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TECHNOLOGICAL AND ECONOMIC ASPECTS OF USING LEGUMES IN FOOD TECHNOLOGY: A MINI-REVIEW

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Abstract

Today there is a tendency of reducing the daily intake of animal protein according to the recommended amount, so legumes are becoming more and more popular among the population of different countries. They are a valuable source of vegetable protein, fiber, and nutrients and an alternative to animal protein. The main advantages are the rich chemical composition, the availability of the population of different countries, high yields, soil enrichment with nitrogen, the possibility of using by-products after harvest, waste-free, storage periods. At the same time, legumes contain anti-nutritional substances, shortcomings in cultivation and long cooking time, which requires a comparative analysis with other food products. The economic factor, profitability, technological features and basic chemical composition should also be taken into account. This review article aims to identify the main advantages and disadvantages of using raw legumes in the chain from cultivation to food production.

Keywords: beans; chickpeas; lentils peas; yellow split peas; legumes.

ТЕХНОЛОГІЧНІ ТА ЕКОНОМІЧНІ АСПЕКТИ ЗАСТОСУВАННЯ БОБОВИХ В ТЕХНОЛОГІЯХ ХАРЧОВОЇ ПРОДУКЦІЇ: МІНІ-ОГЛЯД

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Анотація

На сьогодні існує тенденція до зменшення добової норми споживання тваринного білку від рекомендованої кількості, тому серед населення різних країн все більше стають популярними альтернативні джерела білку, а саме бобові культури, адже вони – цінне джерело рослинного білку, клітковини, нутрієнтів. Основними перевагами бобових культур виступає їх багатий хімічний склад, доступність для населення різних країн, висока врожайність, збагачення ґрунту азотом, можливість використання побічної продукції після збору врожаю, безвідходність, терміни зберігання. Одночасно із зазначеними перевагами бобові культури мають у своєму складі антипоживні речовини, недоліки у вирощуванні, довготривалий термін приготування, що вимагає проведення порівняльного аналізу із іншими харчовими продуктами із врахуванням економічного фактору, рентабельності, технологічних особливостей та основного хімічного складу. Ця оглядова стаття направлена на визначення основних переваг та недоліків використання бобової сировини в ланцюгу від вирощування до виробництва харчової продукції.

Ключові слова: квасоля; нут; сочевиця; горох жовтий колотий; бобові.

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Introduction

Legumes take a special niche among the wide range of vegetable raw materials. According to the research from the Department of Food Science and Human Nutrition, the University of Colorado and the Cancer Prevention Laboratory at Colorado State University, legumes are an important part of the daily diet. They are rich in protein, reduce the deficiency of dietary fiber and potassium, are used in the prevention of obesity, chronic diseases and have a unique chemical composition [1]. The main value of legumes lies in the content of a significant amount of vegetable protein, which is an alternative replacement of animal proteins.

In industrially developed countries legumes make up 20–25 % of the human diet, and in developing countries this amount is up to 75 %. After the Second World War the annual consumption of legumes was about 20 kg/capita, while the consumption of cereals was 105–115 kg/capita and meat was about 15 kg/capita. For the five-year period 2010–2015, the average consumption of cereals and meat was 175 kg/capita and 80 kg/capita respectively, while the consumption of legumes was 1.5–2.0 kg/capita [2].

Today, there is a trend towards a reduced level of protein consumption by the World's population, in addition, one-in-ten people in the world do not get enough to eat [3], which reflects the urgency of this issue.

Therefore, the advantages of legumes are widely studied, since vegetable protein is easier to grow in different regions. Legumes are better stored, transported and can cover the growing needs of mankind in protein, reducing dependence on meat protein [4].

According to the Ukrainian Business and Trade Association, Ukraine is the leader in the export of legumes among medium-sized countries. It ranks 19th in the global ranking of legumes suppliers [5]. Romania, Bulgaria, Serbia, Montenegro, Macedonia, Moldova, Albania have similar leading characteristics of the export of agricultural products in Europe. Other European countries grow agricultural products in small quantities, mainly to meet their own needs.

In Ukraine, according to the commodity structure of foreign trade for 2021, products of vegetable origin amounted to 22.8 % of all exports of goods. Comparing to the present, in 2014 the percentage of export of products of plant origin was only 16.2 % [6]. Such indicators demonstrate an increase in the acreage of products under plant origin and the presence of an expanded product sales market. The imports of plant products constitutes 2.9 % of the total volume, while 1.1 % accounts for edible fruit and nuts, which cannot be import substituted in Ukraine, taking into account the climatic and geographical features of the country.

According to the online platform Observatory of Economic Complexity [7], Estonia exports 2.6 % of plant products, 7.54 % of them are rapeseed, 37.85 % is wheat, 13.1 % is barley and 6.82 % are legumes. Latvia exports 8.7 % of plant products, which is dominated by wheat 35.5 %, rapeseed 11.4%, and dry legumes are 2.76 %. Romania exports 5.57% of plant products, 30.1 % of them is corn, 28.75% is wheat, sunflower seeds are 16.1 % [7].

Economic factors: from cultivation to storage

According to information posted by the international trade statistics database of UN Comtrade, a wide range of leguminous crops is grown in many European countries. This is because of economic prerequisites and the fact that farmers are constantly looking for more cost-effective and popular agricultural crops on the market, but their sown areas are less than the world leaders have [8] (Table 1). Usually, preference is given to growing peas, then to other crops.

Table 1

Beans that are grown for export in different countries of the world [8]

The name of legumes	India	Canada	USA	China	Mexico	Turkey	Ukraine
Chickpeas	+	_	_	_	+	+	+
Beans	+	-	+	+	+	+	+
Yellow split peas	_	+	+	+	_	+	+
Lentils peas	_	+	-	_	_	+	+

Taking into account various indicators, it is promising to grow legumes. It was determined that the following legumes were most popular for export: chickpeas, peas, beans and lentils. In Table 2 the mentioned indicators are determined for Ukraine as an example of a country with a moderately cool climate, which is necessary for cultivation of the main types of legumes [9, 10].

Table 2

Summarized data on the cultivation of legumes in Ukraine [9; 10]

Characteristic	The name of legumes			
	Chickpeas	**Beans**	**Yellow split peas**	**Lentils peas**
Average yield t/ha	1.4	1.59	2.28	1.39
Sown area in Ukraine, thousand ha	36.0	42.0	347.0	8.0
Gross collection, thousand tons	774.91	71.19	774.91	19.54
By-products, t/ha	1.8	2.2	3.2	1.7
Production leaders by region for 2021	Odesa, Kharkiv, Kirovohradsk	Khmelnytska, Vinnytsia, Ivano-Frankivsk	Zaporizhzhia, Donetsk, Mykolaiv, Odesa, Kharkiv	Zaporizhzhia, Odesa, Kherson, Kharkivska
Disadvantages	Minimum yield with a large amount of precipitation	High requirements for light	Dependence on sudden changes in weather conditions	Instability of growing, lack of technology
Benefits	Drought- and heat-resistant culture	Resistance to fluctuations in soil pH, resistance to pests	Early sowing dates	Early sowing dates
Profitability, %	52	69	76	71

Most European countries grow legumes for domestic needs like food production and animal feed. Some countries specialize in growing certain types of crops: 2/3 of lupine is grown in Poland; peas, beans are in France; 40 % of soybeans are produced in Italy. The lowest rates among all European countries are for lentil cultivation (5.2 %) and for chickpea (4 %), because 80% of the world's chickpea production is in India, since its cultivation requires a subtropical climate [11].

Table 3

Summary data on yield and price of legumes [12–14]

Characteristic	The name of legumes	Countries								
		Ukraine	**Ireland**	**Spain**	**Italy**	**France**	**Greece**	**Belgium**	**Belarus**	**Lithuania**
Yield, t/ha	beans	1.77	1.69	1.83	1.87	2.21	2.30	4.61	2.06	2.14
Production, thousands of tons	beans	71.19	21.00	17.09	11.98	11.05	18.23	0.56	240.17	149.68
Price, per 1 kg USD	beans	2.30	2.80	1.58	3.49	2.02	4.23	4.66	2.64	2.95
Yield, t/ha	Yellow split peas	1.82	2.43	1.76	2.80	3.30	5.18	3.64	1.96	2.01
Production, thousands of tons	Yellow split peas	775.6	1.7	262.6	50.2	615.7	0.5	2.6	58.0	213.7
Price, per 1 kg USD	Yellow split peas	0.23	1.37	0.87	0.81	0.45	0.90	0.77	0.68	0.27

Among the crops studied by us, peas have the highest profitability, while chickpeas have the lowest (Table 2) [9]. The advantages of growing legumes for farmers are the enrichment of the soil with organic matter, calcium, potassium, phosphorus, nitrogen, which not only reduces the load on the soil, but also enriches it. The by-products that remain during the growing of legumes include straw and stalks, where the

indicators of nitrogen and phosphorus content exceed the indicators of cereals [10].

The second important factor is the price, which is the lowest for peas and the highest for beans, depending on the variety, region and method of cultivation. If we take into account the losses of enterprises for the creation of various agricultural products during 2020, which are relevant for Ukraine, Latvia, Estonia, then legumes had higher profitability indicators than animal husbandry. At the same time they had slightly lower characteristics than other crop production [6]. Based on the data of losses of enterprises for the production of various agricultural products, which is posted on the website of the State Statistics Service for 2020, the highest costs were 1,285,369.63 USD for growing meat, 666,469.19 USD for poultry, and 305,003.08 USD for eggs. Accordingly, the lowest indicators were for dried leguminous crops 62 713.39 USD, taking into account the fact that the total cost of crop production was 6 420 426.96 USD.

Average prices of agricultural products sold by enterprises for 2015–2021 were analyzed [6], excluding VAT, subsidies, transport, delivery and overhead costs. It was revealed that the lowest price for products in Ukraine were observed in 2015 at 79.32 USD per ton of grain and leguminous compared to 171.4 USD per ton in 2021. That means that the price from 2015 to 2021 increased by 92.08 USD per ton, but prices fluctuate. In 2019, prices fell to 12.18 USD per ton, and already in 2020 they rose to 25.24 USD per ton.

The situation with price fluctuations is observed in all countries of Europe, where the lowest prices were observed in 2016 and slightly increased only in 2019. So, using the example of the cheapest representative of legumes is peas, the price per ton has changed: in Luxembourg in 2016 it was 480.98 USD, and already in 2019 it was 1205.13 USD; in Poland in 2016 – 548.76 USD, and in 2019 – 661.96 USD; in France in 2016 – 437.41 USD, in 2019 – 456.82 USD [13].

The prices of grains and legumes are connected, first of all because of fluctuations in the situation on the world market, climatic conditions, giving preference in the production of a certain type of product variety, energy prices and the political situation in the world. So, in 2019, due to India's protectionist policy, the number of legumes exported from Ukraine decreased [15], which led to a drop in prices and a decrease in planted areas in 2020. In 2022–2023 an increase in prices for agricultural crops is predicted in connection with the political situation in the world. In these unstable modern realities it is advisable to expand the production of our own products from legumes, because it is possible to sell finished products more expensive than raw materials. There is a wide range of products made from legumes on the international market: bread [16], noodles [17], bars [18], cookies [19], breakfast cereals [20]. Unfortunately, in the countries of Eastern Europe the assortment of products from legumes is quite limited; in most of them it is represented only by canned products.

The unequivocal advantage of legumes is the shelf life, which, under any circumstances, meat or fish raw materials cannot compete with. So, according to the legislative and regulatory documents [21], the loss of legumes during storage in elevators is 0.045 % during 3 months, 0.06 % during 6 months, 0.095 % during 1 year. If they are stored in warehouses in bulk, then the loss is 0.07 %, 0.09 %, 0.115 % respectively, and in containers it is 0.04 %, 0.06 %, 0.08 % in accordance with the same storage periods. The humidity of 15–16 % is allowed at a temperature of 10–15 °C for legumes which are stored for up to 1 year.

At the same time, the standards of natural losses of other protein-containing raw materials depend on the thermal state of storage. According to the legislative and regulatory documents [22], when freezing at –23 °C and below, the losses are 0.7–0.79 % for beef and 0.81–0.92 % for pork; at a temperature above 23 °C the loss of beef is 0.9–1.02 % and the loss of pork is 0.91–1.04 %. When freezing fresh meat at a temperature not higher than –8 °C in the thickness of the muscles, the natural loss is 2.23–2.5 % for beef and 1.6–2.20 % for pork. Regarding fish and poultry, their loss rates, according to legislative and normative documents [22] are: live fish – 0.1 %, chilled fish – 0.6–0.65%, unglazed frozen fish – 0.27–0.31 %; frozen chicken – 0.19–0.25 % and chilled chicken is 0.37–0.5 %.

Based on regulatory documents, compared to other raw materials, legumes have fewer natural losses and can be stored for a long time without much loss of their properties. Such properties make them versatile natural preserves, which have simpler storage requirements while maintaining maximum biological and chemical characteristics.

Chemical composition

High indicators of nutritional and biological value of legumes, their economic availability, unpretentious storage conditions led to special attention from scientists who solve the issue of protein deficiency and rational nutrition of the population.

Currently Ukrainian and foreign scientists have developed food technologies with using legumes. The purpose of these technologies is spreading and making diversity of the range of products with a balanced chemical composition. Many studies are focused on the development of technologies for processing legumes and their use in food products, where they play the role of a functional additive or fortifier. The chemical composition of legumes (Tables 4, 5) differs depending on the variety and species. It also has advantages and disadvantages compared to other raw materials.

Table 4

Chemical composition of dry grain legumes [23, 24]

The name of legumes	Content, %									
	Water	Protein	Fat	Saturated Fatty Acid	Cholesterol	Mono and disaccharides	Starch	Carbohydrates	Dietary fiber	Ash
Soybean	8.5	36.5	19.9	2.9	0.0	5.7	11.6	30.2	9.3	4.9
Chickpea	7.8	20.5	6.0	0.7	0.0	3.6	39.0	63.0	12.2	2,8
Beans	11.3	23.4	2.0	0.3	0.0	3.2	42.4	48.0	15.2	4.2
Yellow split peas	8.7	23.1	3.8	0.3	0.0	4.6	44.9	49.5	22.2	2.7
Lentils peas	7.8	23.9	1.5	2.1	0.0	2.9	47.6	63.1	10.8	3.0

Table 5

Vitamins and minerals composition of legumes [23, 24]

The name of legumes	Content per 100 g of dry grain														
	mg %									µg %					Kcal
	Na	K	Ca	Mg	P	Fe	B1	B2	B3	Tocopherol equivalent	Niacine equivalent	Retinolic equivalent	β- Carotene	Retinol	Energy value
Soybean	2	1800	277	280	704	15.70	0.87	0.87	1.62	0.85	9.70	12	70	0	446
Chickpea	24	718	57	79	252	4.31	0.48	0.21	1.54	0.82	1.54	0	40	0	378
Beans	16	1800	240	190	301	10.40	0.44	0.15	0.48	0.60	6.40	0	0	0	333
Yellow split peas	5	852	114	106	334	4.73	0.72	0.24	3.61	0.70	6.50	0	89	0	364
Lentils peas	7	668	48	59	294	7.39	0.51	0.11	1.80	0.50	5.50	5	30	0	358

Comparing with raw meat, the advantage of legumes is the absence of cholesterol, which is found in meat dishes, for example: chicken in its own juice has 84 mg of cholesterol, boiled lamb – 97 mg, boiled pork – 78 mg, boiled rabbit – 76 mg per 100 g of the portion [23]. In addition, vegetable crops contain dietary fiber (Table 6), which can cover the daily human need and are completely absent in raw meat.

Table 6

Dietary fiber content (%) in legumes [25]

The name of legumes	Insoluble dietary fiber	Soluble dietary fiber	Total oligosaccharides (raffinose + stachyose + verbascose)	Total dietary fiber
Chickpeas	14.4–17.1	2.0–5.8	1.0–3.5	19.5–24.9
Beans	12.3–15.7	5.8–9.8	3.6–5.2	24.1–27.4
Yellow split peas	14.2–19.8	3.3–5.3	4.0–5.4	22.3–28.0
Lentils peas	12.3–14.7	2.7–3.9	3.0–3.7	18.4–21.3

Table 7

The content of resistant starch (ARE) in raw and freeze-dried cooked legumes [26]

The name of legumes	Content, g/100g	
	AR raw legumes	AR freese-dried cooked legumes
Chickpeas	3.39 ± 0.96	2.23 ± 1.15
Beans	3.72 ± 0.79	2.33 ± 1.23
Yellow split peas	2.45 ± 0.30	1.89 ± 0.71
Lentils peas	3.25 ± 0.42	2.46 ± 0.16

The disadvantage is a large percentage of resistant starch, which is absent in raw meat and can cause bloating and flatulence. But scientists from the Department of Food and Nutrition, Faculty of Food Engineering, State University of Campinas determined that heat treatment, namely the combination of cooking with lyophilization, can reduce the amount of resistant starch (Table 8) [26].

Contrary to the common perception of resistant starch, scientists from the Department of Nutrition and Integrative Physiology of the College of Health and Human Sciences at Florida State University found that resistant starch, especially in legumes, can exhibit prebiotic properties, improving the metabolic state of the body by increasing the number of intestinal bacteria [27]. According to the conclusions of the scientists, the obtained results need to be confirmed on the basis of long-term studies among different population groups, but these results may change the general opinion about legumes.

In addition to the above-mentioned facts, the level of saturated fatty acids (SFAs) in legumes is quite low: peas and beans – 0.3 %, lentils – 2.1 %, soy – 2.9 %, pork – 10.0 %, chicken – 3.9 %, beef – 12.5 %. But the addition of various oils can increase the level of NFA, so for 100 ml of sunflower oil, the indicator is 12.5 %, and olive oil is 16.8 %.

Compared to poultry, pork and beef, legumes have a higher mass fraction of such macroelements as K, Ca, P, but a lower amount of sodium [23].

Legume dishes are a source of vitamins that to a certain extent satisfy the human body in their daily needs (Table 8). Thus, on the basis of the reference nutrition information, there is data on the vitamin composition in Table 8, during the consuming of 100 grams of legumes [28-30]. The composition of legumes includes vitamins necessary for the human body: B5 – participates in the exchange of fats and steroid hormones; B6 – participates in the exchange of proteins and amino acids; H – necessary for the processes of biosynthesis of higher fatty acids, proteins, nucleic acids; vitamin E – natural antioxidant and antihypoxant that controls the synthesis of nucleic acids; silicon Si – improves the assimilation of calcium, minerals and settles the properties of other vitamins [31].

Table 8

Meeting the daily need for vitamins and trace elements after using legumes [28-30]

The name of legumes	Satisfying daily needs, %/100 g legumes															
	E	**B_3**	**B_4**	**B_5**	**B_6**	**B_9**	**H**	**I**	**Zn**	**Se**	**Cu**	**S**	**F**	**Cr**	**Si**	**Mn**
Chickpeas	5.5	7.7	19	32	27	139	0	2	24	52	66	20	0	0	307	107
Beans	4	32	19	24	45	23	1	8	27	45	58	16	1	20	307	67
Lentils peas	7	33	40	44	14	4	38	3	27	24	75	19	1	18	277	88
Red lentils	5	28	0	24	0	23	0	3	20	36	66	16	1	22	267	60
Green lentils	3.3	13	19	43	27	120	0	0	40	15	52	0	0	0	0	67
Soybean	19	49	54	35	43	50	120	5	17	0	50	24	3	32	590	140

By the amount of protein, leguminous raw materials can compete with fish, but slightly lose to chicken and red meat (Table 9). Calorie content is lower, which is ambiguous for different groups of people. If necessary, it can be increased with a help of combination with other products, or it can be left at the same level, depending on the required calculation of macronutrients per day. It is important to note that the caloric content and protein content indicated in various sources slightly differ (tables 4, 5). Discrepancies can be caused by the region of cultivation, a variety of temperature conditions, soil properties, the method of pre-treatment of raw materials and a number of other factors.

Table 9

Protein content and calorie content of food products [29]

The name of legumes	**Chickpeas**	**Beans**	**Yellow split peas**	**Lentils peas**	**Chicken**	**Beef**	**Pork**	**Salmon**	**Mackerel**
Protein, g	18.5	20.9	21.9	20.6	27.3	25.9	27.3	19.8	18.5
Calorie, cal	127	123	130	111	244	254	375	152	211

Technological properties of raw materials

In addition to high nutritional value, legumes are interesting from the point of view of their technological properties. The consumer properties of ready-made legume products are formed during the technological process and are the result of physical and chemical changes that occur during mechanical cooking, heat treatment and storage. It should be noted that the presence of certain technological operations is determined precisely by the morphological and chemical composition of legumes.

So, legumes have rather low humidity, starch and protein in the form of dry dehydrated corns. This determines the feasibility of soaking legumes before heat treatment. Soaking shortens the cooking time and helps preserve the shape of the seeds. The weight and volume of the beans increase during soaking. This is explained by the swelling of protein substances and carbohydrates of the cell walls of seeds, as well as the ability of starch grains to adsorb water on their surface and retain it in microcapillaries. The swelling of beans during soaking is accompanied by the release of soluble substances — non-protein nitrogenous, sugars and vitamins.

The morphological structure and chemical composition of legumes determine only one method of heat treatment — cooking, during which the hydration processes of cellular hydrocolloids are intensified. Cooking legumes is also accompanied by a change in their physical and chemical properties. It also leads to a change in consistency (softening) and mass.

With an increase in temperature, the penetration of water into the kernels of bean seeds accelerates, where it is first bound by proteins and carbohydrates of the cell walls, and then by starch. In the temperature range from 50°C to 70°C, bean proteins are denatured. Meanwhile, protein jelly is compacted, releasing water, which is absorbed by pasteurized starch. Apart from the water, which is separated by proteins, starch pasteurization uses water in which the product is cooked. Strong starch jelly is formed inside the bean cells. Absorption of water by starch gelatinization causes an increase in the mass and volume of cooked beans.

Moistening of seeds in the process of soaking changes their structural and mechanical properties. During the heat treatment the change in carbohydrates and proteins of the cell walls leads to softening of the kernels of leguminous seeds.

The cell walls of beans consist of approximately 50 % hemicellulose and 20 % fiber; the proportion of pectin substances is approximately 30 %. Cellulose and a significant part of hemicelluloses partially swell during cooking. Some of the hemicelluloses dissolve. During heat treatment of beans protopectin is split under the influence of temperature, as a result of which water-soluble pectin is formed. The cell walls loosen under these conditions.

Humidity of boiled legumes is 56…63 %. The mass of legumes during swelling and cooking

increases by 2.0...2.8 times, and in the practical activities of food industry establishments it is called welding. This process is connected with the fact that proteins are in the form of dry gels, which swell and increase in weight during soaking. But during the heat treatment moisture is not lost, but absorbed by starch [32]. Meat raw materials have high rates of weight loss during heat treatment, so chicken loses 28 % of the total mass during cooking, fish 20 %, beef 38 %, and pork 40 %. These processes are associated with the properties of proteins, which turn from hydrophilic into hydrophobic and lose their ability to retain moisture. Water excretion is active at 45–75 °C and continues up to 100 °C, while in fish the process is completed already at 75 °C [33].

The heat treatment of beans is accompanied by the accumulation of soluble substances. The amount of water-soluble substances during cooking increases unequally. It is explained by the different properties of starch, as well as the different content of other water-soluble substances, including nitrogenous and mucous. There is also an increase in the total sugar content, which is caused by partial hydrolysis of starch and high molecular weight of oligosaccharides and depends to a certain extent on the duration of the heat treatment.

The article "Grain of leguminous plants, General characteristics and application in technology of food concentrates" indicates that during heat treatment, water-soluble proteins diffuse to the aqueous phase (Table 10) [33]. The resulting liquid (decoction) has surface-active properties. This liquid has become a value-added product and is called aquafaba. Aquafaba has found a widespread use as an egg substitute, including egg white. Due to the pronounced surfactant properties, aquafaba is used in food technology with an emulsion and foam structure [34].

Table 10

Soluble protein content in legumes [33]

The name of legumes	Content in leguminous proteins of the solution for use as a solvent		
	Water	10% NaCl	0,2% NaOH
Chickpeas	49–51	42–45	6–8
Beans	62–95	2–25	1–13
Yellow split peas	36–87	7–51	6–13
Lentils peas	48–65	27–43	8–9

The cooking time, the boiling factor and the increasing in the increase in mass of legumes are the main technological prerequisites when we determine the feasibility of their use in the manufacturing of a new food product (Table 11).

The presence of starch in the composition of legumes, the polysaccharides of which show the ability to retrograde, determines the deterioration of the organoleptic properties of dishes during storage. These changes reduce the technological stability of food systems based on legumes and determine the short-term shelf life of finished food products.

Table 11

Technological properties of legumes [32]

The name of legumes	Cooking time, min	Cooking property	Swelling, %
Chickpeas	91–124	1.62–2.99	110
Beans	90–135	1.62–3.70	110
Yellow split peas	75–100	1.60–5.70	150
Lentils peas	40–60	2.10–2.80	110

According to the analysis of the technological properties of the selected raw materials, the cooking time is expensive in the production of finished products (Table 11), but it can be significantly reduced by combining various hydrothermal and culinary treatments, pre-soaking, and extrusion.

Boiling beans causes some loss of essential amino acids, vitamins and trace elements, which partially pass into the decoction. Losses of riboflavin (43...46 %) and especially niacin (16...17 %) during the cooking of beans are lower than losses of thiamine (59...68 %), which is explained by their greater resistance to heat treatment.

The greatest losses of vitamins are observed when beans are cooked without soaking, which is explained by the extension of the cooking time. If

boiled beans are used to cook mashed potatoes, cutlets, casseroles, additional processing causes the destruction of some more vitamins. At the same time, heat treatment improves the digestibility of bean proteins.

Extrusion reduces the content of trypsin and increases the digestibility of the protein. It was determined that during the extrusion of peas, the expansion and bulk density indicators correspond to corn flour due to the high amount of starch. Chickpea extrudant has the lowest expansion rates [35]. With this processing, legumes can be widely used in bakery products.

Microionization, in which legumes are treated with high-intensity infrared heat, reduces the necessary cooking time. At the same time it increases the amount of pectin substances and gelatinized starch, but decreases the amount of soluble protein and phytic acid [36].

It was determined that it was possible to reduce the time of heat treatment by increasing the pH and soaking legumes at elevated temperatures of soft water. The adding of salt leads to the dissolution of pectin. After soaking the use of blanching helps to deactivate enzymes that affect quality, texture and taste [37]. Although there are enough options to speed up the cooking time of legumes, the traditional method still does not lose its relevance. Its use increases the amount of dietary fiber and reduces the following anti-nutrients: phytates and phytic acids, which interfere with the assimilation of minerals. It also reduces the trypsin inhibitors, which reduce the nutritional value of protein [38]. Autoclaving (a steam sterilization method) increases the digestibility of starch and protein in cooked legumes compared to soaking and sprouting. All three methods are effective in reducing trypsin inhibitors, phytates and tannins [39]. Unwanted carbohydrates that are the part of legumes include oligosaccharides that cause flatulence, but research has shown that at 77 °C and long-term soaking for 12 hours, it is possible to reduce them by up to 80 % [34; 40].

It was found that the speed of cooking legumes affects the retention of nutrients in finished products [41], because the cooking time is proportional to their loss. Scientists at the Autonomous University of Madrid found that after soaking and boiling the percentage of protein in legumes decreases and their digestibility increases. At the same time, lost proteins can be increased by 10% by dehydrating of cooked legumes [42].

Conclusions

It has been analytically proven that legumes play an important role in the food chain. They have a high potential as a basis for the development of new food products. Regarding the economic prerequisites of use, it is indicated that legumes reduce the load and at the same time enrich the soil with organic substances. They have high profitability, long shelf life and low rates of natural losses. The specified chemical composition of legumes can compete with other protein-containing raw materials, and according to some indicators it has advantages in the vitamin and mineral composition. As for the disadvantages, according to recent studies, a large amount of resistant starch can show the properties of prebiotics. Researched technological aspects of the use of pre-treated legumes make them a functional basis for further use. In addition, aquafaba, which is formed in the result, is a universal protein supplement. According to the defined properties, leguminous raw materials are a valuable, but insufficiently disclosed component, which contains a high potential for the development of new products.

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