous studies confirm the beneficial effects on the body of regular consumption of legumes and legume-based products for functional purposes, as there is a decrease in the severity of a number of chronic diseases, such as cardiovascular diseases, diabetes, high cholesterol, immune disorders, some types of cancer and obesity [9-12]. For this reason, the development of technology for the production of dietary products based on legume raw materials is a subject of increasing scientific interest due to its potentially beneficial effect on human health.

It is noted that in recent years, gastronomic interest in traditional products of other countries, in particular Asian ones, such as Japan, Korea and China, has been growing among the Russian population. In particular, new soy-based products that were previously unusual for domestic consumers began to appear on the Russian food market, for example, tofu soy cheese, fermented Korean pastes such as gochujang and twenjang, fermented Japanese miso paste, whole fermented natto soybeans, Indonesian fermented tempeh product and many others.

Natto, a traditional Japanese dish with more than a thousand years of history, is boiled whole beans fermented with Bacillus subtilis var. Natto. For production, only 3 components are needed: soybeans, water and Bacillus subtilis spores [16-19]. This product will serve as a prototype in our research.

The studies presented in this article present materials on the production of fermented food products from various legumes. The main technological parameters of fermentation were established, the amino acid composition was analyzed and conclusions were drawn about the prospects for using the proposed options.

2 Materials and methods

2.1 Technological diagram of fermentation

The sequence of operations when obtaining a fermented product is as follows:

- Cleaning and sorting of raw materials.
- Selection of the mass required for the study (100 grams).
- Soaking raw materials for 12 hours at a temperature of 20±2°C in a thermostatic chamber. Measurement of mass and moisture capacity of samples.
- Boiling samples for 60 minutes followed by separation of water. Cooling of samples to a temperature of 20±2°C.
- Inoculation of samples with Bacillus subtilis bacteria.
- Fermentation of samples at a temperature of 30±2°C. Sampling for measurement of alpha-amine nitrogen, after 12, 24, 36, 48 hours.

2.2 Determination of moisture capacity and swelling of bean mass before and after hydrothermal treatment

The weight of the samples was measured in the native state, before hydrothermal treatment and after it using a MASSA-K VK-1500 scale.

2.3 Determination of amine nitrogen content

The method is based on the ability of most amino acids and peptides to form soluble complex compounds with copper ("copper method"). Excess copper is titrated, and its amount equivalent to amine nitrogen is converted into acetic acid salt with acetic acid and quantified by iodometric titration.

3 Results and Discussion

As a result of the operations of soaking bean raw materials and heat treatment, it was found that the increase in the total weight of semi-finished products increased by 100 - 120% due to an increase in moisture content. At the same time, the greatest weight gain was observed in samples from black lentils and mung beans. The lowest moisture absorption was observed in green lentils and chickpeas. The results are presented in Table 1.

Table 1. Swelling capacity of bean mass before and after hydrothermal treatment.

Type of legume	Dry weight (g)	Weight after soaking (g)	Weight after hydrothermal treatment (g)	Weight gain after hydrothermal treatment, %	Consistency after hydrothermal treatment
Soy	100.0 ± 0.5	217.3 ± 1.1	266.4 ± 1.3	22.5	Whole beans
Red beans	100.0 ± 0.5	216.4 ± 1.1	230.4 ± 1.2	6.5	Whole beans
Read lentils	100.0 ± 0.5	210.0 ± 1.1	224.1 ± 1.1	6.6	Homogeneous with whole beans
Green lentils	100.0 ± 0.5	205.1 ± 1.0	282.2 ± 1.4	37.5	Homogeneous with whole beans
Black lentils	100.0 ± 0.5	228.1 ± 1.1	238.5 ± 1.2	4.3	Whole beans
Green peas	100.0 ± 0.5	208.2 ± 1.0	238.4 ± 1.2	14.4	Homogeneous with whole beans
mung beans	100.0 ± 0.5	224.1 ± 1.1	307.2 ± 1.5	37.1	Homogeneous with whole beans
chickpeas	100.0 ± 0.5	198.4 ± 1.0	217.1 ± 1.1	9.6	Whole beans

After hydrothermal treatment, the weight of the samples increased in the range from 4.3% to 37.5%, which indicates very different resistance of the raw materials to such effects.

The consistency of the samples after hydrothermal treatment varied from homogeneous with inclusions of whole beans to a structure with predominantly whole beans. At the same time, a significant accumulation of moisture, as a rule, provoked a stronger boiling of the product.

For the preparation of the traditional Asian food product - natto, beans that have undergone the least destruction are advantageous: soybeans, red beans, black lentils, chickpeas.

It seems important to note that the greatest integrity is observed in crops with intense coloring. The authors attribute this to a probably stronger framework consisting of the "phenolic compounds - protein" system, as well as to the different content of cellulose fibers in different types of feedstock.

As a result of measuring the concentration of amine nitrogen during the fermentation of legume substrates by microorganisms Bacillus subtilis, the main patterns of changes in this indicator were established (Figure 1).

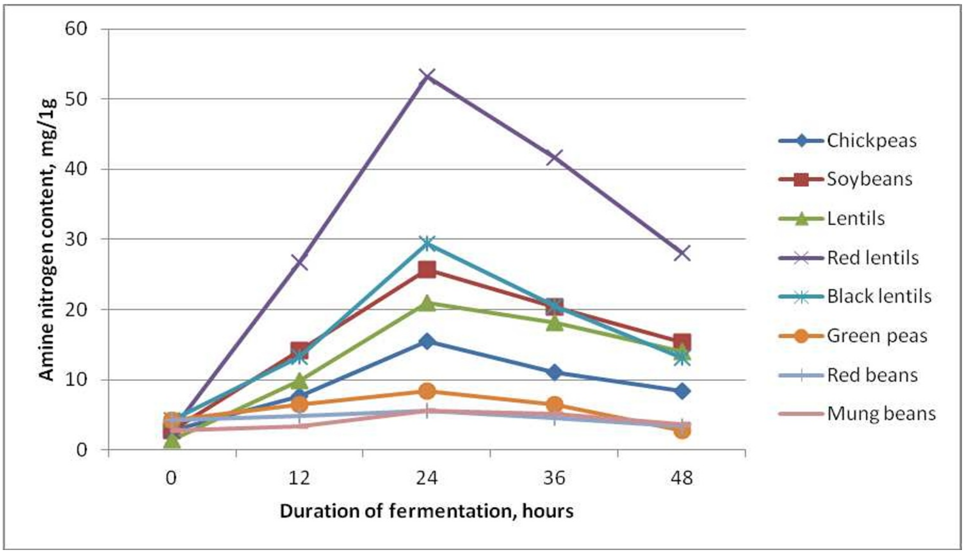

Fig. 1. Result of measuring the concentration of amine nitrogen.

All samples accumulated amine nitrogen during 24 hours of fermentation; red lentils, black lentils and soybeans showed themselves especially intensively. The authors associate such kinetics with intense protein hydrolysis due to the activity of the *Bacillus subtilis* enzymatic system.

Over the next 24 hours, all samples showed a decrease in amine nitrogen content, this is due to the active consumption of the accumulated component by bacteria at the previous stage.

The most intense decrease in concentration was observed in samples from chickpeas (45.8% of the accumulated potential), red lentils (47.4% of the accumulated potential) and black lentils (55.4%).

The least intense decrease in amine nitrogen content was recorded in samples from red beans (29.3% of the accumulated potential) and mung bean (35.7% of the accumulated potential).

The authors associate such a significant difference in the level of consumption of this component by Bacillus subtilis bacteria with a complex difference in the nutrient medium for bacteria, that is, the presence of other nutritional factors that stimulate or inhibit the consumption of amine nitrogen.

In general, the authors consider the fact of a pronounced difference in amine nitrogen concentrations during the fermentation of such a product to be established. This, to a significant extent, will make it possible to predict the final composition of the food product, since this dynamics indirectly indicates the degree of hydrolytic processes, and therefore the biological value of the product.

4 Conclusion

Hydrothermal treatment of legumes makes it possible to obtain starting plant biomass of various structures. From a homogeneous mixture including whole beans to a more compact structure, without homogenization.

During hydrothermal processing of legumes, different moisture absorption is observed, which is important to consider when making product calculations and developing technological production schemes.

Fermentation of legume raw materials with bacteria *Bacillus subtilis* shows multidirectional changes in the concentration of amine nitrogen. During the first 24 hours its concentration increases, and during the final 24 hours it decreases.

The obtained patterns are assessed as an important step in the development of industrial technology for functional food products from valuable agricultural crops.

References

1. R.A. Good, Nutritional deficiency, immunologic function, and disease, The American journal of pathology, **84**, **3**, 599 (1976)
2. U.C. Gupta, S.C. Gupta, Sources and deficiency diseases of mineral nutrients in human health and nutrition: a review, Pedosphere, **24**, **1**, 13-38 (2014)
3. M.H.N. Golden, The nature of nutritional deficiency in relation to growth failure and poverty, Acta Paediatrica, **80**, 95-110 (1991)
4. J.I. Macdiarmid, Is a healthy diet an environmentally sustainable diet? Proceedings of the Nutrition Society, **72**, **1**, 13-20 (2013)
5. M. Donati, Towards a sustainable diet combining economic, environmental and nutritional objectives, Appetite, **106**, 48-57 (2016)
6. S.S. Martinelli, S.B. Cavalli, Healthy and sustainable diet: a narrative review of the challenges and perspectives, Ciencia & saude coletiva, **24**, 4251-4262 (2019)
7. J.I. Macdiarmid, Sustainable diets for the future: can we contribute to reducing greenhouse gas emissions by eating a healthy diet? The American journal of clinical nutrition, **96**, **3**, 632-639 (2012)
8. M. Springmann, Health and nutritional aspects of sustainable diet strategies and their association with environmental impacts: a global modelling analysis with country-level detail, The Lancet Planetary Health, **2**, **10**, e451-e461 (2018)
9. M. Friedman, D.L. Brandon, Nutritional and health benefits of soy proteins, Journal of agricultural and food chemistry, **49**, **3**, 1069-1086 (2001)
10. C.R.D'Adamo, A. Sahin, Soy foods and supplementation: a review of commonly perceived health benefits and risks, Altern Ther Health Med, **20**, **1**, 39-51 (2014)
11. G. Dukariya, Soybean and its products: Nutritional and health benefits, J Nut Sci Heal Diet, **1**, **2**, 22-29 (2020)
12. F.J. He, J.Q. Chen, Consumption of soybean, soy foods, soy isoflavones and breast cancer incidence: Differences between Chinese women and women in Western countries and possible mechanisms. Food Sci. Human Wellness, **2**, 146–161 (2013)
13. R. Kamboj, V. Nanda, Proximate composition, nutritional profile and health benefits of legumes-a review, Legume Research-An International Journal, **41**, **3**, 325-332 (2018)
14. M.A. Martín-Cabrejas, Legumes: Nutritional quality, processing and potential health benefits, Royal Society of Chemistry, 8 (2019)

15. M. Bouchenak, M. Lamri-Senhadji, Nutritional quality of legumes, and their role in cardiometabolic risk prevention: a review, Journal of medicinal food, **16**, **3**, 185-198 (2013)
16. M. Afzaal, Nutritional health perspective of natto: A critical review, Biochemistry Research International (2022)
17. S.R.B. Ruiz Sella, Bacillus subtilis natto as a potential probiotic in animal nutrition, Critical Reviews in Biotechnology, **41**, **3**, 355-369 (2021)
18. C. Nagata, Dietary soy and natto intake and cardiovascular disease mortality in Japanese adults: the Takayama study, The American journal of clinical nutrition, **105**, **2**, 426-431 (2017)
19. Y. Nishito, Whole genome assembly of a natto production strain Bacillus subtilis natto from very short read data, BMC genomics, **11**, 1-12 (2010)