Technological solutions and prospects for obtaining protein preparations and composites from legumes

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Abstract. To eliminate the deficit of proteins in the diet of humans and animals, as an alternative to polymers of animal origin, modern methods and technological solutions for isolating preparations from various types of plant materials with modern physicochemical and biotechnological techniques are being developed. The most effective are the methods and processes with enzyme preparations, eliminating the destruction of the structure and composition of protein fractions of raw materials, in contrast to solutions of acids and alkalis. Protein preparations from peas and chickpeas, having a high biological value, along with polypeptides, also contain useful biologically active substances (fiber, minerals, vitamins, antioxidants, etc.), the presence of which benefits human body and animals. The analysis of the state of production of leguminous crops in the country indicates that, on the existing domestic raw material base, the production of food and feed protein concentrates from pea and chickpea grain is promising to organize with the maximum preservation of biological value, composition and properties. It is also advisable to use biosynthetic processes with various types of fungal and / or bacterial enzymes, physical and physico-chemical methods of exposure to obtain safe products with high yield. In order to obtain a balanced diet of humans and animals, along with ensuring the complementarity of amino acids, it is advisable to include minerals, vitamins, antioxidants, etc., in the form of additives or by synthesis of functional ingredients from components of leguminous raw materials with selected microorganisms.

1. Introduction

Current trends in food production indicate that the prices of animal products will continue to rise, and industry will increasingly need new high-quality protein sources. The number of hungry people in the world is increasing, for the moment it has reached one third of the total population of the Earth, and part of the population is deficient in high-grade protein [1]. Concerns about high cholesterol levels in food, allergies, high food prices and the negative environmental impact of some food products have led to increased interest
in alternative protein sources [2]. One of the solutions to address these shortcomings is to obtain protein preparations from plant materials. Legumes from ancient times are used in the diet of people, including those that, for one reason or another do not eat meat [2, 3]. One of the traditional leguminous crops for European countries is of particular interest, including Russia, peas, the use of which allows the creation of technologies for protein concentrates, flour, isolates and by-products [4]. Recently, interest has grown in another leguminous crop - chickpeas. In conditions of repeated drought and global warming, resistant to a hot climate, this crop is an excellent addition to peas [5]. The urgency of solving the problem of providing the population with protein dictated by an analysis of the raw material base of these types of leguminous crops, technological schemes for the production of protein preparations of various forms and purposes from them and the prospects for using the latter in food products of various compositions and properties.

2. Main part

2.1. The state of production of pea and chickpea grain in the Russian Federation

Peas and chickpeas are leguminous crops with different food and feed value. According to the data for 2018, 2303 thousand tons of peas collected in the Russian Federation, which is 30% less than in the previous year. However, compared to 2013, the gross harvest of peas increased by 71% (Figure 1). Despite a drop in growth in 2018, pea production is growing across Russia as a whole [6]. Pea sown areas in 2018 were at the level of 1,434.7 thousand ha. Over the year, they grew by 8.1%, over 5 years - by 29.3%, over 10 years - by 119.7% (by 781.8 thousand ha), which testified to their stable growth. The largest areas in 2018 were the following regions, thousand hectares: Stavropol Territory - 200.0; Altai Territory - 92.3; Krasnodar Territory - 83.1; Rostov - 134.7; Omsk region - 86.0, which amounted, respectively, 13.9%; 6.4%; 5.8%; 9.4%; 6.0% of the total land. The average pea yield in 2018 amounted to 16.6 cwt / ha, in 2017 - 25.3 cwt / ha, in 2013 - 14.0 cwt / ha, in 2008 - 19.8 cwt / ha, in 2001 - 19.7 cwt / ha. The analysis of average annual productivity indicators allows determining the contribution of the use of advanced technologies to the changes in the conditions for growing peas. The average annual yield of peas in Russia in 1991-2000 reached 11.5 cwt / ha. In 2001-2010 it increased to 16.7 cwt / ha, in 2011-2018. - increased to 18.1 cwt / ha. Consequently, there was a steady increase in pea yields in Russia. The highest average annual pea yield in 2018 was noted in the Oryol region (30.8 cwt / ha), Tambov (21.3 cwt / ha), Novosibirsk (19.2 cwt / ha) regions, Krasnodar Territory (21.1 cwt / ha), Altai Territory (17.8 cwt / ha), the Republic of Bashkortostan (16.3 cwt / ha).

![Figure 1. Dynamics of pea and chickpea production in Russia](image_url)

In 2018, chickpea production in Russia was at the level of 620.4 thousand tons, which amounted to an increase in the yield, compared to 2017 and 2013, by 48.2% and 22%, respectively (Figure 1). After
falling in 2015, the gross harvest of chickpeas has gradually increased in recent years. Chickpea sown areas in 2018 amounted to 851.2 thousand ha. Over the year, they increased by 71.6% (by 355.2 thousand ha), over 5 years - by 26.5% (by 178.1 thousand ha). Despite some fluctuations in the direction of decrease, the cultivated areas of chickpeas tend to increase. The largest regions in terms of chickpea area in 2018 were the areas producing the following thousand hectares: Saratov - 266.6; Volgograd - 191.3; Orenburg - 114.6; Samara - 88.5; Rostov - 74.1. This amounted to 31.3%, respectively; 22.5%; 13.5%; 10.4%; 8.7% of the total area of chickpea crops in the Russian Federation. The average yield of chickpeas in Russia in 2018 amounted to 7.6 cwt / ha of harvested area, which is 17.4% (1.6 cwt / ha) less than in 2017. Compared to the level of five years ago, the yield of chickpeas decreased by 3.4% (0.3 cwt / ha), which indicated some problems in the cultivation of chickpeas, including the peculiarities of soil and climatic conditions. The average annual yield of chickpeas in 2011-2018 was at marks of 8.4 cwt / ha. Among the regions, the highest average annual chickpea productivity in 2018 was noted in Voronezh (13.1 cwt / ha), Belgorod (11.7 cwt / ha), Samara (10.5 cwt / ha), Krasnodar Territory (10.4 cwt / ha) [7]. In the Astrakhan region, the methods for organizing proper nutrition of leguminous crops to obtain high grain yields at the level of 1.8...3.3 t / ha for beans and chickpeas were developed. The elements of resource-saving technology for the cultivation of leguminous crops under irrigation conditions, which provide highly productive products, were substantiated [5]. Thus, the data indicate the presence of a raw material base for leguminous crops in the Russian Federation (2.9-3.7 million tons per year) for organizing the domestic production of protein preparations of various shapes and compositions.

2.2. Chemical composition and medical and social aspects of the use of protein preparations from pea and chickpea grains

According to Shelepina N.V. et al. [8] the chemical composition of peas is as follows, % on dry substance (DS): protein - 23.33...28.12; ash - 2.73...3.35; fat - 1.63...2.48; carbohydrates - 50.3...68.9. Chickpeas, according to [9], % of DS has the following composition: protein - 22.19...32.3; ash - 2.76...3.60; fat - 4.1...7.2; carbohydrates - 20.0...70.0. Legumes have great potential in terms of eliminating hunger and smoothing out the lack of protein, which is a source of deficient essential amino acids. In contrast to the protein of cereals, the protein of leguminous plants contains an increased amount of 7 essential amino acids (EAA) (threonine, isoleucine, leucine, valine, phenylalanine, lysine and tryptophan). Among them, an important role is played by lysine, which is involved in various biochemical processes in animals and humans. Lysine pea protein contains about 7 g per 100 g of product, and chickpea protein contains more than 7 g per 100 g (Table), which makes chickpeas an attractive raw material for the production of protein preparations. The biological value of chickpea proteins often exceeds the value of peas. Sulfur-containing amino acids are considered to be deficient in EAA, given the composition of the reference protein published in the 1971 FAO / WHO documents [10].

### Table 1. Mass fraction of essential amino acids (EAA) in pea, chickpea and reference proteins

| Name of EAA          | EAAg/100 g of reference protein[10] | EAA g /100 g of peas [11] | ScoreEAA of peas, % | EAA g /100 g of chickpeas [12] | Score EAA of chickpeas, % |
|----------------------|-------------------------------------|---------------------------|---------------------|-------------------------------|--------------------------|
| Tryptophan           | 1.0                                 | 0.94                      | 94                  | 0.94                          | 112                      |
| Threonine            | 4.0                                 | 3.59                      | 89                  | 3.95                          | 200                      |
| Isoleucine           | 4.0                                 | 3.33                      | 83                  | 4.14                          | 138                      |
| Leucine              | 7.0                                 | 6.58                      | 94                  | 6.58                          | 170                      |
| Lysine               | 5.5                                 | 6.84                      | 124                 | 7.62                          | 184                      |
| Methionine + Cystine | 3.5                                 | 2.58                      | 73                  | 3.12                          | 68                       |
| Phenylalanine + Tyrosine | 6.0                             | 7.35                      | 122                 | 7.58                          | 216                      |
| Valine               | 5.0                                 | 3.89                      | 77                  | 4.06                          | 154                      |
The fractional composition of pea proteins, depending on the variety, varies in the following ranges: albumin - 8 ... 21.5%, globulins - 58.6 ... 76.6%, glutenins - 10.0 ... 19.8% [11]. Prolamins (alcohol-soluble) and scleroproteins (insoluble) protein fractions found in pea grains in insignificant amounts [3].

Proteins of chickpeas, like peas, also mostly represented by albumin and globulins, the mass fraction of which is up to 97% [12]. Compared to other plant proteins, proteins from legumes are the most hypoallergenic [13], and for their isolation are limited to the use of salt solutions (0.5-3.0 mol \cdot l^{-1}).

Along with proteins with nutritional value, legumes include antialimentary substances - protease inhibitors and lectins, which lower the nutritional value of protein products [14]. Protease inhibitors inhibit the activity of enzymes of the gastrointestinal tract, such as trypsin, chymotrypsin and an enzyme in blood plasma. Lectins can cause agglutination (gluing) of red blood cells, cells and bacteria. Agglutination occurs by binding lectins to the carbohydrate components of cells. Therefore, the technology for the production of protein products from legumes requires compliance with sanitary and hygienic requirements to reduce the activity of anti-nutrients in the finished product. The activity of protease inhibitors is achieved by steam treatment, soaking, boiling or other methods. The lectin inactivation conditions are milder than protease inhibitors - heating at 80 °C [14].

Legumes are a source of not only biologically valuable proteins, but also lipids and carbohydrates. They contain dietary fiber, choline, a component of lecithin, acting as a neurotransmitter, vitamins E, B1, B6, PP, etc., as well as calcium, potassium, magnesium, iron, zinc and other macro- and microelements [4]. The medical and social aspects of the use of legume proteins in food are that they help to improve blood supply and recommended for people suffering from hypertension. Proteins of these cultures reduce the risk of cardiovascular and oncological diseases [13]. Lysine, which is found in large quantities in legumes, is used in the production of collagen, which is necessary for the connective tissue of the body, and carnitine, which plays an important role in the “burning” of fat [2, 4]. Antioxidants are present in cultures, which, being part of concentrates, can affect immunity, making it stronger, and remove toxins from the body, protecting the brain from aging [15].

In the pharmaceutical industry, wide variety of pulses is widely used as raw materials for the production of therapeutic and prophylactic preparations of directed action. Pharmacological properties possessed by phytosteroids, pea lectins, chickpeas, proteinase inhibitors and other biologically active substances, which can be obtained before the process of isolating protein products. It was established, that seeds of leguminous crops, primarily pea and chickpea proteins “absorb” bile acids and cholesterol, and pea proteinase inhibitors inhibit the proliferation of cancer cells in vitro [16]. On the other hand, the presence of inhibitors in protein preparations regulated due to their negative effect on the functioning of the gastrointestinal tract.

Extracts and low molecular fractions of phenols and tannins from pea and chickpea grains have antioxidant activity. Flavonoids contained in the grain have choleretic, hypoglycemic, hypoaathermic, antiviral and antitumor activity. Sitosterols form insoluble complexes that reduce the risk of developing cardiovascular and oncological diseases. Saponins have a tonic effect, positively affect lipid metabolism and improves sexual function, spermatogenesis, increase immunity, lower blood pressure [17]. The presence of such compounds in protein preparations has to be controlled, as well as proteinase inhibitors, and their separate isolation may be provided for in the integrated processing of grain along with the production of protein preparations.

The compliance with all the requirements for the characteristics of the chemical and biochemical composition of pea and chickpea grains is a prerequisite for the development of new technologies for the production of protein preparations in the processing of legumes, which expand the range of feed and food products, as regular mass-market products, as functional, special or dietary products. At the same time, the possibilities of obtaining and using various types of individual ingredients as biologically active additives are expanding [4].

2.3. Technological features and solutions for the production of protein products from peas and chickpeas
The processes of production of protein products, which used to obtain protein-containing products such as flour, isolates and concentrates, can be classified as “dry” and “liquid” [18]. “Dry” processes include grinding and air separation, designed to separate the particles of legume grains by size and density into two fractions: light - protein and heavy - starch. After flour fractionation by air separation, the heavy (starch) fraction is re-separated and a second protein and obtained more “purified” starch fraction. The efficiency of separation of protein from starch is determined by the percentage in both protein fractions and expressed as a percentage of the total protein content in flour [3]. Dry methods have an advantage over liquid extraction methods, since they preserve the natural functionality of proteins, they require less energy and no water is used [19], while dry processes for the production of protein flour or concentrates are characterized by a relatively low protein yield (40 ... 75%) [20]. So, at the All-Russian Research Institute for Starch Products, pneumatic classification of pea flour was divided into a protein fraction with a mass fraction of protein of 60-40% and a yield of 8.5-9.5% and a starch fraction with a mass fraction of polysaccharide of 68.5-71.1% and a yield of 90, 5-91.5%.

Liquid methods provide concentrates and isolates with a mass fraction of proteins from 70 to 90% and above 90%, respectively. The extraction of proteins depends on the chemical nature of the reagent, the pH and ionic strength of the solution, temperature, particle size, the ratio of the solvent to the mass of proteins and / or to the mass of raw materials. The methods for the extraction of proteins are developed in a way to maximize their yield, without compromising on functionality and biological value [3].

Liquid methods of protein extraction, in turn, are divided into acid, alkaline, salt, filtration and enzymatic. One of the first in 1820 recorded acid extraction. It took several decades to commercialize processes with various types of acid modification, and today this method involves the use of hydrochloric or sulfuric acid, but mainly to obtain hydrolyzed proteins as flavor enhancers [20]. A small part of drugs after protein extraction using acids is obtained in biotechnology, more often after the use of enzyme preparations [21] or for partial or complete removal of salt [3]. Some manufacturers remove salt by nanofiltration or using ion exchange resins. During acid hydrolysis, some of the essential amino acids (tryptophan, methionine, cystine and cysteine) are destroyed, and glutamine and asparagine can turn into glutamic and aspartic acids, respectively. Acid treatment is able to hydrolyze proteins into individual amino acids or peptides with a lower molecular weight.

In the process of alkaline isolation of proteins, flour or other grain grinding products treated with metal hydroxide solutions with a pH of 9-11, after which insoluble substances separated by separation, the proteins are precipitated at an isoelectric point at a pH of 4.2 and centrifuged. During alkaline extraction, some authors previously solubilize the proteins by heating, followed by the addition of alkaline agents (calcium, sodium, potassium hydroxides) and maintaining the temperature to the desired value (27-55 °C). Extraction or hydrolysis continued for several hours to a predetermined degree, the product evaporated, pasteurized and spray dried [20]. In the food industry, however, alkali extraction concentrates with a protein content of more than 70% are often used [3]. Isolates contain 90-95% of proteins with a total yield of 60-80%. During alkaline extraction or hydrolysis, some amino acids (serine, threonine) might be destroyed due to racemization of amino acids, leading to a decrease in protein digestibility. But, since, along with high yield and quality, an important factor for manufacturers is the maximum preservation of composition and functionality, today the improvement of extraction processes and improvement of properties continues in the direction of replacing alkali solutions with other agents and techniques.

The techniques for improving technology include salt extraction, in which the globulin proteins separated from albumin in the form of a precipitate. Usually, in the extraction procedure, proteins initially dissolved in an aqueous solution of 0.3–0.5 mol / dm³ NaCl at a neutral pH, and then precipitated. The process of protein deposition carried out either by dilution with water to lower ionic strength, or by removing the salt by dialysis [3]. At the same time showed that protein products obtained from chickpea and pea using alkaline extraction had a higher mass fraction of protein (85.4% and 88.8%, respectively), compared to those that were obtained by salt extraction (81.6% and 81.1%, respectively).

Filtration is also a method of isolating proteins, which is their fractionation on a membrane basis with pressure as the driving force for separation. Filtration divided into micro and ultrafiltration.
Microfiltration is used to separate particles or macromolecules larger than 0.1 microns, while ultrafiltration removes particles in the range of 0.001-0.02 microns. Both methods are often used to increase the amount of extracted protein after alkaline or acid extraction [22]. Precipitated protein products characterized by higher functional properties and fewer anti-nutritional substances, compared to the deposition method at the isoelectric point. The ultrafiltration method also showed a higher mass fraction of protein in the final product - 83.9%, against 81.7% of the protein product obtained at the isoelectric point [3, 23].

One of the modern processes of protein extraction is fermentation without heat treatment and exposure to acids or alkalis. The use of bacterial or fungal proteases is of great importance for fermentation processes, since they not only initiate partial protein breakdown, but also facilitate the release of peptides with different molecular weights from other components (fiber, hemicellulose), which are interrelated. Fermentation also helps to reduce the content of anti-nutritional factors in protein ingredients and helps to improve the absorption of minerals by forming organic acids, which form soluble complexes with them, making minerals inaccessible for interaction with phytates [20].

To obtain hydrolyzed proteins, enzymes made from animals, plants, and microbial sources are used. Advances in protein hydrolysis methods are the most often obtained with proteases. At the same time, the hydrolysis conditions are mild and the enzymes are more specific, which allows manufacturers to precisely control the degree of hydrolysis and adapt products for end users. Hydrolysis of proteins might be achieved using a single enzymatic stage or a series of consecutive ones using several enzymes of different principles of action. The choice of enzyme depends on the nature of the protein and the requirements of the user. For example, if a protein has a higher content of hydrophobic amino acids, then the enzyme should preferably cleave residues of hydrophobic amino acids, if hydrophilic amino acids, then the enzyme should more actively cleave the bonds formed by hydrophilic amino acids [20].

For many years, legumes, without separation into components, had been used to prepare healthy nutritious meals in combination with other food sources or ingredients. Peas and its processed products mixed with regionally grown cereals are of great importance today to satisfy the nutritional needs of people using protein-carbohydrate diets [23]. However, the processes of processing composite raw materials are now reaching new levels using various degrees of depth of its fractionation and designing new types of protein formulas and / or composites. The task of such composites is to balance the amino acid composition of the diet, enrich food with biologically active substances while maintaining or exceeding the indicators of technological properties of food products. The construction of composites is based on mathematical methods of planning [24], computer programs that ensure the balance of amino acid or other composition. We created protein composites with products from wheat bran, the amino acid composition of which supplemented by the composition of amino acids in legumes, biologically active fats and oils, lecithin in order to balance and lipid composition. Composites contained 35-40% protein, 30-35% fat, 40-45% carbohydrates, 5-10% lecithin, vitamins E and C. Products are easily digestible, conveniently stored, and the determination of various forms of connectivity, lipid groups, electrophoretic composition and functional properties of proteins and served as the basis for the use of protein-fat composites, developed on the basis of protein products from cereals and legumes, in the production of bakery, flour confectionery, candy products for mass and functional nutrition [25].

The next direction of using the high biological value of leguminous crops is the joint use of secondary products of the processing of leguminous crops (peas, chickpeas), for example, to starch (extracts, whey, pulp, etc.) with products formed from grain crops (flour, bran, flour, grains, etc.) or the use of biosynthetic enzymatic processes between finished protein preparations to ensure the complementarity of the amino acid composition and the directed construction of functional technological properties of protein products [26, 27].

Thus, enzymatic methods for isolating protein preparations and constructing composites based on them are more effective than alkaline or acid methods, while it follows from the analysis of the literature that information on the use of enzymes, especially other subclasses of the hydrolase class, except for proteases, to ensure high values the yield of proteins, their mass fraction in preparations, the composition and functional properties of leguminous crops is not enough. Therefore, the further development of
technological solutions and methods for extracting protein from peas and chickpeas for their implementation in domestic enterprises remains relevant.

2.4. Functional properties and use of protein preparations from peas and chickpeas

Functional properties of protein preparations includes: solubility, fat emulsifying, water and fat retention ability, foaming, foam stability, gelation, etc. Properties determine the competitiveness of the protein product in the market, as they can affect the organoleptic and physico-chemical characteristics of the product. The functional properties of the proteins of legumes vary significantly due to the peculiarities of the properties and structure of the proteins of the raw materials, the methods of their extraction and processing [12-13, 28].

The solubility of the protein plays an important role in various food systems, since other functional properties (foaming, gelation, emulsification) depend on it. The high solubility of protein can be useful in the production of baby milk and simulation milk, which requires fast solubility. For example, simulated milk with lentil protein isolate was of the same quality as milk made from soy protein isolate, but had a lower quality than with pea protein isolate. A study of five different leguminous crops (peas, chickpeas, beans, lentils, soybeans) showed a higher solubility of isolates obtained by alkaline extraction (85.9%), compared with those obtained using salt extraction (61.5%). On the other hand, during alkaline extraction, the bean protein isolate had the lowest solubility (61.4%), the soybean isolates had the highest solubility (96.5%), and the pea, lentil and chickpea isolates were intermediate in this indicator (more than 90.0 %) [3].

Water-binding and fat-binding ability are the properties of proteins to bind to water and fat, respectively. These properties are important to ensure product quality, shelf life and organoleptic characteristics (texture, pleasant mouth feel). The inability of the protein to bind water can lead to fragility and dryness of the product [3]. Values of water-binding ability for protein concentrates of various species and varieties of leguminous crops (peas, beans, lentils, chickpeas) are in the range of 0.6–4.9 g / g of product, which suggests that both the type of crop and the processing method may affect the ability to absorb water. Pea and chickpea proteins characterized by increased moisture-binding ability and solubility [4, 29].

The fat-binding ability also depends on the type, variety and processing method of the leguminous crop and is in the range of 1.0–3.96 g / g of product [3]. The ability to bind water and fat is important for the manufacture of foods such as meat products, pasta, cookies, etc. The possibility of adding chickpea protein, for example, to ground beef proved in an amount of 15% without loss of organoleptic properties of the product.

Emulsions are thermodynamically unstable and eventually separate into layers of oil and liquid due to collisions and coalescence of droplets. Emulsifiers are used to obtain stable emulsions. Thus, a protein as an emulsifier adsorbs at the oil-water interfaces with the formation of a viscoelastic film surrounding an oil drop. Studies carried out for peas, chickpeas, beans, soybeans, and lentils showed that both the nature of the proteins and the method of their extraction (alkaline, ultrafiltration) affected the activity, stability, and other physicochemical properties of the emulsion [22].

The functional properties of proteins can be improved by modifications, such as limited enzymatic hydrolysis using proteases (e.g., trypsin). The hydrolysis reaction leads to partial unwinding of protein molecules, thereby opening up more ionic and hydrophobic groups to interact with oil droplets [3]. The properties of the formation and stability of the emulsion of proteins of leguminous crops play an important role in the formation of a number of such foods as sausages, meat analogues, cakes, soups, etc. Some ingredients (dried wheat gluten, rice, mushrooms, tofu, etc.), when added, can imitate ready-made meat products (chicken, beef, sausage, etc.) The market for meat analogues is large and is in demand among vegetarians, vegans and people who do not eat meat products due to religious or cultural customs [3].

Foaming is the ability of a protein to foam. Like emulsions, foams also have two immiscible phases (water and gas). Proteins in the solution are adsorbing at the gas-liquid interface, forming a viscoelastic film surrounding the gas bubbles, which helps to resist rupture and coalescence of the bubbles. Various
food products are known in which protein (meringues, whipped desserts, mousses and bakery products) is used as a stabilizer. It has been proving that the foaming properties of pea isolate are higher than that of skimmed milk powder, wheat flour and soy protein isolates. A group of scientists [13] in the study of the foaming ability of pea and chickpea protein products obtained by ultrafiltration and alkaline extraction methods found that the ability to form foam in samples of pea concentrate was independent of the extraction method. However, the chickpea concentrate obtained by the alkaline extraction method had higher foaming. In general, chickpea concentrate had a higher foaming ability, but lower foam stability, compared to pea concentrate.

Recently, there has been growing interest in the use of protein from peas and chickpeas in new products due to their nutritional value, accessibility, low cost, desired functional properties and beneficial health effects [3, 15, 28]. Protein concentrates and isolates from peas are used in the production of bakery, pasta, drinks, imitation milk, cottage cheese, yogurt, meat analogues, sausages, baby food, sports nutrition, complex nutritional supplements, etc. Moreover, the addition of protein does not adversely affect the quality characteristics finished products [30-32]. Flour and protein products obtained from chickpea grain are used in a composition with wheat, soy flour and animal products as a high-protein ingredient for the preparation of various flour products, tofu cottage cheese, a combined meat product, modified by preliminary germination of grain to increase the biological value of the product [3, 9, 17, 33].

2.5. Microbiological transformation of secondary products of processing raw materials into food and feed additives

New technologies for obtaining feed and food products are developed for modern conditions of conducting the traditional processing industry. One of such resource-saving techniques is the involvement in the scheme of processing of raw materials of the method of bioconversion of secondary processed products into food and feed additives. Microorganisms on certain compositions of the nutrient medium have a high growth rate and the ability to synthesize a spectrum of nutrient compounds: proteins, lipids, carbohydrates, carotenoids, etc. [34-35]. The biomass of microorganisms can be used as part of the diets of farm animals and poultry to increase productivity, and humans - to obtain new sources of proteins. The basis for the cultivation of biomass of microorganisms is a variety of raw materials, mainly by-products of the food industry and agriculture. Thus, a preparation obtained during the fermentation of corn stalks with saccharomyces or a consortium of saccharomyces L. plantarum and L. casei had a positive and safe effect on the animal organism and the environment [36]. The yeast introduced into the feed of broiler chickens in an amount of 0.8% also increased the efficiency of feed use [37]. A study of the microbiota of fecal samples on days 21 and 42, carried out using the polymerase reaction, revealed a positive effect of the additive on the microflora of broiler chickens, and the introduction of yeast Sacch cerevisiae in ruminant feed increased the digestibility of fibers and increased the population of cellulolytic bacteria R. flavefaciens rumen. Also, it was proven, that adding to a cattle dietstro Sacch. cerevisiae and or Asp. oryzae increased milk yield and fat content of milk [38].

Existing feed additives from hard-to-digest coffee slurry, from distillery stillage with wheat bran by joint cultivation of yeast Sacch. diastaticus and carotene-forming yeast Rh. species with a 41% increase in the content of essential amino acids. Feed additive with carotenoids and lipids by growing yeast Rh. glutinis, Rh. mucilaginosa and Rh. gracilis on a medium consisting of deproteinized wastewater are received from potato processing and glycerol waste. Mushroom biomass with Asp. Niger and yield of 35 g / dm³ also obtained at the liquid wastes of distilleries with the complete utilization of monosaccharides.

Information regarding the processing of secondary products formed from leguminous crops in this area is still limited, despite their promise. Thus, on the base of by-products formed during the extraction of pea protein, using mycelial fungi, a food mycoprotein concentrate synthesized to “replace” meat. Studies conducted with 5 strains of fungi (A. oryzae, F. venenatum, M. purpureus, N. Intermedia, R. Oryzae), fermentation at 35 ± 2°C for 48 hours. The protein content in the biomass of fungi reached 43.13-59.74%. It was shown that the introduction of this process into the processing of peas can
provide about 680 kg of mushroom biomass with 38% additional protein for every 1 ton of by-product [39].

3. Conclusion

The analysis of the sown area and the yield of legumes in the country attests to the availability of the raw material base of legumes in the Russian Federation (2.9-3.7 million tons per year) in order to organize domestic production of protein preparations. Pea and chickpea proteins have high biological value and amino acid rate, which allows ensuring complementarity of the composition of essential amino acids with amino acids of protein crops. Legumes, along with proteins, contain useful components such as fiber, minerals, vitamins, antioxidants that can interact with polypeptides and in small amounts be part of protein preparations. To eliminate protein deficiency in the human diet, as an alternative to proteins of animal origin, various methods and technological solutions for the isolation of proteins from leguminous crops developed using modern physicochemical and biotechnological methods. Such methods include processes with enzyme preparations, eliminating the destruction of the structure and composition of protein fractions of raw materials, and, consequently, functional properties, in contrast to processes with acids and alkalis. It is promising to increase the production of food and feed protein concentrates from pea and chickpea grain processing products to proteins and starch with the maximum preservation of their biological value with various types of mushroom and / or bacterial enzymes available in the country in terms of raw materials.

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