Agronomy Research **18**(S3), 1804–1815, 2020
https://doi.org/10.15159/AR.20.067

Low-fat high-protein fermented milk product with oat extract as a nature stabilizer

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Abstract. Nowadays, the use of plant components in terms of their pronounced functional properties is of high relevance. Oat extract contains gums, β-glucans, vitamins (A, B1, B5, B9, PP, H), minerals (Fe, I, K, Si, Mn, Cu, Mo, etc.) and essential amino acids. It has been proven that a long-term use of β-glucans showed the reduction of the risk of cardiovascular disease and diabetes and the regulation of cholesterol and blood sugar. B-glucans also have immunoprotective, anti-inflammatory, antimicrobial, prebiotic effects and improve intestinal motility. The aim of study was to develop the technology of low-fat high-protein fermented milk product with functional characteristics. Oat extract was used as a natural stabilizer and a source of β-glucans. Maceration technique was used for the extraction. The recommended extraction parameters were established and physicochemical characteristics of the extract were studied. The recommended doses of oat extract when introduced into milk and the optimal heat treatment conditions of the milk-oat mixture were determined. The influence of temperature on the gel-forming properties of oat extract was investigated. The effect of oat extract on rheological behavior, water-holding ability and shelf life of the finished product was studied. Regular consumption of lactic acid microorganisms has a positive effect on the digestive system and metabolism. Based on the organoleptic characteristics and physicochemical changes during the fermentation process in comparison with the control sample (without oat extract), the recommended starter culture combinations (*Lactobacillus acidophilus*, *Lactococcus lactis subsp*, *Lactobacillus bulgaricus*) were proposed.

Key words: β-glucans, oat extract, fermented milk product.

INTRODUCTION

In the modern world, one of the main causes of death is cardiovascular disease. According to the WHO data, people of various socio–economic classes, age categories and gender are affected by this group of diseases.

Risk factors for cardiovascular disease can be represented as uncorrectable (which cannot be changed) and correctable. The first group includes gender, age, and heredity. It is proved that men are more likely to suffer from cardiovascular diseases and for the first time, symptoms are detected at a younger age than women. However, with age, the risk of developing cardiovascular disease increases in both sexes. People with predisposing heredity are most susceptible to cardiovascular disease. This fact cannot be changed, and in this case, it is necessary to develop an individual program of preventive

measures. Separately, diabetes can be identified as the cause of cardiovascular disease. Correctable factors include mainly dyslepidermia (a violation of the level of cholesterol and or triglycerides in the blood plasma), hypertension (high systolic pressure syndrome), smoking, decreased physical activity, overweight, psychological stress, etc. these factors are determined by a person's lifestyle, his social adaptability, and the level of organization of informing the population about the need for disease prevention at the state level (Krulev, 2008; Oganov & Maslennikova, 2017).

From the point of view of the food industry, the use of functional nutrition can be positioned as a way to implement the WHO health policy 'Health 2020' and considered as a means of reducing the risk of CVD.

The aim of this work was to study the effect of oat extract on consumer and technological properties of a dairy product with desired properties.

Fermented dairy products are popular among the population of different countries in view of their unique organoleptic characteristics and the positive effect exerted on the state of the body, in particular, on the organs of the gastrointestinal tract. As a rule, it is typical for functional nutrition to use probiotic strains of microorganisms as a starter culture (*Streptococcus thermophilus*). Probiotics affect not only the intestinal microflora, but also the musculoskeletal system, the normalization of mineral–ion metabolism and the absorption of vitamins (Winkler et al., 2005; Katharina et al., 2007; Scholz-Ahrens, 2007; Kolsoom et al., 2013).

Mass consumption of fermented milk products is the main reason why the developed product was fermented.

In order to optimize resource conservation in this work, skim milk was used as the basis for a dairy product.

Oat extract was chosen as a functional ingredient, which was also a natural stabilizer and a source of β-glucans and gum.

Whey protein concentrate was used to increase the biological value of the product.

Oat extract is a homogeneous viscous liquid, light brown in color with a gray tint, obtained by aqueous extraction (maceration). In view of the fact, that mainly polysaccharide components (β-glucans and arabinoxylans) pass into the aqueous phase during extraction, during heat treatment (85 °C) followed by cooling, gel formation is observed, the strength of which depends on the dry matter content in the extract. Repeated studies prove the content of β-glucans in oat extract (Sangwan et al., 2014).

β-glucans or 1,3:1,4- β-D glucans are specific water-soluble high molecular weight polymers of glucose with glycosidic bonds, which help to lower cholesterol (Kusmiati & Dhewantara, 2016), triglycerides and glucose in the blood, contribute to weight loss, have oncoprotective (Yoona, 2013), antimicrobial, immunomodulatory properties (Wood, 2007; Novak, 2008).

Such physiological effects are explained by the fact that when it enters the gastrointestinal tract, the viscosity of the natural environment of the colon and its contents increases at the time of digestion of food. The resulting mucus makes it difficult to assimilate nutrients, mainly carbohydrates, cholesterol, bile acids and their derivatives (Khoury, 2011; Nwachukwu et al., 2015).

The whey protein concentrate has valuable functional characteristics, high nutritional value, in comparison with casein, which is explained by a high content of sulfur-containing amino acids and essential amino acids (isoleucine, tryptophan, lysine,

tyrosine). Using WPC gives certain technological properties to the product, in view of the good hydrophilic and lipophilic properties (Ertaş et al., 2015).

MATERIALS AND METHODS

Skimmed milk powder (manufactured by Bob's Red Mill, U.S.A.) was used as a raw material. Recovery was carried out based on the protein content of 3% reduced skim milk. For this, the required amount of milk powder was hydrated with filtered tap water at a temperature of 40 ± 2 °C with continuous stirring until the dry residue was completely dissolved on an IKA EUROSTAR 20 digital mixer (1,000 rpm) and left for 2 hours to swell the protein component. The reconstituted milk was filtered through a fabric filter.

Milk preparation

Whey protein concentrate is added to the restored skim milk t = 37 ± 2 °C to a protein content of 6% with constant stirring until it is completely dissolved.

In order to prevent protein coagulation during heat treatment, a mixture of citric and pyrophosphoric salts was used in an amount of 0.6 g per 1,000 g of the mixture (0.03%).

The milk protein mixture was subjected to heat treatment at a temperature of 76 ± 2 °C with a holding time of 15 min, followed by cooling and storage on demand at a temperature of 4 ± 2 °C.

Preparation of oat extract

To obtain oat extract, oat bran was used in accordance with GOST 21149-93. Extraction was carried out by maceration at temperatures of 20, 30 and 40 °C. The hydraulic module was determined empirically in the range of 1:1–1:10. The end time of the extraction was determined by the dry matter content, which was determined by the arbitration method.

Before extraction, oatmeal was preliminarily subjected to autoclaving at a temperature of 121 ± 2 °C for 10 min in order to prevent side enzymatic processes caused by the presence of extraneous microflora (yeast, mold, etc.)

Preparation of milk-oat mix

At the temperature of 37 ± 2 °C, oat extract was added to the prepared milk protein mixture in an amount of 20%. The determination of the amount applied depended on the organoleptic and thixotropic properties of the finished product.

The milk-oat mixture was pasteurized at t = 87 ± 2 °C with a holding time of 30 seconds. The pasteurization mode is due to the ability of the oat extract to gel and the final structural and mechanical properties of the finished product.

The percentage of introduced starter culture was determined empirically in relation to the process of acid accumulation over time in the range of 3–5% in increments of 1%.

METHODS

Method for the determination of solids in oat extract

The determination of solids was carried out by drying to constant weight at a temperature of 105 ± 2 °C in an oven with forced air circulation according to GOST 3626-73.

Method for the determination of β-glucans

The content of β-glucans in oat extract was determined in accordance with GOST R 57513-2017. The method is based on the enzymatic hydrolysis of β-glucan using lichenase and β-glucanosidase enzymes to gluco-oligosaccharides and glucose, respectively. Hydrolyzed β-glucan is determined by the colorimetric method according to the degree of staining of glucose molecules with a glucose oxidase reagent at a wavelength of 510 nm compared to a control sample of glucose.

Method for determination of protein in oat extract

Protein determination in oat extract was carried out using a Shimadzu UV-1800 spectrophotometer at a wavelength of 280 nm. The method is based on the ability of proteins to absorb light in the ultraviolet region due to the presence of aromatic amino groups (mainly tyrosine and tryptophan) according to OFS.1.2.3.0012.15.

Method for determination of active and titratable acidity

pH values were measured using a pH-410 pH meter with a combined glass electrode (Research and Production Association TECHNOKOM, Russia).

Acidity was determined by titration in accordance with the AOAC method 947.05 (AOAC, 2007).

Method for determining water retention capacity

The water holding capacity was determined by centrifugation at 1,000 rpm. 10 mL of the fermented product was subjected to centrifugal treatment for 30 minutes. The amount of serum excreted was evaluated every 5 minutes. A fermented milk-protein mixture without oat extract was taken as a control sample.

Method for determining thixotropic properties

Thixotropic properties were measured using a Rheotest 2 rotational viscometer (RHEOTEST, Germany). The measurement was carried out after ripening after cooling to 4 ± 2 °C with a shear rate range from 1.00 to 437.4 min^{-1}. To achieve a homogeneous consistency, the samples were subjected to 10-fold mixing.

The ability to recover was estimated as the ratio of the initial effective viscosity of the experimental and control samples at the same selected velocity gradient to the effective viscosity after the relaxation time (15 min).

The ability to recover was estimated as a percentage by the formula:

$$B = \frac{n_p \cdot 100}{n_H} \quad (1)$$

where B – recovery ability, n_p – effective viscosity after relaxation for 15 minutes at a given speed gradien, $n_н$ – effective viscosity at the initial time with a given velocity gradient.

For this, the sample was sheared in a rotating ring, the readings of the device are taken every 15 seconds for 2 minutes. Then the sample is left alone for 15 min to restore coagulation bonds, after which the value of the restored structure was recorded.

The mechanical stability coefficient was calculated by the formula:

$$K = \frac{n_H}{n_p} \quad (2)$$

where K – mechanical stability coefficient, n_p – effective viscosity after relaxation for 15 minutes at a given speed gradien, $n_н$ – effective viscosity at the initial time with a given velocity gradient.

The coefficient of viscosity loss was calculated by the formula:

$$\Pi = \frac{(n_н - n_р) \cdot 100}{n_н} \quad (3)$$

where Π – viscosity loss coefficient, n_p – effective viscosity after relaxation for 15 minutes at a given speed gradien, $n_н$ – effective viscosity at the initial time with a given velocity gradient.

The method of determining the number of microorganisms

Streptococcus thermophilus were calculated according to GOST 33951-2016.

Method for assessing organoleptic properties

Assessment was carried out in accordance with GOST ISO 4121-2016 and GOST ISO 6658-2016.

The hedonic scale used for the assessment is summarized in Table 1.

Organoleptic indicators (taste, smell, texture, appearance, color) were evaluated by a group of tasters from 28 people of different age groups and in equal percentage by gender on a hedonic scale with a neutral desirability level of '0', 4 positive and 4 negative levels.

For the reliability of the sensory evaluation, the tasters rinsed the mouth with clean water after testing each sample to remove the residual taste and paused for 1–2 minutes.

Table 1. Hedonic scale for assessing the quality of products

Desirability Levels
1. Very desirable (+4)
2. Highly desirable (+3)
3. Middling (+2)
4. Unwanted (+1)
5. Neutral (0)
6. Slightly desirable (-1)
7. Middling (-2)
8. Highly Unwanted (-3)
9. Very unwanted (-4)

RESULTS

The solids content in the oat extract, depending on the hydromodule and the temperature of extraction (Table 2).

When using a hydraulic module 1:1–1:3, it is difficult to separate the extract due to the strong swelling of the bran and its increased viscosity. At an extraction temperature of 30 and 40 °C, enzymatic processes begin and the extract acquires an acidic taste and is unsuitable for further use due to the negative effect on the organoleptic properties of the finished product. When using hydraulic modules 1:6–1:10, the finished product acquired a watery consistency. The choice between extracts with a 1:5 and 1:4 hydromodule was based on the content of β-glucans, which were determined using a Shimadzu UV-1800 spectrophotometer.

The content of β-glucans in the oat extract with hydromodules 1:4 and 1:5 are shown in Table 3.

Table 2. The solids content in the oat extract with a hydromodules of 1:1–1:10

Hydromodules	The temperature of extraction, (°C)	Solids content, (%)
1:10	20	1.233 ± 0.006
	30	1.542 ± 0.032
	40	1.611 ± 0.012
1:9	20	2.354 ± 0.054
	30	2.442 ± 0.035
	40	2.645 ± 0.162
1:8	20	3.676 ± 0.055
	30	3.783 ± 0.024
	40	3.995 ± 0.087
1:7	20	4.132 ± 0.034
	30	4.787 ± 0.034
	40	4.945 ± 0.032
1:6	20	5.236 ± 0.034
	30	6.696 ± 0.052
	40	7.035 ± 0.062
1:5	20	8.312 ± 0.023
	30	8.967 ± 0.024
	40	9.225 ± 0.045
1:4	20	9.882 ± 0.081
	30	10.407 ± 0.022
	40	11.071 ± 0.065
1:3	20	12.277 ± 0.084
	30	13.132 ± 0.142
	40	13.797 ± 0.344
1:2	20	15.235 ± 0.141
	30	16.056 ± 0.062
	40	17.324 ± 0.044
1:1	20	17.565 ± 0.032
	30	17.832 ± 0.252
	40	18.024 ± 0.041

Table 3. The content of β-glucans in the studied samples

Hydromodules	Extraction temperature, (°C)	The content of β -glucans, (%)
1:4	20	4.74 ± 0.02
	30	5.02 ± 0.01
1:5	20	3.72 ± 0.03
	30	4.63 ± 0.01

According to the results of the experiment, an extract with a 1: 4 hydromodule obtained at a temperature of 20 °C was used for further studies.

The protein content in the oat extract with a 1:4 hydraulic module is 1.02 ± 0.02%

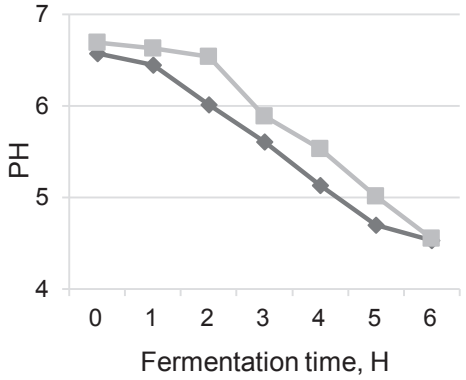

Figure 1. Changes in pH during fermentation: ■ – control sample, ◆ – sample with oat extract.

The dependence of the active and titratable acidity during the fermentation time is presented in Figs 1, 2.

The fermentation process was carried out until all samples reached pH = 4.55 and the titratable acidity was not lower than 65 °T. The control and prototypes reach the set values after 6 hours. In this case, the indications of active acidity do not differ significantly, therefore, oat extract does not inhibit the growth of starter microflora. It is worth noting that after 3 hours of fermentation, the consistency of the prototype changes. Compared to the control sample, it has a stronger casein gel, while the control remains liquid.

The percentage of introduced starter culture varied from 3 to 5% of the total weight of the fermented mixture. The leaven was previously activated in order to achieve a uniform distribution of the culture of microorganisms in the samples, as well as to reduce the time of adaptation of microorganisms to fermentation conditions. In all cases, the process of acid accumulation in the first 2 hours of fermentation proceeds slowly, which is probably due to the increased solids content in the samples. Changes in pH and titratable acidity are noticeable only 3 hours after the start of fermentation. In this case, the following relationship can be established: an increase in the concentration of starter culture for every 1% reduces the time of ripening by about 1 hour in both the control and the experimental sample. However, the presence of oat extract is not an inhibitory factor for the starter culture, but rather contributes to a more intensive fermentation process. The ripening time is not more than 6 hours subject to temperature conditions (Hurda, 2019). The percentage of leaven introduced was 3%.

Water retention studies are shown in Fig. 3.

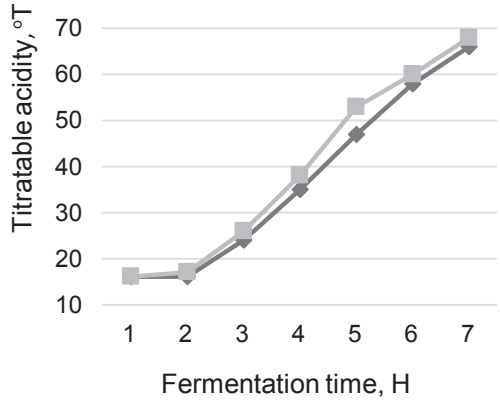

Figure 2. Changes in titratable acidity during fermentation: ◆ – sample with oat extract; ■ – control sample.

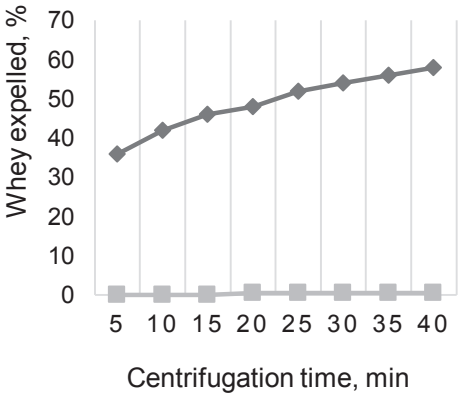

Figure 3. Water holding capacities of yogurt samples: ■ – sample with oat extract; ◆ – control sample.

In the experimental sample, the serum practically does not separate. After 30 minutes of centrifugation, the amount of serum released was 0.5 mL. The control sample was centrifuged until the amount of serum released stopped changing.

The thixotropic properties of the product characterize its ability to restore the structure after mechanical action and, accordingly, model the behavior of the fermented milk product when it is moved along production lines after the fermentation process. In production conditions, it is more profitable to use the reservoir method, but not every product is able to restore the coagulation structure after packaging. The use of stabilizers in this case of β-glucans increases the degree of structural restoration and improves the structural and mechanical characteristics of yogurt (Jingyuan et al., 2013).

Thixotropic properties are shown in Figs 4 and 5.

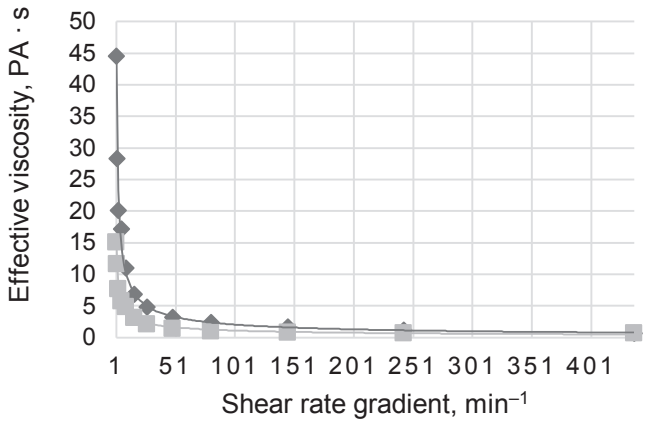

Figure 4. Dependence of the apparent viscosity of samples with oat extract on the shear rate at 4 °C.

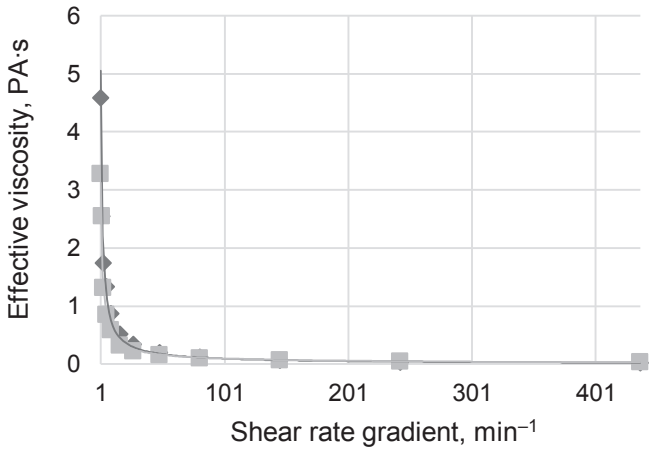

Figure 5. Dependence of the apparent viscosity of control samples on the shear rate at 4 °C.

Despite the fact that the area between the ascending and descending branches of the hesteresis loop in the control sample is smaller, the effective viscosity of the prototype is much higher.

Thixotropic characteristics are shown in Table 4.

Table 4. Thixotropic characteristics of the control and experimental samples

Significative	Value	
	development type	control sample
The ability of the coagulation structure to recover, (%)	90.44	85
Mechanical stability coefficient	1.11	1.18
Viscosity loss coefficient	9.56	15

The effective viscosity of the sample decreases over time with the same velocity gradient. Various parameters influence rheological properties: mass fraction of fat, solids content, properties of starter culture (viscous and inviscid strains), and the presence of stabilizers.

In this work, we used the starter culture produced by Danisco (France), which contains viscous strains and exopolysaccharide-producing strains, which affects the thixotropic and water-holding properties.

The hedonic scale is shown in Fig. 6.

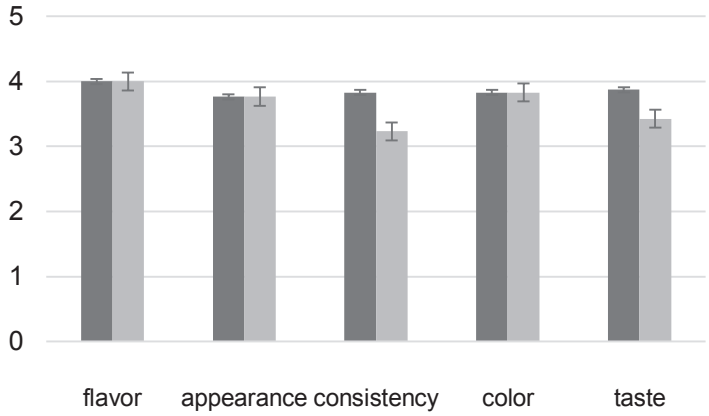

Figure 6. Hedonic scale for appearance and overall acceptability of the samples: ▫ – control sample. ■ – samples with oat extract.

The taste of the finished product was evaluated by a group of tasters as pleasant, sour-milk, with a slight aftertaste of oatmeal. There are no extraneous unpleasant tastes. By consistency, the finished product is homogeneous without impurities, the clot is elastic despite the fact that the product is low-fat, does not spread, during testing, the volume of the product in the container is not broken. After mixing, no separation of serum is observed, but the product acquires a stretching and viscous consistency, which does not cause negative opinions about it. The color is light beige.

Recommended technological scheme for producing fermented milk with oat extract (Fig. 9).

CONCLUSION

The effect of oat extract on consumer and technological properties of fermented skim milk product was investigated. The data obtained confirm that the use of the extract at a concentration of 20% does not adversely affect the organoleptic properties of the finished product, and also increases its rheological properties. Oat extract does not affect the development of microorganisms in the starter culture during fermentation. The extract has the greatest influence on the water-holding ability.

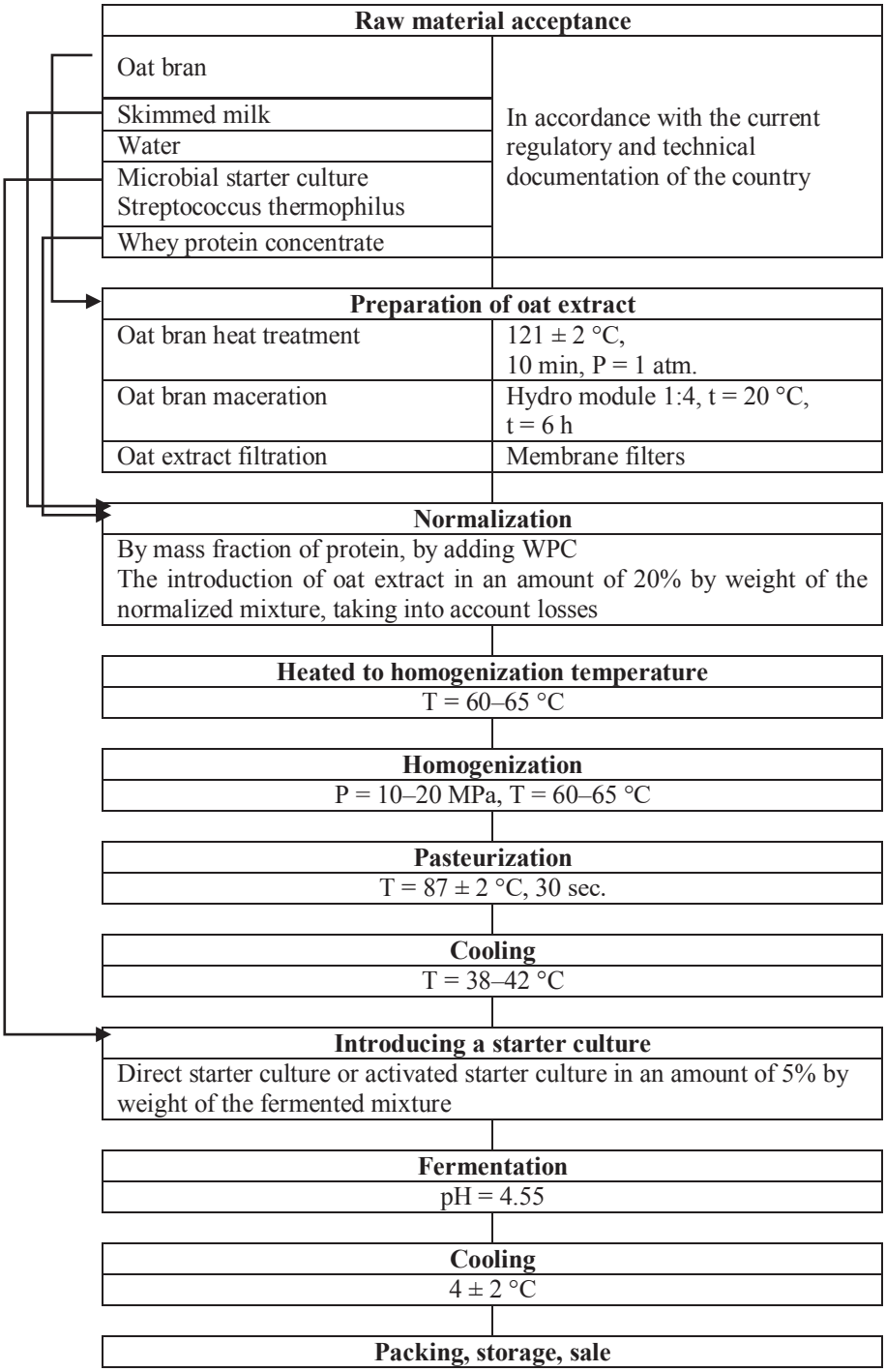

Figure 9. Technological scheme for producing fermented milk with oat extract.

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