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ASSESSMENT OF GOAT MILK AND DAIRY PRODUCTS IN THE FOOD CHAIN IN THE CONTEXT OF GOAT BREEDING DEVELOPMENT IN ARMENIA

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ABSTRACT

The aim of the research is to study the effect of heat treatment on biochemical parameters and chemical composition of goat milk and dairy products with the perspective of finding out the indicators of accurate pasteurization, milk quality evaluation and the development of dairy goat breeding in Armenia.The study indicates that the lactose, total caseine, fat content in the milk do not undergo significant changes depending on the lactation, flactuate totally between 4.14-4.35%, 2.37-2.57% and 3.51-3.93% respectively, while after pasteurization a significant reduction of the nutrients is recorded in gross milk. The pasteurization affected furosine generation, the concentration of which increased to 47.8±0.3 mg/100 g protein in pasteurized milk. Although there is no difference between goat ripened cheese and curd furosine levels, nonetheless the concentration is increased by 11.6 and 11.5 times compared to the raw milk. ALP and LP activity is stable in raw milk, while heat-treatment caused thermal inactivation of the enzymes in pasteurized milk, cheese and curd, compared with unpasteurized. The levels of ammonia and urea significantly decrease in heat-treated milk, cheese and curd compared with raw heterogeneous gross milk. The percentage of dairy goats fertility in the farm trends to increase by 63.0%. ALP, LP activity in combination with furosine can serve as complex biochemical indicators in the food chain for proper pasteurization and processing of goat milk and production of safe dairy products in Armenia. The implementation of breeding new technology will contribute to the development of dairy goat breeding in the RA.

Keywords: alkaline phosphatase, furosine, lactoperoxidase, food chain, goat fertility

INTRODUCTION

Goat breeding is one of the strategic areas for agriculture development in Armenia since goats are becoming vitally important in food production. Goat breeds specifically designed for milk and dairy production are attracting more and more attention in the study of milk quality and milk production **(Zobel & Nawroth, 2020)**. With its non-allergenic nature, digestibility and contribution to reducing poverty and hunger at the community level, goat milk should be introduced globally. The quality of milk depends on its composition, which varies depending on the breed, age, stage of lactation, breast size, diet, duration of dry period, environmental temperature **(Haenlein & Park, 2010)**. Many studies have investigated the chemical composition of goat milk as a nutritional advantage over cow milk. Compared to cow milk, the compositional differences of goat milk, such as lower αs1-casein content and higher β-casein content, small fat globules and medium-chain fatty acids, cause difficulties in the production of goat milk products **(Nayik et al., 2021)**. Global production of goat milk is increasing, and most goat milk is used fresh or in processed products such as cheese, yogurt, and other dairy products **(Miller & Lu, 2019; Sepe & Argüello, 2019)**. It is noteworthy that a number of factors affect the physico-chemical indicators of milk, including feeding, number of lactation, age of the animal, climatic conditions. **Ibrahim et al. (2024)**, studied the physico-chemical parameters of unpasteurized and pasteurized milk of Saanen goat breed bred in Malaysia. Compared to heat treated non-skimmed milk, after milk pasteurization the decrease of lactose, fat and protein in quantity was recorded. **Ospanov (2021)** recorded an average of 3.43% of fat in the total milk of Saanen goat breed bred in Kazakhstan during the summer months of lactation, the amount of dry matter is inferior and amounts to 10.4-10.9%.

Worldwide studies have clarified biological markers of cow milk, whereas small cattle studies are still under clarification **(Silva et al., 2020; Clawin-Rädecker et al., 2021; Buys & Seifu, 2022)**. Thus, the European Food Safety Authority (EFSA) urges scientists to find out the standards in terms of small ruminants **(Clawin-Rädecker et al., 2021)**.

High-quality milk and dairy products require an adequate process control to ensure the heat load applied during the processing. Assessment of the extent of the heat damage can be achieved by the analysis of furosine **(Mendoza et al., 2005)**. Pasteurization is a heat treatment applied in dairy industry to destroy harmful microorganisms in milk **(Ritota et al., 2017)**. Furosine Ɛ-N-(2-furoylmethyl-1-lysine) is considered the earliest indicator of the Maillard reaction related to the type and the intensity of the food-processing conditions. **Liu et al. (2020)** research concluded that furosine was one of the key indicators for discrimination of reconstituted milk. The literature review shows that the presence and amount of furosine varies depending on the heating method (temperature and time parameters), product type, processing technology and animal type **(Mendoza et al., 2005; Ritota et al., 2017)**. It is argued that adequate heat treatment is necessary to destroy microbes in raw milk, however the excessive heat treatment can result in inactivation of active compounds or loss of nutrients. As for cheese, scientists argued that the furosine level depends on the type and even size of the ripened cheese **(Pellegrino et al., 1997; Villamiel et al., 2000)**.

Main determinants of urea formation in milk are the amount of crude protein intake and ratio between protein and energy proportion in diet. Goat diet with excessive amount of crude protein and energy unbalanced diet cause the excess of nitrogenous substances in rumen along with release of ammonia, rise in concentration of urea in blood, and milk **(Bendelja et al., 2020)**. **Hanus et al. (2008)** reported that since the milk urea concentration is a respected indicator of the health and nutrition status, the results of their study demonstate that reliability of results of milk urea analyses depend on various methods used, and the photometrical method showed acceptable values in this context. A significant effect of lactation stage on the Norwegian goat milk urea levels were found, probably linked to variation of energy and protein distribution through lactation **(Kvaal, 2021).**

ALP and LP are the enzymes naturally available in all types of raw milks and because the heat stability of the enzymes is greater than that of pathogens available in milk, both of them are suggested to be used as markers for the proper pasteurization and indicators of product hygienic safety. Complete and proper pasteurization will inactivate the enzyme to low levels **(Rankin et al., 2010; Dairy Foods Science Notes, 2022; Klotz et al, 2008; Banks & Muir, 2002; Dumitrașcu et al. 2012; Boulares et al., 2011)**.

Since goats are among the most versatile of farm animals, they can thrive in many regions and in challenging environmental conditions **(Haenlein & Park, 2010)**. For many years local goats of low milk yield have been bred in Armenia. Since the year 2000 dairy goat farming has been developing more intensively, when goats of high milk yield were imported to the Republic of Armenia (RA), and were first bred in Vayots Dzor Province. Our scientific research began immediately after the introduction of goats with high milk yield to Vayots Dzor Province of Armenia, and the first report about it was published in 2001 **(Marmaryan & Kamalyan, 2001)**. The Saanen breed of goat is the most adaptable one to the climatic conditions of Armenia and is currently widespread. As a supplementary information on dairy goat breeding situation in Armenia, the **Figure 1** demonstrates the year 2024, with the total number of goats in provinces of Armenia according to the official data of the Statistical Committee of the Republic of Armenia **(ArmStat, 2024)**. Greatest head count was registered in Vayots Dzor, Aragatsotn, Syunik, Shirak and Tavush provinces of Armenia.

This research is a logical continuation of our previous study **(Grigoryan et al., 2023)**, which outlined the prerequisites of searching for biochemical indicators of accurate pasteurization of goat milk in the food chain from milk to dairy products in Armenia. According to the Code for Milk and Milk Products "pasteurization is the application of heat to milk and milk products aimed at reducing the numbers of any pathogenic microorganisms to a level at which they do not constitute a significant health hazard" **(FAO, 2004)**. In this regard, the research was carried out in raw and pasteurized milk, ripened cheese and curd, since the quality of dairy products depends on milk quality from which the products are made. Wrong pasteurization can influence the final product by inactivation of enzymes, denaturation of proteins, destruction of beneficial bacteria or chemical changes, which can affect an increase or decrease in substrate availability for bacteria **(Sosnowski, 2010)**.

Taking into account the above-mentioned factors and trends, an interdisciplinary research carried out by us, aimed to study the effect of heat treatment on biochemical parameters and chemical composition of goat milk and dairy products with the perspective of finding out the indicators of accurate pasteurization, milk quality evaluation and the development of dairy goat breeding in Armenia

Figure 1 The number of goats in the Provinces of Republic of Armenia according to the data of the Statistical Committee of the Republic of Armenia, as of January 1, 2024

MATERIALS AND METHODS

Experiment design and material

The research was carried out on Krashen goat breeding farm of Shirak Province of Armenia and included the results of the 2022-2023 study. The study materials were goat milk, ripened cheese and curd. The experimental animals were 2-, 3-, 4- and 6-year-old female Saanen breed goats. The physico-chemical parameters of milk for the number 1st and 2nd lactation were estimated for the 6 femail goats, which means that for the purpose of sampling the milk of 1st and 2nd lambing was used; while for the evaluation of biochemical and physico-chemical parameters of raw and heat treated heterogeneous milk 35 goats were used in the experiment. For this purpose the milk was sampled in the third month of lactation in 2023. The milk yield in 2022 was measured for 24 and in 2023 for 35 goats. For the purpose of ripened cheese evaluation 5 different units of product were estimated. Raw milk not subjected to heat treatment was considered as a control. The measurement of control milk yield started on the 8th day of lactation, in the morning, taking into account the time intervals between milking in 10 days, 3 times a month and once a month after control milking period during the lactation. The control milking continued the first three months of the lactation (March-May), since starting from the 4th month the milk productivity of goats begins to stabilize. The amount of milk for 10 days is determined by multiplying its amount per day by 10 and per month by 30 or 31 (depending on the number of days in month), based on which the milk productivity per lactation was calculated (**Jonson et al., 2018**). The kids were separated from the mothers one day prior to the control milking day and were not breastfed on the control day.

Ripened cheese and curd sampling were carried out in the final stage of maturation (on the 55th day of maturity in case of cheese and at the fifth hour in case of curd). Cheese ripening was carried out at 10-12°C, samples were taken from the core and just under the rind from 5 pieces of cheeses, for each cheese 5 x 5 cm section was applied. Cheese and curd were ripened and produced on Krashen goat-breeding farm and made from heat-treated milk.

Milk was pasteurized on Krashen goat breeding farm according to the Technical Regulations of the Customs Union TP TC 033/2013 **(TP TC, 2013)**, which specifies the proper pasteurization of milk: high-temperature for short-time (HTST, at least 72˚C for 15 min.), which is applied for milk used for the production of cheese and curd and low-temperature for long-time pasteurization method (LTLT, 63˚C for 30 min.), used for heat treatment milk as a food product. The milk, cheese and curd samples were transported to the laboratory in 4˚C frozen conditions **(TP TC, 2013)**. Biochemical and physico-chemical experiments were carried out in the Food Quality Control Laboratory of the Armenian National Agrarian University.

Cheese and curd sample preparation

Five grams of cheese and curd for each sample were crushed and homogenised by the Digital Homogenizer *(*IKA-T18 digital ULTRA-TURAX, Staufen, Germany*)*, 45 mL of distilled water was added per sample (according to the guide of CDR FoodLab Analyser) and centrifuged with 2000 RPM speed for 20 min. (iFuge D06, Neuation Technologies, Gujarat, India). For the purpose of water distillation Glass Water Stiller was used (BioStill 4, Witeg Labortechnik, Wertheim, Germany).

Determination of physico-chemical and biochemical parameters

The determination of physico-chemical data of milk was carried out in accordance with national standards. The mass fraction of fat was determined according to GOST 5867-90; the determination of density was according to GOST 3625; the mass fraction of protein was determined according to GOST 25179. The physico-chemical parameters were measured by the Milk Analyser "Expert Standard" (Laboratorika; Novosibirsk, RF). The Analyser operates according to the GOST 22261-94. The method is based on the principle of measuring the speed and the degree of ultra sound fluctuations through the milk samples.

The hydrogen ion concentration was measured by digital pH-meter/conductivity meter (Jenway 3540; Keison Products, Essex, England, UK). The pH meter was standardized with buffer solutions at pH 2.0; 4.0; 7.0; and 10.0.

Furosine concentration, Alkaline Phosphatase (ALP) and Lactoperoxidase (LP) activity were measured by photometric method on CDR FoodLab Analyser (CDR; Florence, Tuscany, Italy) for milk and dairy products, the results of which are correlated with the reference method. Furosine determination principle is based on Redox reaction during which the tetrazol salt reacts with Ɛ-fructosyl-lysine, forming a purple compound whose intensity is measured at λ_{max}= 545 nm. ALP activity measuring method is based on the reaction by which ALP induces the hydrolysis of p-nitrophenyl phosphate and forms a yellow-colored complex, the absorbance was measured at λ_{max}= 420 nm. LP activity measuring principle is that if hydrogen peroxide is available, milk peroxidase catalyzes forming a red compound with an intensity that is proportional to the concentration of peroxidase in the sample; the absorbance was measured at 505 nm. Urea and ammonia level was determined by spectrophotometric method using UV/Vis spectrometer (Jenway 7315; Keison Products, Essex, England, UK). Urea was calculated according to the urease activity **(Tabacco et al., 1979)**, intensity was measured at λ_{max}= 430 nm. Ammonia determination was carried out by using ninhydrin, a red color was formed if sodium hydroxide was available at wavelength of λ_{max}= 508 nm **(Baker & Alzboon, 2015)**.

Goats feeding and rearing

The daily feeding ration per goat unit included 2.0 kg hay, 0.5 combined pelleted forage, which contained barley, sunflower, mize, meal, soybeans. The outdoor stall barn housing system was applied for goats. The goat breeding in farm was done through natural mating with the implementation of new methodology: the first mating of goats was carried out at the age of 10 -11 months, taking into account the fact that the live weight of the doeling goats should be 70% or more of the average live weight of goats. Evaluation of fertility was expressed as kidding number by goats and rate, expressed in percentage.

Statistical analysis

The results of data analysis were obtained using the Microsoft Office Excel (2018) software application by using Descriptive Statistics. The experiments' results were pointed as mean value and mean deviation (M±m). Mean is the average to determine the central value, standard error measures the accuracy value of the sample distribution and deviation to find out the mean. The experiments and statistical analysis of the biochemical and physico-chemical parameters of raw heterogeneous, heat treated heterogeneous milk and curd was carried out by 4-fold repetition. The statistical significance of the results were considered at $p<0.05$ and calculated using the one-way ANOVA.

RESULTS AND DISCUSSION

Physico-chemical properties of Saanen goat milk

The physico-chemical characteristics of the Saanen goat milk in different numbers of lactation, as well as in raw and heat treated heterogeneous milk are provided in **Table 1**. The summary data indicate that the lactose, total caseine, fat, dry matters concentration and density of different lactations milk and in raw milk did not undergo significant changes, while after pasteurization in milk, a significantly reduction of the mentioned nutrients is recorded ($p<0.05$). The results of the research confirm that the amount of lactose in raw milk ranges from 4.14 to 4.35%, and after pasteurization it decreases to 3.85%. The total casein content is 2.37-2.57% and after heat treatment it decreases to 1.87%. The amount of fat and dry matter is 3.5-3.9%, 2.7%, 14.7-14.9% and 13.8% respectively. Similarly, **Ospanov (2021)** recorded a fat content in milk of Saanen goat, bred in Kazakhstan. It should be noted that the in our study the mass fraction of fat in raw milk was lower than the norms (4.5-4.7%) defined in the technical conditions of "Pure goat milk" adopted by the National Body of Standardization and Metrology of Armenia **(Marmaryan et al., 2014)**, which was probably due to the ration. Our study presents that the salt content does not undergo significant changes, while in terms of density, the milk of goats of the second lactation (23.9%) exceeds the data obtained in the first lactation (21.9%).

Table 1 Physico-chemical characteristics of Saanen goat milk in Shirak Province, Armenia

Parameters	Number of lactation	
	1st (n=6)	2nd (n=6)
Lactose (%)	4.16±0.01^{ns}	4.35±0.01^{ns}
Total caseine (%)	2.57±0.02^{ns}	2.37±0.02^{ns}
Fat (%)	3.51±0.2^{ns}	3.93±0.3^{ns}
Dry matters (%)	14.9±0.12^{ns}	14.7±0.08^{ns}
Density (%)	21.9±0.39^{ns}	23.9±0.42^{ns}
Salt (%)	0.72±0.01^{ns}	0.65±0.01^{ns}

*Significant correlation at $p<0.05$; ns, not significant at $p\geq0.05$.

Biochemical characterization of Saanen goat milk and dairy products

The dairy industry is continually searching for products with high quality and stable properties due to the increasing interest of consumers not only in nutritious and tasty foods but in products that provide health benefits too.
Table 2 reports the biochemical characterization of goats' raw and heat treated heterogeneous milk, cheese and curd. The resulting data indicate that the furosine concentration in raw heterogeneous milk is 5.2±0.02 mg/100 g protein. LTLT pasteurization significantly affected the furosine generation in milk and after heating, the content in pasteurized milk increased to 47.8±0.3 mg/100 g protein, hence the heat treatment leads to the formation of early stage of Maillard reaction product, such as furosine. The outcome of the study confirms that although there is no difference between goat cheese and curd furosine level, which is 60.6 and 60.3 mg/100 g protein, nonetheless the concentration is significantly increased by 11.6 and 11.5 times compared to the untreated milk. The results of our research are also consistent with the given literature **(Li et al., 2021; Dong et al., 2019; Lan et al., 2010)**. **Mendoza (2005)** demonstrated that the furosine content in pasteurized milk varied from 8.6 to 35.8 mg/100 g of protein in ewe and goat milk respectively and depends on the type of animal. **Ibrahim (2016)** shows the fluctuation of furosine level in pasteurized and 4˚C storage camel milk respectively, which is between 3.7 in raw and 7.55 mg/100 g of protein. **Li et al. (2021)** emphasized the wide range of furosine content in treated milk in China which is 0.13-150.0 mg/L. **Fejnberg et al. (2006)** showed that the furosine content in high-treated milk was 7 times higher than that of mildly-treated.

Table 2 Biochemical parameters of Saanen goat milk and dairy products in Shirak Province, Armenia

Parameters	Raw heterogeneous milk (n=35)	Heat treated heterogeneous milk (n=35)	Cheese (n=5)	Curd
Furosine (mg/100 g protein)	5.2±0.02^{**a}	47.8±0.3*	60.6±0.28^{ns*a}	60.3±0.61^{ns*a}
Urea (mmol/L)	2.87±0.06*	2.17±0.14*	0.02±0.01^{ns}	0.018±0.001^{ns}
Ammonium (mg/100 mL)	0.47±0.05*	0.29±0.03*	0.25±0.01^{ns}	0.23±0.01^{ns}
pH	6.6	7.0	5.07	6.2

*Significant correlation at $p<0.05$; ^{*a} indicates significant correlation in the same rose between cheese, curd in compare with untreated gross milk; ns, not significant at $p\geq0.05$.

What refers to the final products of protein metabolism ammonia and urea, our study indicates that the levels are significantly decrease in heat-treated milk in compare with raw heterogeneous milk and constitute 0.47±0.05 mg/100 mL to 0.29±0.03 mg/100 mL and 2.87±0.06 mmol/L to 2.17±0.14 mmol/L respectively.
It is interesting that the amount of urea both in cheese and curd reliably decreased after pasteurization, in the form of traces and is 2.17±0.14 mmol/L, 0.02±0.01 mmol/L and 0.018±0.001 mmol/L, respectively. This circumstance is probably due to the technological process of the food, in particular the ripening process. Although a similar trend was recorded in the case of ammonia, it is more weakly expressed compared with urea. It is noteworthy that, compared with the results of our previous research, the level of urea in raw heterogeneous milk exceeds the same data examined in milk of different lactations, which is probably due to the intensity of feeding and protein energy exchange processes **(ArmStat, 2024)**.
The literature data reported that nevertheless the milk urea comes from feeding, it influences directly cheese acidification kinetics and texture characteristics of matured cheeses, but it is not directly involved in forming the tastes **(Martin et al., 1997)**.
Our research demonstrated thermal inactivation of the ALP (**Figure 2**) and LP enzymes (**Figure 3**). The enzymes' activity was significantly decreased in heat-treated milk, cheese and curd compared with raw milk ($p<0.05$). The fact that the activity of ALP in raw heterogeneous milk is 7.05±0.3 U/L, is close to the results obtained in our previous study of three different periods of lactation **(Grigoryan et al., 2023)**. It allows us to assert that in raw goat milk this data is stable and varies between 6.9 and 7.05 U/L. Data available in scientific literature show that if ALP activity decreases after pasteurization, milk can be considered microbiologically safe **(Malissiova et al., 2022; Rankin et al., 2010)**. Considering the fact that the European Food Safety Authority shows with 95-99% probability that the ALP activity in pasteurized goat milk is below the limit of 300 mU/L **(European Food Safety Authority, 2021)**, it can be noted that the results of our studies are constituent with the results reported by EFSA.

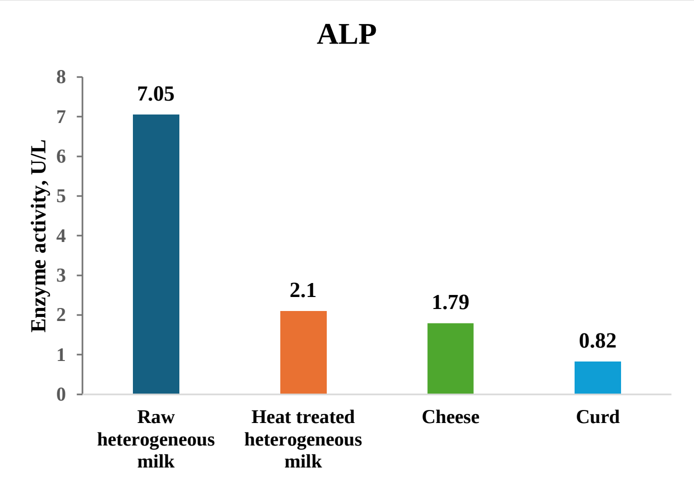

Figure 2 ALP activity trend in goat milk and dairy products

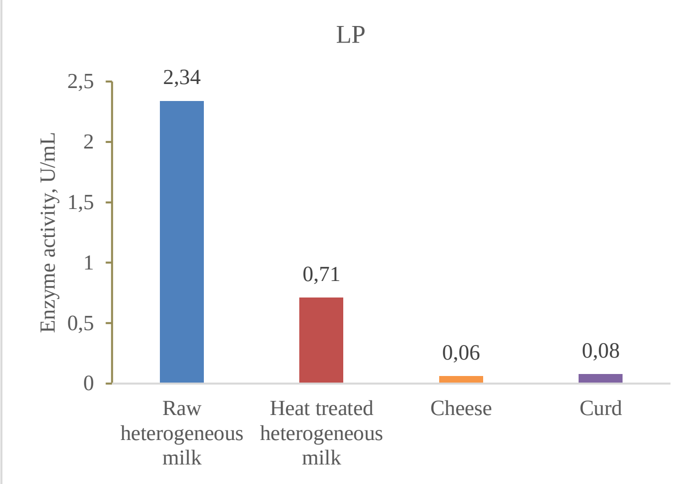

Figure 3 LP activity trend in goat milk and dairy products

Our studies confirm that the activity of ALP in cheese and curd obtained from goat milk decreased by 3.9 and 8.6 times compared with raw milk and amounted to 1.79 and 0.82 U/L, respectively, and compared with heat treated heterogeneous milk by 3.3 times. **Todaro et al. (2021)** concluded in their research that the activity of ALP in cheese varies widely depending on the type of cheese, technological process, heat treatment, and even on the factor whether raw or pasteurized milk was used as cheese raw material.
After pasteurization of milk, LP activity (0.71±0.03 U/L) decreased for about 3.3 times compared to raw milk (2.34±0.3 U/L). It is noteworthy that although the trend of LP activity in raw milk and dairy products is consistent with ALP activity, the activity of the enzyme in raw milk was within the normal limits. Nevertheless, it exceeds by 3.5 times the results obtained in our previous reports in different lactations, which was 0.66-0.71 U/mL. This is positive, especially considering that the effectiveness of the enzyme against a wide range of pathogenic microbes, including bacteria, fungi, has been confirmed **(FAO/WHO, 2005)**. Therefore, we believe that such a result is probably due to the difference in the antimicrobial properties of milk in our last two studies. Such a result is a prerequisite for further research from the point of view of studying the antimicrobial properties of goat milk and dairy products.
The results of the study indicate the lowest LP activity 0.06±0.01 U/mL at the pH 5.07, which is probably justified by the fact that cheese sampling was realized in the final stage of maturation and the LP reduced acidification in fresh milk. The cheese pH below 5.2 is considered acidic, this flavor produces lactic acid bacteria, which produces lactic acid and lowers pH. Measuring the pH of cheese is crucial not only in terms of manufacturing, including the ripening stage, but for controlling the growth of bacteria and protecting the safety of the product too. Depending on the type of cheese, pH of matured cheese is rated between 5.0 (hard cheeses: salty, cheddar, mozzarella, parmesan) and 6.65 (soft cheeses: camembert). The proportion of moisture, amount of salt added influences the final pH of cheese and the overall flavor and texture **(Silva et al., 2020)**. It is noteworthy that the LP activity of curd in our research is close to the result of enzyme activity in cheese and is 0.08±0.002 U/mL, which probably occurs in the pH range of 6.2, while in case of cheese it is 5.07. This fact is probably due to the different duration of the ripening process of cheese and curd.

The literature data indicate that LP activity in milk and dairy products varies depending on the animal, type of food, number of lactation, lactation period, starter cultures used in the technological process, heat treatment, and can vary between 0.03 and 4.45 U/mL. The enzyme has antimicrobial activity against milk spoilage and pathogen microorganisms, including bacteria and can be applied to reduce spoilage of milk where refrigeration is not immediately available **(Zarei et al., 2016; Silva et al., 2020; FAO/WHO, 2005)**.
For the purpose of producing safe milk and dairy products, the Republic of Armenia is guided by the Technical Regulations of the Customs Union TP TC 033/2013, (Decree No 67) "On Safety of Milk and Dairy Products" **(TP TC, 2013)**. The document sets the conditions for the heat treatment of milk (temperature, duration), the requirements for its transportation, storage and disposal, as well as the approved norms for the following markers for the safe production of raw cow milk and dairy products: microbial, including pathogenic, physical and chemical markers (fat, protein, dry matter, density), norms for somatic cells, substances causing toxic and oxidative spoilage – heavy metals, radionucleotides, mycotoxins, pesticides, melamine, dioxins, benzapyrene, organoleptic indicators, requiremets for yeast and enzymes used in dairy production.
With regard to the goat milk, the only standard document in RA is the "Pure Goat Milk" technical conditions **(Marmaryan et al., 2014)** which sets the reference standards for the raw milk: sensory attributes, physical and chemical markers (fat, protein, acidity, density), packaging, labelling.
Given that the mentioned literature review **(EFSA, 2021; Dairy Foods Science Notes, 2022; Klotz et al., 2008; Banks et al, 2002; Dumitraşcu, et al., 2012; Boulares et al., 2011; Malissiova et al., 2022)** shows that the heat stability of the ALP and LP enzymes is greater than that of pathogens available in milk and complete pasteurization will inactivate the enzymes to low levels, milk can be considered microbiologically safe and properly pasteurized. With this regard, our study was in line with the trend of the enzymes activity, thus, both enzymes and furosine level are suggested to be used as indicators for proper pasteurization and markers of goat milk and dairy product safety in Armenia.

Table 3 Milk production of Saanen goats in Shirak Province and control milking

Number of lactation (age group)	Control milking results according to the lactation (kg, per day, n=24)			Milk production during lactation period (10 month, kg)	
	1st month	2nd month	3rd month	Year 2022 (n=24)	Year 2023 (n=35)
1st (2 years-old)	0.75±0.11ns	0.58±0.16ns	0.60±0.23ns	368.3 ±48.9*	353.3±2.8*
3rd (4 years-old)	0.87±0.23ns	0.67±0.42ns	0.50±0.17ns	454.0 ± 48.8*	464.5±2.8*
5th (6 years-old)	0.87±0.12ns	1.08±0.09ns	0.83±0.03ns	470.8±2.8*	448.6±2.8*

*Significant correlation at p<0.05; ns, not significant at p≥0.05.

Milk production of goats in Shirak Province

Table 3 shows the total milk yield level of 10 months lactation from different ages of Saanen breed goats in 2022 and 2023 and the results of control milking in 2022. The results of the control milking show that although there were no significant differences in the milk yield of goats of different ages during the first three months of lactation, the highest amount of milk is obtained in the first and second months of lactation, except for 2-year-old goats. In the 3rd month of lactation, a decrease in the level of milk yield was recorded, which is more conveyed in three-year-old goats compared to the first month of lactation and was 0.50 kg and 0.87 kg, respectively. It should be noted that the results from a two-year research show that the milk yield of goats of different ages bred in Shirak Province of Armenia varies between 353.3 and 470.8 kg during a 10-month lactation and the age factor affects the milk yield. Thus, in 2022, the milk yield of 2-, 4- and 6-year-old goats reliably increases with the age and amounts to 368.3 kg; 454.0 kg and 470.8 kg respectively. The same trend was registered in 2023, except for 6-year-old goats (**Grigoryan et al., 2023**).
Varlyakov et al. (2018) studied the effect of the age on different traits, including milk yield of Saanen goats in Bulgaria and recorded that the age, which influenced productivity, was more emphasized in terms of high production animals. According to the above-mentioned study, the daily milk production fluctuated between 0.4 kg (low-yielding goats) and 1.9 kg (high-yielding goats). The results

of our research allow us to record that along with the increase in milk yield of goats in the 3rd number of lactation, the specific gravity of lactose and fat in milk increases, compared to the previous lactation. Therefore, the given number of lactation

is more suitable for obtaining dairy products with higher nutritional content from goat milk: cheese, curd, yogurt, butter, baby milk products and even ice cream. From the point of the development of dairy goat breeding in Armenia, it is positive that the Saanen goats bred in Shirak Province is superior to local goats in terms of milk production, whose yield during three lactations ranged from 186.8 to 206.7 kg, while as the results of our previous study show, in terms of milk yields, they were inferior to Saanen goats in Vayots Dzor Province of Armenia, whose milk yield for three lactation amounted to 499.2-625.8 kg **(Marmaryan, 2013)**. This fact is due to the feeding of animals in different farms of different provinces of Armenia.

Mioč et al. **(Mioč et al., 2008)** studied the factors affecting goat milk yield and its composition and recorded that Saanen goats in Croatia in terms of lactation and milk yield significantly exceeded the Alpian breed, 720 kg versus to 577 kg.

Fertility performance of Saanen goats

It is clear from the technology of goat breeding on Krashen farm of Shirak Province that the milk yield of goats is in a certain relationship with fertility. Therefore, along with the increase in fertility, the level of milk yield increases too, which is a biological feature. **Table 4** shows the results of two-year fertility, from which it can be seen that in 2022, 40 kid goats were born from 24 goats, and in 2023, 64 kids were born from 35 goats. The increase was also recorded in the circumstances when goats have both one and two or more kid goats. It is noteworthy that in 2023, the number of goats raising triplets not only increased five times, but the presence of quadruplets was also recorded. Our research indicates that the percentage of fertile (two or more) goats in the farm was increased by 62.5-63% in 2022-2023. It should be noted that such an achievement was recorded on this farm due to the introduction of new technology of goat breeding, which is a novelty in Armenia. The implementation of this technology will contribute to the increase of the total number of goats, which in its turn will have a positive effect on economic efficiency. **Santosa et al. (2022)** research indicates that in Indonesia the number of single birth Saanen goat was lower in flock (48%) than the number of twins (52%).

Table 4 Fertility of Saanen goats in Shirak Province, Armenia

Numbers of goats according to fertility					
Year 2022			Year 2023		
Number of femail goats	Fertility		Number of goats	Fertility	
	Number of borned kid goats	% of borned kid goats		Number of borned kid goats	% of borned kid goats
9	1	37.5	13	1	37.14
14	2	58.3	16	2	45.71
1	3	4.16	5	3	14.28
			1	4	2.86
Totally from 24 goats	40	166	Totally from 35 goats	64	180

CONCLUSIONS

The present study indicates that the lactose, total caseine, fat content in the milk do not undergo significant changes depending on the lactation and flactuate totally between 4.14-4.35%, 2.37-2.57% and 3.51-3.93% respectively, while heat treatment leads to the significant reduction of the nutrients in heterogeneous milk. The pasteurization causes a significant increase of furosine in goat milk and dairy products, with the same level in ripened cheese and curd (60.6 and 60.3 mg/100 g protein), which is about 1.26 times higher than that in heat-treated milk and 11.6 times higher compared with raw milk. The results of the research confirm that in pasteurized goat milk, ripened cheese and curd there is a trend of decrease in enzyme activity, while in raw milk the enzymes are stable. Scientific and practical input of the study is that ALP and LP activity, in combination with furosine, can serve as complex biochemical indexes for precise pasteurization and proper processing of goat milk in the context of heat damage extent and producing functionally safe dairy products in Armenia. It has been proven that the implementation of new technology in breeding has had a positive impact on fertility, from the perspective of increasing the specific gravity of multiple goats, implementation of which will contribute dairy goat breeding development in Armenia. The results of the study set the stage for further studies to make the evaluation more extensive, from the point of view of investigating the antimicrobial properties of goat milk and food, which, together with biochemical indicators, will form a comprehensive toolkit for evaluating the quality of goat milk and dairy products.

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REFERENCES

ArmStat. (2024). Statistical Committee Republic of Armenia. Yerevan, Republic of Armenia. https://www.armstat.am/am/?nid=82

Baker, H.M., Alzboon, K.F. (2015). Spectrophotometric determination of ammonia using ninhydrin assay and kinetic studies. *European Journal of Chemistry*, 6(2), 135-140. https://doi.org/10.5155/eurjchem.6.2.135-140.1178

Banks, J.M., Muir, D.D. (2002). Variability of alkaline phosphatase in goat milk in relation to its use as an effective index of pasteurization. Final report on Project SO 1003 to Food Standards Agency Scotland. Food Standards Scotland. Hannah Research Institute. pp.1-169. https://www.foodstandards.gov.scot/downloads/Variability_of_alkaline_phosphatase_in_goat_milk.pdf

Bendelja Ljoljić, D., Špehar, I.D., Prpić, Z., Vnučec, I., Samaržija, D. (2020). Urea concentration in goat milk: Importance of determination and factors of variability. *Journal of Central European Agriculture*, 21(4), 707–721. https://doi.org/10.5513/JCEA01/21.4.3058

Boulares, M., Mankai, M., Hassouna, M. (2011). Effect of activating lactoperoxidase system in cheese milk on the quality of Saint-Paulin cheese. *International Journal of Dairy Technology*, 64(1), 75–83. https://doi.org/10.1111/j.1471-0307.2010.00646.x

Buys, E.M., Seifu, E. (2022). Enzymes Indigenous to Milk: Lactoperoxidase. *Encyclopedia of Dairy Sciences. Elsevier*, Academic Press, 3rd edition, 3, pp.670-676. https://doi.org/10.1016/b978-0-12-818766-1.00252-x

Clawin-Rädecker, I., De Block, J., Egger, L., Willis, C., Da Silva Felicio, M.T. et al. (2021). European Food Safety Authority (EFSA). The use of alkaline phosphatase and possible alternative testing to verify pasteurization of raw milk, colostrum, dairy and colostrum-based products. *European Food Safety Authority Journal*, 19(4), EFSA-Q-2020-00331. https://doi.org/10.2903/j.efsa.2021.6576

Dairy Foods Science Notes. (2022). Alkaline phosphatase testing for milk pasteurization. Cornell-University. Ithaca. Version 11-07. https://cals.cornell.edu/sites/default/files/2023-04/fact-phos07-2022.pdf

Dong, M., Tekliye, M., Pei, X. (2019). RP-HPLC determination of Furosine in fermented milk of different brands retailed in China. *International Journal of Agricultural Science and Food Technology*, 5(1), 064–067. https://doi.org/10.17352/2455-815x.000044

Dumitrașcu, L., Stanciuc, N., Stanciu, S., Râpeanu, G. (2012). Thermal inactivation of lactoperoxidase in goat, sheep and bovine milk - A comparative kinetic and thermodynamic study. *Journal of Food Engineering*, 113(1), 47–52. https://doi.org/10.1016/j.jfoodeng.2012.05.028

FAO (2004). Code of hygienic practice for milk and milk products. CAC/RCP 57-2004. pp.1-28. https://www.fao.org/fileadmin/user_upload/livestockgov/documents/CXP_057e.pdf

FAO/WHO. (2005). Benefits and Potential Risks of the Lactoperoxidase system of Raw Milk Preservationt. Report of an FAO/WHO technical meeting. Food and Agriculture Organization of the United Nations and World Health Organization. Rome, Italy, pp. 1-73. https://www.fao.org/4/a0729e/a0729e00.pdf

Feinberg, M., Dupont. D., Efstathiou, T., Louâpre, V., Guyonnet, J.P. (2006). Evaluation of tracers for the authentication of thermal treatments of milks. *Food Chemistry*, 98(1), 188–194. https://doi.org/10.1016/j.foodchem.2005.07.052

Grigoryan, H., Navasardyan, D., Marmaryan, G., Gevorgyan, S., Hambardzumyan, G. (2023). The Study of Biochemical Markers of Goat Milk in Shirak Region, Republic of Armenia. *Animal Science and Biotechnologies*, 56(1), 58-61.

Hanuš, O., Hering, P., Frelich, J., Jílek, M., Genčurová, V., Jedelská, R. (2008). Reliability of results of milk urea analysis by various methods using artificial milk control samples. *Czech Journal of Animal Science*, 53(4), 152-161. https://doi.org/10.17221/376-cjas

Ibrahim, A.H. (2016). Determination of lactulose and furosine contents during heat treatment of camel milk: as a new method for discriminating the degree of heat treatment given to camel milk. *Zagazig Journal of Food and Dairy Research*, 43(5), 1673-1684. https://www.researchgate.net/publication/324648452

Ibrahim, N.S., Zahari, N.A., Nizam, N.I.S. (2024). Evaluating the Shelf Life of Chilled Raw and Pasteurized Goat Milk: An Analysis of Physicochemical and Microbial Content. *Indonesian Journal of Agricultural Research*, *7*(1), 1–13. https://doi.org/10.32734/injar.v6i3.15241

Jonson, D., Voort, M., Hogeveen, H. (2018). *Journal Dairy Science*, 101, 10428-10439. https://doi.org/10.3168/jds.2017-14134

Klotz, V., Hill, A., Warriner, K., Griffiths, M., Odumeru, J. (2008). Assessment of the Colorimetric and Fluorometric Assays for Alkaline Phosphatase Activity in Cow's, Goat's and Sheep's Milk. *Journal of Food Protection,* 71(9), 1884-1888. http://meridian.allenpress.com/jfp/article-pdf/71/9/1884/1681439/0362-028x-71_9_1884.pdf

Kvaal, S.V. (2021). Factors affecting urea levels in goat milk. *Master's Thesis.* Norwegian University of Life Sciences. Norway. 75. https://nmbu.brage.unit.no/nmbu-xmlui/bitstream/handle/11250/2823222/Kvaal2021.pdf?sequence=2&isAllowed=

Lan, X.Y., Wang, J.Q., Bu, D.P., Shen, J.S., Zheng, N., Sun, P. (2010). Effects of heating temperatures and addition of reconstituted milk on the heat indicators in milk. *Journal of Food Science*, 75(8), 653-658. https://doi.org/10.1111/j.1750-3841.2010.01802.x

Li, Y., Wu, Y., Quan, W., Jia, X., He, Z., Wang, Z. et al. (2021). Quantitation of furosine, furfurals, and advanced glycation end products in milk treated with pasteurization and sterilization methods applicable in China. *Food Research International. Elsevier*, *140*, 110088. https://doi.org/10.1016/j.foodres.2020.110088

Liu, H., Huang, R., Zeng, G., Xu, Z., Sun, Y., Lei, H., et al. (2020). Discrimination of reconstituted milk in China market using the content ratio of lactulose to furosine as a marker determined by LC-MS/MS. *Journal LWT Food Science and Technology*, 117, 108648. https://doi.org/10.1016/j.lwt.2019.108648

Malissiova, E., Fotiadou, S., Tzereme, A., Cheimona, D., Soultani, G. et al. (2022). Alkaline Phosphatase (ALP) in Non-Cow Milk and Dairy Products: A Review of Current Evidence and Future Trends. *Ruminants*, 2(4), 435–447. https://doi.org/10.3390/ruminants2040030

Marmaryan, G. (2013). Biochemistry aspects of milk and tissues of different genotype goats. Monograph. LAP Lambert Academic Publishing. Saarbrücken, Germany. pp. 27-32.

Marmaryan, G., Beglaryan, R., Ter-Isahakyan, L. (2014). Goat whole milk. Technical conditions. TP AM 10043453 7348-2014.

Marmaryan, G., Kamalyan, R. (2001). Some immune indices and nitrogen interchange of the blood serum of different breed of goats bred in Armenia. International Scientific Conference. Agricultural and Environmental Problems in Transcaucasus; Yerevan, Armenia, 224-227.

Martin, B., Coulon, J., Chamba, J., Bugaud, C., Coulon, J., Chamba, J. (1997). Effect of milk urea content on characteristics of matured Reblochon cheeses. *Le Lait, Dairy Science and Technology*, hal-00929543, 77(4), 505-514. https://hal.science/hal-00929543

Mendoza, M.R., Olano, A., Villamiel, M. (2005). Chemical indicators of heat treatment in fortified and special milks. *Journal of Agricultural and Food Chemistry*, *53*(8), 2995–2999. https://doi.org/10.1021/jf040406l

Microsoft Excel. (2018). Microsoft Corporation, Redmond, WA, USA. https://office.microsoft.com/excel

Miller, B.A., Lu, C.D. (2019). Current status of global dairy goat production: An overview. *Asian-Australasian Journal of Animal Sciences*, 32(8), 1219–1232. https://doi.org/10.5713/ajas.19.0253

Mioč, B., Zvonimir, P., Vnucec, I. et al. (2008). Factors affecting goat milk yield and composition. *Mljekarstvo: journal for dairy production and processing improvement*, 58(4), 305-313. https://www.researchgate.net/publication/27214269

Nayik, G.A., Jagdale, Y.D., Gaikwad, S.A., Devkatte, A.N., Dar, A.H., Dezmirean, D.S. et al. (2021). Recent Insights into Processing Approaches and Potential Health Benefits of Goat Milk and its Products: A Review. *Frontiers in Nutrition,* 8, 1-16. https://doi.org/10.3389/fnut.2021.7891

Ospanov, A.B. (2021). Research study of physical and chemical composition and technological properties of sheep and goat milk during summer lactation. *Journal Storage and Processing of Farm Products*, 2, 64–74. https://doi.org/10.36107/spfp.2021.237

Park Y.W., Haenlein, G.F.W. (2010). Goat Science and Production. 1st edition. Publisher Wiley Blackwell, New York, USA, pp. 275-292. https://www.researchgate.net/publication/282024926

Pellegrino, L., Battelli, G., Resmini, P., Ferranti, P., Barane, F., Addeo, F. (1997). Effects of heat load gradient occurring in moulding on characterization and ripening of Grana Padano. *Lait, Elsevier/INRA*, 77(2), 217-228.

Rankin, S.A., Christiansen, A., Lee, W., Banavara, D.S., Lopez-Hernandez, A. (2010). Invited review: The application of alkaline phosphatase assays for the validation of milk product pasteurization. *Journal of Dairy Science*, 93(12), 5538–5551. https://doi.org/10.3168/jds.2010-3400

Ritota, M., Di Costanzo, M.G., Mattera, M., Manzi, P. (2017). New trends for the evaluation of heat treatments of milk. *Journal of Analytical Methods in Chemistry,* ID 1864832, 1-12. https://doi.org/10.1155/2017/1864832

Santosa, S., Hindratiningrum, N., Purwantini, D., Susanto, A., Candrasari, D. (2022). Goat Saanen Productivity at the Dairy and Forage National Breeding Centre Baturraden, Central Java, Indonesia. KnE Life Sciences. The 3-rd International Conference on Advance and Scientific Innovation (ICASI), Java, Indonesia. pp. 309-317. https://doi.org/10.18502/kls.v0i0.11813

Sepe, L., Argüello, A. (2019). Recent advances in dairy goat products. *Asian-Australasian Journal of Animal Sciences*, 32(8), 1306-1320.

Silva, E., Oliveira, J., Silva, Y., Urbano, S., Sales, D., Moraes, E. et al. (2020). Lactoperoxidase system in the dairy industry: Challenges and opportunities. *Czech Journal of Food Sciences*, 38(6), 337–346. https://doi.org/10.17221/103/2020-CJFS

Sosnowski, M. (2010). Determination of alkaline phosphatase activity in milk and milk products by fluorimetric method. *Bulletin of the Veterinary Institute in Pulawy*, 54(4), 537-542. https://www.researchgate.net/publication/275647658

Tabacco, A., Meiattini, E., Moda, E., Tarli, P. (1979). Simplified enzymic/colorimetric serum urea nitrogen determination. *Clinical Chemistry*, 25(2), 336-337.

Todaro, M., Lo Presti, V., Macaluso, A., Alleri, M., Licitra, G., Chiofalo, V. (2021). Alkaline phosphatase survey in pecorino siciliano PDO cheese. *Foods*, *10*(7), 1648. https://doi.org/10.3390/foods10071648

TP TC 033/2013. (2013). (Decree No 67). Technical Regulation of the Customs Union "On Safety of Milk and Dairy Products". Kazan, RF.

Varlyakov, I., Slavov, T., Radev, V. (2018). Milking behaviour of Saanen goats. *Bulgarian Journal of Agricultural Science,* 24(1), 109-118.

Villamiel, M., Mari´, M., Arias, M., Corzo, N., Agusti´, A., & Olano. (2000). Survey of the Furosine Content in Cheeses Marketed in Spain. *Journal of Food Protection,* 63(7), 974-975. https://doi.org/10.3390/ruminants2040030

Zarei, M., Shahriari, A., Tarazoudar, F., Paknejad, M. (2016). Comparing the activity and thermal inactivation behavior of Lactoperoxidase in Iranian cow and buffalo milk and whey. *Journal of Food Quality and Hazards Control*, 3(2016), 141-145. https://www.alta.ru/tamdoc/13sr0067/

Zobel, G., Nawroth, C. (2020). Current state of knowledge on the cognitive capacities of goats and its potential to inform species-specific enrichment. *Elsevier, Small Ruminant Research*, 192(2020), 106-208. https://doi.org/10.1016/J.SMALLRUMRES.2020.106208