Original Article
Food Science and Technology

ISSN 0101-2061 (Print)
ISSN 1678-457X (Online)

DOI: https://doi.org/10.1590/fst.61722

Impact of vacuum freeze-drying on the reconstituted camel milk composition

Ukilim TASTEMIROVA[1], Rauan MUKHTARKHANOVA[2], Mariam ALIMARDANOVA[1], Ravshanbek ALIBEKOV[3*], Azret SHINGISOV[4]

Abstract

In the dairy technology, for the preserving of initial nutritional properties of whole milk commonly a vacuum freeze-drying approach is used. However, a significant impact on the quality indicators of the resulting products within vacuum freeze-drying has a temperature of the product sublimation in the freeze-drying chamber. From the point of view of energy savings and maximum preservation of the initial qualities, the optimal sublimation temperature value is recommended at the t = -15 °C within vacuum freeze-drying process. The physicochemical indicators of whole and reconstituted camel milk have similar values within acceptable limits. Nevertheless, partial denaturation of amino acids that leading to the decreasing in the content of low molecular weight protein fractions and for the increasing of protein fractions with higher molecular weight are occurred. Thermolabile whey protein compounds, such as Albumin and Globulin fractions are especially susceptible to denaturation changes, due to the hydration membrane of proteins present on the surface is destroyed, leading to minor changes in the amino acid composition.

Keywords: reconstituted camel milk; chemical composition; amino acids; fatty acids; minerals.

Practical Application: Specifically, increasing of Aspartic and Glutamic acids values, as well as sulfur-containing amino acids such as Histidine, Leucine, Methionine can improve the organoleptic characteristics of the final product.

1 Introduction

Camel belongs to the family Camelidae in the request Artiodactyla. There are two types of camels, the Bactrian two humped camel (Camelus bactrianus) and the Arabian or dromedary one humped camel (Camelus dromedarius). Camel's milk is an important part of staple diet in several parts of the world, particularly in the arid and semi-arid zones (Swelum et al., 2021). Camel milk so called white gold of the desert is more similar to human milk than any other milk and differs from other ruminant milk because it contains low cholesterol, low sugar, high minerals (sodium, potassium, iron, copper, zinc and magnesium), high vitamin C, protective proteins like as lactoferrin, lactoperoxidase, immunoglobulins, lysozyme (Yadav et al., 2015; Akan, 2021).

Camel milk is generally opaque-white. It has a sweet and sharp taste, but sometimes can also be salty. The changes in taste are caused by the type of fodder and availability of drinking water. The pH of camel milk ranges from 6-5 to 6-7 with an average value of 6.56, and the density from 1.025 to 1.032 with an average of 1.029. Both values are lower than those of cows' milk (Farah, 1993). Camel milk is unique containing various protective proteins like lysozyme, lactoferrin, lactoperoxidase, immunoglobulins which exert antioxidatives, antibacterial, antiviral, antifungal, hypoglycaemic, antiparasitic, growth promotion, aging prevention, autoimmune diseases and anti-tumor activity (Kula & Tegegne, 2016; Wajahat et al., 2022). Total protein of camel's milk varies from 2.15 to 4.90%. Camel's and cow's milk have similar content of casein (αs1, αs2, β, and κ-casein), but they differ in the content of whey proteins. Thus, casein to whey proteins ratio in cow's milk is higher than that of camel's milk. This affects the firmness of coagulum, and camel's milk forms softer gel than cow's milk (Park et al., 2013).

The fat content in camel's milk varies in a fairly wide range, which depends on the species, season, forage, individual and other factors (Shingisov et al., 2015). The fat content ranges from 1.2 to 4.5% (Kumar et al., 2016). However, authors (Park et al., 2013) reported that the content of fat in camel's milk may reach up to 6.4%, and its profile is characterized with the presence of unsaturated and long chain fatty acids at higher amounts. This assists in lowering the level of lipids in human serum. The content of long-chain fatty acids is 9299%, and the percentage of unsaturated acids is 35-50% (Izadi et al., 2019). These structural differences impart "waxy texture" to the camel's milk fat. The lower content of carotene makes the color of camel's milk whiter compared to cow's milk (Kumar et al., 2016). In addition, the content of ascorbic acid is higher in camel's milk. Therefore, it can extend the shelf-life of its products and increase its antioxidant and antiradical abilities (Izadi et al., 2019).

Camel milk is rich source of various minerals *like* Na, K, Ca, P Mg Fe, Zn, Cu are present in camel milk (Onjoro et al., 2006;

Received 01 June, 2022
Accepted 31 July, 2022
[1] *Department of Technology of Food Products, Almaty Technological University, Almaty, Republic of Kazakhstan*
[2] *Section of Science Management, Almaty Technological University, Almaty, Republic of Kazakhstan*
[3] *Department of Food Engineering, M. Auezov South Kazakhstan University, Shymkent, Republic of Kazakhstan*
[4] *Department of Technology and Safety of Food Products, M. Auezov South Kazakhstan University, Shymkent, Republic of Kazakhstan*
*Corresponding author: alibekov7806-1@educ.com.pl

Adlerova et al., 2008). The mean values for zinc, manganese, magnesium, iron, sodium, potassium and calcium in mineral contents of dromedary camel milk (100 g-1) are 0.53, 0.05, 10.5, 0.29, 59, 156 and 114 mg respectively (Abbas et al., 2013). The concentrations of mineral salts and vitamins in camel's milk depend on breed, feed, water intake, and stage of lactation. Besides, camel's milk contains higher concentration of vitamin C and niacin compared to cow's milk. But it is deficient in B_1, B_2 and A vitamins, pantothenic acid and folic acid. Both camel's and cow's milk have almost the same content of vitamins B_6 and B_{12} (Kumar et al., 2016). In connection with the numerous advantages of camel milk, compared to cow's milk, it may become more popular in the market in the future. It is also important that camels are unpretentious in maintenance, which makes their by-product even more economically profitable (Mohamed et al., 2022).

Camel milk and fermented milk products prepared from it are easily digestible and therefore natural for the human body. Camel milk protein is dominated by immunoglobulin - the record holder for the amount of lactoferrin, which has therapeutic antioxidant, anticarcinogenic and immunostimulating properties that protect the human body from pathogenic bacteria and viruses. Doctors recommend this milk in the treatment of diseases of the gastrointestinal tract, liver, pancreas (Zouari et al., 2020; Ebrahimi et al., 2021).

On average camel milk contains 81.4-87% water, 10.4% dry matter, 1.2-6.4% milk fat, 2.15-4.90% protein, 1.63-2.76% casein, 0.65-0.80% whey protein, 2.90-5.80% lactose and 0.60-0.90% ash (Brezovečki et al., 2015). The main composition of camel milk (in g/100 mL) according to the data in the literature was 3.82 ± 1.08 for fat matter, 3.35 ± 0.62 for total protein, 4.46 ± 1.03 for lactose, 12.47 ± 1.53 for dry matter and 0.79 ± 0.09 for ash (Konuspayeva et al., 2009). However, shelf life of raw camel milk is 8-9 h at 37 ^{0}C and more than a week at 4-6 ^{0}C. For the effective in preserving raw camel milk, Lactoperoxidase system in fresh camel milk can be activated within half an hr of the milking using various levels of thiocyanate and hydrogen peroxide up to 18-20 h at 37 ^{0}C (Singh et al., 2017). Also, food fortification is one of the well-known public health interventions and one of the most effective methods in the preventing nutritional deficiencies (Alimardanova et al., 2015; Shingisov et al., 2016; Alibekov et al., 2020; Alibekov et al., 2021; Zheleuova et al., 2021).

Another way to preserve a high-quality composition of dairy products for long time storage is a drying and obtaining of the milk powder. Milk powder results from extracting water content out of milk. The main purpose of converting milk into milk powder is to convert the liquid perishable raw material to a product that can be stored without substantial loss of quality, preferably for some years. Today, milk powder is usually made by spray-drying. Alternatively, the milk can be dried by drum (roller)-drying and freeze-drying. Freeze-drying preserves almost all the nutrients in milk but it is very expensive (Kalyankar et al., 2016).

The greatest impact on the quality indicators of the resulting products within vacuum freeze-drying has a temperature of the product sublimation in the freeze-drying chamber (Shingisov et al., 2015). In addition, the energy costs for drying it also depend on the numerical value of this temperature. Currently, among the researchers engaged in the drying processes, there is absent a consensus on the application of the lower limit of the sublimation temperature. For example, to preserve the initial content of the milk, the lower limit of the sublimation temperature in the sublimation chamber has been recommended in the range of since minus T = - 20 ^{0}C until minus T = -40 ^{0}C (Tastemirova et al., 2020).

It was considered that the initial quality of the dried milk can be achieved at the temperature range: t = -10...- 13 °C, where until 90-92% of water in milk are frozen, residual water content is not available for the spoilage of food or in remain, it will be 8% of water that has an insignificantly value (Shingisov & Alibekov, 2017). From the point of view of energy savings, lowering the minus temperature below t = -15 °C is economically disadvantageous. Therefore, in the case of using of vacuum – freeze drying process of cow milk and camel milk, the lower limit of the sublimation temperature, a temperature of -13 °C ...- 15 °C is recommended. In our previous study it has been concluded that, at the minis temperature of t = -15 °C, more than 95% of the water consisted in cow' and camel' milks are frozen, and further reducing of temperature had monotonously insignificantly increasing behaviour of the freezing. Therefore, from the point of view of energy savings and maximum preservation of the initial qualities during the shelf-life of cow milk and camel milk, the optimal freezing temperature range is recommended (Tastemirova et al., 2019; Solanki et al., 2022).

The purpose the present work was to study the qualitative composition of reconstituted camel milk versus whole milk, by application the established lower limit of the sublimation temperature of t = -15 °C within vacuum sublimation drying process.

2 Materials and methods

2.1 Methodology of physicochemical and chemical indicators

Fresh whole camel milk from healthy and uninfected camels (*Camelus dromedarius)* was obtained from the "Gulmaira" peasant farm in the Ordabassy region, Turkestan oblast, Kazakhstan. The following definitions have been used: Whole milk is milk no fat removed and sometimes named as "regular milk" because the amount of fat in it has not been altered. *Reconstituted milk* products are the products resulting from addition of water to the dried or condensed form of product in the amounts necessary to re-establish the specified water/solids ratio (Tetra Pak Group, 2021). Physicochemical indicators were studied by using the following standard analytical instruments and methods:

- milk density was determined by using the hydrometer GOST 18481-81 (USSR State Committee for Standards,1981);
- mass fraction of fat was determined according to GOST 5867-90 (USSR State Committee for Standards, 1991);
- mass fraction of protein was determined according to GOST 23327-98 (State Committee for the Russian Federation for Standardization and Metrology, 2000);

- solubility index, cm^3 was determined according to GOST R ISO 8156-2010 (Federal Agency on Technical Regulating and Metrology, 2010);
- mass fraction of ash was determined according to GOST 54668-2011 (Federal Agency on Technical Regulating and Metrology, 2011);
- mass fraction of moisture was determined according to GOST ISO 5537-2015 (Federal Agency on Technical Regulating and Metrology, 2015a);
- titratable acidity was determined according to GOST ISO-6091-2015 (Federal Agency on Technical Regulating and Metrology, 2015b);
- active acidity pH was determined by using the "SCHOTT Instrument" Lab 850 ionomer (Germany);
- content of mineral substances was studied by using Atomic Absorption Spectrometry (AAS);
- quantitative content of amino acids was determined by using High Performance Liquid Chromatography (HPLC Waters, Alliance e2695, USA) based on the internal standards and single point calibration.

The composition of fatty acids was determined by gas chromatography on the Kristall-4000 gas-liquid chromatograph with a flame ionization detector and NetChrom software (GOST 30418-96, State Committee for the Russian Federation for Standardization and Metrology, 1998), within interesterification of milk fat by methylate sodium in methanol. Separation of methyl esters was provided on the capillary column with a length 30 m and internal diameter 0,25 mm, carrier gas – hydrogen was passed at the speed 40 mL/h. Separation was done on the polar stationary phase SUPELCOQAX-10 by increasing a temperature from 60 ^{0}C until 180 ^{0}C at the speed 20 ^{0}C per minute, maximal temperature in the column was 230 ^{0}C.

2.2 Methodology of camel milk drying and reconstitution from powdered camel milk

Before a freeze-drying process, camel milk was poured into metal plates (there used four units) sizes of 500 x 300 x 30 mm with a layer thickness of 3 ... 3.2 mm and frozen in the Midea HS-324 C refrigerating chamber at a temperature of -18 ÷ -20 °C within 24 h. Then, the plates with frozen samples were input to the sublimation chamber. Drying was carried out by a vacuum sublimation including a sublimation chamber unit that consists in a round heat-insulated body and a top, connected to a vacuum pump and a desublimator, as well as a refrigeration machine that provides cold to the sublimation chamber and a desublimator. The evaporator of the refrigeration machine was made in the form of a spiral of copper pipe and tightly wrapped around the entire outer surface of the sublimation chamber. The sublimation chamber has four sections for the plates' installation (Tastemirova et al., 2019).

During the drying process, the air temperature and the residual pressure in the sublimation chamber are constantly were monitored. At the beginning of the experiment, the refrigeration machine was turned on and upon reaching the preset sublimation temperature of -15 °C, and then the vacuum pump was switched on. When the residual pressure in the sublimation chamber was reached value of P = 80-90 bar, the drying process was begun. The drying process stops after reaching the required moisture content of the product, the freeze-drying chamber was depressurized, the dried milk was unloaded and then subjected to the grinding.

Before a dissolving process, distillated water was heated up to T = 55... 60 °C. For a required amount of dried powder, a first part of water was filled in small portions and thoroughly mixed until the consistency of thick homogeneous slurry and further the remaining water was added. For completely dissolve of the solid particles, the resulting mixture is intensively mixed within 7-8 minutes by using a stirring device at a speed of 3000 rpm, and then it was kept during 15 min with cooling to a temperature of 20-24 °C.

In the present work, the dry matter content of camel milk was taken as a criterion for the assessment. The content of dry matter in the investigated camel milk during the determination was 13%. This value is a normal in comparing to the known data (Tastemirova et al., 2020). And the moisture content of camel milk after drying was determined, and this indicator was 3.5%. To achieve the dry matter content in the initial camel milk, the amount of distilled water for recovery was determined by calculation as follows (Equation 1):

$$\begin{aligned} &100 - W_{c.\Pi.} = 96.5 \\ &96.5 / 13 = 7.4 \end{aligned} \qquad (1)$$

Thus, the reconstitution of dried camel milk by distilled water was carried out in a ratio of 1:7.4. This ratio is based on the standard amount of dry matter in camel milk. It was taking into account the fact that the dry matter content in camel milk was equal 13%.

3 Results and discussion

3.1 Physicochemical indicators

The physicochemical indicators of whole and reconstituted camel milk are shown in Table 1.

As can be seen from the data in Table 1, the main physicochemical indicators of camel milk reconstituted from a dry powder differ slightly from its whole milk. As a result of drying, in the composition of reconstituted camel milk, the

Table 1. Physicochemical indicators of whole and reconstituted camel milk.

Name	Whole camel milk	Reconstituted camel milk
Protein	3.81	3.79
Fat	4.53	3.75
Density	1029	1028
Acidity, ^{o}T	18.0	18.0
pH	6.38	6.37
Solubility indicator, cm^3, at T = 24 ^{0}C	-	0.22
Ash	0.50	0.51

mass fraction of fat decreases by 17.21%, and the mass fraction of protein decreases by 0.53% compared to whole milk. The rest variations of reconstituted camel milk are insignificant, or less than 0.1% compared to whole camel milk. Based on the study results of the physicochemical indicators, it can be concluded that after vacuum freeze drying of camel milk at a temperature of -15 °C is available insignificant variation.

The amino acid composition of whole camel milk and reconstituted camel milk was studied by using High Performance Liquid Chromatography (HPLC Waters, Alliance e2695, USA). The chromatograms are shown in Figure 1 and Figure 2. In addition, the chromatograms processed data are presented in Table 2.

As the data analysis of Table 2 shows, after drying, there is a significant decrease in the amount of essential amino acids, with the exception of Lysine and sulfur-containing amino acid – Methionine. The amount of essential amino acids Leucine and Isoleucine decreased by 47%, while the amount of Valine and Phenylalanine decreased 2.6 times. As for the nonessential amino acids, it was found a significant decrease in their amount after drying camel milk, with the exception of Arginine. The increase in the amount of Arginine was 2.53 times, while the decrease in the amount of other nonessential amino acids was the following: Glycine – by 13.16 times; Proline – 2 times; Alanine – 6.34 times; Serine – 2.26 times.

A significant decrease in the amino acid composition of camel milk might explained by the fact that in the process of vacuum-freeze drying, denaturation changes of thermolabile protein substances of camel milk are possible. At the partial denaturation, there is a decrease in the content of fractions of low molecular weight proteins and an increase in fractions of proteins with a higher molecular weight. Thermolabile whey protein substances such as Albumin and Globulin fractions are especially susceptible to denaturation changes. It is known that camel milk belongs to the Albumin type, not to the casein type, like cow's milk, therefore, such fluctuations in the amino acid composition of camel milk before and after vacuum-freeze drying have been revealed. It is known that proteins have colloidal properties. On the surface of simple and complex proteins there is a hydration membrane that under certain conditions of vacuum freeze drying can partially to collapse. This phenomenon can lead to the partial denaturation of thermolabile protein substances in camel milk and to the accumulation of free amino acids. Specifically, increasing of Aspartic and Glutamic acids, as well as sulfur-containing amino acids such as Histidine, Leucine and Methionine can improve the organoleptic characteristics of the final product – reconstituted camel milk.

With Glutamic and Cysteine amino acids, Glycine participates in the synthesis of a short peptide – Glutathione, the concentration

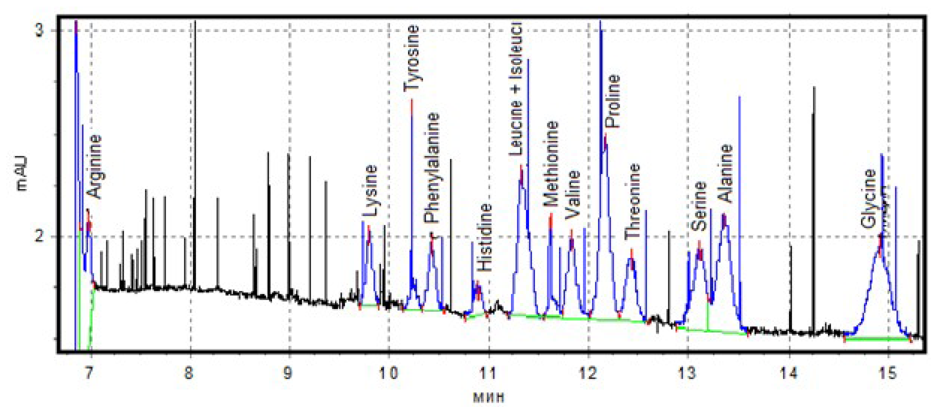

Figure 1. Chromatogram of the amino acids composition of whole camel milk.

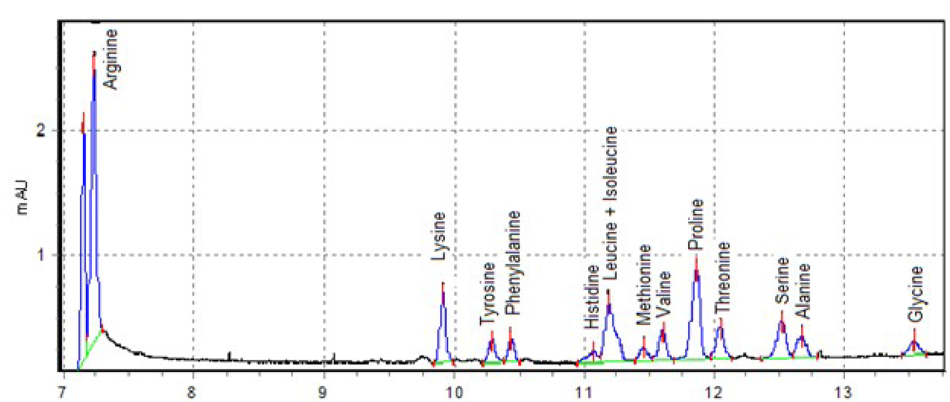

Figure 2. Chromatogram of the amino acids composition of reconstituted camel milk.

of which is important for the function of an antioxidant enzymatic system called Glutathione peroxidase. In this regard it was observed a significant decrease in the amount of the Glycine after vacuum freeze drying of camel milk.

3.2 Fatty acids composition

The fatty acids composition of whole camel milk and reconstituted camel milk was studied by using gas chromatography on the Kristall-4000 gas-liquid chromatograph with a flame ionization detector and NetChrom software (GOST 30418-96). The chromatograms are shown in Figure 3 and Figure 4. In addition, the chromatograms processed data are presented in Table 3.

Analysis of the Table 3 data indicates that the 21 types of fatty acids were discovered. In the process of preparing camel milk for drying, i.e. in its mechanical cleaning, stirring for the purpose of crushing fat globules, cooling and freezing, weighs of saturated fatty acids particularly decrease, as example: Butyric, Caproic, Undecylic, Pentadecanoic, Palmitic, Margaric, Stearic, Arachidic, Heneicosanoic, Behenic and Ligoneceric acids. Also, such variations are available for the unsaturated fatty acids: Cis10-Pentadecanoic, Linoleic, Oleic, Elaidic, Eicosapenentaenoic, Arachidonic, Dihomo-Gamma-Linolenic and Docosadiaenoic. However, with the exception of Capric, Tridecylic and Heneicosanoic acids those are increased.

Simultaneously, there is an increase in the amount of some unsaturated fatty acids such as Eicosapentaenoic (omega-3), Dihomo-Gamma-Linolenic (omega-6) and Docosadiaenoic (omega-6) acids that indicate structural changes in the fat content of camel milk in the process of vacuum-freeze drying. On the

Table 2. Amino acids composition of whole camel milk and reconstituted camel milk.

Amino acids	Whole camel milk		Reconstituted camel milk	
	Amount, mg/l	Weigh, %	Amount, mg/L	Weigh, %
Essential amino acids				
Histidine	9.40	0.14 ± 0.07	5.50	0.14 ± 0.07
Leucine + Isoleucine	21.0	0.32 ± 0.08	10.0	0.25 ± 0.07
Lysine	8.30	0.13 ± 0.04	8.60	0.22 ± 0.07
Methionine	6.60	0.10 ± 0.03	4.50	0.11 ± 0.04
Phenylalanine	16.0	0.25 ± 0.07	6.10	0.15 ± 0.06
Threonine	16.0	0.25 ± 0.10	7.30	0.18 ± 0.07
Valine	18.0	0.28 ± 0.11	7.00	0.18 ± 0.07
Non-essential amino acids				
Arginine	47.0	0.72 ± 0.29	72.0	1.80 ± 0.72
Glycine	25.0	0.38 ± 0.13	1.90	0.05 ± 0.02
Proline	42.0	0.64 ± 0.17	21.0	0.53 ± 0.14
Tyrosine	9.70	0.15 ± 0.04	7.50	0.19 ± 0.06
Alanine	26.0	0.40 ± 0.10	4.10	0.10 ± 0.03
Serine	19.0	0.29 ± 0.08	8.40	0.21 ± 0.06

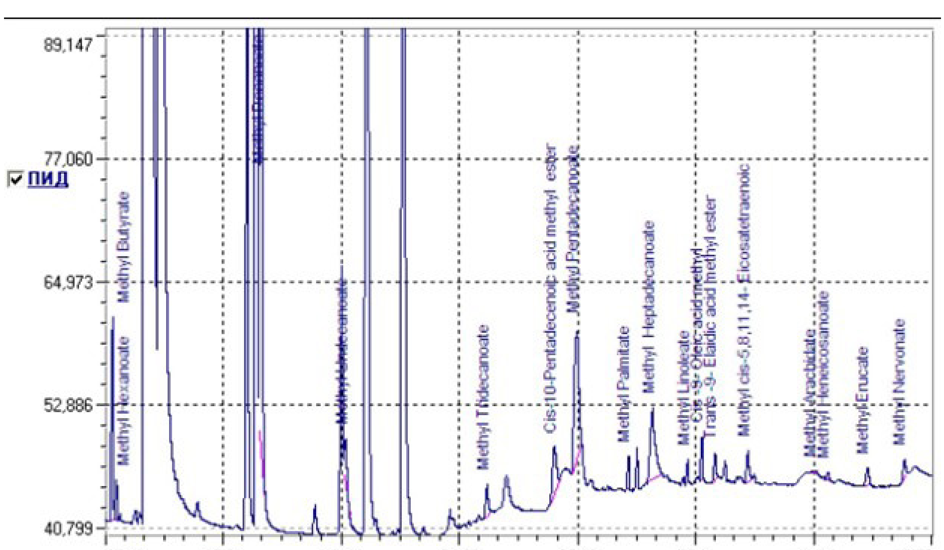

Figure 3. Chromatogram of the fatty acids composition of whole camel milk.

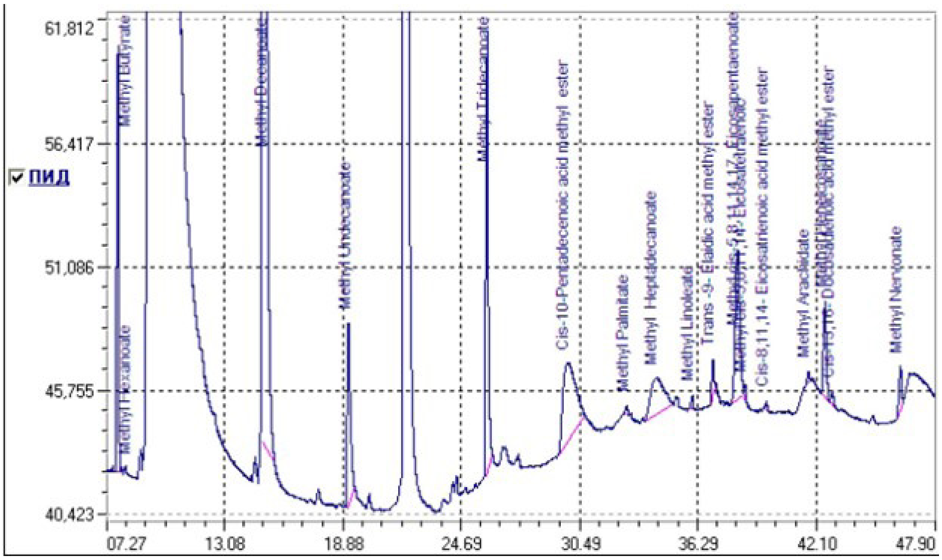

Figure 4. Chromatogram of the fatty acids composition of reconstituted camel milk.

Table 3. Fatty acids composition of whole camel milk and reconstituted camel milk.

Fatty acids	Common name	C:D (carbon atom: double bond)	Raw camel milk	Reconstituted camel milk
			Weigh, %	Weigh, %
MethylButyrate	Butyric acid	C4:0	83.54	0.9
Methyl Hexanoate	Caproic acid	C6:0	25.18	0.28
Methyl Decanoate	Capric acid	C10:0	43.547	93.09
Methyl Undecanoate	Undecylic acid	C11:0	1.037	0.646
Methyl Tridecanoate	Tridecylic acid	C13:0	1.193	1.741
Methyl cis-10-Pentadecanoate	Cis10-Pentadecanoic acid (omega-3)	C15:1 cis10	1.533	1.033
MethylPentadecanoate	Pentadecanoic acid	C15:0	10.73	-
Methyl Palmitate	Palmitic acid	C16:0	2.266	0.08
MethylHeptadecanate	Margaric acid	C17:0	6.146	-
Methyl linolelaidate	Stearic acid	C18:0	0.192	-
Cis-9,12-Methyl Linoleate	Linoleic acid (omega-6)	C18:2 cis 9,12	0.412	0.091
Methyl cis-9-Octadecenoate	Oleic acid (omega-9)	C18:1 cis 9	0.904	-
Methyl trans-9-Octadecenoate	Elaidic acid (omega-9)	C18:1 trans9	0.696	0.111
Methyl cis-5,8,11,14,17- Eicosapentaeonate	Eicosapenentaenoic acid (omega-3)	C20:5 cis 5,8,11,14,17	-	0.641
Methyl-5,8,11,14-Eicosatetraenoate	Arachidonic acid (omega-6)	C20:4 cis 5,8,11,14	0.981	0.028
Methyl Dihomo-Gamma-Linolenate	Dihomo-Gamma-Linolenic acid (omega-6)	C20:3 cis 8,11,14	-	0.019
Methyl Arachidate	Arachidic acid	C20:0	0.256	0.105
MethylHeneicosanoate	Heneicosanoic acid	C21:0	0.132	0.251
Methyl cis-13,16-Docosadienoate	Docosadiaenoic acid (omega-6)	C22:2 cis13,16	-	0.041
MethylErucate	Behenic acid	C22:0	0.584	0.672
MethylNervonate	Ligoneceric acid	C24:0	0.671	0.191

basis of the above mentioned, it can be concluded that during freeze drying at a freeze temperature of -15 °C, there are slight changes in the fatty acid composition in the fat of camel milk.

3.3 Vitamins composition

The water-soluble vitamins B composition of whole camel milk and reconstituted camel milk was studied by using the method M 04-41-2005 technique (Certificate of attestation of the measurement procedure No. 224.04.17.035/2006) proposed in Trineyeva et al. (2017). Basically, the method consists in the extraction of Thiamine from a sample of the analyzed product by a solution of sulfuric acid, its oxidation with a solution of iron-cyanide potassium into thiochrome, extraction of the oxidized form from the aqueous phase with isobutyl alcohol, and measurement of the fluorescence intensity (by the method of capillary electrophoresis).

To determine vitamin A, GOST R54635-2011 was used (Method for determining the mass fraction of vitamin A in the form of retinol, retinol acetate, retinol palmitate by using High Performance Liquid Chromatography (Trineyeva et al., 2017).

The recent studies show that the content of vitamins in camel milk depends on the season of the year, breed, age, conditions of keeping animals and the chosen drying method (Shingisov et al., 2014; Tastemirova et al., 2020). The chromatograms are shown in Figure 5 and Figure 6. In addition, the chromatograms processed data are presented in Table 4.

Comparative analysis of Table 4 shows that in the recombined camel milk after vacuum freeze drying among the vitamin composition, the significant losses are vitamin C (Ascorbic acid) more than 3 times, and the content of other types of vitamins changes in the direction of both decrease and increase, for example vitamin B_1 (Thiamine) is reduced by 7.69%, while B_2 (Riboflavin) is more than doubled and B_6 (Pyridoxin) by 22.22% compared to whole camel milk. However, fat-soluble vitamin A (Retinol) was absent in recombined camel milk.

3.4 Study of the minerals composition of reconstituted camel milk

The content of mineral substances was studied by using Atomic Absorption Spectrometry (AAS). The research results are presented in Table 5.

The data of Table 5 shows that the content of macroelements in recombined camel milk undergoes significant changes in comparison with whole camel milk. For example, the content of the chemical element – potassium in recombined milk is more than 1.31 times, calcium – 1.48 times, sodium – 1.068 times,

Table 4. The vitamins content.

Name	Raw camel milk	Reconstituted camel milk
	Weigh, mg %	Weigh, mg %
A (Retinol)	0.048 ± 0.002	Missed
B_1 (Thiamine)	0.056 ± 0.011	0.052 ± 0.011
B_2 (Riboflavin)	0.018 ± 0.008	0.039 ± 0.016
B_6 (Ppyridoxin)	0.070 ± 0.001	0.099 ± 0.020
C (Ascorbic acid)	3.5 ± 1.19	1.094 ± 0.372

Table 5. The minerals content.

Name	Raw camel milk	Reconstituted camel milk
	Weigh, mg %	Weigh, mg %
Potassium	149.4 ± 2.14	196.18 ± 2.1
Calcium	98.72 ± 1.7	146.24 ± 3.3
Magnesium	missed	Missed
Sodium	50.02 ± 0.62	53.42 ± 0.51
Ferrum	0.24 ± 0.01	0.13 ± 0.05
Zinc	0.38 ± 0.006	0.27 ± 0.02

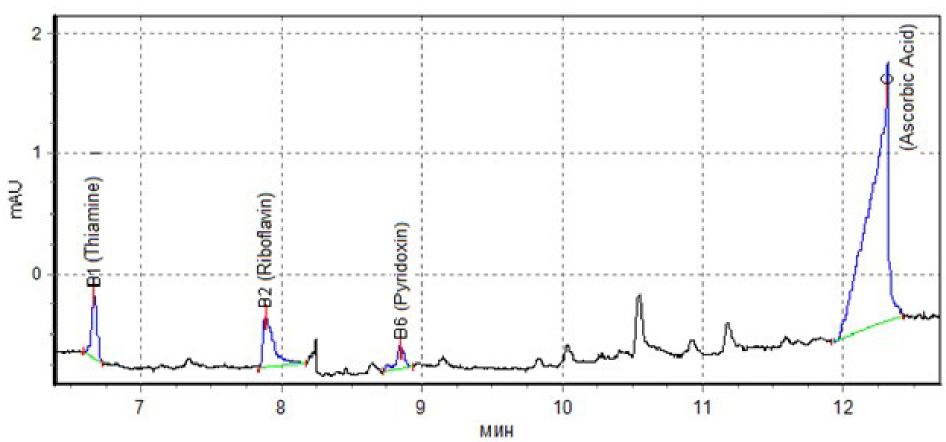

Figure 5. Chromatogram of the vitamins composition of whole camel milk.

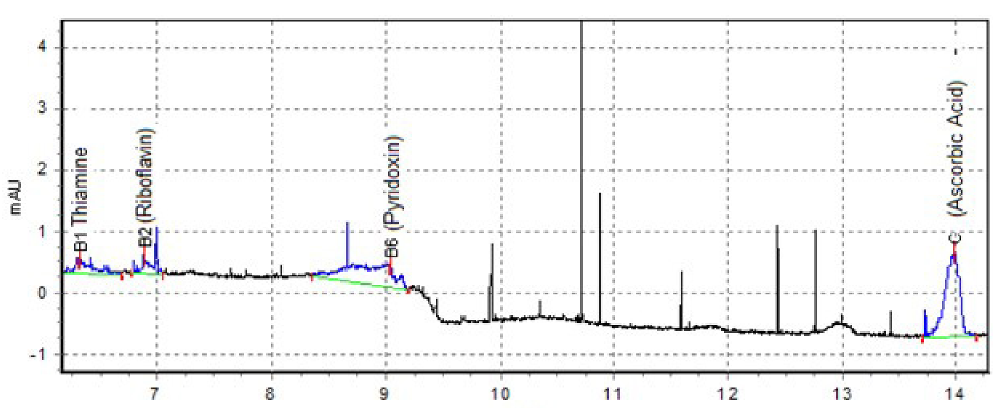

Figure 6. Chromatogram of the vitamins composition of reconstituted camel milk.

and the content of iron times zinc decreased respectively 1.80 1.41 times less compared to natural camel milk. Probably this fact is related with used for the recovering of a dry powder of camel milk, distilled water that meets the requirements of GOST 51232-98.

4 Conclusion

The physicochemical indicators of whole and reconstituted camel milk have similar values within acceptable limits. As a result of drying camel milk, a partial denaturation of its amino acid composition occurs that leading to the decreasing in the content of low molecular weight protein fractions and for the increasing of protein fractions with a higher molecular weight. Thermolabile whey protein substances such as Albumin and Globulin fractions are especially susceptible to denaturation changes, as a result of which the hydration membrane of proteins present on the surface is destroyed, leading to the minor changes in the amino acid composition. Specifically, increasing of Aspartic and Glutamic acids values, as well as sulfur-containing amino acids such as Histidine, Leucine, Methionine can improve the organoleptic characteristics of the final product – reconstituted camel milk. During vacuum freeze drying at a sublimation temperature of minus -15 ^{0}C in the reconstituted camel milk, there is a significant decrease in the amount of saturated fatty acids, with the exception of Capric, Tridecylic and Heneicosanoic acids with increasing in the amount of unsaturated fatty acids were observed that related to the structural variations in the fatty acids phase of camel milk in the process of vacuum-freeze drying.

Based on the results of the study of the vitamins and minerals compositions of the reconstituted camel milk, it was concluded that within vacuum freeze drying of camel milk at the temperature of minus -15 ^{0}C, insignificant changes in the contents of vitamins and macroelements have happened.

References

Abbas, S., Ashraf, H., Nazir, A., & Sarfraz, L. (2013). Physico-chemical analysis and composition of camel milk. *Intestinal Research*, 2(2), 85-98.

Adlerova, L., Bartoskova, A., & Faldyna, M. (2008). Lactoferrin: a review. *Veterinarni Medicina*, 53(9), 457-468. http://dx.doi.org/10.17221/1978-VETMED.

Akan, E. (2021). An evaluation of the in vitro antioxidant and antidiabetic potentials of camel and donkey milk peptides released from casein and whey proteins. *Journal of Food Science and Technology*, 58(10), 3743-3751. http://dx.doi.org/10.1007/s13197-020-04832-5. PMid:34471298.

Alibekov, R. S., Gabrilyants, E. A., Utebaeva, A. A., Nurseitova, Z. T., Konarbayeva, Z. K., & Khamitova, B. M. (2021). Cottage cheese fortified by natural additives. *Food Research*, 5(Suppl. 1), 152-159. http://dx.doi.org/10.26656/fr.2017.5(S1).013.

Alibekov, R. S., Kenzhibayeva, G. S., Utebaeva, A. A., Urazbayeva, K. A., Tursynbay, L. M., & Kulanova, D. A. (2020). Enriched plum filling for the confectionery. *Food Research*, 4(Suppl. 6), 26-34. http://dx.doi.org/10.26656/fr.2017.4(S6).014.

Alimardanova, M. K., Tlevlesova, D. A., Simov, Z., Dimitrov, D., & Matibayeva, A. I. (2015). Incorporating Allium odorum as a vegetable ingredient of processed cheeses. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, 6(3), 330-338.

Brezovečki, A., Čagalj, M., Dermit, Z. F., Mikulec, N., Ljoljić, D. B., & Antunac, N. (2015). Camel milk and milk products. *Mljekarstvo: Journal for Dairy Production and Processing Improvement*, 65(2), 81-90.

Ebrahimi, A., Moosavy, M.-H., Khatibi, S. A., Barabadi, Z., & Hajibemani, A. (2021). A comparative study of the antibacterial properties of milk from different domestic animals. *International Journal of Dairy Technology*, 74(2), 425-430. http://dx.doi.org/10.1111/1471-0307.12757.

Farah, Z. (1993). Composition and characteristics of camel milk. *The Journal of Dairy Research*, 60(4), 603-626. http://dx.doi.org/10.1017/S0022029900027953. PMid:8294611.

Federal Agency on Technical Regulating and Metrology. (2010). *GOST R ISO 8156-2010 – dried milk and dried milk products – determination of solubility index*. Moscow: Federal Agency on Technical Regulating and Metrology.

Federal Agency on Technical Regulating and Metrology. (2011). *GOST 54668-2011 – milk and milk products – methods for determination of moisture and dry substance mass fraction*. Moscow: Federal Agency on Technical Regulating and Metrology.

Federal Agency on Technical Regulating and Metrology. (2015a). *GOST ISO 5537-2015 – dried milk – determination of moisture content, reference method*. Moscow: Federal Agency on Technical Regulating and Metrology.

Federal Agency on Technical Regulating and Metrology. (2015b). *GOST ISO 6091-2015 – dried milk – determination of titratable acidity, reference method*. Moscow: Federal Agency on Technical Regulating and Metrology.

Izadi, A., Khedmat, L., & Mojtahedi, S. Y. (2019). Nutritional and therapeutic perspectives of camel milk and its protein hydrolysates: a review on versatile biofunctional properties. *Journal of Functional Foods*, 60, 103441. http://dx.doi.org/10.1016/j.jff.2019.103441.

Kalyankar, S. D., Deshmukh, M. A., Chopde, S. S., Khedkar, C. D., Lule, V. K., & Deosarkar, S. S. (2016). Milk powder. In B. Caballero, P. M. Finglas & F. Toldrá (Eds.), *Encyclopedia of food and health* (pp. 724-728). Amsterdam: Elsevier. http://dx.doi.org/10.1016/B978-0-12-384947-2.00465-7.

Konuspayeva, G., Faye, B., & Loiseau, G. (2009). The composition of camel milk: a meta-analysis of the literature data. *Journal of Food Composition and Analysis*, 22(2), 95-101. http://dx.doi.org/10.1016/j.jfca.2008.09.008.

Kula, J. T., & Tegegne, D. (2016). Chemical composition and medicinal values of camel milk. *International Journal of Research Studies in Biosciences*, 4(4), 13-25.

Kumar, D., Verma, A. K., Chatli, M. K., Singh, R., Kumar, P., Mehta, N., & Malav, O. P. (2016). Camel milk: alternative milk for human consumption and its health benefits. *Nutrition & Food Science*, 46(2), 217-227. http://dx.doi.org/10.1108/NFS-07-2015-0085.

Mohamed, H., Ranasinghe, M., Amir, N., Nagy, P., Gariballa, S., Adem, A., & Kamal-Eldin, A. (2022). A study on variability of bioactive proteins in camel (Camelus dromedarius) milk: insulin, insulin-like growth factors, lactoferrin, immunoglobulin G, peptidoglycan recognition protein-1, lysozyme and lactoperoxidase. *International Journal of Dairy Technology*, 75(2), 289-297. http://dx.doi.org/10.1111/1471-0307.12836.

Onjoro, P. A., Njoka-Njiru, E. N., Ottaro, J. M., Simon, A., & Schwartz, H. J. (2006). Effects of mineral supplementation on milk yield of free-ranging camels (camelus dromedarius) in northern Kenya. *Asian-Australasian Journal of Animal Sciences*, 19(11), 1597-1602. http://dx.doi.org/10.5713/ajas.2006.1597.

Park, Y. W., Haenlein, G. F., & Ag, D. S. (2013). *Milk and dairy products in human nutrition*. Ames: Wiley-Blackwell. http://dx.doi.org/10.1002/9781118534168.

Shingisov, A. U., & Alibekov, R. S. (2017). Analysis of the moisture evaporation process during vacuum freeze-drying of koumiss and shubat. *Heat and Mass Transfer*, 53(5), 1571-1578. http://dx.doi.org/10.1007/s00231-016-1920-4.

Shingisov, A. U., Alibekov, R. S., Myrkalykov, B. S., Musayeva, S. A., Urazbayeva, K. A., Iskakova, S. K., Taspoltayeva, A. R., & Kobzhasarova, Z. I. (2016). Physicochemical characteristics of the new polyphyto-component composition for food industry. *Biosciences Biotechnology Research Asia*, 13(2), 879-886. http://dx.doi.org/10.13005/bbra/2110.

Shingisov, A., Alibekov, R., Nurseitova, Z., Orymbetova, G., Kantureeva, G., & Mailybaeva, E. (2015). Desorption isotherms of the koumiss and shubat clots enriched by various additives. *Modern Applied Science*, 9(8), 409-416. http://dx.doi.org/10.5539/mas.v9n8p409.

Shingisov, A., Alibekov, R., Nurseytova, Z., Kantureeva, G., & Mailybaeva, E. (2014). Study of the content of minerals in koumiss and shubat with the addition of the antioxidants. *Industrial Technology and Engineering*, 3, 47-50.

Singh, R., Mal, G., Kumar, D., Patil, N. V., & Pathak, K. M. L. (2017). Camel milk: an important natural adjuvant. *Agricultural Research*, 6(4), 327-340. http://dx.doi.org/10.1007/s40003-017-0284-4.

Solanki, D., Sakure, A., Prakash, S., & Hati, S. (2022). Characterization of Angiotensin I-Converting Enzyme (ACE) inhibitory peptides produced in fermented camel milk (Indian breed) by Lactobacillus acidophilus NCDC-15. *Journal of Food Science and Technology*, 59(9), 3567-3577. http://dx.doi.org/10.1007/s13197-022-05357-9. PMid:35875214.

State Committee for the Russian Federation for Standardization and Metrology. (2000). *GOST 23327-98 – milk and milk products – determination of mass part of total nitrogen by Kjeldahl method and determination of mass part of protein*. Moscow: State Committee for the Russian Federation for Standardization and Metrology.

State Committee for the Russian Federation for Standardization and Metrology. (1998). *GOST 30418-96 – vegetable oils – method for determination of fatty acid content*. Moscow: State Committee for the Russian Federation for Standardization and Metrology.

Swelum, A. A., El-Saadony, M. T., Abdo, M., Ombarak, R. A., Hussein, E. O. S., Suliman, G., Alhimaidi, A. R., Ammari, A. A., Ba-Awadh, H., Taha, A. E., El-Tarabily, K. A., & El-Hack, M. E. A. (2021). Nutritional, antimicrobial and medicinal properties of camel's milk: a review. *Saudi Journal of Biological Sciences*, 28(5), 3126-3136. http://dx.doi.org/10.1016/j.sjbs.2021.02.057. PMid:34025186.

Tastemirova, U. U., Alibekov, R. S., Ciprovica, I., Shingisov, A. U., Mukhtarkhanova, R. B., & Mailybaeva, E. U. (2019). The optimal freezing temperature of cow milk and camel milk. *News of the National Academy of Sciences of the Republic of Kazakhstan: Series Chemistry and Technology*, 3(435), 19-24.

Tastemirova, U., Ciprovica, I., & Shingisov, A. (2020). The comparison of the spray-drying and freeze-drying techniques for camel milk. *Research for Rural Development*, 35, 102-105. http://dx.doi.org/10.22616/rrd.26.2020.015.

Tetra Pak Group. (2021). *Dairy processing handbook*. Retrieved from https://dairyprocessinghandbook.tetrapak.com/chapter/recombined-milk-products. Recombined milk products. Online.

Trineyeva, O. V., Rudaya, M. A., & Slivkin, A. I. (2017). Determination of B vitamins in medicinal plant raw materials. *Voronezh State University Bulletin Series: Chemistry, Biologija, Farmacija*, 3, 131-134.

USSR State Committee for Standards. (1981). *GOST 18481-81 – glass hydrometers and cylinders – general specifications*. Moscow: USSR State Committee for Standards.

USSR State Committee for Standards. (1991). *GOST 5867-90 – milk and dairy products – method of determination of fat*. Moscow: USSR State Committee for Standards.

Wajahat, W., Azad, Z. R. A. A., Nazir, S., & Nasir, G. (2022). Real time-PCR coupled with melt curve analysis for detecting the authenticity of camel milk. *Journal of Food Science and Technology*, 59(4), 1538-1548. http://dx.doi.org/10.1007/s13197-021-05164-8. PMid:35250077.

Yadav, A. K., Kumar, R., Priyadarshini, L., & Singh, J. (2015). Composition and medicinal properties of camel milk. *Asian Journal of Dairy and Food Research*, 34(2), 83-91. http://dx.doi.org/10.5958/0976-0563.2015.00018.4.

Zheleuova, Z. S., Uzakov, Y. M., Shingisov, A. U., Alibekov, R. S., & Khamitova, B. M. (2021). Development of halal cooked smoked beef and turkey sausage using a combined plant extract. *Journal of Food Processing and Preservation*, 45(1). http://dx.doi.org/10.1111/jfpp.15028.

Zouari, A., Mtibaa, I., Triki, M., Jridi, M., Zidi, D., Attia, H., & Ayadi, M. A. (2020). Effect of spray-drying parameters on the solubility and the bulk density of camel milk powder: a response surface methodology approach. *International Journal of Dairy Technology*, 73(3), 616-624. http://dx.doi.org/10.1111/1471-0307.12690.