ANALYSIS OF PERSPECTIVE FOR USING CHICKPEA SEEDS TO PRODUCE FUNCTIONAL FOOD INGREDIENTS

The food industry is now increasingly focusing on changing existing technologies in order to improve the efficiency of raw materials processing and increase the production of high quality food products and functional ingredients with a minimum amount of waste. That is why chickpea seeds were chosen as the object of research as a source of valuable vegetable protein, which is similar in composition to animal protein and at the same time is the richest source of functional ingredients.

The research used the method of analysis of literary sources that correspond to the research topic. A number of scientific works related to the sprouting and soaking of chickpeas, the biological value of chickpeas in the form of hummus, the prospects for processing chickpea for the production of meat and bakery products were analyzed.

The paper shows the features of the general chemical composition and characteristics of individual nutrients and biologically active substances of chickpea. The given health-improving and physiological features of products from chickpea, in particular, a distinctive feature of chickpea is shown – its ability to accumulate selenium, which is absorbed 5–10 times better than from other chemical compounds. This in turn helps prevent the onset and development of cancer and other diseases. It has been shown that food preparation and heat treatment in general usually leads to a decrease in food quality and phytochemical composition of food products. However, they can inactivate thermolabile anti-nutrients, such as legume antitrypsin factors, that negatively affect protein bioavailability. Cooking food reduces unwanted factors in legumes, such as phytates, and modulates amino acid composition and protein digestibility. The regularities of increasing the biological activity of chickpea seeds during germination have been established. Based on the research results, conclusions were drawn on the formation of protein in chickpea seeds depending on the climate.

On the basis of the research results, the expediency of using chickpea seeds processing products in the technology of food products with improved biological value has been theoretically substantiated and confirmed.

**Keywords:** dietary and therapeutic-and-prophylactic nutrition, food chickpea, antinutrients, functional ingredients.

1. Introduction

Modern economic realities and trends towards climate change towards drainage require the introduction of new non-traditional crops into agricultural production, one of which is chickpea [1]. The collection of brutal respect, through something, not in the whole world of power and commitment, in not such a wide spectrum of the spectrum as in different parts of the world, one of which is Ukraine, in a fit with other countries of the East. Recently, most healthcare organizations have changed their concept on the consumer. Now they are encouraging «eating more plant foods», especially whole grains [2].

Chickpea is among the biggest human-cultivated plants, widespread in the suite, in terms of the sown area of the third place in the middle of leguminous crops, second only to soybeans and beans. Traditional approaches to breeding made it possible to obtain more than 350 improved varieties, helped to increase productivity, reduce yield fluctuations and improve adaptation in new niches [3–6].

Generously, the world’s cultivated areas of chickpea exceed 12.5 million. Hectares, and the main producers are countries located in arid regions. According to expert estimates, the size of the areas under organic chickpeas, lentils and beans in 2020 can be set up to 30 % in the general flat parcels for the conditions of passing the appropriate certification of a strong spirits.

Currently, legumes are very developed, but chickpea is an actual plant. Chickpea seeds are not in such demand as, for example, soybeans or beans. In terms of their composition, chickpea seeds are in no way inferior to the aforementioned legumes, and vice versa, it has many other properties and components that surpass its competitors. That is why chickpea seeds were chosen as the object of research as a source of valuable vegetable protein, which is similar in composition to animal protein and at the same time is the richest source of functional ingredients. The aim of research is to evaluate new inheritance and step-by-step methods for testing its biological activity. This will make it possible to obtain a functional food ingredient with
increased biological value, which in further processing can be used in food production, or as an independent product.

2. Methods of research

Due to the fact that this work is a review, a theoretical study was carried out on the prospects for obtaining functional food ingredients from chickpea seeds. The research used the method of analysis of literary sources that correspond to the research topic. A number of scientific works related to the sprouting and soaking of chickpea were analyzed, which reported the biological and nutritional value of chickpea in the form of hummus, the prospect of processing chickpea seeds for the production of meat and bakery products. And also the relevance of the use of chickpea, as legumes with high biological value, has to be. During the analysis of scientific theoretical studies, it was found that increasing the nutritional and biological value of seeds is advisable to create a functional food ingredient for further use in production.

3. Research results and discussion

3.1. Characterization of chickpea as a botanical culture.

Chickpea are one of the main legumes adapted to dry and hot growing conditions. Chickpea is an annual plant that is self-pollinating and has the third largest legume production in the world. The genome of chickpea is diploid and medium in size. Chickpea provides a protein-rich supplement in cereal diets and a very important food crop in developing countries [7–10]. It is highly regarded as a food product as it is an important source of zinc and folic acid. It is also high in dietary fiber and low in fat, most of which is polyunsaturated fatty acids and, therefore, is a natural source of carbohydrates for diabetics [11, 12].

Chickpea also has high frost resistance. Seedlings can withstand frosts up to 6–8 °C, which allows sowing at the earliest possible date and the most productive use of spring soil moisture to obtain seedlings [13, 14].

Fig. 1 illustrates the structure of chickpea seeds. The largest fraction is the embryo, which consists of two cotyledons connected on their adaxial surfaces, a small hypocotyl (embryonic axis) and a root (embryonic root) located in the chickpea beak. The embryo is surrounded by a seed coat that acts as a protective covering. The most prominent external structures on the ventral side are the hilum, the funicular scar, marks the point at which the seeds were attached to the pod wall during development, and the micropyle, a pore, which controls the penetration of moisture into the seeds. Both are surrounded by a corona (rim of hilum). The container runs in a line from the corona bottom to the spermatophyll (arylate), which contains the chalaza (the embryo base). These structures are present in both Desi and Kabul seeds, but may differ slightly in appearance (color, size, and bulge) [15].

In Ukraine, in recent years, significant success has been achieved in the impact of chickpea breeding on yield, and most of the new varieties combine high yield with seed size. The task of creating highly productive varieties is to achieve the optimal combination of the main elements of the struct-

| Type number and name | Seed color | Content of seeds of another type, %, not more than | List of varieties characterizing the type |
|----------------------|------------|--------------------------------------------------|----------------------------------------|
| I – food             | White to yellow-pink | 5.0                                      | Antaeus, Ornament, Pamiat, Slobodianskyi, Triumph |
| II – stern           | Red-brown to black | not limited                           | Alexandri, Colorty, Luhanets, Stoic    |

Table 2

| Quality indicators of food chickpea |
|------------------------------------|
| Index                | Norm       |
| Humidity, %, not more than        | 14.0       |
| Mass fraction of protein in terms of dry matter, %, not less | 20.0       |
| Grain admixture, %, not more than | 2.0        |
| Weed admixture, %, not more than  | 1.0        |
| In particular, mineral impurity   | 0.1        |
| As part of the mineral impurity:  | –          |
| – pebbles, slag, are             | Not allowed|
| – harmful impurity               | 0.2        |
| As part of a harmful impurity:   | –          |
| – pubescent heliotrope and gray-haired trichodesma | Not allowed |
| Pest infestation                 | Not allowed|
The content of toxic elements, mycotoxins and pesticides in chickpea seeds, which are used for food needs, as well as for export, should not exceed the permissible levels established by the «Medical and biological requirements and sanitary standards for the quality of food raw materials and food products». The maximum permissible content of harmful substances in chickpea seeds is given in Table 3.

Features of the general chemical composition and characteristics of individual nutrients and biologically active substances (Table 4).

### Table 3
The maximum permissible content of harmful substances in chickpea seeds

| Index                  | Norm for chickpea seeds, which is used for food needs and export |
|------------------------|---------------------------------------------------------------|
| Toxic elements, mg/kg: |                                                               |
| lead                   | 0.5                                                           |
| cadmium                | 0.1                                                           |
| arsenic                | 0.2                                                           |
| mercury                | 0.02                                                          |
| copper                 | 10.0                                                          |
| zinc                   | 50.0                                                          |
| Mycotoxins, mg/kg:     |                                                               |
| aflatoxin B1           | 0.005                                                         |
| zearalenone            | 1.0                                                           |
| T-2 toxin              | 0.1                                                           |
| deoxynivalenol (vomitoxin) | 0.5–1.0                                                    |
| Radionuclides, Bq/kg   |                                                               |
| strontium-90           | 30.0                                                          |
| cesium-137             | 50.0                                                          |
| Pesticides             |                                                               |
| The list of pesticides for which chickpea seeds are controlled depends on their use in a specific territory and is agreed with the services of the Ministry of Health and Veterinary Medicine of Ukraine |

### Table 4
Chickpea chemical composition*

| Nutrients                  | Average value of indicators, g/100 g |
|----------------------------|---------------------------------------|
| Protein                    | 19.5–21.8                             |
| Total fat                  | 6.7–6.8                               |
| – saturated                | 0.66–7.0                              |
| – unsaturated              | 2.60–3.0                              |
| – monounsaturated          | 1.40–1.5                              |
| Carbohydrates              | 50–60                                 |
| Food fiber:                | 18–26                                 |
| – soluble                  | 4–8                                   |
| – insoluble                | 10–18                                 |
| Starch                     | 28–29                                 |
| Sugar                      | 5.4–10.7                              |
| – restoring                | 1.5–3.1                               |
| – not restoring            | 3.5–6.8                               |
| Minerals (ash)             | 2.7–3.6                               |
| General composition of polyphenols | 1300–1500**                            |
| Flavonoids                 | 400–450**                             |
| Anti-food substances-solutions | –                                   |
| Phytic acid                | 230–265**                             |
| Tannins                    | 460–480**                             |

Note: * – built on the basis of data [20]; ** – mg/100 g
digestibility of starch in chickpea varies from 37 to 60% and is higher than in other legumes such as black mung bean, lentils and beans [30].

Food fiber. The total fiber content in chickpea is 18–22 g/100 g of raw chickpea seeds. The soluble and insoluble fractions of dietary fiber are about 4–8 and 10–18 g/100 g of raw chickpea seeds, respectively. The content of fibers in chickpea shells calculated on dry weight is lower (75%) compared to lentils (87%) and peas (89%) [31, 32].

Fat content. The total fat content of raw chickpea seeds ranges from 2.70 to 6.48%. The fat content of chickpea (6.04 g/100 g) is higher than other legumes such as lentils and red beans (1.06 g/100 g), mung beans (1.15 g/100 g) and pigeon peas (1.64 g/100 g). Chickpea is composed of about 66% polyunsaturated fatty acids (PUFA), about 19% monounsaturated fatty acids (MUFA) and about 15% saturated fatty acids (SFA). Linolenic acid is the dominant fatty acid in chickpea, followed by oleic and palmitic acids [33–35].

Chickpea can’t be regarded as an oilseed crop as their oil content is relatively low (3.8–10%). However, chickpea oil contains medicinal nutritionally important tocopherols, sterols and tocotrienols. The amount of \( \alpha \)-tocopherol in combination with the concentration of \( \delta \)-tocopherol, which has strong antioxidant properties, makes chickpea oil resistant to oxidation and contributes to an increase in shelf life [35, 36].

Minerals. Raw chickpea seeds contain on average about 5.0 mg/100 g iron, 4.1 mg/100 g zinc, 138 mg/100 g magnesium and 160 mg/100 g calcium. Chickpea is known to contain other trace minerals including Al (10.2 µg/g), Cr (0.12 mg/g), Ni (0.26 µg/g), Pb (0.48 µg/g), and Cd (0.01 µg/g). The indicated concentrations do not pose any toxicological hazard [37–39].

Vitamins. Chickpea is relatively inexpensive and are a rich source of folate and tocopherols. It is characterized by a relatively high content of folate combined with more modest amounts of other water-soluble vitamins such as riboflavin, pantothenic acid, and pyridoxine. The amount of these vitamins is similar or higher than in other legumes [40, 41].

**Carotenoids.** Important carotenoids found in chickpea include \( \beta \)-carotene, lutein, zeaxanthin, \( \beta \)-cryptoxanthin, lycopene, and \( \alpha \)-carotene. The average concentration of carotenoids (except for lycopene) is higher in wild chickpea specimens than in domesticated varieties. \( \beta \)-carotene is the most important and abundant carotenoid in plants and is more efficiently converted to vitamin A than other carotenoids. In terms of the weight of dry seeds, chickpea contains more \( \beta \)-carotene than the endosperm of «golden rice» or red wheat [42].

**Isoflavones.** Chickpea seeds contain several phenolic compounds. Of these, two important phenolic compounds found in chickpea are isoflavones, biochanin A, and formononetin. The structures of genistein, biochanin A, and formononetin are shown in Fig. 2. Other phenolic compounds found in chickpea oil are daidzein, genistin, metasesinol, and secoisolariciresinol [43–45].

### 3.2. Health and physiological features of chickpea products.
A distinctive feature of chickpea is its ability to accumulate selenium (up to 600 µg/kg) in the form of selenium-methionine, which is absorbed 5–10 times better than from other chemical compounds, which in turn helps to prevent the onset and development of cancer, as well as other diseases [4, 46, 47].

The daily requirement for iodine for a person ranges from 100 to 200 mcg, depending on the age and physiological characteristics of the human body. Lack of iodine causes serious metabolic disorders, promotes the development of Graves’ disease, decreased immunity, and causes changes in chromosomes. Children, pregnant women, adolescents during puberty are especially sensitive to its lack. The results of experimental studies have shown the high efficiency of enrichment of chopped semi-finished products with iodine by the proposed method. The use of a food ingredient made from sprouted chickpea enriched with iodine made it possible to achieve the required iodine content in the finished product, taking into account the daily requirement from 60 to 70% [48].

![Fig. 2. Structures of genistein, biochanin A and formononetin](image-url)
Chickpea has a low glycemic index. However, very few studies have evaluated the glycemic effect of hummus in vivo. The postprandial glucose response after a meal was four times lower in a study of 10 healthy people who consumed hummus than when they consumed white bread. Blood glucose levels were significantly lower 45 minutes after subjects received hummus with 25 grams of available carbohydrates (in the form of white bread), compared to 25 grams of available carbohydrates alone. This suggests that hummus may partially mitigate the effects of foods with a higher glycemic index when consumed together. Long-term consumption of chickpea also significantly improved glycemic scores with a 20-week cross-over of 45 distinct cardiovascular risk factors [7, 24, 49].

Traditional hummus contains a unique combination of chickpea, tahini, olive oil, lemon juice, and spices that can provide additional benefits beyond meeting nutrient needs [7, 50]. Traditional hummus has a fat content 4–5 times higher than chickpea, which may be related to improved blood glucose levels and insulin response, as dietary fat delays gastric emptying and therefore slows down the absorption of carbohydrates. In addition, there is epidemiological evidence that the consumption of legumes, in particular chickpea, is associated with a reduced risk of type 2 diabetes [51].

A controlled dietary study has shown that isoenergetic wheat-based chickpea supplementation in Australian-style diets resulted in significant reductions in total serum cholesterol and low-density lipoprotein cholesterol [7].

Systolic blood pressure decreased in overweight and obese people after eating legumes for eight weeks. Animal studies have shown that the activity of lipoprotein lipase in epidymal adipose tissue and hepatic triacylglycerol lipase in the liver was normalized in high-fat rats that food chickpea in addition to the traditional diet. Rats fed a high-fat diet supplemented with chickpea also showed a decrease in visceral adipose tissue, and an improvement in lipid profile at eight months, compared to those fed only a high-fat diet. Thus, further studies to evaluate in vivo and clinical antihypertensive effect will be critical to confirm the observed results [52–54].

Several studies have also shown an increase in the benefits of consuming plant-based protein for cardiovascular health. The higher amounts of dietary fiber and protein in chickpea and, possibly, the presence of enzyme inhibitors and «antinutrients» such as tannin may also partially explain these results [55].

Butyrate is a short-chain essential fatty acid obtained from diets that contain chickpea. It is widely known that butyrate inhibits cell proliferation and induces apoptosis, which may reduce the risk of colorectal cancer. Several other dietary biologically active compounds such as lycopene, biochanin A and saponins, which are present in chickpea and hummus, have also been shown to reduce the risk of certain types of cancer [7, 46, 56].

The high concentration of saponins in chickpea flour may partly explain the 64 % decrease in lesions with azoxymethane in rats fed with 10 % chickpea flour. In addition, it was shown that the inclusion in the diet of fiber from chickpea seeds reduces the toxic effect of N-nitrosodiethylamine on lipid peroxidation and antioxidant potential [7, 51, 57].

In addition, there are eight priority allergens (wheat, soy, dairy, peanuts, tree nuts, fish, crustaceans, and eggs) that should be noted when present in foods. Beans such as peas, chickpea, and lentils have been consumed for thousands of years, and although they contain allergenic proteins, they are not included in the list of priority allergens that require labeling, and therefore may serve as alternatives to priority allergens that require labeling [58, 59].

3.3. The anti-nutritional properties of chickpea and their elimination. Anti-nutritional compounds are molecules that interfere with the digestion process. It is believed that the accumulation of anti-nutritional substances in the grains of leguminous plants has developed as a defense mechanism in adverse environmental conditions [60–62].

The anti-nutritional compounds found in legumes fall into two categories, protein anti-nutritional components and non-protein anti-nutritional components, and their effects range from relatively harmless polyphenols to harmful protease inhibitors. Anti-nutritional protein compounds: alkaloids, phytic acid, oligosaccharides, phenolic compounds such as tannins and saponins. Non-protein anti-nutritional compounds that are isolated from legumes include lectins, agglutinins, trypsin inhibitors, chymotrypsin inhibitors, or an antifungal peptide [63, 64].

Anti-nutrients commonly found in plant foods can have both deleterious and health benefits at the same time. One common example is phytic acid, which forms insoluble complexes with calcium, zinc, iron, and copper. Another particularly common form of antinutrient is flavonoids, which are a group of polyphenolic compounds containing phenolic compounds (tannins), saponins, and enzyme inhibitors (amylases and proteases) [65].

The content of tannins and phytic acids in raw seeds is 466.10 and 233.04 mg/100 g in terms of dry weight, respectively. It is known that the germination process leads to a significant decrease in the content of tannins and phytic acids [66, 67]. The largest reduction was caused by germination within 6 days. A decrease in the content of phytates and phytic acids during the germination of various legume seeds can result from a significant increase in phytase activity. This can be explained by the fact that sprouting is mainly a catabolic process that supplies important nutrients to the growing plant through the hydrolysis of reserve nutrients [68].

Due to dry roasting, steeping, peeling, sprouting and boiling, the tannin content was reduced by 25, 50, 69, 75 and 82 %, respectively. The boil method showed the largest reduction in tannin content in chickpea. Tannin is a water-soluble phenolic compound and is mainly found in the seed coat. Thus, tannin is washed out from chickpea, in addition, the solubility of tannin increases. The phytic acid content was reduced by 6 %, 15 %, 31 %, 36 %, and 57 %, respectively, for dry roasting, steeping, peeling, sprouting, and boiling. The maximum reduction of phytic acid during boiling of chickpea and in hummus was due to its leaching into water during soaking [69, 70].

Ultrafiltration treatment of chickpea also removes polyphenolic compounds, but to a lesser extent than protein precipitation at the isoelectric point. The reduction of saponins and condensed tannins present in chickpea kernels is possible when used in conventional and microwave cooking methods, as well as in autoclaving. The largest reduction (50.1 %) of condensed tannins was obtained using microwave heating. Cooking reduced the concentration of saponins by 51.65 %. All these processes caused
a significant decrease in the inhibitory activity of trypsin by 80.5–83.9 % [63, 71].

Cooking and thermal processing in general usually results in a decrease in the nutritional quality and phytochemical composition of foods. However, they can also inactivate thermolabile anti-nutrients such as legume antitrypsin factors that negatively affect protein bioavailability, reduce unwanted factors in legumes such as phytates, or modulate amino acid composition and protein digestibility [72].

3.4. Processing prospects. Traditional soybean supplements are expensive imported raw materials. The Volga region research institute for the production and processing of meat and dairy products offered them an alternative – chickpea with a unique amino acid composition and a set of macro- and microelements, including selenium. Chickpea protein is close to animal protein in terms of amino acid content [73].

Taking into account the problems of shortage of raw meat, replacing it with a vegetable high-protein product is an urgent and timely task. At the same time, the most promising use is not of the seeds themselves, which may contain anti-nutritional substances (inhibitors of digestive enzymes, etc.), but of its seedlings, which are rich in active high- and low-molecular substances – enzymes, vitamins, microelements and have a higher nutritional value compared to seeds.

Analysis of literature data showed that already on the third day in germinated seeds, the amount of oligosaccharides decreases by 39–43 %, which is associated with the activation of amyloses in seeds. The activation of respiratory and hydrolytic enzymes during seed germination leads to increased protein synthesis. According to literature data, in sprouted chickpea grains, the protein content increases by 4.7 times, vitamins of group B – by 3.0, calcium – by 1.7, and potassium – by 3.2 times. Thus, seedlings are rich in protein, vitamins, micro- and macromolecules and other useful substances. Therefore, a meat product using chickpea seedlings will have an increased physiological value [27, 74–77].

In order to produce an inexpensive functional semi-finished product from meat and vegetable raw materials (homemade cutlets), it is recommended to introduce five-day chickpea seedlings into the meat system, pretreated with salicylic acid with a concentration of 0.16·10–8 % concentration. The seeds, freed from sprouts, can be used in the manufacture of combined products, such as canned meat and vegetable preserves, pates [43, 78–80].

Considering the economic feasibility of chickpea production and its significant resources, it is of scientific and practical importance to involve it in the production cycle as a valuable source of vegetable protein. And also the study of the possibility of using products of its processing in the technology of bakery products in order to increase their biological value.

An efficient technology of bread from wheat flour based on chickpea has been developed. The regularity of the ripening of the sourdough from chickpea flour without introducing pure cultures of lactic acid bacteria has been established, its role in the wheat dough during fermentation, in ensuring the quality and digestibility of finished products, has been determined. The possibility of reducing anti-nutritional substances in chickpea seeds as a result of processing in an aqueous solution of sodium bicarbonate has been proven.

The technology of bakery products with improved biological value based on «chickpea puree» obtained from processed chickpea seeds has been developed [81–83].

The regularities of increasing the biological activity of chickpea seeds during germination have been established. An efficient technology of wheat bread balanced with proteins and carbohydrates based on sprouted chickpea seeds has been developed.

On the basis of the research results, the expediency of using chickpea seeds processing products in the technology of bakery products with improved biological value was theoretically substantiated and experimentally confirmed.

4. Conclusions

Thus, the expediency of further studies of the possibilities of obtaining functional food products and ingredients from chickpea has been proved, since it has been shown that using biotechnological approaches in the processing of chickpea, its composition can be improved. In addition, it is promising to apply the methods of biomodification of chickpea to obtain targeted positive properties and effects on the human body.

Research results prove that traditional methods of processing beans can be beneficial for improving the nutritional values of chickpea. The best seed treatment method is germination and boiling. Compared to other traditional processing methods, these methods are most effective in suppressing the presence of antinutrients in chickpea.

Thanks to this direction, it is possible to obtain many functional food ingredients and use them in various branches of the food industry (for bakery, confectionery and culinary products, in meat and dairy products). This line of research will ensure the possibility of mutual enrichment of the resulting products with irreplaceable ingredients, and will also allow regulating their composition in accordance with the basic requirements of nutritional science.

References

1. Malik, S. R., Bakhsh, A., Asif, M. A., Iqbal, U. M. E. R., Iqbal, S. M. (2010). Assessment of genetic variability and interrelationship among some agronomic traits in chickpea. International Journal of Agricultural and Biology, 12 (1), 81–85.

2. Silva-Cristobal, L., Osorio-Díaz, P., Tozar, J., Bello-Pérez, L. A. (2010). Chemical composition, carbohydrate digestibility and antioxidant capacity of cooked black bean, chickpea, and lentil Mexican varieties Composición química, digestibilidad de carbohidratos, y capacidad antioxidante de variedades mexicanas coci-das de frijol negro, garbanzo, y lenteja. CyTA-Journal of Food, 8 (1), 7–14. doi: https://doi.org/10.3390/cytafood8010007

3. Gaur, P. M., Jukanti, A. K., Varshney, R. K. (2012). Impact of Genomic Technologies on Chickpea Breeding Strategies. Agronomy, 2 (3), 199–221. doi: https://doi.org/10.3390/agronomy203199

4. De Camargo, A. C., Favero, B. T., Morzelle, M. C., Franchin, M., Alvarez-Parrilla, E., de la Rosa, L. A. et al. (2019). Is Chickpea a Potential Substitute for Soybean? Phenolic Bioactives and Potential Health Benefits. International Journal of Molecular Sciences, 20 (11), 2644. doi: https://doi.org/10.3390/ijms20112644

5. Ali, M. Y., Biswas, P. K., Shahrir, A. S., Nasif, S. O., Raihan, R. R. (2018). Yield and Quality Response of Chickpea to Different Sowing Dates. Asian Journal of Research in Crop Science, 1 (4), 1–8. doi: https://doi.org/10.9734/ajrcs/2018/41731

6. Sichkar, V., Krivenko, A., Volkova, N. (2019). Results and prospects of leguminous crops breeding in Ukraine. Confereina «Life sciences in the dialogue of generations: connections between universities, academia and business community», 49–50.
41. Meher, H. C., Singh, G., Chawla, G. (2018). Metabolic alternations of some amino acids, coenzymes, phytotoxins, and vitamins in chickpea crop grown from seeds soaked with defense stimulants. *Acta Physiologica Plantarum, 40 (4)*. doi: https://doi.org/10.1007/s12221-017-0536-5

42. Abbo, S., Molina, C., Jungmann, R., Grussak, M. A., Berkvist, Z., Reifen, R. et al. (2005). Quantitative trait loci governing carotenoid concentration and weight in seeds of chickpea (*Cicer arietinum* L.). *Theoretical and Applied Genetics, 111 (21)*, 185–195. doi: https://doi.org/10.1007/s00122-005-0390-6

43. Flowers, T. J., Gaur, P. M., Gowda, C. L. L., Krishnamurthy, L., Saini, S., Siddique, K. H. M. et al. (2010). Salt sensitivity in chickpea. *Plant, Cell & Environment, 33 (4), 490–509*. doi: https://doi.org/10.1111/j.1365-3040.2010.02055.x

44. Lou, Z., Wang, H., Zhang, M., Wang, Z. (2010). Improved extraction of oil from chickpea under ultrasound in a dynamic system. *Journal of Food Engineering, 98 (1), 13–18*. doi: https://doi.org/10.1016/j.jfoodeng.2009.11.015

45. Li, P., Shi, X., Wei, Y., Qin, L., Sun, W., Xu, G. et al. (2015). Synthetic and Biological Activity of Isoflavone Derivatives from Chickpea as Potent Anti-Diabetic Agents. *Molecules, 20 (9), 17016–17040*. doi: https://doi.org/10.3390/molecules200917016

46. Aisa, H. A., Gao, Y., Yili, A., Ma, Q., Cheng, Z. (2019). Beneficial Role of Chickpea (*Cicer arietinum*) L Functional Factors in Theoretical and Applied Genetics, 111 (2), 185–195. doi: https://doi.org/10.1007/s00122-005-0390-6

47. Rachwa-Rosiak, D., Nebesny, E., Kravić, N. (2015). Variations in level of oil, protein, and some antioxidants in chickpea and peanut seeds. *Chemical and Biological Technologies in Agriculture, 2 (1), 2*. doi: https://doi.org/10.1186/s40538-015-0031-7

48. Shang, X. B., Pascual, C. Y., Eshel, D., Teper-Bammolker, P. (2013). Vicilin and the basic subunit of legumin are putative chickpea allergens. *Food Chemistry, 138 (1), 13–18*. doi: https://doi.org/10.1016/j.foodchem.2012.10.031

49. Boye, J. I., Aksay, S., Roufik, S., Ribéreau, S., Mondor, M., Farnworth, E., Rajamohamed, S. H. (2010). Comparison of the functional properties of pea, chickpea and lentil protein concentrates processed using ultrafiltration and isoelectric precipitation techniques. *Food Research International, 43 (2), 537–546*. doi: https://doi.org/10.1016/j.foodres.2009.07.021

50. Sharma, S., Yadav, N., Singh, A., Kumar, R. (2013). Nutritional and antinutritional profile of newly developed chickpea (*Cicer arietinum*) L varieties. *International Food Research Journal, 20 (2), 805–810.

51. Mittal, R., Nagi, H. P. S., Sharma, P., Sharma, S. (2012). Effect of Processing on Chemical Composition and Antinutritional Factors in Chickpea Flour. *Journal of Food Science and Engineering, 2 (3), 180–186*. doi: https://doi.org/10.17265/2159-5828/2012.03.008

52. Mondor, M., Aksay, S., Drolet, H., Roufik, S., Farnworth, E., Boye, J. I. (2009). Influence of processing on composition and antinutritional factors of chickpea protein concentrates produced by isoelectric precipitation and ultrafiltration. *Innovative Food Science & Emerging Technologies, 10 (3), 342–347*. doi: https://doi.org/10.1016/j.ifset.2009.01.007

53. Bhat, H. A., Nguyen, L. S., Trinh, V. H. (2012). Nutrients and antinutrients in cowpea and horse gram flours in comparison to chickpea flour: Evaluation of their flour functionality. *Food Chemistry, 131 (2), 462–468*. doi: https://doi.org/10.1016/j.foodchem.2011.09.008

54. Haileslassie, H. A., Henry, C. J., Tyler, R. T. (2016). Impact of household food processing strategies on antinutrient (phytate, tannin and polyphenol) contents of chickpea (*Cicer arietinum*) L and beans (*Phaseolus vulgaris*) L: a review. *International Journal of Food Science & Technology, 51 (9), 1947–1957*. doi: https://doi.org/10.1111/ijfs.13166

55. Choudhary, S., Kaur, J., Kaur, S., Singh, S., Singh, S. (2015). Evaluation of antinutritional factors in kabuli chickpea cultivars differing in seed size. *Indian Journal of Agricultural Science, 85 (1), 92*. doi: https://doi.org/10.3923/ijas.2015.85.92

56. Fouad, A. A., Rehab, F. M. A. (2015). Effect of germination time on proximate analysis, bioactive compounds and antioxidant activity of lentil (*Lens culinaris Medik.*) sprouts. *Acta Sciientiarum Pomorum Technologia Alimentaria, 14 (4), 233–246*. doi: https://doi.org/10.17306/j.afs.2015.3.25

57. Olika, E., Abera, S., Fikre, A. (2019). Phytochemical Properties and Effect of Processing Methods on Mineral Composition and Antinutritional Factors of Improved Chickpea (*Cicer arrietinum*) L Varies Grown in Ethiopia. *International Journal of Food Science, 2019, 1–7*. doi: https://doi.org/10.1115/2019.9614570

58. Portari, G. V., Tavano, O. L., Silva, M. A. da, Neves, V. A. (2005). Chickpea (*Cicer arrietinum*) L germination on the major globulin content and in vitro digestibility. *Ciência e Tecnologia de Alimentos, 25 (4), 897–902*. doi: https://doi.org/10.1590/s0101-20612005004000029

59. Alaja, S. A. E., El-Adawy, T. A. (2006). Nutritional composition of chickpea (*Cicer arrietinum*) L affected by microwave cooking and other traditional cooking methods. *Journal of Food Composition and Analysis, 19 (8), 806–812*. doi: https://doi.org/10.1016/j.jfca.2006.03.015

60. Margier, M., Georgis, S., Hafnaoui, N., Remond, D., Nowicki, M., Du Chauffet, L. et al. (2018). Nutritional Composition and Bioactive Content of Legumes: Changes and Loss during Processing. Frequently Consumed in France and Effect of the Cooking Method. *Nutrients, 10 (11), 1668*. doi: https://doi.org/10.3390/nu10111668
73. Kilincereker, O., Kurt, Ş. (2010). Effects of chickpea (Cicer arietinum) flour on quality of deep-fat fried chicken nuggets. *Journal of Food, Agriculture & Environment, 8* (2), 47–50.

74. Brennan, C. S., Brennan, M. A., Mason, S. L., Patil, S. S. (2016). The Potential of Combining Cereals and Legumes in the Manufacture of Extruded Products for a Healthy Lifestyle. *EC Nutrition, 5* (2), 1120–1127.

75. Serrano-Sandoval, S. N., Guardado-Félix, D., Gutiérrez-Uribe, J. A. (2019). Changes in digestibility of proteins from chickpeas (Cicer arietinum L.) germinated in presence of selenium and antioxidant capacity of hydrolysates. *Food Chemistry, 285*, 290–295. doi: https://doi.org/10.1016/j.foodchem.2019.01.137

76. Domínguez-Arispuro, D. M., Cuevas-Rodríguez, E. O., Milán-Carrillo, J., Lojo-López, L., Gutiérrez-Dorado, R., Reyes-Moreno, C. (2017). Optimal germination condition impacts on the antioxidant activity and phenolic acids profile in pigmented desi chickpea (Cicer arietinum L.) seeds. *Journal of Food Science and Technology, 55* (2), 638–647. doi: https://doi.org/10.1007/s13197-017-2973-1

77. Marengo, M., Carpen, A., Bonomi, F., Casiraghi, M. C., Meroni, E., Quaglia, L. et al. (2017). Macromolecular and Micronutrient Profiles of Sprouted Chickpeas to Be Used for Integrating Cereal-Based Food. *Cereal Chemistry Journal, 94* (1), 82–88. doi: https://doi.org/10.1094/cchecm-04-16-0108-fi

78. Asmare, H., Admassu, S. (2013). Development and evaluation of dry fermented sausages processed from blends of chickpea flour and beef. *East African Journal of Sciences, 7* (1), 17–30.

79. Siddiqui, M., Khan, M. A. (2011). Comparative study on quality evaluation of buffalo meat slices incorporated with finger millet, oats and chickpea. In *11th International Congress on Engineering and Food:*

80. Gorlov, I. F., Mikhailov, T., Sitnikova, O. I., Slezhenkin, M. I., Zlobina, E. Y., Karpenko, E. V. (2016). New Functional Products with Chickpeas: Reception, Functional Properties. *American Journal of Food Technology, 11* (6), 273–281. doi: https://doi.org/10.3923/ajft.2016.273.281

81. Ozulu, G., Arçıl, M. (2017). Characterization of the rheological and technological properties of the frozen sourdough bread with chickpea flour addition. *Journal of Food Measurement and Characterization, 11* (3), 1493–1500. doi: https://doi.org/10.1007/s11094-017-9528-z

82. Shrivastava, C., Chakraborty, S. (2018). Bread from wheat flour partially replaced by fermented chickpea flour: Optimizing the formulation and fuzzy analysis of sensory data. *LWT, 90*, 215–223. doi: https://doi.org/10.1016/j.lwt.2017.12.019

83. Iinya, U., Ibanga, U., Enioki, S. (2018). Changes in Amino Acids, Anti-Nutrients and Functional Properties of African Yam Bean Flour Caused by Variation in Steeping Time Prior to Autoclaving. *Asian Journal of Biotechnology and Bioresource Technology, 3* (1), 1–10. doi: https://doi.org/10.9734/ajb2tr/2018/39747

---

Hevryk Vladyslav, Postgraduate Student, Department of Biochemistry, Microbiology and Physiology of Nutrition, Odessa National Academy of Food Technologies, Ukraine, e-mail: vlad.gevrik@gmail.com, ORCID: http://orcid.org/0000-0003-4856-3112

Kaprelyants Leonid, Doctor of Technical Sciences, Professor, Head of Department of Biochemistry, Microbiology and Physiology of Nutrition, Odessa National Academy of Food Technologies, Ukraine, e-mail: leonid@onaft.edu.ua, ORCID: http://orcid.org/0000-0003-2136-5669

Trufkati Liudmyla, PhD, Associate Professor, Department of Biochemistry, Microbiology and Physiology of Nutrition, Odessa National Academy of Food Technologies, Ukraine, e-mail: trufkati@gmail.com, ORCID: http://orcid.org/0000-0003-2136-5669

Pozhitkova Liliia, PhD, Department of Biochemistry, Microbiology and Physiology of Nutrition, Odessa National Academy of Food Technologies, Ukraine, e-mail: pozhitkova@ukr.net, ORCID: http://orcid.org/0000-0002-7652-3305