Milk protein clots obtained by the addition of purple corn powder

Viktor Grek, Tetiana Pshenychna, Olena Onopriichuk, Olena Grek

National University of Food Technologies, Kyiv, Ukraine

Keywords:

Milk
Protein
Clots
Purple corn
Whey

Article history:

Received 01.12.2023
Received in revised form 23.03.2024
Accepted 2.07.2024

Corresponding author:

Olena Onopriichuk
E-mail:
olena.onopriychuk@gmail.com

DOI:
10.24263/2304-974X-2024-13-2-4

Abstract

Introduction. The aim of the present study was to determine the technological functions of purple corn powder on the qualitative and quantitative characteristics of milk protein clots from goat's milk.

Materials and methods. Milk protein clots were obtained by acid-rennet coagulation of proteins from goat's milk with the addition of purple corn powder. The dispersion of purple corn powder particles and the ability to swell were determined by microscopy and the weight method, active acidity – potentiometrically; content of moisture and moisture retention capacity by the thermogravimetric methods; color and turbidity by the colorimetric method.

Results and discussion. The dispersion of purple corn powder was determined, which was represented by particles up to 60 µm in size (70–75%). The parameters for the preparation of a grain additive for introduction into goat milk have been specified.

It was found that under the same conditions of the process of acid-rennet coagulation of milk proteins, the use of purple corn powder in the amount from 2% to 10% contributed to an increase in the yield of milk-protein clots by 3.5–17.9%, compared to the control, and the mass fraction of moisture, on the contrary, decreased from 73.4% to 67.2%. With an increase of the amount of grain additive, the active acidity of milk-protein clots decreased from 4.75 to 4.50 pH units. The highest values of moisture retention capacity were observed in samples with the addition of 8±2% purple corn powder and were an average by 19–34% higher than for the control. Taking into account sensory limitations, the yield of milk protein clots and their quality properties, the optimal amount of purple corn powder was determined at the level from 6% to 8% of the mass of milk. The milk protein clots had a pronounced sour milk taste, with the aroma of the introduced additive, homogeneous to the extent of butter consistency and a purple color, uniform throughout the mass.

The colored whey obtained as a result of the production of milk protein clots had improved taste and color characteristics, the content of dry substances ranging from 6.1 to 7.3%, including protein 0.36–0.50%, turbidity and color according to optical density (1.57–1.75 and 1.02–1.19 conv. units, respectively).

Conclusions. The colored whey could be classified as a functional raw material, which has original taste and color characteristics and expands the use of colored whey drinks in technology. The use of colored products as a base for various dairy products will avoid using artificial food colors and flavors.

Introduction

The chemical composition and properties of goat's milk are close to cow's milk, but it differs favorably in a larger amount of protein – 3.6% (3.0% in cow's milk), including casein, 3.0% (2.7% in cow's milk), fat 4.3% (3.4% in cow's milk), and minerals, 0.85% (0.74% in cow's milk (Getaneh et al., 2016). Compared to cow's milk, the content of milk sugar is reduced to 4.5% (cow's milk has 4.8%) and is completely dissolved, while goat milk proteins show lower allergenicity than cow's milk (Antonenko et al., 2019; Benjamin-van Aalst et al., 2024).

According to the content of casein protein, which determines the syrupiness of milk, goat and cow's milk do not differ significantly; however, compared to cow's milk, goat's milk has a lower content of α-caseins and a higher content of β-caseins, which under certain conditions can complicate the formation milk-protein clots. The density of goat milk is about 1.033 g⁄ml, while for cow's milk this indicator varies between 1.024–1.037 g⁄ml (Stergiadis et al., 2019).

Goat milk contains the essential amino acids that enter the human body only with food: valine (0.242 g), isoleucine (0.209 g), lysine (0.291 g), leucine (0.315 g), methionine (0.082 g), threonine (0.164 g), tryptophan (0.045 g), phenylalanine (0.156 g). In terms of mineral content, goat milk has also advantages. Compared to cow's milk, goat's milk contains about 13% more calcium, 50% more copper and 33% more selenium (Singh et al., 2021), and the bioavailability of minerals in goat milk is higher than of minerals in cow milk (Turkmen, 2017).

Goat's milk has a higher biological value than cow's milk in terms of its vitamin composition. This is especially true for vitamin A, which is the most important difference in the content of vitamins in goat's milk and cow's milk (Turkmen, 2017). Goat's milk contained vitamin A by 47%, tiamin (vitamin B1) by 51%, riboflavin (vitamin B2) by 31%, vitamin C by 37% and niacin (vitamin B3) more by 3.4 times more than cow's milk (Park et al., 2007).

Goat's milk protein clots are absorbed by the human body faster than cow's ones, which is explained by its flake-like structure, compared to the dense characteristic of cow's milk protein clot, and will also be enriched with calcium, potassium, phosphorus, sodium, magnesium and antioxidants (Turkmen, 2017). Therefore, goat's milk is a promising raw material for milk protein products.

Craft products made in small batches, in-house, using unique high-quality raw materials, according to original individual recipes, are relevant.. Goat farms are very common in European countries. The obtained milk is processed into cheese, butter, kefir, or yogurt. However, cheese is one of the main and best products of goat milk processing.

Different countries have their traditional types of cheese. For example, for France it is Brie and Camembert, for Italy it is Parmesan and Mozzarella, for the Netherlands it is Gouda and Edam. They have a characteristic taste of goat's milk and can be of different consistency from soft to hard. It is possible to use goat's milk in Camembert-type cheese technology (Gyorgy et al., 2021). The leading European countries in the production of goat cheese are France, Greece, and Spain (Hamad et al., 2012; Raynal-Ljutovac et al., 2011; Sant'Ana et al., 2013). In Ukraine, there is a tendency to produce cheese at craft cheese factories. Production centers and cheese factories can be found in almost all regions, but they are most concentrated in the west of Ukraine (Transcarpathian and Ivano-Frankivsk regions), where a unique product is produced from goat, cow, or sheep milk and their mixture (Abbas et al., 2014; Kochubei-Lytvynenko et al., 2019).

Goat's milk has a lower titrated acidity, a higher dispersion of fat globules and casein micelles. In addition, goat's milk differs favorably from cow's milk in the content of retinol, thiamine and ascorbic acid, as well as in the content of allergenic αs1-casein and α-lactoalbumin, which causes its increased biological value (Park et al., 2007; Turkmen, 2017).

Over the past few decades, the lifestyle of the population has changed significantly, and people's nutrition is characterized by high calorie content and a deficiency of vitamins, trace elements, plant fibers and other biologically active substances (Mendonca, 2023). A new trend in the manufacturing of dairy products to increase their biological value is incorporation of plant additives in them (Stabnikova et al., 2021). The addition of vegetable raw materials increases the nutritional and biological value, and expands the range of dairy products (Caleja et al., 2016; Hashim et al., 2009; Rabie et al., 2020).

Development and implementation of craft technologies of dairy and vegetable products allow reducing the costs of the main dairy raw materials. Grains, seeds and products of their processing are increasingly used in the recipes of dairy products. Thanks to this technological technique, a high level of balance of the dairy product in terms of amino acid composition is achieved, its digestibility increases and structural and mechanical properties are improved.

It is recommended to use wheat, rice, buckwheat, corn, and oats grain products in different forms (crushed grain, flour, malt) (Aparna et al., 2015; Grek et al., 2020a). The production technologies of fermented milk products using rice flour, corn flour, barley flour, oat flour, wheat germ, and wheat bran are well known. The introduction of these additives in the amounts from 5% to 10% significantly increases the nutritional value of cheese products (Romanchuk et al., 2016). The developed products meet the body's daily need for protein by 14-18%. The introduction of fillers increases the content of thiamine, riboflavin, and tocopherols. The use of corn flour and wheat bran somewhat slows down protein proteolysis.

Germinated wheat was added, 7%, in cheese (Denisova, 2015). As a filler that does not dictate the color and taste of the cereal supplement, it was recommended to add dried apricots or other chopped, brightly colored fruit and berry ingredients. The calorie content of the cheese product with cereal additives was changed slightly, while the product was enriched with dietary fibers, vitamins, and minerals.

Functional fermented milk products have been developed – curds and curd mass with cereal fillers and curd paste with crushed flakes (Ghanbari et al., 2017). Cereal grains that are introduced are obtained by the extrusion method and have a high moisture absorption capacity. In finished products, the content of fat, protein, carbohydrates increases by 15-17%, vitamins, macro- and microelements – by 5%.

The introduction of 3% dietary fibers from *Acacia senegal* var. *kerensis* contributed to an increase in the yield of soft cheese, an extension of the shelf life and an improvement of its quality characteristics (Kiiru et al., 2018). The use of fiber increases the nutritional value of the product and has a positive effect on the human digestive system (Kiiru et al., 2018).

Introduction of rice extrudate and apple fiber into the milk mixture before fermentation had a positive effect on the formation of the consistency of the finished product (Malyarenko, 2015). Oat flour added in a fermented product acted as a structure-builder of a dispersed system, increased the content of carbohydrates, proteins, and vitamins, and provided nutrients to lactic acid bacteria (Sukhova et al., 2019).

The combination of dairy and grain raw materials ensures the enrichment of nutritional value of products, reduction of caloric content and consumption of animal fats, sugars, cholesterol. However, when producing milk-protein products with grain components, it is necessary to take into account the chemical composition and functional properties of plant raw materials, the peculiarities of the technology of obtaining ingredients of plant origin and their compatibility at the sensory level with the milk base. Their use should not significantly complicate the technology of dairy products and provide sensory characteristics that are not inherent to finished products on a milk-protein basis.

Criteria for the selection of the above-mentioned ingredients for use in the technology of milk-protein products have been developed, which are presented in Figure 1.

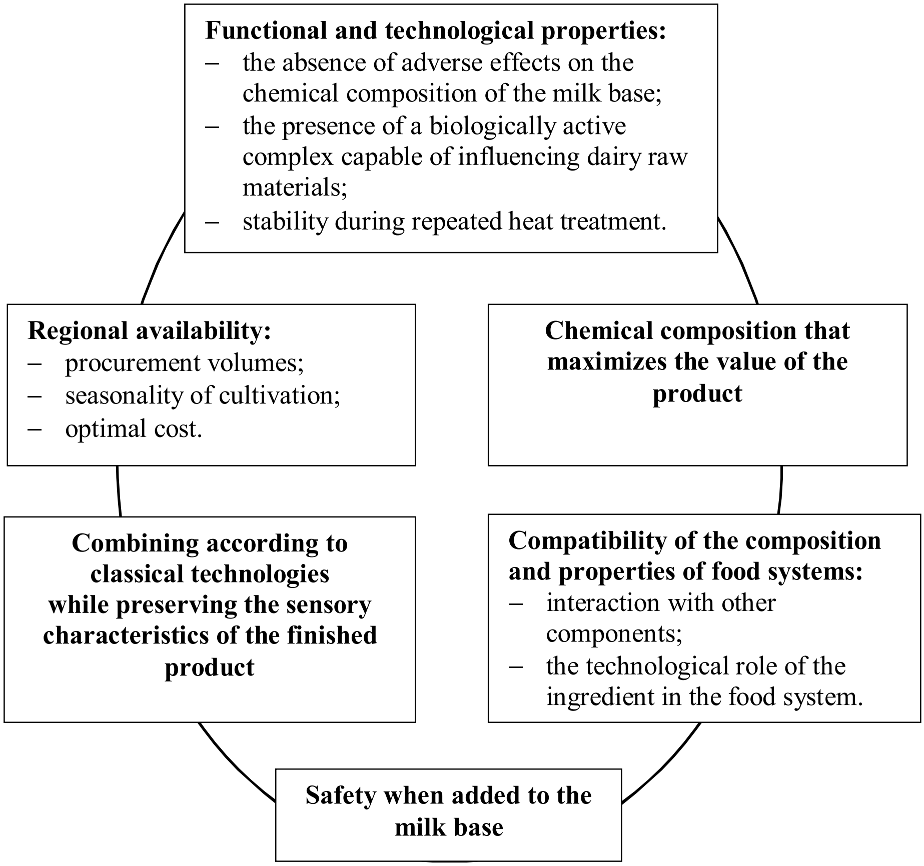


Figure 1. Criteria for selecting ingredients of plant origin

Some plants are considered as a possible source of ingredients to replace synthetic colors with natural ones, which meets consumer demands to minimize the use of synthetic additives in food products (Stabnikova et al., 2023). It can be elderberry juice or pomace (Cais-Sokolińska and Walkowiak-Tomczak, 2021; Delgado-Vargas et al., 2000; Domínguez et al., 2021), blackcurrant pasta (Grek et al., 2020b), or beetroot betalains (Güneşer, 2016). Purple corn can also be used to correct the color of dairy products.

Purple corn (*Zea mays* L.) is an annual plant of the cereal family, brightly purple in color due to the content of special anthocyanins, cyanidin-3-*O*-glucoside, the presence of which ensures the grain antioxidant properties. Purple corn flour contained, %, protein, 8.58; fat, 5.73; ash, 0.02, moisture 11.75; fiber, 2.91, and carbohydrates, 71.06 (Vilcacundo et al., 2020). Total phenolic content in purple corn flour was estimated as 140.7 mg gallic acid equivalent (GAE)/100 g dry matter (DW) (Mora-Rochin et al., 2010), and antioxidant activity detrmined using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method was 77000–84000 µM Trolox equivalent (TE)/100 g (Trehanet al., 2018). The content of total anthocyanins in purple corn dye powder with moisture content of 3.83% was 771 mg/100 g DM (Tacca et al., 2018). The content of minerals, mg/100 g, were as follows: potassium, 1200, calcium, 120, magnesium, 88, iron, 27, zinc, 2.7, copper, 0.3, manganese, 1, chromium, 63, molybdenum, 54. Calorie content in 100 g of purple corn is 283 (Ramos-Escudero et al., 2012).

The aim of the present research was to study the effect of purple corn powder addition on the qualitative and quantitative characteristics of milk protein clots from goat's milk.

Materials and methods

Materials

The object of the study was milk protein clots obtained by acid-rennet coagulation of goat milk proteins with the addition of purple corn powder.

Purple corn (RS. E4513813N – KBEOSA) ground to a powdery state was used for research.

To obtain samples of milk protein clots, pasteurization of goat milk was carried out at a temperature of 76±2°C with a holding time of 15-20 seconds.

Purple corn powder was mixed with goat's milk in a ratio of 3:1, brought to a temperature of 80 °C and kept for 20 minutes to swell the proteins and obtain a uniform consistency. The resulting mixture was cooled to the fermentation temperature (30±2) ºC and added to the total volume of milk, in amounts from 2% to 10% with a variation step of 2% and mixed for 3-5 minutes.

Then, the bacterial leaven *Vivo* for sour milk cheese, which contains the following strains of microorganisms, was added to the milk-cereal mixture prepared for fermentation: *Lactococcus lactis* subsp. *lactis, L. lactis* subsp. *cremoris, L. lactis* subsp. *lactis biovar. diacetylactis*, a calcium chloride solution at the amounts of 20-40 g of dry calcium chloride per 100 kg of milk and aqueous solution of the enzyme Vivo of plant origin chymosin at the amount of 1 g per 100 kg of milk. Fermentation of the mixture was carried out for 7-8 hours until the formation of a clot with a titrated acidity of 65±2 °T. The following technological operations were carried out to produce sour milk cheese from milk: processing (cutting, heating) of milk protein clot, whey separation and pressing of milk protein clot, cooling of 4±2 °C.

The control sample of the milk-protein clot was obtained according to the classical technology by fermenting pasteurized goat's milk using the acid-rennet method of protein coagulation with subsequent removal of serum.

Methods

Standard and well-known methods of research of technological and functional properties and quality indicators were used.

Deterimination of functional and technological properties of fine powder from purple corn

The dispersion of purple corn powder particles was determined by counting their sizes on a MICROmed XS-2610 microscope at a magnification of 150 times.

The ability to swell purple corn powder was determined by the weighing method, which consists in determining the change in the mass of the grain ingredient after immersing it in a solvent for a certain period. Quantitatively, this indicator is characterized by the degree of swelling (K), which shows the relative increase in the mass of the system, mg/mg. The degree of swelling was calculated according to the formula:

$$K = \frac{m_1 - m_0}{m_0} = \frac{m_p}{m_0}$$

where m_0, m_1 – mass of the system, respectively, before and after swelling, mg; m_p – mass of absorbed solvent, mg.

Quality indicators of milk-protein clots and whey

Sensory characteristics – appearance, color were controlled visually; taste and smell, consistency – sensoryally at the temperature of the milk-protein curd from 18°C to 20°C.

The yield of milk-protein clots (in g) was determined by the weighing method – the sample was weighed after self-pressing the clot for 30±2 minutes, which was obtained from 3000 ml of goat's milk.

The mass fraction of moisture retention capacity was measured by an accelerated method on a QUARTZ-21M-33 moisture meter by drying the sample to a constant mass and by a thermogravimetric method on a laboratory electronic scale-moisture meter of the ADS series manufactured by the company "AXIS" (Poland).

The active acidity of moisture retention capacity and stained serum was determined potentiometrically on a Sartorius PB-20 universal pH meter.

The moisture-retaining capacity of milk-protein clots was studied modification gravimetric method, based on the determination of the amount of water released from the product when lightly pressed and absorbed by the filter paper.

The content of dry matters in the coloured whey was found by the refractometric method according to the light refractive indices. First, check the correctness of the refractometer readings for distilled water at a temperature of 20±0.1 °C. With one or two water drops applied to the prism, the refractometer reading should be zero. The refractometer prism is wiped with a paper filter and one or two drops of a test whey sample are applied. On the right refractometer scale, the content of dry matters was found, which coincides with the distribution boundary of the dark and light fields.

Determination of chroma and turbidity of stained serum is based on measurement of optical density and comparison with relevant standards: colored solutions for chroma and turbidity suspensions (Grek et al., 2020b).

The study of the optical density of the filtered serum was carried out by the colorimetric method on a Helios Omega spectrophotometer (Thermo Scientific Spectronic, USA). The value of the optical density Dgen consists of D due to chroma due to coloring substances, and D_k due to turbidity due to the presence of proteins that scatter the light flux.

Results and discussion

Determination of functional and technological properties of purple corn powder

The quality of milk-protein products is significantly affected by the degree of dispersion of the additives introduced into their composition, since solid particles over 100 microns in size can be felt sensoryally and cause consistency defects. Considering the above, the dispersibility of purple corn powder, shown in Figure 2, was investigated.

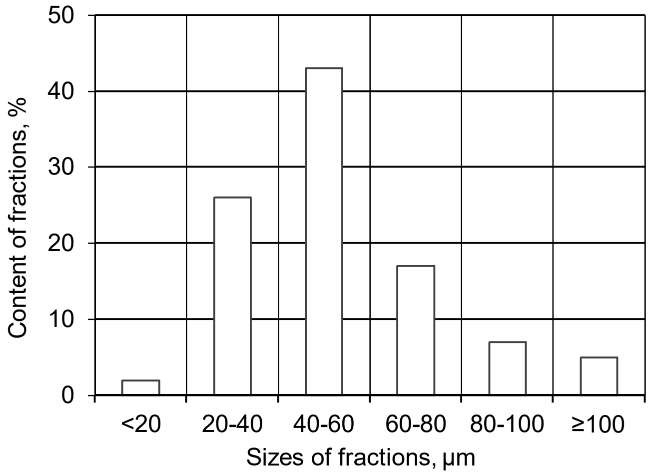


Figure 2. Dispersity of purple corn powder

According to the results of microstructural analysis, purple corn powder is characterized by high dispersion. The main fractions of its particles, mostly oval in shape, are in the range of 20–40 µm (26±1.3%) and 40–60 µm (43±2.1%), which dissolve in water at temperatures above 40 °C with the formation colloidal solutions, which in the future will not cause defects in the consistency of the product. Fractions larger than 100 µm do not exceed 10%.

For better distribution of purple corn powder in the structure of milk-protein clots, it is necessary to dissolve them beforehand. The relative increase in the mass of the system due to water absorption is characterized by the degree of swelling (K) and depends on the type of dispersion medium. Water and goat's milk were used as a liquid basis for swelling purple corn powder. The ability to swell purple corn powder at different temperatures is presented in Figure 3.

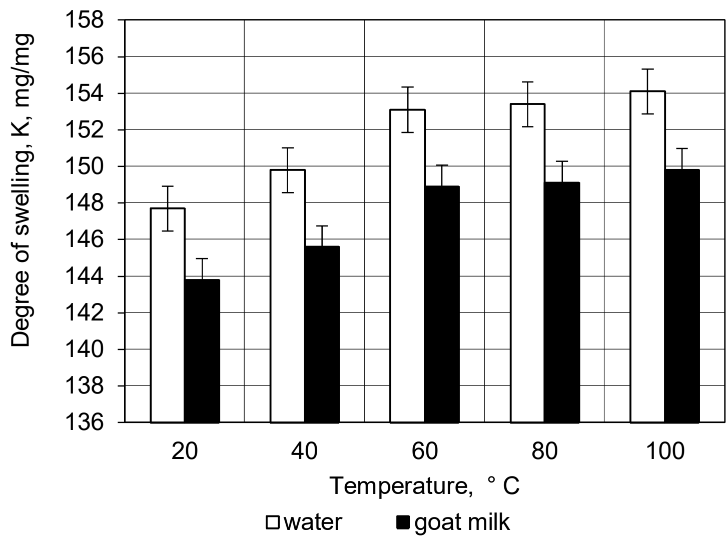


Figure 3. Swelling ability of purple corn powder

Swelling capacity is a technological characteristic of food systems and depends on the type of raw material, process temperature, degree of dispersion of components, type of solvent, etc. It was found that the degree of swelling of purple corn powder in water is 2.7-2.9% higher than in goat's milk. Pre-mixing purple corn powder with water before adding it to the normalized milk mixture reduces the nutritional value of the product. Replacing water with goat's milk prevents the occurrence of the above defect. The optimal dissolution temperature was determined at the level of 80 ºC, which is the closest to the pasteurization regime and provides the necessary microbiological indicators.

The dependence of the swelling process of purple corn powder in goat's milk on the time and temperature of holding is shown in Figure 4.

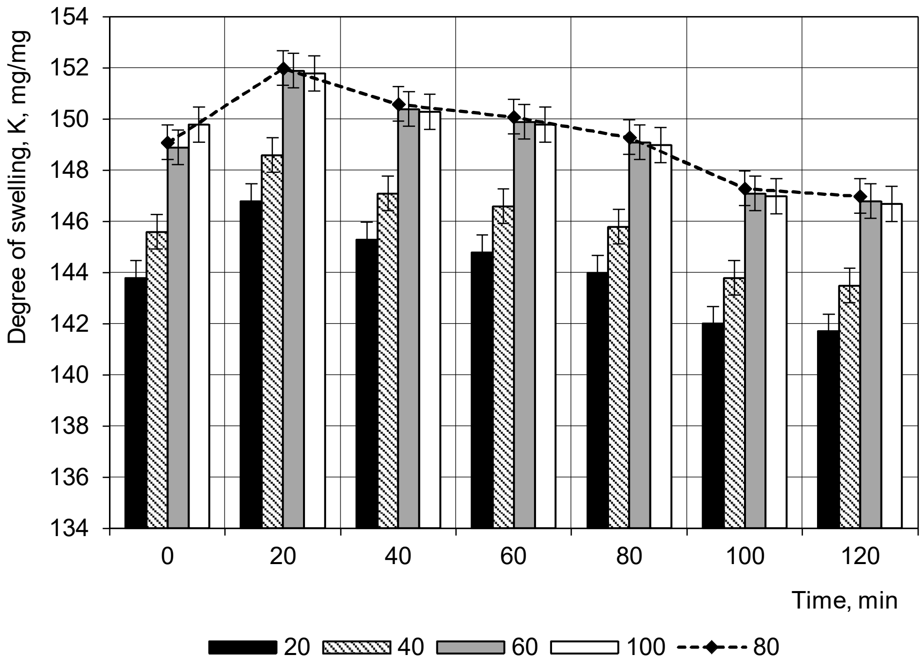


Figure 4. Dependence of the swelling process of purple corn powder in goat milk on the time and temperature of holding

The most intensive swelling of purple corn powder occurs during the first 20 minutes at temperatures above 40 °C (Fig. 4). When interacting with goat's milk, the water-soluble substances of the grain additive absorb a significant amount of it and swell. The swelling process, caused by the interaction between the particles of the dispersed phase and the dispersion medium, slows down over time and is accompanied by the formation of a continuous spatial structure between the swollen particles of the ingredients. It was established that at a temperature of 80 °C and holding for 20 minutes, the value of the degree of swelling (K) is the highest and is 152 mg/mg, and the transition of dry substances into the solution is the lowest – at the level of 1.4%. With further interaction of purple corn powder with goat's milk, the swelling gradually decreases – on average by 1.03 times. Based on this, it can be assumed that the swelling and dissolution of purple corn powder occurs similar to these processes for polymers.

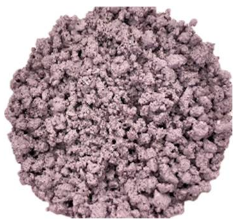
Determination of qualitative and quantitative indicators of milk protein clots and whey

The obtained milk protein clots and whey system is a polydisperse colloidal one, in which the dispersion medium is whey, and the dispersed phase is milk proteins and dry substances of the grain additive. The structure of milk protein clots is formed by the interaction between goat milk proteins and corn powder starch molecules. This process begins at the pasteurization stage of the mixture of goat milk and purple corn powder and ends during fermentation. The structure of milk protein clots characterizes the sensory properties. The resulting milk protein clots have a thixotropic coagulation-type structure with liquid interlayers between the particles. Liquid interlayers cause lower structural strength, but give milk-protein clots plasticity and elasticity (Grek et al., 2019).

The choice of the optimal amount of powder from purple corn was based on the preservation of normative sensory characteristics of milk-protein clots, which can be the basis for the production of various types of cheese. Table 1 shows the results of the sensory evaluation of milk-protein clots with purple corn powder.

Table 1

Sensory evaluation of milk-protein clots obtained with the addition of purple corn powder

<table>
<tr><th rowspan="2">Amount of purple corn powder, %</th><th colspan="3">Sensory characteristics</th></tr>
<tr><th>Consistency and appearance</th><th>Taste and smell</th><th>Colour</th></tr>
<tr><td>2</td><td rowspan="2">Homogeneous, not viscous enough, too thin</td><td rowspan="2">Pure, sour-milk, unexpressed taste and aroma of purple corn powder</td><td rowspan="2">Barely noticeable light purple uniform over the entire mass</td></tr>
<tr><td>4</td></tr>
<tr><td>6</td><td rowspan="2">Uniform, soft, moderately greasy</td><td rowspan="2">Pure sour milk with a light aroma of purple corn powder</td><td rowspan="2">Purple is uniform throughout the mass
</td></tr>
<tr><td>8</td></tr>
<tr><td>10</td><td>Uniform, slightly brittle, floury</td><td>Pure sour milk with a pronounced taste and aroma of purple corn powder</td><td>Too pronounced saturated purple uniform throughout the mass</td></tr>
</table>

The best taste properties and consistency of milk protein clots were achieved with the addition of purple corn powder in the amounts of 6% and 8% to weight of milk. The samples had a pronounced sour milk taste with the aroma of the introduced additive, homogeneous to the extent of butter consistency and a purple color, uniform throughout the mass. The introduction of a filler in an amount greater than 8% causes negative changes in the sensory properties of milk protein clots: a floury aftertaste and a fragile, floury consistency appear. The addition of purple corn powder in an amount of less than 6% did not have a noticeable positive effect on the structure of the product or on its sensory properties, and also did not significantly enrich the curd with biologically active nutrients – antioxidants, vitamins, dietary fibers, micro- and macroelements.

To confirm the obtained results of the sensory evaluation, further studies of the effect of different amounts of purple corn powder on the output of milk protein clots and the moisture content were conducted. The yield and content of moisture of milk protein clots depending on the amount of purple corn powder introduced are shown in Figure 5.

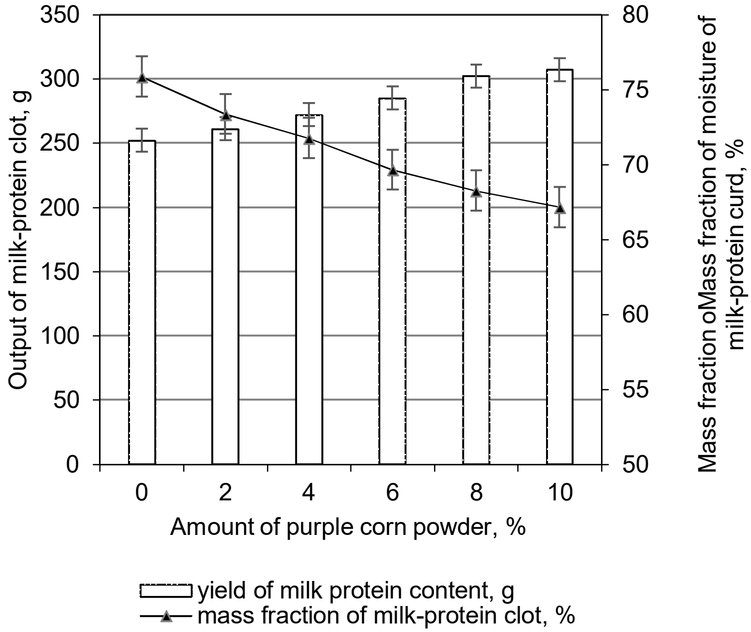


Figure 5. Yield and content of moisture in milk protein clots depending on the amount of purple corn powder

In general, the yield of milk protein clot is influenced by the type, composition and quality of milk, the amount of casein, pasteurization regimes, the type of coagulant and leavening agent, the density of the clot when cut, and technological parameters of production (Abd et al., 2011).

It was shown that under the same conditions of the acid-rennet coagulation process of milk proteins, the use of purple corn powder in an amount of 2% to 10% contributed to an increase in the yield of milk protein clots from 3 liters of goat milk by 9–55 g, and amounted to 3.45–17.91%, compared to the control. This allows reducing the consumption of dairy raw materials. (Fig. 5). The addition of more than 10% of purple corn powder did not have a significant effect on the yield increasing.

The content of moisture in milk-protein clots decreased from 73.36% to 67.15% when purple corn powder was added in amounts from 2 to 10%, respectively, and was 2.49–8.70% lower than in the control sample. Probably, the interaction of milk proteins with the carbohydrates of the cereal supplement leads to the formation of additional complexes that differ in the presence of strong bonds between starch, fiber and whey proteins. The swelling of carbohydrates and, as a result, the reduction of the share of free moisture between the molecules of the milk protein clot leads to a stabilizing effect, due to the enveloping and strengthening of the protein framework. From a practical point of view, this is how you can justify the use of purple corn during acid-rennet coagulation of milk proteins to bind free moisture and prevent syneresis during curd storage.

At the next stage of research, the change in active acidity and moisture-retaining capacity of of milk protein clots was studied depending on the amount of purple corn powder (Fig. 6).

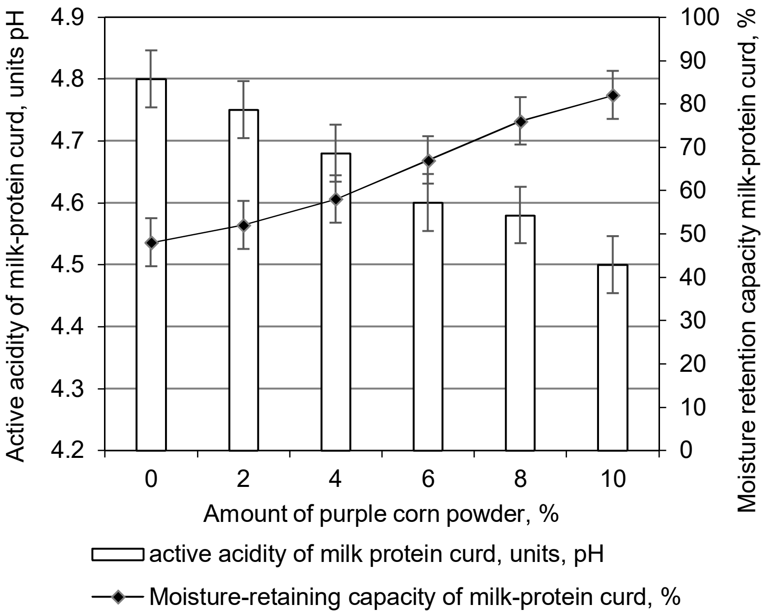


Figure 6. Active acidity and moisture-retaining capacity of milk-protein clots depending on the amount of purple corn powder

An increase in the content of purple corn powder during the production of milk protein clots, their active acidity decreased. pH, indicators of active acidity, ranged from 4.75 to 4.50 units, in samples of milk protein clots with a grain ingredient in the amount from 2% to 10%. The value of the active acidity of the experimental samples was by 0.05–0.30 pH units lower than in the control sample. When purple corn powder was added, the active acidity of the curd decreased, which indicates the effect of the grain additive on the microflora, in particular on the content of lactic acid bacteria.

From the obtained values of moisture-retaining capacity (Fig. 6) it can be seen that with an increase in the content of purple corn powder, this indicator changes for all milk protein clots, while the dynamics are different. This is due to the appropriate content of starch in corn powder, whose polysaccharides absorb water. When adding a grain additive 2% to 4%, the difference between the indicators of the moisture-holding capacity of the control and experimental samples was less pronounced and consisted 4–10%. The highest values of retention capacity samples were observed in samples with the addition of 8±2% purple corn powder and were on average by 19–34% higher than for the control sample. In addition, the formation of a denser consistency than the control was characteristic of the above-mentioned samples of milk-protein clots.

During the production of protein clots, about 80% of the colored whey was obtained from the volume of milk raw materials. Serum samples had a natural purple color due to the high content of specific coloring substances in corn grains – bioflavonoids and anthocyanins, which are powerful antioxidants.

The qualitative characteristics and optical density reflected the turbidity and color of the dyed whey were determined and compared with the control, which are listed in Table 2.

Table 2

Qualitative characteristics and optical density of stained serum

Amount of powder from purple corn, %	**Serum content**		**Active acidity, units pH**	**Optical density, D_k, cond. unit**	**Optical density after filtering, D, cond. unit**
	dry substances, %	**protein, %**			
2	7.3±0.15	0.50±0.02	6.15±0.12	1.75±0.05	1.03±0.03
4	7.1±0.13	0.46±0.01	6.10±0.12	1.72±0.05	1.07±0.03
6	6.8±0.14	0.40±0.02	5.99±0.11	1.64±0.05	1.12±0.03
8	6.3±0.13	0.37±0.02	5.92±0.12	1.60±0.048	1.16±0.04
10	6.1±0.12	0.36±0.01	5.85±0.11	1.58±0.05	1.20±0.04
Control	7.5±0.12	0.52±0.02	6.19±0.12	–	–
Control*	–	–	–	1.63±0.05	1.15±0.03

* Colored whey drink "Actual" with watermelon-melon flavor produced by "Danon Dnipro" LLC

The content of dry substances of colored serum was at the level of 6.1–7.3%, including protein 0.36–0.50%. Compared with the control sample, the dyed serum had a lower content of dry matter and, accordingly, protein, which confirms the effectiveness of acid-serum coagulation of proteins. The active acidity of the dyed serum samples was within 5.85–6.15 units. The pH depended on the amount of purple corn powder added during the production of milk protein clots.

The optical density of serum samples when determining turbidity and color ranged from 1.57 to 1.75 and 1.02 to 1.19 um. Almost all of these values have deviations from control up to 5%.

Coloured whey obtained as a result of the production of milk-protein clots with the addition of various amounts of grain additives can be used with or without additional processing (clarification, deacidification) as a base and recipe component for whey drinks of the type "pasteurized whey" or "pasteurized whey with sugar". This allows eliminating the use of artificial food colourings in their composition.

Conclusions

The possibility of effective use of purple corn powder in the production technology of milk protein clots by acid-rennet coagulation of goat milk proteins has been shown.

The dispersion of purple corn powder was determined, the main particle fractions of which were in the range from 20 to 40 microns (26±1.3%) and from 40 to 60 microns (43±2.1%). Parameters to prepare purple corn powder for addition to goat's milk are as follows: the swelling and dissolution temperature is 80 ºC and the holding time is 20 minutes.

It was found that when the amount of purple corn powder increased from 2 to 10%, the yield of milk protein clots increased from 3.45% to 17.91%, the content of moisture decreased from 73.36% to 67.15%, and their active acidity decreased from 4.75 to 4.50 pH units. The optimal amount of purple corn powder was 6% to 8% of the mass of goat's milk.

Milk protein clots can be used in the recipes of curd products with an adjustable content of moisture, active acidity, moisture-retaining ability and natural color.

The obtained colored whey could be classified as a functional raw material, which has original taste and color characteristics and expands the use of colored whey drinks in technology.

References

Abbas H. M., Hassan F. A., Abd El-Gawad M. A., Enab A. K. (2014), Physicochemical characteristics of goat's milk, *Life Science Journal*, 11, pp. 307–317.

Abd El-Gawad M. A. M., Ahmed N. S. (2011), Cheese yiteld as affected by some parameter, *Acta Scientiarum Polonorum, Technologia Alimentaria,* 10(2), pp. 131–153, https://www.food.actapol.net/volume10/issue2/1_2_2011.pdf

Antonenko P. P., Chumak S. V., Chumak V. O. (2019), Physical and chemical composition of goat milk during smallholder production in the conditions of the natural and agricultural zone of the steppe of Ukraine, *Theoretical and Applied Veterinary Medicine*, 7(4), pp. 198–204, https://doi.org/10.32819/2019.74035

Aparna S., Patel K., Patel S., Pinto S. (2015), Wheat and its application in dairy products, *Research & Reviews: Journal of Dairy Science and Technology*, 4(2), pp. 19-34.

Benjamin-van Aalst O., Dupont C., van der Zee L., Garssen J., Knipping K. (2024), Goat milk allergy and a potential role for goat milk in cow's milk allergy, *Nutrients*, 16, 2402, https://doi.org/10.3390/nu16152402

Caleja C., Ribeiro A., Barros L., Barreira J.C., Antonio A.L., Oliveira M.B.P., Barreiro M.F., Ferreira I.C. (2016), Cottage cheeses functionalized with fennel and chamomile extracts: Comparative performance between free and microencapsulated forms. *Food Chemistry*, 199(15), pp. 720–726, https://doi.org/10.1016/j.foodchem.2015.12.085

Delgado-Vargas F., Jiménez A.R., Paredes-López O. (2000), Natural pigments: carotenoids, anthocyanins, and betalains — characteristics, biosynthesis, processing, and stability. *Critical Reviews in Food Science and Nutrition*, 40(3), 173–289, https://doi.org/10.1080/10408690091189257

Denisova E.A. (2015), Cheese and cereal products, *Food and Processing Industry,* 2, pp. 12–13 (in Ukrainian).

Domínguez R., Pateiro M., Munekata P.E.S., Santos López E.M., Rodríguez J.A., Barros L., Lorenzo J.M.(2021), Potential use of elderberry (*Sambucus nigra* L.) as natural colorant and antioxidant in the food industry. A review, Foods, 10(11), 2713, https://doi.org/10.3390/foods10112713

Getaneh G., Mebrat A., Wubie A., Kendie H. (2016), Review on goat milk composition and its nutritive value, *Journal of Nutrition and Health Sciences*, 3(4), 401, https://doi.org/10.15744/2393-9060.3.401

Ghanbari M., Mortazavian A.M., Ghasemi J.B., Mohammadi A., Hosseini H., Neyestani T.R. (2017), Formulation and development of a new prebiotic cereal-based dairy dessert: rheological, sensory and physical attributes, *Food Science and Technology Research*, 23(5), pp. 637-649, https://doi.org/10.3136/fstr.23.637

Grek O., Tymchuk A., Tsygankov S., Onopriichuk, O., Savchenko O., Ochkolyas O. (2019), Methods for determining the characterization of mashes with fiber for semi-finished products on the milk-protein base, *EUREKA: Life Sciences,* 6, pp. 50–56, https://doi.org/10.21303/2504-5695.2019.001046

Grek O., Ovsiienko K., Tymchuk A., Onopriichuk O., Kumar A. (2020a), Influence of wheat food fiber on the structure formation process of wheycreamy cheeses, *Ukrainian Food Journal*, 9(2), pp. 332–343. https://doi.org/10.24263/2304-974X-2020-9-2-6.

Grek O., Pshenychna T., Chubenko L., Onopriichuk O. (2020b), Polyphenol composition and technological characteristics of the coloured whey from various origin, *Ukrainian Food Journal*, 9(4), pp. 832–843, https://doi.org/10.24263/2304-974X-2020-9-4-9

Güneşer O. (2016), Pigment and color stability of beetroot betalains in cow milk during thermal treatment, *Food Chemistry*, 196, 220–227, https://doi.org/10.1016/j.foodchem.2015.09.033

Gyorgy E., Laslo E. (2021), Influence of milk used for cheese making on microbiological aspects of Camembert-type cheese. *Acta Universitatis Sapientiae Alimentaria,* 14, pp. 84–94, https://doi.org/10.2478/ausal-2021-0005

Hamad M.N., Ismail M.M. (2012), Quality of soft cheese made with goat's milk as affected with the addition of certain essences, *Journal of Animal and Veterinary Advances*, 2(2), pp. 121–127, https://doi.org/10.21608/jfds.2011.81945

Hashim I.B., Khalil A.H., Afifi H.S. (2009), Quality characteristics and consumer acceptance of yogurt fortified with date fiber, *Journal of Dairy Science*, 92(11), pp. 5403–5407, https://doi.org/10.3168/jds.2009-2234

Kiiru S., Mahungu S., Omwamba M. (2018), Preparation and analysis of goat milk mozzarella cheese containing soluble fiber from Acacia senegal var. kerensis, *African Journal of Food Science,* 12(3), pp. 46–53, https://doi.org/10.5897/AJFS2017.1652

Kochubei-Lytvynenko O., Korolchuk I., Yushchenko N., Kuzmyk U., Frolova N., Pasichny V., Mykoliv I. (2019), Perspective the use of goat milk in the production of soft milk cheeses, *Ukrainian Journal of Food Science*, 7(2), pp. 250-263, https://doi.org/10.24263/2310-1008-2019-7-2-9

Malyarenko T.V. (2015), The effect of plant components on the consistency of fermented milk curds, *Scientific Bulletin "Askania-Nova",* 8, pp. 68-78

Mendonca V. (2023), Modern food habits and its impact on human health, *International Journal of Innovative Research in Engineering and Management,* 10 (4), pp. 182–185, https://doi.org/10.55524/ijirem.2023.10.4.24

Mora-Rochin S., Gutiérrez-Uribe J.A., Serna-Saldivar S.O., Sánchez-Peña P., Reyes-Moreno C., Milán-Carrillo J. (2010), Phenolic content and antioxidant activity of tortillas produced from pigmented maize processed by conventional nixtamalization or extrusion cooking, *Journal of Cereal Science*, 52, pp. 502–508, https://doi.org/10.1016/j.jcs.2010.08.010

Park Y., Juarez M., Ramos M., Haenlein G. (2007), Physico chemical characteristics of goat and sheep milk, *Small Ruminant Research*, 68(1–2), pp. 88-113, https://doi.org/10.1016/j.smallrumres.2006.09.013

Rabie M.M., Faten Y.I., Youssif M.R.G., El-Ragal N.M.E. (2020), Effect of *Moringa oleifera* leaves and seeds powder supplementation on quality characteristics of cookies, *Journal of Food and Dairy Sciences*, 11(2), pp. 65–73, https://doi.org/10.21608/jfds.2020.78888

Ramos-Escudero F., Muñoz A. M., Alvarado-Ortíz C., Alvarado Á., Yáñez J.A. (2012), Purple corn (*Zea mays* L.) phenolic compounds profile and its assessment as an agent against oxidative stress in isolated mouse organs, *Journal of Medical Food,* 15(2), pp. 206-215, https://doi.org/10.1089/jmf.2010.0342

Raynal-Ljutovac K., Le Pape M., Gaborit P., Barrucand P. (2011), French goat milk cheeses: An overview on their nutritional and sensorial characteristics and their impacts on consumers' acceptance, *Small Ruminant Research*, 101(1–3), pp. 64-72, https://doi.org/10.1016/j.smallrumres.2011.09.026

Romanchuk I.O., Rudakova T.V., Moiseeva L.O., Gondar O.P. (2016), Rice flour as a stabilizer in fermented milk products, *Food Resources,* 7, pp. 46–52 (in Ukrainian)

Ryzhkova T., Odarchenko A., Silchenko K., Danylenko S., Verbytskyi S., Heida I., Kalashnikova L., Dmytrenko A. (2023), Effect of herbal extracts upon enhancing the quality of low-fat cottage cheese, *Innovative Biosystems and Bioengineering*, 7(2), pp. 22–31, https://doi.org/10.20535/ibb.2023.7.2.268976

Sant'Ana A. M. S., Bezerril F. F., Madruga M. S., Batista A. S. M., Magnani M., Souza E.L., Queiroga R.C.R.E. (2013), Nutritional and sensory characteristics of Minas fresh cheese made with goat milk, cow milk, or a mixture of both, *Journal of Dairy Science,* 96(12), pp. 7442-7453, https://doi.org/10.3168/jds.2013-691

Singh S., Kaur G., Partap R., Preet G. (2021), Goat milk composition and nutritional value: A review, *The Pharma Innovation Journal,* 10(6), pp. 536–540.

Stabnikova O., Marinin A., Stabnikov V. (2021), Main trends in application of novel natural additives for food production, *Ukrainian Food Journal*, 10(3), pp. 524–551, https://doi.org/10.24263/2304-974X-2021-10-3-8

Stabnikova O., Stabnikov V., Paredes-López O. (2024), Fruits of wild-grown shrubs for health nutrition, *Plant Foods for Human Nutrition*, 79(1), pp. 20–37, https://doi.org/10.1007/s11130-024-01144-3

Stergiadis S., Nørskov P., Purup S., Givens I., Lee M.R. (2019), Comparative nutrient profiling of retail goat and cow milk, *Nutrients*, 11, pp. 2-26, https://doi.org/10.3390/nu11102282

Sukhova I.V., Romanova T.N., Korosteleva L A., Baimishev R.H., Dolgosheva E.V. (2019), The effect of hydrated oatmeal on quality of the symbiotic fermented milk product, *BIO Web of Conferences,* 17, pp. 1–8, https://doi.org/10.1051/bioconf/20201700052

Tacca L.E., Guzmán F.F., Yanamango E.G., Socantaype F.V. (2018), Evaluation of some functional properties of purple corn (Zea mays L.) dye, during its processing at pilot scale, *Innovation in Education and Inclusion* : Proceedings of the 16th LACCEI International Multi-Conference for Engineering, Education and Technology, July 18–20, 2018, Lima, Perú, https://doi.org/10.18687/LACCEI2018.1.1.290

Trehan S., Singh N., Kaur A. (2018), Characteristics of white, yellow, purple corn accessions: Phenolic profile, textural, rheological properties and muffin making potential, *Journal of Food Science Technology*, 55, pp. 2334–2343, https://doi.org/10.1007/s13197-018-3171-5

Turkmen, N. (2017). The nutritional value and health benefits of goat milk components. In: R.R. Watson, R.J. Collier, V.R. Preedy (Eds.), *Nutrients in Dairy and their Implications on Health and Disease*, pp. 441–449, https://doi.org/10.1016/b978-0-12-809762-5.00035-8

Vilcacundo E., García A., Vilcacundo M., Morán R., Samaniego I., Carrillo W. (2020), Antioxidant purple corn protein concentrate from germinated andean purple corn seeds, *Agronomy*, 10(9), 1282, https://doi.org/10.3390/agronomy10091282

Cite:

UFJ Style

Grek V., Pshenychna T., Onopriichuk O., Grek O. (2024), Milk protein clots obtained by the addition of purple corn powder, *Ukrainian Food Journal*, 13(2), pp. 247–261, https://doi.org/10.24263/2304-974X-2024-13-2-4

APA Style

Grek, V., Pshenychna T., Onopriichuk, O., & Grek O. (2024). Milk protein clots obtained by the addition of purple corn powder. *Ukrainian Food Journal, 13*(2), 247–261. https://doi.org/10.24263/2304-974X-2024-13-2-4