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Research Article

Conditions for making plant dispersions based on nature-like technologies

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Abstract

An objective of this study was to examine the possible use of sprouted grains of domestically selected legumes to produce dairy alternative products. The paper presents the results of a comprehensive assessment of the food properties of 'Chishminskii 95', 'Chishminskii 229', 'Pamiati Hangildina', 'Iuldash' pea varieties and 'Nerussa', 'Lukeria', 'Omichka' bean varieties of Russian selection. The work investigated the water absorption kinetics under different temperature conditions and established germination patterns for a model medium (drinking water treated with an electromagnetic field) being as follows: germination temperature is 18 ± 2 °C; the soaking period lasts from 5 to 8 hours (depending on the variety); the germination time from 0.54 - 0.62 to 0.70 - 0.81 days (depending on the variety). The work analyses their microstructure and changes in the germination process. The proteolytic activity of bean trypsin before and after germination has been proved to be lower than that of peas. At the same time, the proteolytic activity of trypsin after pea and bean grain germination increased in all samples. The grain digestibility as a result of germination has increased; the ratio of essential and non-essential amino acids has changed in favor of the former; the fractional composition of protein has changed to higher content of albumin and globulin and lower level of glutelin. The results of this study indicate that the most suitable varieties to produce vegetable milk are 'Omichka', 'Lukeria' beans and 'Pamiati Hangildina' peas.

Keywords: beans; germination; peas; plant dispersion; vegetable milk

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Introduction

One of the main trends of the present time is a healthy lifestyle and healthy eating; functional plant-based foods and drinks being dairy alternatives are becoming increasingly popular. Legumes, especially beans and peas, are hardly used for their production, despite their high phytochemical potential.

One of the most effective ways to increase the biological value of plant raw materials, including the protein digestibility rate, is grain bioactivation resulting from its germination (EFSA Panel on Biological Hazards (BIOHAZ), 2011; European Sprouted Seeds Association, 2016; Mir *et al*., 2017; Treadwell *et al*., 2020). Bioactivation refers to the process of grain sprouting when enzymatic depolymerization occurs under the effect of moisture saturation, heat and oxygen (Sagar *et al*., 2018). Usually, the germination process lasts 20-36 hours. During the first 20 hours, the enzymes have time to be activated while the organic substrates have not been consumed out, and pathogenic microflora is minimal.

After getting swollen, grains quickly restore their metabolic activity, including remobilization, degradation and accumulation, resulting in biochemical, physical, nutritional and sensory changes in food products (Bewley, 1997; Dziki *et al*., 2015). Seed coats become softened; metabolic activity and gene transcription are initiated, the walls of embryonic cells get relaxed, and organelle reassembly and biogenesis (Logan *et al*., 2001). The emerging primary and secondary metabolites of sprouted grain have an increased physiological effect on human health compared to non-sprouted grain (Gan *et al*., 2019; Gioia and Renna, 2017).

Genotype, species, genus and variety, climatic conditions of cultivation (Shewry *et al*., 2010), technological parameters of hydrothermal action (soaking) and germination, including temperature (Guo *et al*., 2016; Oh and Rajashekar, 2009; Świeca and Baraniak, 2014) and the qualitative composition of the solvent, largely determine the germination period (Koneva, 2017; Samofalova and Safronova, 2017), sprouting energy and property, microbiological, biochemical, physical-technological, etc. indicators. Data from several sources have identified the increased γ-aminobutyric acid in wheat and barley (Youn *et al*., 2011), enlarged anthocyanins in buckwheat, especially in epidermal cells that remove ROS and lower the osmotic potential of cells (Nagata *et al*., 2003).

Legumes also produce useful secondary compounds, many of which have properties beneficial for human health (Duranti, 2006). In addition, the symbiotic relationship with nitrogen-fixing bacteria and mycorrhizal fungi makes them a valuable source of nitrogen for other crops (Gepts *et al*., 2005).

Natural biologically active anti alimentary substances as phytates, lectins, condensed tannins, trypsin and α-amylase inhibitors, urease are known to significantly reduce the nutritional value of legume proteins, making their use difficult. There are many practices, methods and processing technologies for reducing the activity of anti-alimentary substances (Valueva and Mosolov, 1995). Sprouting is the simplest and most available way to increase the digestibility of cereal and legume grains. Applying the germination process cuts the content of anti-alimentary substances and increases the phytochemical potential of the grain (Shaskolsky and Shaskolskaya, 2007).

The use of sprouting bioprocess can improve the biological value of legumes and thereby expand the raw material base to produce functional beverages and new plant-based food products for the fast-growing sector of dairy alternatives (Egoshin *et al*., 2018; Yelchibayeva *et al.*, 2021). Plant-based drinks can serve as an alternative medicine for lactose intolerance and heart diseases. As Lancet magazine claims, most adults (about 65-70% of the world's population) suffer from lactose intolerance (Storhaug *et al*., 2017).

A growing body of domestic and foreign literature is devoted to developing production technologies for the "dairy alternatives" sector (Kundu *et al*., 2018). Thus, soy milk, one of the most consumed in this segment, contains proteins with different ratios of βCG and glycine, having different nutritional and physiological effects (Clarke, J. Wiseman, 2000; Poysa *et al*., 2006; Singh *et al*., 2014; Wang *et al*., 2021). The digestibility of soy proteins can be increased by deactivating trypsin inhibitors during heat treatment (Yuan and Chang, 2007).

Currently, dairy alternatives are produced from soy. Far too little attention has been paid to products from legumes like peas and beans, and no previous study has investigated barley being a promising cereal crop for the industry. This indicates a need to identify the most suitable varieties for producing dairy alternatives by conducting a systematic, comprehensive assessment of pea and bean varieties of domestic selection.

Materials and Methods

Protein digestibility was determined by treating the product sample with a hydrochloric acid solution of pepsin and keeping it in a thermostat at 42-45 °C for 16 hours under methodological guidelines for assessing the fodder quality and nutritional value (Central Research Institute Agrochemical Services for Agriculture, 2002). The resulting suspension was then filtrated, centrifugated and examined to determine the weight of the residual sample fraction non-hydrolyzed by pepsin M_1.

The digestibility of protein concentrate (X_1), %, was calculated by the equation (1):

$$X_1 = 100 \bullet (1 - \frac{M_1}{m}) \quad (1)$$

where M_1 is the weight of the residual sample fraction non-hydrolyzed by pepsin, g; m is the sample weight taken for testing, g.

The protein fraction composition was found by the Osborn method; the protein content and individual protein fractions were determined by burning extracts, followed by Kjeldahl nitrogen determination (Russian state standard GOST 10846-91, 1991).

The seed coat content was examined by soaking samples in hot distilled water, followed by removing the seed coats, drying them to a constant weight, weighing and calculating their percentage to the weight of unbroken seeds (Russian State Standard GOST 10843-76, 1976).

To assess the grain suitability for germination, its sprouting energy and property were detected (Russian state standard GOST 10968-88, 1988). The proportion of sprouted pea grains was found based on the instructions for the techno-chemical control in brewing production (Ministry of Agriculture of the Russian Federation, 1991). To do this, 100 grains were germinated four times on wet filter paper in Petri dishes in a thermostat at 19.5 ° C. Counting and removal of sprouted grains was carried out after 24 (N_{24}), 48 (N_{48}) and 72 (N_{72}) hours of germination. Grains were considered sprouted when their embryo roots emerged. The proportion of sprouted grains (D) was determined by the equation (2) (Narciss, 2007; Russian state standard GOST 10968-88, 1988; Russian state standard GOST 12039-82, 1982):

$$D = \frac{(N_{24} + N_{48} + N_{72})}{400} \bullet 100\ \% \quad (2)$$

where N_{24} is the number of grains sprouted after 24 hours; N_{48} is the number of grains sprouted after 48 hours; N_{72} is the number of grains sprouted after 72 hours.

The average germination time (T_{av}) was determined by the equation (3):

$$T_{av} = \frac{(N_{24} + 2 \cdot N_{48} + 3 \cdot N_{72})}{(N_{24} + N_{48} + N_{72})} \cdot 100\% \quad (3)$$

The sprouting index (I_{spr}) was calculated by the equation (4):

$$I_{spr} = \frac{10}{?N_{av}} \quad (4)$$

The grain microstructure and the seed coat thickness were analyzed using a Micromed 3-20M scanning microscope with real-time image output to a PC screen using a video eyepiece. The magnification of the microscope was 1600 times.

The active acidity (pH) of the studied varieties was determined by the potentiometric method using a Mettler Toledo SevenGo pH meter with a measurement error of 0.01 pH units. The samples were analyzed in three-fold repetition, with an accuracy of 0.01 pH units.

The weight of 1000 grains was found by the weight method (Russian state standard GOST 10842-89, 1989).

The proteases hydrolyzing N, a-benzoyl-DL-arginine-paranitroanilide (BAPNA, Sigma, USA) were determined by the Erlanger method with modifications (Solomintsev and Mogilny, 2009). The activity of the enzyme was expressed in optical units (arbitrary units of enzymatic activity, E).

The enzyme activity was expressed in optical unites (conditional units of enzyme activity, E). The activity of trypsin inhibitors was determined by the Hoffman-Weisblay method with modifications. The analysis was carried out similarly to the assessment of enzymatic activity; the buffer solution contained 1 mg/ml of trypsin.

To make a reliable evaluation of the proteolytic activity of enzymes, the samples were subjected to temperature exposure at $t = 60$ °C τ=20 min, to denature their enzymes, given that the total proteolytic activity is the total effect of proteolysis of the set of enzymes contained in the studied objects.

The urease activity was measured in pH units on a pH meter. The calculation was based on a phosphate buffer solution pH = 6.86, which changes due to the urease action on the urea contained in the solution (Russian state standard GOST 13979.9-69, 1969).

The amino-acid composition of pea and bean protein was determined in the scientific and educational centre (research laboratory) of the Kemerovo State University with a Kapel-105 M analyzer using the Kapel capillary electrophoresis system (Russian state standard GOST 31480 – 2012, 2012).

The content of water-soluble vitamins was measured by the spectrophotometric method using the capillary electrophoresis system "Kapel-105/105M" with subsequent detection on the Shimadzu UV-1800 spectrophotometer at the Scientific and Educational Center of the Kemerovo State University (Trineeva *et al.*, 2017).

The results of experimental studies were subjected to statistical processing by parametric methods using standard MS Excel software Packages. Experiments had five replications as required by methods of statistical analysis.

Two temperature conditions were investigated to optimize the soaking parameters; these were 14 ± 2˚C (ordinary soaking) and 18 ± 2˚C (warm soaking). Trial No. 1 used a solvent model medium, drinking water of a centralized potable water supply system treated with an electromagnetic field of 15 mT induction (Table 1). Water was treated in an experimental laboratory installation of a solenoid type. The installation scheme is shown in Figure 1.

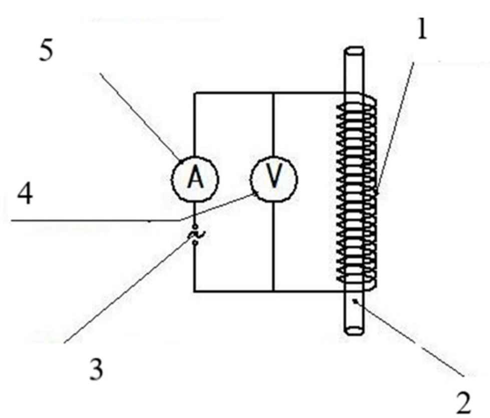


Figure 1. Scheme of experimental laboratory installation: 1 – coil; 2- glass tube; 3 – AC power source; 4 – voltmeter; 5 – ammeter

Table 1. Comparing qualitative indicators of the model environment

Indicator	Unit of measure	Model environments*		
		Control No. 1	Control No. 2	Trial No. 1
		Characteristic		
The hydrogen index	unit pH	7.60	7.82	8.02
Total hardness	degree of hardness	2.19	2.14	2.00
Alkalinity	mmol/dm ^{3}	1.85	1.66	1.56
Residual active chlorine (total content of free and bound chlorine)	mg/dm ^{3}	0.90	0.79	0.78
Turbidity	mg/dm ^{3}	< 0.58		
Total microbial count	CFU/1cm ^{3}	Not detected		
Total coliforms	CFU/100 mm ^{3}	Not detected		
Thermotolerant coliform bacteria	CFU/100 mm ^{3}	Not detected		

*Control No. 1 - drinking water of the centralized potable water supply system;
Control No. 2 - drinking water of a centralized potable water supply system, standing for 24 hours at a temperature of 10 ± 2 °C

The studied pea and bean samples were hydrothermally treated (soaked) in a ratio (1:3) and kept in contact with solvents; the samples were kept there up to 16 hours (with water being replaced every 60 minutes to avoid grain contamination). Seeds were soaked in a model medium in thermostatically controlled cells at two temperature conditions: 14 ± 2 °C and 18 ± 2 °C. The experiment was carried out in three replications.

The experiment determined the minimum hydrothermal treatment (soaking) time when legume grains reached the maximum swelling and size enlargement (Butavin *et al*., 2019; Pankina and Borisova, 2016).

The quantitative measure of swelling (swelling degree) was found by the weighting method by the degree of swelling (α) from the equation (5):

$$\alpha = \frac{M_\tau + M_0}{M_0} \quad (5)$$

α is the swelling degree during hydrothermal treatment (soaking);

M_τ is the grain weight of the studied pea and bean varieties during hydrothermal treatment (soaking), g;

M_0 is the grain weight of the studied pea and bean varieties before hydrothermal treatment (soaking), g.

Grain geometric characteristics (length (L), thickness (B), width (A) of peas and beans were measured using a calliper. 100 grains of each variety were taken for the measurements. The radius, arithmetic mean and geometric mean diameters, spherical shape, volume and area of the outer surface of the grains, the aspect ratio of the bean grains were calculated by standard equations (Danko, 2020; Kydyraliev, 2015).

The arithmetic mean grain diameter was calculated by the equation (6):

$$D_{ar} = \frac{L+B+A}{3} \quad (6)$$

The geometric mean grain diameter was found by the equation (7):

$$D_g = \frac{L \cdot B \cdot A}{3} \quad (7)$$

where L is the length (mm), B is the thickness (mm), A is the width (mm).

The bean grain sphericity (Bn), in %, was measured by the equation (8).

$$\mathrm{Bn} = \frac{(\mathrm{L \cdot B \cdot A})^{1/3}}{\mathrm{L}} \cdot 100\% \quad (8)$$

The bean grain surface area (S), in mm^2, was determined by the equation (9):

$$S = \pi \cdot D_g^2 \quad (9)$$

The aspect ratio of bean grains (R_a), in %, was found using the equation (10):

$$R_a = \frac{100 \cdot A}{L} \quad (10)$$

The pea grain sphericity (ψ) was determined by the equation (11):

$$? a = \frac{Fsph}{Fg} \quad (11)$$

where Fsph is the surface area of the equivoluminar sphere;
Fg is the area of the outer surface of the grain.
The sphere surface area was determined by the equation (12):

$$Fsph = 4 \cdot \pi r_v^2 \quad (12)$$

where V is the volume of a single grain;
r_v is the radius calculated by the equation (13):

$$r_v = 0.62\sqrt[3]{V} \quad (13)$$

The area of the outer surface of the grain was measured by the equation (14)

$$F_g - 0.35 \cdot (A + B + L) \quad (14)$$

The grain volume was determined by the equation (15):

$$V = k \cdot A \cdot B \cdot L \quad (15)$$

where k is a coefficient that considers the grain shape specifics (Apostolov *et al.*, 2002).

Seeds were sprouted in the original experimental device "Smart Sprouter "Rosinka", manufactured in the Omsk State Agrarian University, named after PA Stolypin. It is based on aeroponics technology (Algazin *et al.*, 2016; Algazin *et al.*, 2017). The installation can simulate a nature-like environment for sprouting legume grains based on automated germination programs (Rybchenko *et al.*, 2022; Zolotov *et al.*, 2022). The technological algorithm of the experiment was as follows. Seeds of the studied crops and varieties were placed on trays and subjected to hydrothermal treatment (soaking) under the established regime. Then the trays were placed into a sprouting container having fixed supports, impenetrable walls, a mesh bottom and a lid. Water vapour (aerosol) is supplied by an ultrasonic steam generator with automatic humidity control from 40 to 90%, which breaks water into fine dust and mixes it with air. As a result, seeds absorb moisture uniformly, and the air is enriched with oxygen. There are humidity and temperature sensors. Infrared emitters maintain the temperature and provide additional seed irradiation that warms seeds and biostimulates the germination process.

Results

Tables 2 and 3 show the morphometric characteristics of pea and bean grains.

All the studied pea varieties had a bright yellow colour with cotyledons translucent through the seed coat. The 'Iuldash' pea variety demonstrated pronounced varietal differences. Its grain is smaller; the minimum weight of 1000 grains and the weight of 1000 grains on a dry-matter basis are 241.8 g; 216.7 g, respectively; it has the highest seed coat content, 9.85%, with a coat thickness of 0.2 microns. The 'Pamiati Hangildina' pea variety had the minimum seed coat content of 8.89% with a coat thickness of 0.2 microns and the maximum actual weight of 1000 grains and 1000 grains on a dry-matter basis 348.9 g; 314.3 g, respectively. The seed uniformity of all studied pea varieties is over 80%, except the 'Iuldash' pea variety (the average value is 77.66%).

Table 2. Morphometric characteristics of pea grain selected in the Bashkir Agricultural Research Institute

Pea variety name	Geometric dimensions			
	Average geometric diameter (D_g), mm	Radius (r), mm	Grain volume (V), mm^3	Grain external surface area (F_3), mm^2
2017 harvest				
'Chishminskii 95'	4.93	2.46	63.00	73.17
'Chishminskii 229'	6.33	3.23	141.92	125.75
'Pamiati Hangildina'	4.93	2.52	67.20	79.80
'Iuldash'	5.00	2.29	50.40	65.87
2018 harvest				
'Chishminskii 95'	5.00	2.29	50.40	65.87
'Chishminskii 229'	6.10	3.11	126.87	116.69
'Pamiati Hangildina'	5.33	2.71	84.00	88.64
'Iuldash'	4.84	2.32	52.92	65.14
2019 harvest				
'Chishminskii 95'	5.13	2.62	75.68	82.69
'Chishminskii 229'	6.16	3.14	131.04	119.23
'Pamiati Hangildina'	5.33	2.71	84.00	88.64
'Iuldash'	5.00	2.29	50.40	65.87

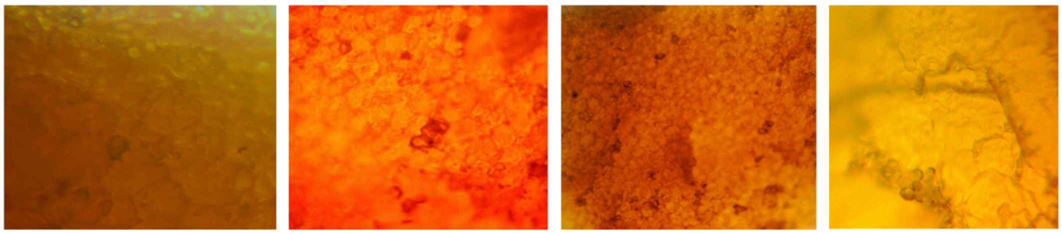
Table 3. Morphometric characteristics of bean grain selected in the Omsk State Agrarian University

	Geometric dimensions							
Name of the bean variety	Length (L), mm	Width (A), mm	Thickness (B), mm	Aspect Ratio (R_a), %	Arithmetic mean diameter (D_{ar}), mm	Average geometric diameter (D_g), mm	Sphericity (F), %	Surface area (S), mm^2
1	2	3	4	5	6	7	8	9
2017 harvest								
'Omichka'	11.00	7.00	6.00	63.63	8.00	7.73	70.00	187.65
'Lukeria'	12.00	6.00	6.00	50.00	8.00	7.75	62.00	179.44
'Nerussa'	8.00	6.00	5.00	75.00	6.33	6.21	77.00	121.26
2018 harvest								
'Omichka'	12.00	7.00	6.50	58.33	8.50	8.17	68.00	209.76
'Lukeria'	12.00	6.50	5.00	54.16	7.83	7.30	60.00	167.61
'Nerussa'	9.00	5.00	7.00	55.55	7.00	6.80	75.00	145.36
2019 harvest								
'Omichka'	12.00	9.00	8.00	75.00	9.66	9.52	79.00	284.84
'Lukeria'	11.00	7.00	8.00	63.63	8.66	8.50	77.30	227.32
'Nerussa'	8.00	6.00	5.00	75.00	6.33	6.21	77.60	11.26

The 'Nerussa' bean grain is white, not large, with uniform linear dimensions (the length is less than 10 mm) compared to the 'Omichka' bean grain (white with grey strokes) and 'Lukeria' (black). The main grain fraction of the 'Omichka' and 'Lukeria' bean varieties is represented by a large grain with a spherical shape from 60.00 to 79.00% and a length from 11 to 12 mm. One unanticipated finding was that the 'Lukeria' and 'Omichka' bean grain is larger (but contains the smallest seed coat content of 10.21; 8.87%, respectively. The maximum value of this indicator of 11.01% was found in the 'Nerussa' variety.

The pea and bean grains of all the studied legumes, except the 'Iuldash' pea variety, had a uniform, soft consistency. They were easily chewed and preserved the seed coat by the time they had sprouted. The 'Pamiati Hangildina' peas and the 'Omichka' beans showed the minimum cooking time. The best taste qualities were found in the 'Pamiati Hangildina' peas (4.8 points), 'Chishminskii 95' and 'Chishminskii 229' (4.5 points) and 'Omichka' (4.5 points), 'Lukeria' beans (4.3 points).

The grain microstructure of all varieties was also studied (Figures 2 and 3). The endosperm sections clearly show differences in structure.



a b c d

Figure 2. Pea grain microstructure: a – 'Chishminskii 95'; b – 'Chishminskii 229'; c – 'Pamiati Hangildina'; d – 'Iuldash'

a b c

Figure 3. Bean grain microstructure: a – 'Omichka'; b – 'Lukeria'; c – 'Nerussa'

Starch granules of 'Iuldash' peas and 'Nerussa' beans are loosely bound to the protein matrix, collected in complex combinations. It is due to the low protein content, insufficient to develop a continuous matrix structure. As a result, the protein has the form of granules. Cotyledons of 'Chishminskii 229' peas, 'Omichka' beans variety, are characterized by a loose microstructure, a fragile connection of starch granules with a protein matrix; most granules do not have protein interlayers. Grains of 'Chishminskii 95', 'Pamiati Hangildina' peas, and 'Lukeria' beans have a developed protein matrix with clearly spaced starch granules. The starch granules of the studied varieties have different shapes, sizes of the protein matrix and starch grains (Table 4). This difference was observed in soaking and germination patterns.

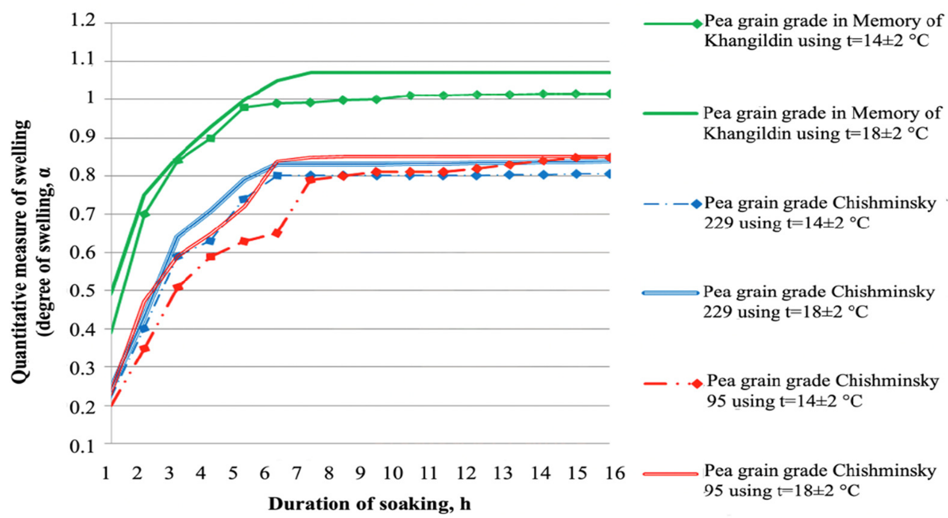
Table 4. Characteristics of starch granules of grain of the studied varieties

Indicator name	Grain characteristics						
	‘Chishminskii 95’ ‘variety	‘Chishminskii 229’ 'variety	‘Pamiati Hangildina’ variety	‘Iuldash’ variety	‘Omichka’ 'variety	‘Lukeria’ variety	‘Nerussa’ variety
The shape of starch grains	Oval, large-oval and round-oval	Oval, large-oval and round-oval	Large-oval and round-oval	Round - oval	Oval, round-oval	Oval, round-oval	Round and round-oval
The main fraction of starch grains	Small	Small	Small	Small	Small	Medium and small	Small
Average size, mcm	5×8	5×7	6×7	4×7	4×5	6×9	3×5

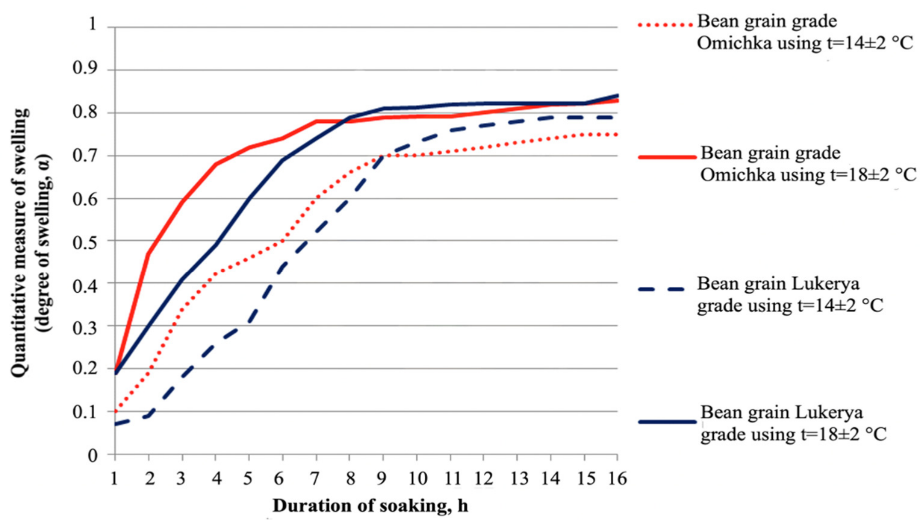
Magnetic water treatment is an alternative to ion exchange, and its ease of use makes it an affordable, cost-effective, environmentally friendly technology (Alexandrov *et al*., 2017; Krasnova, 2018). The magnetic processing efficacy and practicality have been proven in dairy production technology (Fialkov and Kirgintseva, 2011; Fialkov and Kostyuchenko, 2012).

The cumulative evidence was used to analyze ‘Lukeria’ and ‘Omichka’ beans, ‘Pamiati Hangildina’, ‘Chishminskii 95’ and ‘229’ peas. Grains were soaked in a model medium (trial No. 1); their characteristics are given in Table 1.

The results of soaking at two temperature conditions: 14 ± 2 °C and 18 ± 2 °C are shown in Figure 4.



a



b

Figure 4. The dynamics of water absorption when using a model medium (trial No. 1) at a temperature of 14 ±2 ° C and 18 ±2 ° C: a – pea breeding varieties of Bashkir Agricultural Research Institute; b – bean breeding varieties of Omsk State Agrarian University

The qualitative hydrochemical composition of the model medium affects the soaking time. In addition, there are apparent varietal differences between pea and bean varieties resulting from different phytochemical potential and morphometric characteristics, the seed coat thickness ('Lukeria' bean variety (10.21%), 'Omichka' (8.87%), 'Chishminskii 95' (9.61%) and 'Chishminskii 229' (9.72%), 'Pamiati Hangildina' (8.89%) affecting the solvent penetration power.

Using standard mathematical methods, regression equations and the R-squared value for the kinetic curves of hydrothermal treatment (soaking) of the studied legume varieties at a temperature of 14 ±2 °C and 18 ±2 °C were calculated (Table 5). Soaking time (X) ranged from 1 hour to 16 hours.

Table 5. Regression equation and R-squared value

Crop name	Regression equation	Determination coefficient
t = 14±2 ˚C		
Peas, 'Chishminskii 95' variety	y = 0.2434ln(x) + 0.2296	R^2 = 0.9574
Peas, 'Chishminskii 229' variety	y = 0.2028ln(x) + 0.3237	R^2 = 0.8529
Peas, 'Pamiati Hangildina' variety	y = 0.2261ln(x) + 0.5277	R^2 = 0.9142
Beans, 'Omichka' variety	y = 0.2626ln(x) + 0.0637	R^2 = 0.9741
Beans, 'Lukeria' variety	y = 0.3308ln(x) – 0.0978	R^2 = 0.9238
t = 18±2 ˚C		
Peas, 'Chishminskii 95' variety	y = 0.2164ln(x) + 0.336	R^2 = 0.8819
Peas, 'Chishminskii 229' variety	y = 0.201ln(x) + 0.3633	R^2 = 0.8307
Peas, 'Pamiati Hangildina' variety	y = 0.2134ln(x) + 0.6037	R^2 = 0.8924
Beans, 'Omichka' variety	y = 0.2025ln(x) + 0.3247	R^2 = 0.8887
Beans, 'Lukeria' variety	y = 0.2622ln(x) + 0.1712	R^2 = 0.9505

As a result of a comprehensive analysis of the results obtained, the conditions for hydrothermal treatment (soaking) were determined, recommended for further use in the germination process:

When using a temperature regime of 18 ±2 °C, the soaking time for 'Chishminskii 95', 'Chishminskii 229' pea grains is 6 hours, for 'Pamiati Hangildina' is 5 hours; the soaking time for 'Omichka' beans is 7 hours, for 'Lukeria' - 8 hours, it is 1 hour less than at an identical temperature regime and model media of control No. 1, control No. 2 (Table 1).

Further studies showed that the maximum number of sprouted pea grains of 'Chishminskii 95', 'Chishminskii 229', 'Pamiati Hangildina' is 98.75%, the germination index is from 16.13 to 18.51, the minimum average germination time is from – 0.54 to 0.62 days; the maximum number of sprouted bean grains of 'Omichka' and 'Lukeria' is 98.75%, the germination index is from 12.34 to 14.28, the minimum average germination time is from 0.70 to 0.81 days were observed when using the model medium (trial No.1).

The endosperm microstructure of the studied varieties was compared before and after germination. The changes are visible in Figures 5 and 6.

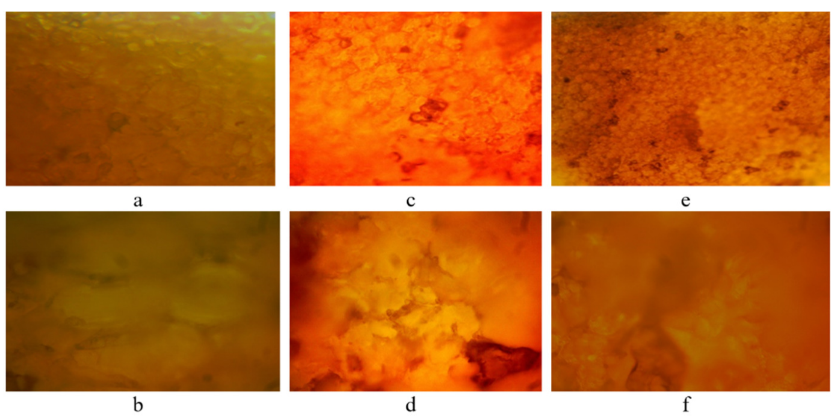


Figure 5. Photo of the grain microstructure of pea varieties selected by Bashkir Agricultural Research Institute: a – 'Chishminskii 95' before germination; b – 'Chishminskii 95' after germination; c – 'Chishminskii 229' before germination; d – 'Chishminskii 229' after germination; e – 'Pamiati Hangildina' 'before germination; f – 'Pamiati Hangildina' after germination.

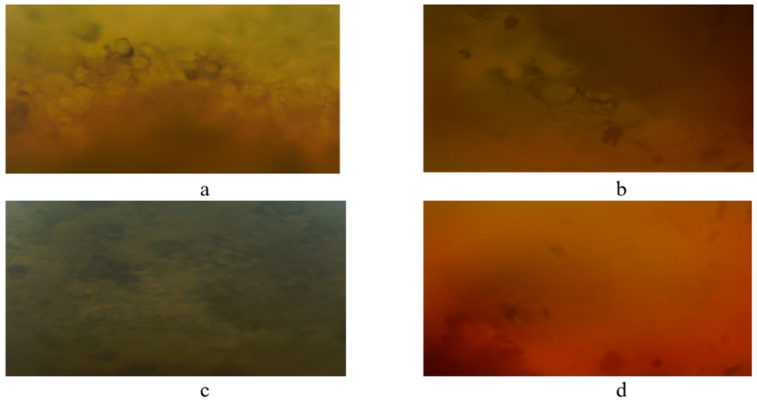


Figure 6. Photos of the bean grain microstructure: a – 'Omichka' before germination; b – 'Omichka' after germination; c – 'Lukeria' before germination; d – 'Lukeria' after germination

There is visible disintegration of starch grains due to the diverse swelling of biopolymers.

Changes in proteolytic activity as a result of germination were also studied. The data in Table 6 indicate differences between the samples (Russian state standard GOST 13979.9-69, 1969).

Table 6. Proteolytic (enzymatic) activity of breeding varieties of beans and peas (harvest 2017-2019) before and after germination

Bean grain variety	Proteolytic activity of unheated samples, E		Proteolytic activity of trypsin, E		Proteolytic activity, own proteases, E	
	Grain at rest	Germinated grain	Grain at rest	Germinated grain	Grain at rest	Germinated grain
2017 harvest						
'Chishminskii 95'	212 ± 4.8	256 ± 3.2	127 ± 6.4	179 ± 7.2	85 ± 6.4	77 ± 7.2
'Chishminskii 229'	200 ± 5.6	230 ± 4.8	120 ± 7.2	175 ± 4.8	80 ± 7.2	55 ± 6.4
'Pamiati Hangildina'	242 ± 4.0	258 ± 6.4	169 ± 4.8	207 ± 4.8	73 ± 4.8	51 ± 6.4
'Omichka'	188 ± 8.1	196 ± 5.6	113 ± 4.2	140 ± 7.2	75 ± 4.2	56 ± 7.2
'Lukeria'	165 ± 10.5	182 ± 5.6	93 ± 7.2	131 ± 7.2	72 ± 7.2	51 ± 5.6
2018 harvest						
'Chishminskii 95'	222 ± 3.2	255 ± 4.0	135 ± 7.2	181 ± 4.8	87 ± 7.2	74 ± 4.8
'Chishminskii 229'	202 ± 5.6	235 ± 4.8	110 ± 7.2	165 ± 4.8	92 ± 7.2	70 ± 6.4
'Pamiati Hangildina'	233 ± 4.8	242 ± 4.8	161 ± 6.4	192 ± 6.4	72 ± 6.4	50 ± 6.4
'Omichka'	196 ± 8.1	205 ± 5.6	111 ± 3.2	138 ± 3.2	85 ± 3.2	67 ± 5.6
'Lukeria'	166 ± 9.7	190 ± 5.6	98 ± 3.2	143 ± 7.2	68 ± 3.2	47 ± 7.2
2019 harvest						
'Chishminskii 95'	239 ± 9.7	261 ± 6.4	141 ± 3.2	180 ± 5.4	98 ± 3.2	81 ± 6.4
Chishminskii 229'	198 ± 3.2	219 ± 5.6	105±7.2	151 ± 7.2	93 ± 7.2	68 ± 7.2
'Pamiati Hangildina'	240 ± 7.2	250 ± 5.6	170 ± 4.0	200 ± 7.2	70 ± 4.0	50 ± 7.2
'Omichka'	184 ± 9.7	199 ± 6.4	111 ± 3.2	142 ± 5.6	73 ± 3.2	57 ± 6.4
'Lukeria'	190 ± 9.7	228 ± 5.0	100 ± 3.2	158 ± 7.2	90 ± 3.2	70 ± 7.2

Studies of the proteolytic activity of grains in the presence of trypsin showed that the proteolytic activity of trypsin in the studied varieties of peas is higher than in the bean grain. Considering that the value of the proteolytic activity of trypsin in the studied varieties depends on the suppressive activity of their inhibitors, it can be concluded: the higher the value of the proteolytic activity of trypsin in the studied varieties, the lower the inhibitory activity.

When summarizing the results of proteolytic (enzymatic) activity of bean and pea breeding varieties before and after germination, it was found that the proteolytic activity of trypsin in bean grains was lower compared to pea grain samples both dormant (native) and germinated. This indicates a higher inhibitory activity of both sprouted and native grains of the studied bean varieties compared to pea grain.

The proteolytic activity of trypsin at the pea and bean grain germination increases on average by 19.76 – 46.42% and by 26.12 – 48.45%, respectively. The activity of its own proteases weakens.

The results of the urease activity analysis of the studied pea and bean varieties before and after germination indicate that bean grains have a very low content of less than 0.01 pH while it is absent in all the pea varieties.

As a result of germination, the protein digestibility increases (Table 7) due to the transformations of nitrogenous substances.

Table 7. Digestibility of pea and bean grains of the studied varieties before and after germination

	Digestible protein, %	
	Before germination	After germination
Peas, ‘Chishminskii 95’ variety	30.32	35.98
Peas, ‘Chishminskii 229’ variety	25.99	30.87
Peas, ‘Pamiati Hangildina’ variety	32.48	37.23
Beans, ‘Omichka’ variety	28.96	30.37
Beans, ‘Lukeria’ variety	19.48	27.62

‘Pamiati Hangildina’ peas and ‘Omichka’ beans had the maximum digestibility value both before and after germination.

A decrease in the content of fat, carbohydrates, and dietary fibre proteins indicates structural changes in the cell (Table 8).

Table 8. Nutritional value of sprouted grain, on the example of ‘Pamiati Hangildina’ peas and ‘Lukeria’ beans

Indicator name	Sprouted grain	
	Peas, ‘Pamiati Hangildina’ variety	Beans, ‘Lukeria’ variety
Weight ratio, %		
moisture	46.00 ± 1.18	47.00 ± 1.37
protein	27.10 ± 0.70	25.60 ± 0.80
carbohydrates	34.30 ± 2.65	39.07 ± 2.90
fat,	1.00 ± 0.06	0.85 ± 0.09
Hydrogen ion activity, pH	6.52 ± 0.02	6.52 ± 0.02
Vitamins		
vitamin B 1 (thiamine), mg/kg	23.51 ± 3.53	100.77 ± 1.61
vitamin B 2 (riboflavin), mg/kg	607.03 ± 91.05	408.11 ± 61.22
vitamin B 6 (pyridoxine), mg/kg	3.24 ± 0.49	1.59 ± 0.29
vitamin A, %	(0.55±0.11) ×10-4	(0.10±0.02) ×10-4
vitamin C, mg%	2.8	2.7

Considering the increased proteolytic activity of proteases in the germination process (Table 5), the legume protein is broken down to amino acids and becomes easily digestible, the content of amino acids increases.

A comparative analysis of the grain amino acid composition before and after germination is given in Table 9.

Table 9. Comparative amino-acid analysis of the pea grain selected in the Bashkir Agricultural Research Institute and beans of the Omsk State Agricultural University selection (harvest 2017-2019) before and after sprouting

Amino-acid name	Beans, 'Lukeria' variety		Peas, 'Pamiati Hangildina' variety	
	Before sprouting	After sprouting	Before sprouting	After sprouting
	Content, %			
Valine	0.114	0.450	0.236	0.710
Phenylalanine	0.300	0.400	0.200	0.690
Isoleucine Leucine	0.311	0.810	0.196	0.950
Lysine	0.340	0.440	0.301	0.840

Sprouting leads to a change in the concentration of individual amino acids relative to the total protein. It should be noted that the ratio of essential and non-essential amino acids changes in favour of the former. Thus, the relative concentration of lysine for beans and peas increases by 1.3 and 2.8 times (respectively), isoleucine-leucine by 2.6; 4.8 (respectively), phenylalanine by 1.3; 3.4 (respectively), valine by 3.9, 3.0 (respectively).

The fractional composition of the protein has also changed (Table 10).

Table 10. Change in the fractional composition of protein before and after sprouting

Name of the crop and variety	Protein fractions, % before sprouting	Protein fractions, % after sprouting
Albumine		
Peas, 'Chishminskii 95' variety	3.85	4.19
Peas, 'Chishminskii 229' variety	3.85	4.19
Peas, 'Pamiati Hangildina'	3.42	3.73
Beans, 'Omichka' variety	3.15	3.43
Beans, 'Lukeria' variety	5.60	6.10
Globulin		
Peas, 'Chishminskii 95' variety	17.50	20.73
Peas, 'Chishminskii 229' variety	17.30	20.51
Peas, 'Pamiati Hangildina'	18.75	22.21
Beans, 'Omichka' variety	20,00	23.70
Beans, 'Lukeria' variety	15,00	17.77
Glutelin		
'Chishminskii 95'	0.85	0.53
'Chishminskii 229'	0.82	0.51
'Pamiati Hangildina'	0.85	0.53
Beans, 'Omichka' variety	0.44	0.27
Beans, 'Lukeria' variety	0.43	0.27

Albumin and globulin fractions have increased while the gluten fraction has reduced. The research findings convincingly show the structural changes in the grain of legumes due to germination, expressed in the higher protein availability and the increased phytochemical potential of legumes. In addition, the specific bean flavour, not always acceptable to potential consumers, practically disappears. It makes sprouted pea and bean grains advisable to use in the production of vegetable milk and other products of the dairy alternative's segment.

Discussion

The production of vegetable milk is based on water extraction, widely used in beverage production not only from legumes, but also from cereals, oilseeds and nuts with varying degrees of particle dispersion.

The technological process of producing vegetable milk from sprouted grain of the studied varieties consisted of a number of sequential operations (compilation of a hydromodule (sprouted grain: water), grinding and dispersing, extraction and filtration) (Veber *et al*., 2021).

The physico-chemical characteristics of vegetable milk from sprouted grain of the studied varieties according to the developed technology are given in Table 11, organoleptic indicators are presented in Table 12.

Table 11. Physico-chemical parameters of vegetable milk

Name of the crop and variety	Mass fraction of fat, %	Mass fraction of protein, %	Mass fraction of carbohydrates, %	pH, units activity
Peas				
'Chishminskii 95'	0.50 ± 0.03	3.0 ± 0.1	4.6 ± 0.8	6.87± 0.02
'Chishminskii 229'	0.50 ± 0.03	3.0 ± 0.1	4.6 ± 0.7	6.85± 0.02
'Pamiati Hangildina'	0.50 ± 0.03	3.2 ± 0.1	4.6 ± 0.5	6.89± 0.02
Beans				
'Omichka'	0.50 ± 0.03	3.2 ± 0.1	4.0 ± 0.4	6.60 ± 0.02
'Lukeria'	0.50 ± 0.03	3.0 ± 0.1	4.2 ± 0.5	6.59 ± 0.02

All samples had consumer characteristics within the limits of organoleptic acceptability.

Table 12. Organoleptic indicators of vegetable milk

<table>
<tr><th rowspan="4">Name of indicator</th><th colspan="4">Vegetable dispersion from germinated grain studied varieties</th></tr>
<tr><th>'Chishminskii 95'
'Chishminskii 229'</th><th>'Pamiati Hangildina'</th><th>'Omichka'</th><th>'Lukeria'</th></tr>
<tr><th>Experienced sample no. 1, no. 2</th><th>Experienced sample no. 3</th><th>Experienced sample no. 4</th><th>Experienced sample no. 5</th></tr>
<tr><th colspan="4">Characteristic</th></tr>
<tr><td>Appearance and texture</td><td colspan="4">Fluid, homogeneous, non-viscous, no perceptible solid particles</td></tr>
<tr><td>Taste and smell</td><td>The taste is pleasant, sweetish with a malty aftertaste.</td><td>The taste is clean, sweetish, pleasant, malty, slightly grassy.</td><td>The taste is clean, sweetish, slightly pronounced bean smell and aroma, grassy</td><td>The taste is sweetish, pronounced bean smell and aroma.</td></tr>
<tr><td>Color</td><td colspan="2">Pleasant, uniform throughout the mass of pale yellow.</td><td>White with a grayish tint.</td><td>Gray color with black tint.</td></tr>
</table>

A comparative analysis of the physico-chemical characteristics of vegetable milk with traditional products (pasteurized skimmed milk. 0.05 % fat and soy milk, 1.0% fat) revealed that vegetable milk, for example, made from sprouted peas of the 'Pamiati Hangildina' variety and beans of the 'Omichka' variety is superior (to pasteurized skimmed milk, 0.05% fat and soy milk, 1.0% fat) 1.2 and 1.6 times, respectively, in terms of protein content; 1.6 and 1.1 times, respectively, in terms of dietary fiber content. The developed dispersions in comparison with soy milk are characterized by a reduced caloric content of 1.26 – 1.35 times and have no significant difference in this indicator in comparison with pasteurized skim milk. It should be noted that the developed vegetable milk contains no allergens, GMOs and trans-isomers of fatty acids.

Conclusions

Summarizing the results obtained, it can be concluded that the proposed method of bean and pea soaking and germination can be successfully used for the vegetable milk production from peas and beans within the dairy alternatives' segment.

Thus, the findings on sprouting conditions for beans and peas of new breeding varieties and the biochemical changes occurring during the germination process provide evidence that dispersions based on sprouted grains of the studied crops can be used to make "dairy alternatives". Vegetable milk, having increased nutritional value and useful consumer properties can be used in the production of vega ice cream, fermented beverages, tofu (Patent No. 2782858, 2017), as well as in baking and to get products significantly superior in nutritional value to traditional ones.

Authors' Contributions

Conceptualization: SL, AV and OK; Data curation: EB; Formal analysis: MZ; Funding acquisition: SL; Investigation: AV; Methodology: OK; Project administration: EB; Resources: MZ; Software: SL; Supervision: AV; Validation: OK; Visualization: EB; Writing - original draft: SL; Writing - review and editing: AV. All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

References

Alexandrov BL, Alexandrov AB, Krasavtsev BE, Simkin VB, Tsaturyan AS (2017). Experimental and theoretical substantiation of the electromagnetic field effect on water. Polythematic Network Electronic Scientific Journal of the Kuban State Agrarian University 131(07):1-11. *www.biophys.ru/archive/congress2012/proc-p1-d.pdf*

Algazin DN, Vorobiev DA, Zabudskii AI, Zabudskaia EA (2016). Grain germination device (Pat. No. 152611 Russian Federation PMK A01S 1/02). Moscow, The applicant and the patent holder P.A. Stolypin OmGAU.

Algazin DN, Vorobyev DA, Zabudsky AI, Danniker AA, Falkovich LL (2017). Smart sprouter "Rosinka". Electronic Scientific and Methodological Journal of Omsk State Agrarian University 1(8). Retrieved 2021 July 12 from: *https://e-journal.omgau.ru/images/issues/2017/1/00283.pdf*

Apostolov SA, Babash SE, Belkina EI (2002). The new reference book of chemists and technologists. Raw materials and industrial products of organic and inorganic substances. St. Petersburg, ANCO NGO "Mir i semia".

Bewley JD (1997). Seed germination and dormancy. The Plant Cell 9(7):1055-1066. *https://doi.org/10.1105/tpc.9.7.1055*

Butavin NYu, Khalyapina YaM, Smirnova TI (2019). Seed swelling in a magnetic field. Bulletin of the Tver State University, Biology and Ecology 13:80-84.

Central Research Institute Agrochemical Services for Agriculture (2002). Methodological guidelines for assessing the fodder quality and nutritional value. Moscow, Ministry of Agriculture of the Russian Federation.

Clarke EJ, Wiseman J (2000). Developments in plant breeding for improved nutritional quality of soya beans I. Protein and amino acid content. The Journal of Agricultural Science 134(2):111-124. *https://doi.org/10.1017/S0021859699007431*

Danko I (2020). Physico-chemical and geometric characteristics of grain. All About Grain. Retrieved 2021 July 12 from: *https://visacon.ru/svoystva-zerna/2318-fiziko-himicheskaya-i-geometricheskaya-harakteristika-zerna.html*

Di Gioia F, Renna M, Santamaria P (2017). Sprouts, microgreens and "baby leaf" vegetables. In: Minimally processed refrigerated fruits and vegetables. Boston, MA, Springer, pp 403-432.

Duranti M (2006). Grain legume proteins and nutraceutical properties. Fitoterapia 77(2):67-82.

Dziki D, Gawlik-Dziki U, Kordowska-Wiater M, Domań-Pytka M (2015). Influence of elicitation and germination conditions on biological activity of wheat sprouts. Journal of Chemistry 2015:649709. *https://doi.org/10.1155/2015/649709*

EFSA Panel on Biological Hazards (BIOHAZ) (2011). Scientific opinion on the risk posed by Shiga toxin-producing *Escherichia coli* (STEC) and other pathogenic bacteria in seeds and sprouted seeds. EFSA Journal 9(11):2424. *https://doi.org/10.2903/j.efsa.2011.2424*

Egoshin VL, Ivanov SV, Savvina NV, Kapanova GZh, Grjibovski AM (2018) Basic principles of biomedical data analysis in R. Ekologiya Cheloveka (Human Ecology) 7:55-64.

European Sprouted Seeds Association (2016). ESSA Hygiene Guideline for the Production of Sprouts and Seeds for Sprouting. Brussels, Belgium, ESSA.

Fialkov DM, Kirgintseva PV (2011). On electromagnetic processing of milk. In Prospects of new generation food production: collected materials of the IV International Scientific Practical Conference dedicated to the 80th anniversary of the Faculty of Dairy Products Technology. Omsk, Omsk State Agrarian University, pp 161-162.

Fialkov DM, Kostyuchenko NV (2012). The effect of electromagnetic processing on the milk protein properties. In: Youth science and agriculture: problems and prospects: proceedings of the V All-Russian Scientific and Practical Conference of Young Scientists. Ufa, Bashkir State Agrarian University, pp 130-132.

Gan RY, Chan CL, Yang QQ, Li HB, Zhang D, Ge YY, Gunaratne A, Ge J, Corke H (2019). Bioactive compounds and beneficial functions of sprouted grains. In: Feng H, Nemzer B, DeVries JV (Eds). Sprouted Grains. St. Paul, MN, USA, AACC International Press, pp 191-246.

Gepts P, Beavis WD, Brummer EC, Shoemaker RC, Stalker HT, Weeden NF, Young ND (2005). Legumes as a model plant family. Genomics for food and feed report of the cross-legume advances through genomics conference. Plant Physiology 137(4):1228-1235. *https://doi.org/10.1104/pp.105.060871*

Guo L, Yang R, Zhou Y, Gu Z (2016). Heat and hypoxia stresses enhance the accumulation of aliphatic glucosinolates and sulforaphane in broccoli sprouts. European Food Research and Technology 242(1):107-116. *https://doi.org/10.1007/s00217-015-2522-y*

Koneva MS (2017). Technology development and evaluation of consumer properties of smoothies enriched with products from sprouted wheat grain. Diss. Cand. Technical Sciences. Kuban, Kuban State Technological University, pp 172.

Krasnova TA (2018). Water treatment in the food industry. Methods and Technology of Food Production 48(1):15-30. *https://doi.org/10.21603/2074-9414-2018-1-15-30.Y*

Kundu P, Dhankhar J, Sharma A (2018). Development of nondairy milk alternative using soymilk and almond milk. Current Research in Nutrition and Food Science Journal 6(1):203-210. *http://dx.doi.org/10.12944/CRNFSJ.6.1.23*

Kydyraliev NA (2015). Study of geometric parameters of some bean grain varieties grown in Kyrgyzstan, before and after hydrothermal treatment. Technique and Technology of Food Production 39(4):35-42.

Logan DC, Millar AH, Sweetlove LJ, Hill SA, Leaver CJ (2001). Mitochondrial biogenesis during germination in maize embryos. Plant Physiology 125(2):662-672. *https://doi.org/10.1104/pp.125.2.662*

Ministry of Agriculture of the Russian Federation (1991). Instructions for techno-chemical control of brewing production, scientific and production association of beverages and mineral waters. Moscow.

Mir SA, Shah MA, Mir MM (2017). Microgreens: Production, shelf life, and bioactive components. Critical Reviews in Food Science and Nutrition 57(12):2730-2736. *https://doi.org/10.1080/10408398.2016.1144557*

Nagata T, Todoriki S, Masumizu T, Suda I, Furuta S, Du Z, Kikuchi S (2003). Levels of active oxygen species are controlled by ascorbic acid and anthocyanin in Arabidopsis. Journal of Agricultural and Food Chemistry 51(10):2992-2999. *https://doi.org/10.1021/jf026179*+

Narciss L (2007) Brewing: malting technology. (7th ed.). St. Petersburg, Professia Publ. (Translated from the German).

Oh MM, Rajashekar CB (2009). Antioxidant content of edible sprouts: effects of environmental shocks. Journal of the Science of Food and Agriculture 89(13):2221-2227. *https://doi.org/10.1002/jsfa.3711*

Pankina IA, Borisova LM (2016). Investigation of swelling and solubility of dry substances of leguminous seeds. Processes and Equipment for Food Production. Research Institute of Precision Mechanics and Optics 2:3-20.

Patent No. 2782858. (2017). RF, MPK A23 S 20/02, A23 S 20/00, A23 J 1/14. A method for producing a bean product as tofu cheese. Applicant and patent holder the Omsk State Agrarian University, applied on 27.10.2021; Bulletin No. 31.

Poysa V, Woodrow L, Yu K (2006). Effect of soy protein subunit composition on tofu quality. Food Research International 39(3):309-317. *https://doi.org/10.1016/j.foodres.2005.08.003*

Russian state standard GOST 10842-89 (1989). Grain of cereals and legumes and seeds of oilseeds. Cereals, pulses and oilseeds. Method for determination of 1000 kernels or seeds weight. (USSR State Committee for Product Quality Management and Standards No. 4039). Moscow, Interstate Council for Standardization, Metrology and Certification.

Russian state standard GOST 10843-76 (1976). Grain. Method for determination of filmness. (USSR No. 74). Moscow, State Committee of Standards of the Council of Ministers of the USSR.

Russian state standard GOST 10846-91 (1991). Grain and products of its processing. Method for determination of protein (USSR No. 1995). Moscow, Committee for Standardization and Metrology of the USSR.

Russian state standard GOST 10968-88 (1988). Grain. Methods for determination of germinating energy and germinating property. (USSR No. 371 1988-07-01). Moscow, Ministry of Bread Products of the USSR.

Russian state standard GOST 12039-82 (1982). Seeds of farm crops. Methods for determination of viability (USSR No. 2331). Moscow, USSR State Committee on Standards.

Russian state standard GOST 13979.9-69 (1969). Oilcakes and outmeals. Measurement of urease activity (USSR No. 204). Moscow, Committee of standards, measures and measuring instruments of the Council of Ministers of the USSR.

Russian state standard GOST 31480 – 2012 (2012). Mixed fodders, raw mixed fodders. Determination of aminoacids (lysine, methionine, threonine, cysteine and tryptophan) content by method of capillary electrophoresis. (Federal

Agency for Technical Regulation and Metrology No. 465-st). Open Joint Stock Company "All-Russian Research Institute of the Feed Industry", the Scientific and Production Company of analytical Instrumentation "Lumex", the Federal State Institution "Leningrad Interregional Veterinary Laboratory".

Rybchenko OI, Suslov VV, Kedik SA, Domnina YuM, Mogaibo AI (2022) Flow dispersion for obtaining ivermectin encapsulated in polycaprolactone microparticles. Drug & Development Registration 11(2):79-86. *https://doi.org/10.33380/2305-2066-2022-11-2-79-86*

Sagar NA, Pareek S, Sharma S, Yahia EM, Lobo MG (2018). Fruit and vegetable waste: Bioactive compounds, their extraction, and possible utilization. Comprehensive Reviews in Food Science and Food Safety 17(3):512-531. *https://doi.org/10.1111/1541-4337.12330*

Samofalova LA, Safronova OV (2017). Methodological approaches to germinate crop seeds and teste successful sprouting. Leguminous and Cereal Crops 3(23):68-74.

Shaskolsky V, Shaskolskaya N (2007). Antioxidant activity of germinating seeds. Bread Products 8:58-59.

Shewry PR, Piironen V, Lampi A-M, Edelmann M, Kariluoto S, Nurmi T, … Ward JL (2010). The HEALTHGRAIN wheat diversity screen: Effects of genotype and environment on phytochemicals and dietary fiber components. Journal of Agricultural and Food Chemistry 58(17):9291-9298. *https://doi.org/10.1021/jf100039b*

Singh BP, Vij S, Hati S (2014). Functional significance of bioactive peptides derived from soybean. Peptides 54:171-179. *https://doi.org/10.1016/j.peptides.2014.01.022*

Solomintsev MV, Mogilny MP (2009). Determining the activity of proteolytic enzyme inhibitors in food products. Bulletin of Universities. Food Technology 1:13-16.

Storhaug CL, Fosse SK, Fadnes LT (2017). Country, regional, and global estimates for lactose malabsorption in adults: a systematic review and meta-analysis. The Lancet Gastroenterology & Hepatology 2(10):738-746. *https://doi.org/10.1016/S2468-1253(17)30154-1*

Świeca M, Baraniak B (2014). Influence of elicitation with H2O2 on phenolics content, antioxidant potential and nutritional quality of Lens culinaris sprouts. Journal of the Science of Food and Agriculture 94(3):489-496. *https://doi.org/10.1002/jsfa.6274*

Treadwell D, Hochmuth R, Landrum L, Laughlin W (2020). Microgreens: A New Specialty Crop. Institute of Food and Agricultural Sciences, University of Florida, HS1164. Retrieved 2022 July 12 from: http: //eco-library.theplanetfixer.org/docs/microgreens/microgreens-a-new-specialty-crop.pdf

Trineeva OV, Rudaya MA, Slivkin AI (2017). Defining B-group vitamins in medicinal plant raw materials (using the example of sea buckthorn fruits and stinging nettle leaves). Bulletin of VSU, Chemistry. Biology. Pharmacy 3:131-134.

Valueva TA, Mosolov VV (1995). Proteins-inhibitors of proteolytic enzymes in plants. Applied Biochemistry and Microbiology 31(6):579-589.

Veber AL, Leonova SA, Zhiarno M (2021). Patent No. 2783686, RF, MPK A23 S 11/10, A23 S 11/00, A23 J 1/14. Method of making vegetable milk; applicant and patent holder the Omsk State Agrarian University. Applied on 04.10.2021; issued on 15.11.22. Bulletin No. 32.

Wang X, Ye A, Dave A, Singh H (2021). In vitro digestion of soymilk using a human gastric simulator: Impact of structural changes on kinetics of release of proteins and lipids. Food Hydrocolloids 111:106235. *https://doi.org/10.1016/j.foodhyd.2020.106235*

Yelchibayeva A, Ryskulova AG, Baimuratova M, Kapanova G, Sharipova G, Maksutova A (2021) Analysis of financial and economic aspects of company functioning and their influence on the tourist cluster. Journal of Environmental Management and Tourism 12(8):2157-2167.

Youn YS, Park JK, Jang HD, Rhee YW (2011). Sequential hydration with anaerobic and heat treatment increases GABA (γ-aminobutyric acid) content in wheat. Food Chemistry 129(4):1631-1635. *https://doi.org/10.1016/j.foodchem.2011.06.020*

Yuan SH, Chang SKC (2007). Selected odor compounds in cooked soymilk as affected by soybean materials and direct steam injection. Journal of Food Science 72(7):S481-S486. *https://doi.org/10.1111/j.1750-3841.2007.00461.x*

Zolotov SA, Demina NB, Ponomarev ES, Dain IA, Zolotova AS (2022) Study of the technological methods effect on dissolution of the X-ray amorphous Efavirenz-mesoporous carrier system. Drug & Development Registration 11(3):84-89. *https://doi.org/10.33380/2305-2066-2022-11-3-84-89*