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IDENTIFICATION OF PATTERNS IN THE PRODUCTION OF A BIOLOGICALLY-ACTIVE COMPONENT FOR FOOD PRODUCTS

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Проведеними дослідженнями встановлені особливості інтенсивної технології виробництва біологічно-активного компонента (проростків бобових) з використанням при пророщуванні натуральних фруктових кислот (лимонної, яблучної, виноградної). Важливим є підбір якісних і безпечних стимуляторів проростання різної зернової сировини. Такими речовинами є саме фруктові кислоти натурального походження. Завдяки їх використанню стало можливим отримання високоцінного компонента харчових продуктів оздоровчого призначення, а саме, проростків різноманітних бобових культур.

Експериментальними дослідженнями доведена ефективність використання фруктових кислот, як дієвих інтенсифікаторів і дезінфектантів процесу отримання проростків бобових. Показано, що їх використання дозволяє не тільки інтенсифікувати пророщування бобових, а й сприяє більш активному формуванню проростків, дезінфікує гряду. Так, при використанні водних розчинів фруктових кислот концентрацією 0,25–1,25 % збільшились наступні показники: енергія проростання–на 4–7 %; здатність до проростання–на 5–8 %; довжина проростків–на 3–11 мм; вага проростків–від 1 до 12 % в залежності від культури. Крім того, був досліджений склад проростків, що підтвердило біологічну повноцінність і раціональність їх включення в склад харчових продуктів в якості біологічно-активного компонента. Дослідження показали, що вони мають в своєму складі підвищений вміст амінокислот (на 3–50 % в залежності від амінокислоти), вітаміни(B1, B2, B3, B6, B12, PP, E, C, A), високий вміст білка (32 %) та екстрактивних речовин (44 %). Це засвідчує біологічну і харчову цінність отриманих за інтенсивною технологією проростків.

Досліджена технологія виробництва проростків бобових є інноваційною. Отримані проростки можуть стати високопоживними компонентами нових оздоровчих харчових продуктів

Ключові слова: біологічно-активний компонент, фруктові кислоти, лимонна кислота, яблучна кислота, виноградна кислота, проростки бобових

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1. Introduction

The issue of the rational nutrition of people is very important; it plays a significant role in ensuring the full-fledged existence of modern humans. The standard diet of people has undergone, over the last several decades, many negative changes. Average consumers prefer food products, which contain many fats, cholesterol, simple carbohydrates, while such extremely important components as fiber and complex carbohydrates are found in modern foods less often. The result of such an unbalanced diet is a mismatch between the weight and height in a large number of people from different age groups; the overweight and the related diseases have become widespread not only in adults but also in children of different ages.

Food is one of the most important factors affecting the health of the population in this country. The development of food products with the enhanced biological and nutritional value is a pressing task; it requires improving the composition of food products to which we are accustomed in everyday diet. An interesting direction of such a search is to increase the biological and nutritional value of foods by introducing the sprouts of various crops to their formulation. The sprouts contain all the nutrients that act on the human body harmoniously because they have a natural vegetable origin and can, in the future, bring significant benefits to the human body as part of the popular and common food products.

The development of a technology for making a biologically active component of food products based on the sprouts of legumes renders relevance to our research. This technology would be scientifically valuable for creating new health food products because the resulting sprouts of legumes could become the indispensable and highly nutritious components of such products. That would not only expand the range of useful foods but also improve their organoleptic properties and chemical composition.

2. Literature review and problem statement

Papers [1–4] report a large body of research findings addressing the development of food products using sprouted grains and sprouts. It is shown that sprouts are a traditional food product in many countries of the world. Foods from sprouts continue to acquire popularity among supporters of healthy eating. However, the use of this grain raw material grain is still very limited in terms of producing new foods. The germination of grain significantly changes the chemical composition and processes occurring in the food system. Enzymes are significantly activated; their content increases. The quantity of anti-nutrients decreases significantly while the proteolytic activity is increased. Easily digestible soluble complexes form, so when using food sprouts as the food it is possible to obtain a set of all the necessary nutrients in the most accessible form. The peculiarity of the sprouts is that they could be stored without loss of quality at a lowered temperature over a few days only. Therefore, more often, along with fresh and chilled sprouts, the sublimated sprouts are used, that is those that underwent the lyophile drying. In addition, the sprouted grain raw materials are used as a dry powder [1]. However, the issue unsolved in work [1] is the production of sprouts, which would have high quality and store well while fresh. In addition, the pressing issue is to provide food production with a sufficient amount of sprouts.

In the food industry, it is advisable to use the sprouts to enrich products that are not subject to long-term storage or as part of frozen food. Work [2] reports the results concerning the use of the whole and crushed raw sprouts in various dairy products, masses of cottage cheese, meat minces, ready salads, ice cream, fillers for ravioli, frozen separately, or mixed with other vegetables. All this allows us to argue that the sprouts could become a universal component in the composition of food products. The main difficulty in using the sprouts arises due to the lack of profile production of such raw materials; that does not make it possible to include them in the formulation of food products at an industrial scale. An option to overcome the difficulties associated with the production, described in work [2], is the introduction of intensive technologies for obtaining sprouts at an industrial scale as they might ensure the demand from producers for the biologically active components.

It is possible to use flour made from sublimated sprouts for making bakery products or to add it to ordinary flour for use in the preparation of a variety of food products – grain sticks, pasta, and confectionery, dry soups, sauces, salads, foods for dietary, diabetic, and baby food, both dry and in the form of a puree. Flakes from the whole sprouts of wheat, rye, buckwheat could become the base for muesli, which would significantly improve its nutritional value. Study [3] described the nutritional value of the sprouted grain raw materials. However, the authors did not pay attention to the technological process of obtaining the sprouts, which is an important stage of production.

In order to improve the nutritional value, it is advisable to make cereals with the addition of sublimated sprouts of various crops. The results of these studies are reported in works [1, 3]; they indicate the prospects for using the sprouts to enhance the nutritional value.

To produce wort fermentation products, one could use, as a malt raw material, the sprouts of wheat, buckwheat, lentils, soy, sesame, sunflower, pumpkin, in a mixture of barley or rye malt. The expansion of the range of malt raw materials by adding the dried shoots of different crops would expand the range of fermentation drinks: concentrated kvass wort, kvass, mead, beer. These products could be enriched with the biologically active components and would have pleasant organoleptic properties [4, 5].

The experiments on the use of soybeans were described in [6]; they could be used to prepare culinary products and bakery. A series of formulations were devised for various salads with the partial replacement of some ingredients with fresh soy sprouts. In addition, the authors developed the formulations for gel-type meals with the addition of soybean sprouts. The authors of [6] established that the introduction of soybean sprouts significantly increases the food value of products, without lowering the organoleptic indicators. However, no attention was paid to the peculiarities of the technology for obtaining the soybean sprouts used in the formulations.

The sprouts are harmoniously combined with any vegetable – zucchini, Bulgarian pepper, broccoli, salads, tomatoes, cucumbers. It is possible to use them with mushrooms.

When analyzing the literary data [1–6], it should be noted that the foods enriched with sprouts should be widely introduced to the diet of a broad range of consumers, by introducing sprouts as a biologically active component to foods in order to enrich them with substances valuable for health. However, there is the issue to provide industrial production with such important components as sprouts. All this allows us to assert that it is advisable to undertake a study that would address the development of new intensive technology for obtaining sprouts that could boost the demand by food enterprises for the biologically active components of natural origin.

It is promising to produce sprouts based on the intensive and environmentally friendly technology of the grain raw material germination. The scientific literature [7, 8] describes various ways to intensify the sprouting. The main methods used in the process of grain germination intensification are as follows: biotechnological, chemical, physical, physical-chemical, complex, and others. Chemical intensifiers include the solutions of organic and inorganic acids. The biotechnological stimulants include phyto regulators, growth regulators, chitosan, Celloviridine G20X, Dysticim P7. The most common physical methods to intensify the germination include the vacuum, ultrasonic treatment, ozonation, ultraviolet, red, and infrared radiation, cavitation germination, micro-electric current acceleration, a bubbling method, and others. The physical-chemical methods to intensify the grain germination process include the use of plasma-chemically activated aqueous solutions. However, there are unresolved issues related to choosing the germination intensifier for legumes, which would make it possible to obtain large biomass of sprouts.

Organic acids have been widespread over recent years. Thus, the most common organic acids used in the germination are lactic, gibberellin, amber, ferulic, coumarin, nicotinic, folic acids [9, 10–13]. The organic acids of various nature have been widely used in the production of the sprouted grain raw materials for different purposes in this country [14, 15]. However, literary sources do not include any data regarding the production of legumes sprouts using organic acids. It is the development and subsequent implementation of the intensive production technology for making sprouts that could provide the food industry with a high-quality biologically active component.

It is extremely important to select such a germination intensifier that would make it possible to obtain high-quality and chemically pure sprouts. Among the many intensifiers (stimulants) of the germination process, we selected fruit acids (citric, malic, grape) for our study. The specified organic acids are of natural origin and could prove a useful addition to the technology of a biologically active grain component. It should be noted that they have already been used to receive the brewing malt [12, 13]. All this allows us to argue that it is advisable to undertake research into obtaining the high-quality legumes sprouts through intensive technology using the aqueous solutions of fruit acids as the germination intensifiers.

3. The aim and objectives of the study

The aim of this study is to establish patterns in the industrial production of a biologically active component, namely, sprouts, which could become part of the formulation for healthy foods. That would make it possible to provide food enterprises with a sufficient amount of sprouts for making products of the elevated nutritional value.

To accomplish the aim, the following tasks have been set:

– to investigate the energy and capability of legumes germination;

– to monitor the length and control the weight of the legume sprouts biomass;

– to investigate the microbiological state of the sprouts;

– to explore the chemical composition, the content of amino acids and vitamins in the sprouts.

4. Materials and methods to study the production of a biologically active component (sprouts) using the intensive technology

Our study was carried out at the scientific-production laboratory for determining the quality of grain and grain products at the Dnipro State Agrarian and Economic University (Ukraine).

4. 1. The studied materials and equipment used in the experiment

4. 1. 1. Selection of the natural intensifiers of germination

The germination process was studied using organic acids as a germination intensifier. We selected the aqueous solutions of the following fruit acids:

1) citric acid (Fig. 1, *a*), which acts as an intermediate carrier of the hydrogen atoms at the initial stages of oxidation of carbohydrates and fatty acids, increases the acidity of the product, reduces the development of a bacteriological background, participates in the metabolism of fats, proteins, amino acids [19];

2) hydroxybutanedioic (malic) acid (Fig. 1, *b*), which has the hygroscopic properties, acts as an antioxidant to the oxidation of carbohydrates and stimulates metabolism, is responsible for strengthening the immune function;

3) grape acid (racemic compounds) (Fig. 1, *c*), which participates in cellular respiration processes, increases flexibility and elasticity. It can expand capillary channels, slows decay processes, protects against the oxidation of carbohydrates, promotes consolidation of proteins. It can stimulate growth and increase the rate of metabolic processes in agricultural plants [20].

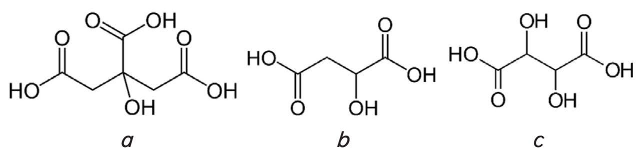

Fig. 1. Fruit acids: *a* — citric acid; *b* — malic acid; *c* — grape acid

The used sprouts growth intensifiers were citric (E 330), malic (E 296), and grape acid (E 334). The acids had the following characteristics: 1-aqueous citric acid, pure, made in China; 1-aqueous malic acid, pure, made in China; 1-aqueous grape acid, pure, made in China. In line with the international classification, all used acids belonged to food acids. The aqueous solutions of citric, malic, and grape acids in the range of concentrations from 0.25 % to 1.25 % were used as fluids for soaking up legume crops.

4. 1. 2. Selection of grain raw materials for germination and the patterns in obtaining high-quality sprouts

The selected grain raw materials to obtain sprouts were the legume crops: peas, soybeans, chickpeas, haricot beans, beans, lentils, lupine. Such a choice was based on the peculiarities in the chemical composition of legumes (Fig. 2), which influences the further composition of sprouts.

The grain was germinated at the laboratory malt setup, which is a set of plastic containers that are covered with a layer of filtration paper and moistened with the aqueous solutions of acids at the defined concentration, %: citric, 1.25–1.0; malic, 1.0–0.75; grape, 0.5–0.25.

The grain material was treated with the aqueous solutions of organic acids in the following way: the grain material prepared for sprouting was saturated with an acid solution of the predetermined concentration in two stages. The preliminary soaking lasted for 4 hours at a temperature of 18–20 °C. Upon completion of the period, the nutrient solution was discharged and the grain was kept for 18 hours without liquid. At the repeated soaking, we used the acid solutions of similar concentration. To prevent the oxidation of solutions, at the second stage of soaking we added the solutions of alkalis to the grain. The air-water soaking lasted for 26 hours until the complete saturation of the grain with the preparation. Sprouting was carried out during 3–15 days at a temperature of 17–21 °C, by periodically moisturizing and stirring the grain layer with a height not exceeding 45–55 mm in order to achieve the uniform distribution of the liquid and prevent the mass from compaction. The final stage of the technological process is the separation of sprouts and their subsequent processing: cooling, grinding, or drying, depending on technological needs.

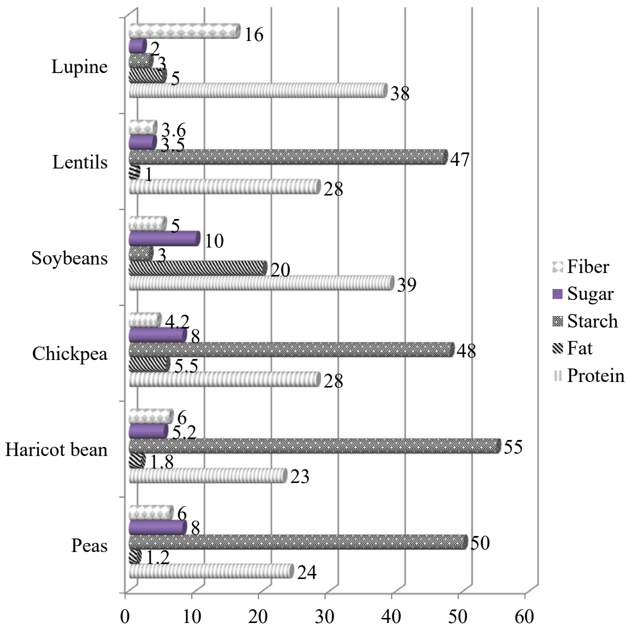

Fig. 2. Chemical composition of legumes, %

4. 2. Procedures for determining the properties of samples

4. 2. 1. Procedures for determining the energy and germination capability of legumes, the length and weight of the sprout biomass, the microbiological state of the material during its germination

For our research, we selected, from each legume variety, four analytical groups of 500 pcs. for small legumes and 250 pcs. for larger ones.

We determined the capability and energy of germination to establish the number of legumes that can form the normally developed sprouts. Simultaneously with the capability, we determined the energy of legumes germination, which characterizes the speed and density of its germination. The capability and energy of germination were expressed as a percentage of the normally sprouted grains to the total quantity. To determine the energy and capability of germination, we applied the generally accepted procedures. After 72 hours after soaking the grain, we determined the energy of germination of the grain material, after 120 hours – the capability to germinate. These indicators were expressed in % to the total numw ber of grains in a batch. The effectiveness of the selected growth intensifiers was compared with the control, which was represented by the grain not exposed to any chemical treatment. In addition, measurements of the length of sprouts were conducted to monitor the activity of grain germination and the speed of sprouts during 15 days. The received biomass was weighed in parallel. All experiments were repeated 5 times.

A change in the microbiological condition of the grain material was observed under the microscope MBS-56; the washings were seeded on the nourishing medium, followed by counting the colonies of microorganisms.

4. 2. 2. Procedures for determining the chemical composition, the content of amino acids and vitamins in legume sprouts

The chemical composition of legumes was determined at the device of the system "Kjeltec Auto 1030 Analyzer".

Determination of ash content. A batch of the crushed material is exposed to ashing by gently baking with free access of air. Carbon, hydrogen, nitrogen and partially oxygen are released, only minerals in the form of oxidative compounds remain. Ashing could be performed without the use of an accelerator or one could use chemically pure nitric acid as an accelerator. Reagents: baked chloride calcium; nitric acid, chemically pure, density 1.20 g/cm^3. Equipment: porcelain crucible (No. 4), crucible tongs, electric muffle furnace.

Determination of raw fiber content. Raw fiber consists of pure fiber, part of hemicellulose, lignin, cutin, some protein substances, and ash elements. A sample is treated with sulfuric acid, alkali, alcohol, and ether, after that the plant residue is weighed.

Determination of fat content (by Rushkovsky). Underlying the method is the principle of determining the fat content based on the degreased residue. The batches of the dried and ground material are placed in bags of filtration paper and are extracted with the diethyl ether in the Soxhlet apparatus until completely degreased. The amount of the extracted fat is calculated based on the difference between the starting batch and the mass of the degreased residue.

To determine the biological value, we analyzed the content of amino acids in the sprouts of legumes; to this end, a method of the ion exchange liquid-column chromatography was used, at the automatic analyzer of amino acids T339, made in Prague, the Czech Republic. The vitamin composition of sprouts was determined also with the help of ion-exchange liquid-column chromatography and other standard procedures.

5. Results of studying the indicators of the technological process for obtaining the sprouts

5. 1. Studying the energy and the germination capability of legumes

The main indicators of the sprouted grains and the sprouts' quality are the energy and the germination capability of legumes (Table 1). We selected, by a preliminary analysis, the concentrations of fruit acids, which showed the maximum increase in these indicators; the study results are given in Table 1. In this case, the selected concentrations of fruit acids in aqueous solutions did not damage the grains during the experiments and did not cause any change in the organoleptic properties of the finished product.

We observed an increased germination activity in the examines samples compared to control, which indicates the possibility of using the solutions of fruit acids in order to intensify the process of obtaining the legume sprouts. This trend was observed in all the investigated crops. Fruit acids intensify the germination process to a different degree but the effect of the increased energy and germination capability indicators is registered for all legumes. That makes it possible to argue about the positive dynamics of the influence of the selected intensifiers on the technological process of obtaining the sprouts of legumes.

Table 1

The energy and germination capability of legumes when using fruit acids

Crop	Energy of germination, %				Germination capability, %			
	control (water)	Aqueous solutions of fruit acids			control (water)	Aqueous solutions of fruit acids		
		citric	malic	grape		citric	malic	grape
Pea	80	85	86	87	87	92	95	94
Soy	82	86	87	88	91	96	96	98
Chickpea	85	89	90	88	91	97	98	99
Haricot bean	86	90	91	92	93	97	99	98
Lentil	83	88	89	87	91	96	98	97
Beans	85	89	88	89	92	95	97	96
Lupin	86	90	91	90	93	97	99	98

The energy and germination capability of legumes are significantly enhanced when using fruit acids with the effect of a positive change of the indicator ranging from 4 to 8 %.

5. 2. Monitoring the length and controlling the weight of sprouts biomass

A change in the length of sprouts after 72 hours after the germination process began was registered. The obtained results are given in Table 2 and shown in Fig. 3.

Table 2

Sprout length, mm

Crop	control (water)	Aqueous solutions of fruit acids		
		citric	malic	grape
Pea	18	20	23	22
Soy	19	24	25	24
Chickpea	20	25	26	25
Haricot bean	31	33	35	34
Lentil	7	10	12	12
Bean	41	48	52	50
Lupin	11	14	14	15

By analyzing the findings, it is possible to draw a conclusion about the more intensive development of sprouts in all legumes when using solutions of fruit acids during steeping.

Important is the number of sprouts (the biomass), obtained after the entire cycle of technological operations; the output of the finished product, namely, the legume sprouts, when fruit acids were used as an intensifier, is given in Table 3.

The results given in Table 3 testify that the biomass of sprouts increases with the use of fruit acids. Therefore, the proposed intensive technology for producing the sprouts could make it possible to obtain a larger amount of the biologically active grain raw materials, a component of new food products.

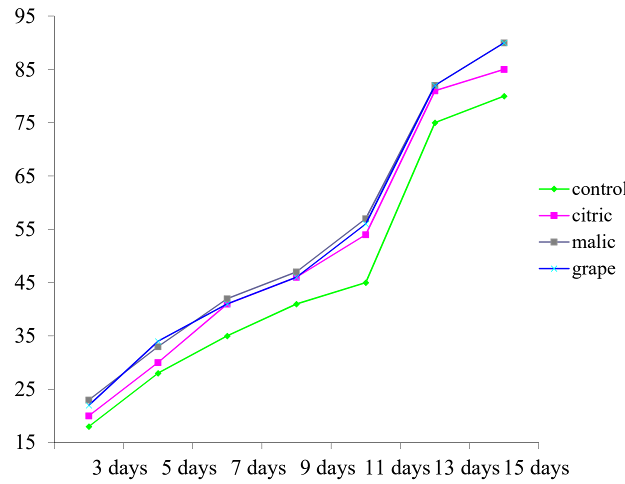

Fig. 3. The dynamics of change in the length of legume sprouts when using fruit acids (using peas as an example)

Table 3

The output of legume sprouts, g

Crop	Aqueous solutions of fruit acids	Aqueous solutions of fruit acids					
		citric		malic		grape	
		weight	weight change effect	weight	weight change effect	weight	weight change effect
Pea	501	526	+25	546	+45	571	+70
Soy	611	639	+28	674	+63	680	+69
Chickpea	581	586	+5	591	+10	601	+20
Haricot bean	594	609	+15	617	+23	624	+30
Lentil	493	500	+7	503	+10	510	+17
Bean	591	597	+6	603	+12	617	+26
Lupin	499	509	+10	510	+11	521	+22

5. 3. Studying the microbiological state of sprouts

An important issue when cultivating legumes is the presence of microorganisms, especially pathogenic, on the surface of the grains and formed sprouts.

Most often, the germination process occurs under non-septic conditions. The seeds, treated under such conditions, may host microbes whose presence is predetermined by the external environment in the course of plant growth or seed storage. The conditions that are maintained during the germination process (heat, moisture) are most favorable for the microbes, sitting on the seeds, which are bred over the entire process. These microbes may exert an undesirable effect on the germination product. This is explained by that the microorganisms, when penetrating a damaged seed, cause its disease and death. Therefore, the selection and use of a high-quality and non-harmful antiseptic preparation is quite an important task that aims to improve the quality of sprouts. The influence of fruit acids of the specified concentrations (0.25–2.0 %) on the microbiological condition of sprouts of different crops is given in Table 4.

The local disinfectant properties of fruit acids were investigated. The number of microorganisms was determined by counting the colonies found on standard environments. Table 4 shows a change in the average number of microorganisms on the surface of sprouts resulting from the use of fruit acids of varying concentrations. The disinfectant capacity was more pronounced in the samples where the concentration of fruit acids was higher. This is explained by that the acidic environment adversely affects those pathogenic microorganisms that sit on the surface of the legumes and their sprouts.

Table 4

Studying the microbiological condition of sprouts of various legumes

Concentration of organic acids, %	Microorganisms			
	control (water)	aqueous solution of citric acid	aqueous solution of malic acid	aqueous solution of grape acid
2.0	$2.4*10^7$	<10	<10	<10
1.5	$2.4*10^7$	$2.5*10^2$	$3.1*10^2$	$5.1*10^2$
1.25	$2.4*10^7$	$1.5*10^3$	$1.7*10^3$	$2.1*10^3$
1.0	$2.4*10^7$	$1.9*10^4$	$1.2*10^4$	$3.1*10^4$
0.75	$2.4*10^7$	$3.1*10^5$	$2.3*10^5$	$5.9*10^5$
0.5	$2.4*10^7$	$4.1*10^6$	$3.5*10^6$	$3.1*10^6$
0.25	$2.4*10^7$	$1.2*10^7$	$1.4*10^7$	$1.3*10^7$

5. 4. Studying the chemical composition, the content of amino acids and vitamins in sprouts

An important stage of research is to determine the composition of sprouts. The main components included in their composition are shown in Fig. 4.

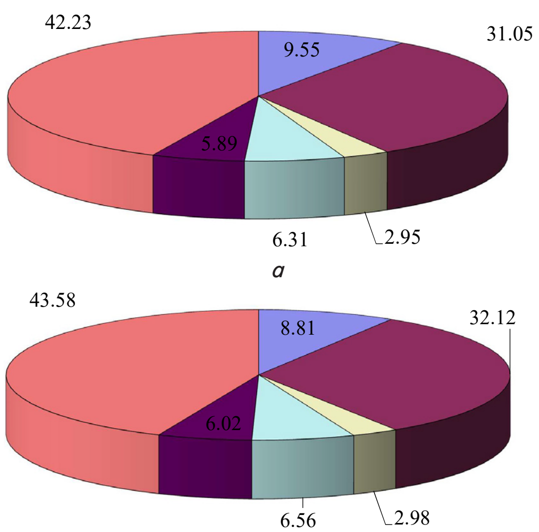

Fig. 4. The chemical composition of legume sprouts: *a* – control; *b* – experiment; ▢ – water; ▢ – raw protein; ▢ – fats; ▢ – cellulose; ▢ – ash; ▢ – extractive substances

By analyzing Fig. 4, one can argue that the legume sprouts obtained when using fruit acids are distinguished by the high content of protein, digestible carbohydrates, mineral substances, free fatty acids, which makes them particularly valuable for human nutrition. The average vitamin composition of the sprouts of various legumes is given in Table 5.

The increased content of vitamins (Table 5) also testifies to the importance of using the sprouts of legumes for food in order to balance the nutrition and enrich it with a vitamin complex contained in the legume sprouts.

To confirm the biological value of the sprouts, the amino acid analysis was conducted; the samples revealed the most important amino acids for the human body in a sufficient amount. When using fruit acids, the content of amino acids increases; the effect of a positive change in the content of each individual amino acid is given in Table 6.

Table 5

Average vitamin composition of sprouts, mg %

Vitamin	control	citric acid	malic acid	grape acid
B_1	0.625	0.680	0.682	0.677
B_2	0.644	0.668	0.659	0.661
B_3	1.870	1.885	1.880	1.882
B_6	0.534	0.559	0.565	0.561
B_{12}	0.515	0.520	0.523	0.525
PP	0.301	0.315	0.310	0.314
E	1.327	1.343	1.337	1.341
C	6.221	6.248	6.244	6.246
A	2.590	2.659	2.652	2.655

Table 6

The effect of change in the content of amino acids in legume sprouts when using fruit acids

Amino acid	Content change effect, %		
	citric acid	malic acid	grape acid
Lysine	+9	+8	+9
Histidine	+13	+14	+15
Arginine	+4	+3	+5
Aspartic acid	+6	+8	+7
Threonine	+20	+20	+21
Serine	+14	+15	+14
Glutamic acid	+3	+2	+3
Proline	+4	+5	+4
Glycine	+50	+49	+50
Alanine	+12	+11	+12
Cystine	+50	+50	+48
Valine	+27	+26	+25
Methionine	+50	+49	+48
Isoleucine	+13	+12	+12
Leucine	+9	+10	+8
Tyrosine	+10	+11	+9
Phenylalanine	+14	+12	+11
Glutamine	+7	+6	+5

By analyzing data in Table 6, one can argue that the result of the more intensive development of sprouts is that the accumulation of amino acids occurs more actively. In the samples treated with fruit acids, we registered the elevated content of most amino acids compared to the control sample, by 3–50 % (Table 6). This is a confirmation of the working hypothesis about the increased content of the biologically active substances in the legume sprouts.

6. Discussion of results of studying the intensive technology for obtaining a biologically active component of food products

By examining the energy and germination capability of legumes when using fruit acids, one can argue that selected concentrations of fruit acids (citric, 1.25–1.0 %; malic, 1.0–0.75 %; grape, 0.5–0.25 %) demonstrated an increase in the indicators: the germination energy, by 4–7 %; the germination capability, by 5–8 %); the results of our study are given in Table 1. It should be noted that the selected concentrations of fruit acids did not damage the grain of legumes when processing the samples. The increase in the germination indicators is due to that the fruit acids can soften (partly destroy) the protective shell of the grain, thereby accelerating the transportation of moisture inside. Such an influence on the grain of legumes contributes to awakening the grain and to the active synthesis of hydrolytic enzymes, which subsequently would directly participate in the process of synthesis of substances for the formation of sprouts.

We observed the increased germination activity in the examined samples compared to control, which indicates the possibility of using the solutions of fruit acids in order to intensify the process of receiving legume crop sprouts. This trend is registered for all investigated crops. Fruit acids intensify the germination process to a different degree but the effect of the increased energy and germination capability is observed in all legumes. That allows us to argue about the positive dynamics of the influence of the selected intensifiers on the technological process of obtaining the sprouts of legumes.

It was established during the research that the use of solutions of fruit acids in the process of legume germination makes it possible to obtain a high-quality grain product in shorter periods, as evidenced by the increase in the energy and germination capability.

Our monitoring of the length and controlling the weight of the legume sprout biomass have also shown a positive result (Table 2), namely, the more intensive development of sprouts in all legumes when using solutions of fruit acids during steeping. The number of sprouts (biomass), when using fruit acids as an intensifier, is given in Table 3. The results testify to that the biomass of sprouts increases, when using fruit acids, from 1 to 12 %, depending on the crop, so the proposed intensive technology to produce sprouts would make it possible to receive a larger amount of the biologically active grain raw materials, a component of new food products.

Our study of the microbiological condition of sprouts showed that the more pronounced disinfectant capability of fruit acids was better demonstrated in the samples whose concentration of fruit acids was higher (Table 4). This is explained by that the acidic environment negatively affects those pathogenic microorganisms that sit on the surface of legumes and their sprouts and can inhibit their activity and reproduction.

A decrease in the microbiological contamination of sprouts enhances their nutritional quality and prolongs their storage duration, which is an important aspect of industrial production.

By investigating the chemical composition of legume sprouts, one can note that the sprouts obtained when using fruit acids are characterized by the higher content of protein, easily digestible carbohydrates, mineral substances, free fatty acids, which makes them especially valuable for human nutrition. All these components play an important role in the formation of sprouts, so the more active the process of germination the more components are involved in it.

The change in the vitamin composition (Table 5) is explained by the activation of all biological processes in grains that are sprouted as there is a new plant formation. The increased content of most amino acids, compared to a control sample, by 3–50 % (Table 6), is explained by the more intensive development of sprouts at which the accumulation of amino acids proceeds much more active since they take part in the formation of a would-be plant.

The use of fruit acids in the process of legume germination will not have any restrictions because the represented acids are non-toxic. Our study of the chemical composition of the sprouts produced positive results because their composition includes the amino acid and vitamin complexes that could significantly improve the composition of food products whose components include the obtained sprouts.

The reported study could form the basis for the launch of a new direction of the grain processing industry, namely, the industrial production of sprouted cereal crops.

The current research would be advanced by applying a biologically active component (sprouts) in the formulations for various food products, as well as by studying the composition of the food products to be made. The technology of legume germination aimed to obtain sprouts could be recommended for implementing at grain processing enterprises. Receiving a high-quality legume sprout biomass would make it possible to produce foods from them with the elevated content of biologically active components.

The technology for obtaining sprouts from legume crops using the aqueous solutions of citric, malic, and grape acids is environmentally safe and effective, so a given technology could be widely implemented in the food and grain processing industries. The main disadvantage of this research could be the reproducibility of experiments because the important factor is to use the high-quality grain material, preferably with a shelf life of not more than a year, as it may affect the quality indicators of the legume sprouts.

Implementing the study results in the industrial production of legume sprouts could make it possible to reduce the technological process by 1.5–2 times because it involves the effective germination intensifiers, fruit acids. Another important aspect of industrial production is the improvement of the microbiological condition of sprouts, which would help prolong the shelf life of the finished product. It is recommended that fresh legume sprouts should be stored chilled, crushed if necessary, depending on technological needs. For long-term storage, it is desirable that the sprouts of legumes should be exposed to lyophilic drying and packaged in air-tight bags, in order to prevent their additional contact with wet air.

Since the proposed fruit acids, when compared with other similar stimulants, have a relatively low price, their use in the technological process would almost not affect the cost of the finished product. In addition, the cost would be affected positively by obtaining the increased number of sprouts and reducing the duration of the production process, as well as by the enhanced biological and nutritional value of the finished product, which is an important aspect of the innovative technology for making a biologically active component of foodstuffs.

The proposed innovative technology is of special practical value in terms of the chemical purity of the finished product. Since fruit acids are natural in origin, their specified concentrations are completely safe for the consumer.

The finished product (the legume sprouts obtained by using an innovative technology) is recommended for industrial production: various dairy products, meat and fish minced meats, ready-made vegetable salads, multicomponent fillers for various semi-finished products, mixed with vegetables, and as a biologically active component for many other foodstuffs.

7. Conclusions

1. We have studied the indicators of legume germination when using the solutions of fruit acids: the energy of germination increased by 4–7 %; the germination capability – by 5–8 %.

2. Monitoring the length of the sprouts has shown that the length increased by 3 to 11 mm. Controlling the weight of the sprout has also produced positive results, namely, the weight of the sprout increased by 1 to 12 %, depending on the crop.

3. Our study of the microbiological condition has demonstrated a stable disinfectant action of fruit acids solutions.

4. The study of the chemical composition of sprouts has shown that they are the biologically active food components because the amino acid composition increased by 3–50 %, depending on the amino acid. The sprouts revealed the following vitamins: B_1, B_2, B_3, B_6, B_{12}, PP, E, C, A. The legume sprouts also demonstrated the high content of protein (32.12 %), extractive substances (43.58 %), which makes them particularly valuable for human nutrition. One can argue about the biological and nutritional value of sprouts obtained using intensive technology.

References

1. Safronova, T., Evtuhova, O. (2014). Development of Technological Parameters for the Hydrotermal Processing of Sprouted Wheat Grain Powder. Foods and Raw Materials, 2 (1), 47–50. doi: https://doi.org/10.12737/4132
2. Shastol'skaya, N. D., Shastol'skiy, V. V. (2000). Pat. No. 2000117496 RF. Sposob prigotovleniya pishchevyh produktov. MPK7 A23 L1/172. A01 S1/02. No. 2000117496/13; declareted: 05.07.2000; published: 10.08.2002.
3. Hübner, F., Arendt, E. K. (2013). Germination of Cereal Grains as a Way to Improve the Nutritional Value: A Review. Critical Reviews in Food Science and Nutrition, 53 (8), 853–861. doi: https://doi.org/10.1080/10408398.2011.562060
4. Myachikova, N. I., Binkovskaya, O. V., Chizhova, S. V., Rudycheva, E. V. (2012). Use of germinated seeds in the foodstuff. Izvestiya vuzov. Prikladnaya himiya i biotehnologiya, 2 (3), 149–152.
5. Butenko, L. I., Legai, L. V. (2013). Researches of the chemical composition of germinated seeds of the buckwheat, oats, barley and wheat. Fundamental research, 4, 1128–1133.
6. Nikolaenko, O. Yu., Korchagin, V. P. (2007). Soevye prorostki i ih ispol'zovanie. Pishchevaya promyshlennost', 5, 36–37.
7. Agu, R. C., Devenny, D. L., Tillett, I. J. L., Palmer, G. H. (2002). Malting Performance of Normal Huskless and Acid-Dehusked Barley Samples. Journal of the Institute of Brewing, 108 (2), 215–220. doi: https://doi.org/10.1002/j.2050-0416.2002.tb00543.x
8. Pivovarov, O. A., Tyshchenko, H. P., Ponomarenko, Yu. V., Kovalova, O. S. (2013). Vplyv plazmokhimichno obroblenoi vody na protses roshchennia zhytnoho solodu i yoho yakisni pokaznyky. Kharchova nauka i tekhnolohiya, 3, 82–86.
9. Shishkova, Yu. S., Simonyan, E. V., Abramovskikh, O. S. et. al. (2014). The study of antimicrobial activity of some dibasic carboxylic acids in combination with propolis. Medical Almanac, 1 (31), 99–101.
10. Szwajgier, D., Pielecki, J., Targonski, Z. (2005). Changes of free ferulic and coumaric acid contents during malting of barley grain. Polish Journal of Food and Nutrition Sciences, 25 (2), 423–429.
11. Kitamura, Y., Yumoto, T., Yamada, K., Noshiro, A. (1990). The development of activated germination malting. Germany: Monatsschrift für Brauwiss, 372–376.
12. Pivovarov, O., Kovaliova, O., Khromenko, T., Shuliakevych, Z. (2017). Features of obtaining malt with use of aqueous solutions of organic acids. Food Science and Technology, 11 (4), 29–35. doi: https://doi.org/10.15673/fst.v11i4.728
13. Pivovarov, O., Kovaliova, O. (2019). Features of grain germination with the use of aqueous solutions of fruit acids. Food science and technology, 13 (1), 83–89. doi: https://doi.org/10.15673/fst.v13i1.1334
14. Chursinov, Y. A., Kovaleva, E. S. (2019). Application of organic acids and its mixtures as a stimulator of seed germination. Vestnik of the Russian agricultural science, 6, 31–34. doi: https://doi.org/10.30850/vrsn/2019/6/31-34
15. Khodunova, O. S., Silant`eva, L. A. (2017). Provision of microbiological safety of oat seed germination. Foods and Raw Materials, 5 (2), 145–150. doi: https://doi.org/10.21603/2308-4057-2017-2-145-150