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Impact of Socioeconomic and Demographic Factors on The Physicochemical and Microbiological Quality of Artisanal Cheeses from Northern Peru

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Abstract

Goat cheese offers significant nutritional benefits due to its enhanced digestibility and assimilation. In Peru, the province of Sullana stands out as the largest producer of this cheese. However, there is limited knowledge regarding the socioeconomic factors of its producers, as well as the physicochemical and microbiological characteristics of the cheese. The study was developed in 3 aspects, socio-economic based on a descriptive exploratory methodology, with a mixed approach, 14 presidents of producer associations participated. Fourteen samples of fresh artisanal cheese from goat producers' associations from Marcavelica, Lancones and Salitral were stored at 4°C under aseptic conditions for physico-chemical characterisation and microbiological analysis. In relation to socioeconomic factors, the findings of the survey indicate that 42.9% were aged 56 years or older and possess only primary education. Additionally, 57.1% received Good Manufacturing Practices (GMP) training, 86% reported a lack of water and drainage services, 21% reported having access to conventional electricity and 79% reported using solar panels. These make an improvement in the training of cheese producers imperative. Regarding the physicochemical properties (pH, acidity, humidity and ash content), the cheeses were within the

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parameters allowed in DS N° 007-2021-MINAGRI. However, it was observed that 29% and 50% of the samples exhibited a high count for *Aerophilic Mesophiles* at 24 (≥ 2.51 x 10^6 CFU/g) and 48 (≥ 2.34 x 10^6 CFU/g) hours, respectively (COVENIN 3338:1997). 79% of the samples tested positive for both total and fecal coliforms (DS N° 007-2021-MINAGRI) in which 43% exhibited a high count for *E. coli* (>3.6 MPN/g). Conversely, the presence of *S. aureu*s (<10) was within the optimal parameters while *Salmonella* spp. and *L. monocytogenes* were not detected. The lack of adequate infrastructure for the milking process, the production, storage and transportation of cheese, is presented as the most significant aspect. These findings may pose a risk to consumers' health, highlighting the necessity to establish projects that strengthen these aspects in order to enhance cheese production.

Introduction

In 2021 the world goat milk production was around 20.72 million of tons, India (6.07), Bangladesh (2.67), Sudan (1.16), Pakistan (0.99), France (0.77), while the production in Peru was 0.024.[1] Piura region demonstrating exceptional proficiency in goat husbandry, thereby yielding the highest production of goat cheese within the country,[2] as well as the production of yogurt and ice cream with functional attributes.[3–6]

Dairy production has enabled the existence of over 2000 varieties of cheeses worldwide, including mature, semi-mature, and fresh types. These cheeses are widely consumed due to their diverse nutritional, sensory, and textural characteristics,[7] highlighting goat cheese has a significant nutritional contribution, due to its greater digestibility and assimilation of phosphorus, copper, magnesium and vitamin A.[8,9] Additionally, its low potassium and lactose content is beneficial for patients with renal insufficiency and does not cause sensitivity in individual with lactose intolerance.[10]

Consumers currently prioritize quality; however, artisanal cheeses carry a higher risk of contamination due to the lack of knowledge of good GMP during the production process,[11] this is attributed to the inadequate hygiene it production facilities and the low sanitary quality of the raw materials.[12] Per capita cheese consumption in Peru has increased from 2.4 kg in 2009 to 4.7 kg today.[13] Cases of salmonellosis and brucellosis due to the consumption of dairy products have been reported in Peru.[14, 15]

Goat milk cheese has a high nutritional value, which makes it an ideal medium for the proliferation of microorganisms such as *Salmonella* spp., *Staphylococcus aureus*, *Listeria monocytogenes*, and *Escherichia coli*. Some of them are capable of producing toxins or deleterious substances, which affect the quality of the product and the consumer's health, causing fever, diarrhea, headache, vomiting, abdominal and body pain, and, in extreme cases, develop chronic symptoms that threaten the consumer's life.[14,15,16 17] This necessitates the implementation of strict control to maintain food safety during goat milk's artisanal cheese production.

The aim of this study was to investigate the socioeconomic and demographic characteristics of goat producers and their impact on the physicochemical and microbiological quality of artisanal cheeses in Sullana, Peru. Sullana is located at an altitude of 65 m.a.s.l. Its climate ranges between 17°C and 33°C,[16] the total population in 2020 according to the National Institute of Statistics of Peru - INEI is 341 490 inhabitants.[17] 92.2% of the population lives in urban areas while only 7.8% live in rural areas.[18]

Materials and Methods

Socioeconomic and Demographic Characteristics

The socio-economic aspect was conducted through an exploratory and descriptive study, employing a questionnaire comprising open and closed questions addressed to the 14 presidents of producer associations participated.

In the province of Sullana, there are 21 associations of goat livestock producers, which are located in the districts of Marcavelica, Lancones, and Salitral. For the purposes of this study, a sample of 14

associations was selected from the total population of associations.

Physicochemical and Microbiological Analysis
A total of 14 samples of goat milk cheese (each weighing of 500 g) from the goat associations of the province of Sullana were analyzed. The samples consisted of 10 cheeses from the Marcavelica district (Faique Quemado, Cañas, Salados, La Peñita, El Chilco, Algarrobillo and La Noria), 3 cheeses from the Lancones district (Panalitos, Pajarobobo, Posas Hondas) and 1 cheese from the Salitral district (Miraflores) under aseptic conditions.

Determination of Humidity and Total Dry Matter
The experiment was conducted based on the gravimetric method using the MX-50 humidity determining scale with infrared light.[19]

Ash Determination
For the determination of ash content,[20] 5 g of the sample were placed in a crucible and heated at 450°C for a period of 12 to 18 hours. The percentage of ashes was estimated as follows:

% Ash = (W2-W1)/W X100

Where:

W2 = Weight of crucible + weight of sample after incineration at 450°C
W1 = Weight of empty crucible (before incineration)
W = wet sample weight

Acidity Determination
1 g of cheese was ground and diluted in 9 mL of distilled water with 4 drops of phenolphthalein and titrated with 0.1N NaOH until color change, according to NOM-243-SSA1-2010.[21] The calculations were carried out according to the following formula:

% Acidity = AXBXC/D X100

Where:

A= mL of NaOH 0.1 N spent on the tritation.
B = Normality of the NaOH solution
C= Lactic acid equivalent weight (0.09)
D= Sample volume or weight

pH Determination
The experiment was conducted using a Hanna pH meter model HI 99163, with a cheese-to-water ratio of 1:9.[22]

Aerophilous Mesophilic Count
The serial dilution technique was carried out, inoculating 100 µL of the dilution 10^{-4} on trypticase soy agar (TSA) plates in triplicate and incubated at 35 °C for 24 and 48 hours. Colonies were counted and the results were expressed in CFU/g (Colony Forming Units per gram).[23]

Total Coliform Count
From the previous dilution, 1000 µL of 10^{-4} of APE was inoculated in brilliant green bile broth tubes containing Durham's tube in triplicate and incubated at 37 °C for 24 hours. After 24h, the presence of gas in the Durham's tube was evaluated, expressed as a percentage. From the tubes that confirmed the presence of gas, 1000 µL were taken and mixed in tubes with 15 mL of melted PCA agar (plate count agar) and homogenized in a vortex shaker and then dispensed into a petri dish. After gellification, it was covered with 5 mL of melted PCA agar and incubated at 37 °C for 24 hours.[23] After the incubation time, the results were expressed as a percentage.

Fecal Coliform Count
From the tubes that confirmed the presence of gas for total coliforms, they were sown and then inoculated into tubes containing 10 mL of *Escherichia coli* broth (EC) and incubated at 45 °C for 24 hours.

The tubes that exhibited bacterial growth attributes (turbidity and gas) were considered positive, with the addition of 4 drops of Kovac's reagent for the formation of a red halo at the top, serving as an indicator of the presence of fecal The positive tubes were surface streaked onto duplicate plates with EC Agar and incubated at 45 °C for 24 h. After the incubation period, the formed colonies were evaluated and expressed as a percentage.[24]

Determination of *Salmonella* spp., *Listeria monocytogenes*, *Escherichia coli* and *Staphylococcus aureus*

Sterile tapers were appropriately marked to indicate the specific quantity of 300 g for each sample and transported to the Société Generale de Surveillance (SGS) laboratories under refrigeration conditions at the temperature of 4 oC for the identification of *Salmonella* spp., *L. monocytogenes*, *E. coli* and *S. aureu*s.

Determination of *Salmonella* spp.

The FDA/BAM Online 8th Ed.Rev.A/1998 method was used. March 2022 - Chapter 5 items A-E (item E: 1,2,3 a and b,5 and 6), 2022.[25]

Detemination of Lysteria Monocytogenes

The FDA/BAM Online 8th Ed.Rev.A/1998 method was used. April 2022 - Chapter 10. Detection of *L. monocytogenes* in Foods and Environmental Samples and Enumeration.[25]

Determination of *Escherichia coli*

The FDA/BAM Online 8th Ed. Rev. A / 1998. October 2020. Chapter 4, Item I: C, E, F method was used; Item IV: A, B, D.2020. Conventional Method for Determining Coliforms and *E. coli*.[25]

Determination of *Staphylococcus Aureus*

The FDA/BAM Online 8th Ed. Rev.A/1998 method was used. January 2001. Chapter 12 (Revision 2016). *S. aureu*s. Direct Plate Count Method.[25]

Data Analysis

The analysis of variance (ANOVA) was used for the examination of the microbiological test data, with a significance level of 5%. The comparison between the obtained samples was carried out using the Tukey mean comparison test. SPSS version 23.0 for Windows (SPSS, Chicago, USA) was used for statistical analysis. Basic descriptive statistics were applied for the standard deviation and expressed in CFU for mesophiles and qualitatively for total and fecal coliforms, for each obtained sample.

Results

Sociodemographic Characteristics of Goat Producer Associations

It was observed that 86% of the associations lack water and sanitation services, while 21% have access to conventional electricity. Additionally, 79% of the associations possess solar panels for the production and commercialization of their products. The producer associations were established since the year 2003. In each association comprises more than 20 goat producers, predominantly male. The majority of these individuals are over 56 years of age and possess only primary education, as indicated in Table 1.

Table 1: Characteristics of goat producers in the associations of the province of Sullana

Number of goat producers per association	**Associations**
n (%)	
1 to 20	5 (36%)
21 to 30	7 (50%)
31 or more	2 (14.3%)
Number of female producers per association	**Associations**
1 to 10	12 (85.7%)
11 or more	2 (14.3%)
Number of male producers per association	**Associations**
1 to 10	3 (21.4%)
11 or more	11 (78.6%)
Age of producers	**Surveyed**
Until 45 years	3 (21.4%)
46 to 55 years	5 (35.7%)
56 or more	6 (42.9%)
Education level of producers	**Surveyed**
Primary	12 (85.7%)
Secondary	1 (7.1%)
Technical superior	1 (7.1%)

In each goat association, on average, each producer has more than 50 goats and produces more than 10 liters of goat milk daily. Each association sells between S/. 2.00 to S/. 3.00 soles per liter of goat milk and there is no agreement to establish prices for the market. Producers choose to market mainly fresh milk and cheese (see Table 2). Goat cattle are

fed through natural pastures; there is no specific barn where the animals are kept to provide them with food. Occasionally, some producers purchase alfalfa, concentrated feed, passion fruit peel and Sudan grass, to complement the goats' diet. Additionally, some producers provide medicines and vitamins throughout the year to prevent seasonal or endemic diseases.

Not all producers have specialized personnel to take care of the animals; and each assumes this function along with their family. The goat milking is done manually, and the majority of producers process the goat milk products in their homes for commercialization in local markets.

Table 2: Characteristics of the production and marketing of goat milk and its derivatives of the associations

Number of goats per member	**Associations (%)**
Until 50 units	2 (14.3%)
51 to 100 units	6 (42.9%)
101 to 150 units	2 (14.3%)
151 to 200 unitd	2 (14.3%)
201 or more	2 (14.3%)
Daily goat milk production per member	**Associations**
1 to 10 liters	8 (57.1%)
11 or more	6 (42.9%)
Goat milk market price per liter	**Associations**
S/2.00	2 (14.3%)
S/2.50	3 (21.4 %)
S/3.00	9 (64.3%)
Production and marketing of goat milk products	**Associations**
Milk and cheese	10 (71.4%)
Milk, cheese and delicacy	1 (7.1%)
Cheese	2 (14.3%)
Cheese and yogurt	1 (7.1%)

Sociodemographic Characteristics of the Associates and their Relationship with the Microbiological Analysis Result

The majority of producers received training about GMP, these trainings were provided sporadically by the Ministry of Agriculture, Luciano Castillo Coloma Subregion.

Producers store goat milk at room temperature that ranges between 25 °C±4 °C, which could be associated with the presence of *Aerophilic Mesophiles* within 24 hours, as well as the presence of total and fecal coliforms (see Table 3).

Chemical Composition of Goat Cheese

Table 4 displays the physicochemical and compositional parameters of fresh goat milk cheese samples, with values ranging from 45.69% to 62.86% for moisture content, 37.14% to 54.31% for dry matter, 3.04% to 6.74% for ash content, 0.77% to 1.89% for acidity, and 5.21 to 6.55 for pH.

Microbiological Analysis of Goat Cheese *Aerophilic Mesophiles* at 24 Hours

Mesophiles were found in the fourteen samples of artisanal fresh cheese evaluated 24 hours after production; 29% of these samples exceeded the permissible limits (see Figure 1).

***Aerophilus Mesophilic* at 48 Hours**

Mesophiles were found in the fourteen samples of artisanal fresh cheese evaluated 48 hours after production; 50% of these samples exceeded the permissible limits (see Figure 2).

Total and Faecal Coliforms

Total and faecal coliforms were detected in the samples of artisanal goat cheese (see table 5). 79% of the samples showed a value higher than the parameters established in the technical standard (5x 10^2 CFU/g).

Table 6 shows the *E. coli* count results in the fresh cheese samples from the Lancones and Salitral associations were optimal compared to the results from Marcavelica according to the standards established in D.S N° 007- 2021-MINAGRI.

Table 3: Microbiological analysis and its relationship with the application of GMP during the production and market of goat milk cheeses

Microorganisms detected in cheese	Producer training/association			Cheese storage			Lugar de comercialización		
	No	Yes	p-value	Room temperature	Refrigeration	p-value	Local market	Residents of the area	p-value
Absence of mesophiles in 24 h	6 (42.9%)	4 (28.6%)	0.040	3 (21.4%)	7 (50%)	0.018	9 (64.3%)	1 (7.1%)	0.512
Presence of mesophiles* in 24 h	0 (0.0%)	4 (28.6%)		4 (28.6%)	(0%)		4 (28.6%)	0 (0%)	
Absence of mesophiles in 48 h	4 (28.6%)	3 (21.4%)	0.280	1(7.1%)	5 (35.7%)	0.031	5 (35.7%)	1 (7.1%)	0.231
Presence of mesophiles* h in 48	2 (14.3%)	5 (35.7%)		6(42.9%)	2 (14.3%)		8 (57.1%)	0 (0%)	
Absence of total and fecal coliforms	3 (21.4%)	0 (0.0%)	0.024	0 (0%)	3 (21.4%)	0.051	2 (14.3%)	1 (7.1%)	0.047
Presence of total and fecal coliforms*	3 (21.4%)	8 (57.1%)		7 (50%)	4 (28.6%)		11 (78.6%)	0(0%)	
Absence of *E. colii*	4 (28.6%)	4 (28.6%)	0.533	4 (28.6%)	4 (28.6%)	1.00	7 (50%)	1 (7.1%)	0.369
Presence of *E. coli**	2 (14.3%)	4 (28.6%)		3 (21.4%)	3 (21.4%)		6 (42.9%)	0 (0%)	
Total	6 (42.9%)	8 (57.1%)							

* Above permissible limits.

Table 4: Composition and physicochemical parameters of goat cheese

Samples	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14
Humidity (%)	47.58	52.62	55.55	48.56	51.29	58.32	62.86	51.10	51.51	45.69	50.85	56.39	54.50	54.55
Dry extract (%)	52.42	47.38	44.45	51.44	48.71	41.68	37.14	48.90	48.49	54.31	49.15	43.61	45.50	45.45
Ashes (%)	4.58	3.49	5.07	3.6	3.7	3.89	3.04	3.65	3.18	4.58	3.74	3.06	3.49	6.74
Acidity (%)	0.9	1.8	1.26	1.67	0.77	1.13	0.81	0.95	1.71	0.68	1.89	1.49	1.62	0.99
pH	5.35	5.38	5.34	5.87	5.8	6.21	5.21	5.58	5.32	6.55	5.97	5.84	5.93	6.35

The samples obtained from the different goat associations in the Marcavelica districts are: S1, S2, S3, S4, S5, S6, S9. S10, S11 and S13, Lancones: S7, S8 and S12 and Salitral: S14 of the province of Sullana, Piura, Peru.

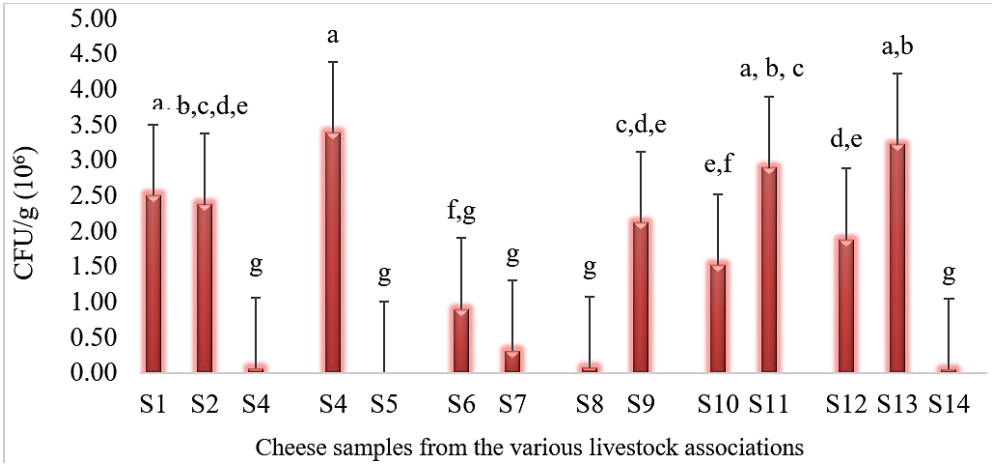

Fig. 1: Aerophilic mesophilic count in the different samples of goat cheese at 24 h of incubation

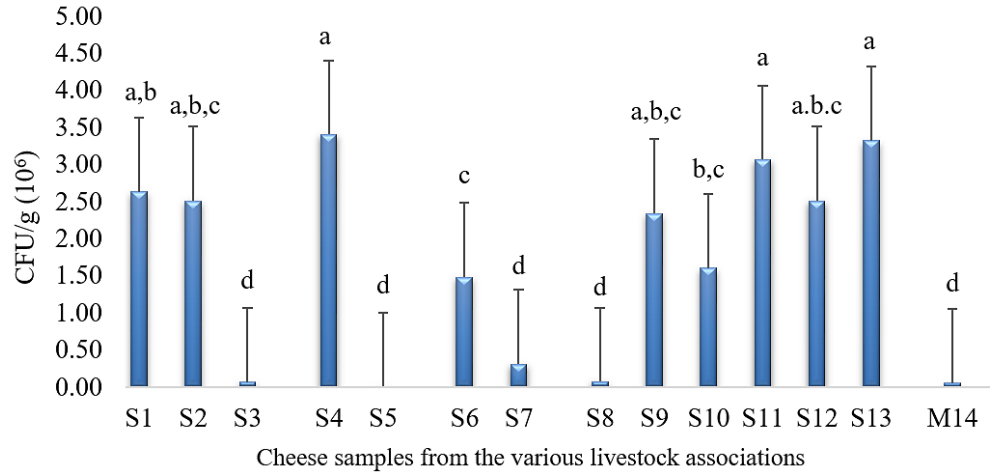

Fig. 2: Aerophilic mesophilic count in the different samples of goat cheese at 48 h of incubation

Tabla 5: Analysis of total coliforms and faecal coliforms in cheese samples

Total, and fecal coliforms*	Analyzed samples	Number of samples	Percentage
+	S1, S2, S3, S4, S5, S6, S9, S10, S11, M12, S13	11	79%
-	S7, S8, S14	3	21%

*+: Presence; -: Absence

Table 6: *Escherichia coli* counts in cheese samples

District	Sample	SGS results (MPN/g)	Interpretation
Marcavelica	S1	3.6	Low risk
	S2	<3.0	Optimum
	S3	230	Extreme risk
	S4	<3.0	Optimum
	S5	93	Moderate risk
	S6	96	Moderate risk
	S9	43	High risk
	S10	3.6	Low risk
	S11	<3.0	Optimum
	S13	<3.0	Optimum
Lancones	S7	<3.0	Optimum
	S8	<3.0	Optimum
	S12	<3.0	Optimum
Salitral	S14	<3.0	Optimum

Table 7: *Staphylococcus aureus* counts in cheese samples

District	Sample	Results (MPN/g)	Interpretation
Marcavelica	S1, S2, S3, S4, S5, S6, S9, S10, S11, S13.	<10	Optimum
Lancones	S7, S8, S12.	<10	Optimum
Salitral	S14.	<10	Optimum

Presence of *Staphylococcus Aureus*

Table 7 shows that all samples were optimal according to the standards established in the D.S N° 007- 2021-MINAGRI.

Presence of *Salmonella* spp. and *Listeria Monocytogenes* (in 25g).

In all the samples analyzed, no presence of *Salmonella* spp. and *L. monocytogenes* was found (in 25g).

Discussion

Since the late Middle Ages of the 13th century, the commercialization of the first pressed cooked cheese produced by local farmers was reported. In the 17th century, business model the cheese production began its expansion.[26] In the case of Sullana, it was observed that in the year of 2004 associations of goat producers began to be established with the purpose of producing and marketing artisanal fresh cheeses. We identified that the producers

do not have specialized education to produce and market cheeses. However, have received sporadic training from the Ministry of Agriculture in Peru and PROCOMPITE, which "is a priority strategy of the state that constitutes a competitive fund to co-finance productive proposals (business plans)".[27]

The goat livestock associations in Sullana consist of family enterprises, whose production is based on grazing, as reported in the literature.[28] Data that coincides with other businesses that sell cheese directly to the consumer and that transmit the recipe to their descendants.[29] Therefore, good manufacturing practices in cheese production are influenced by human capital, behavior, beliefs and attitudes of entrepreneurial producers.[30]

We have identified that the livestock associations are composed of over 20 goat farmers, each of whom owns more than 50 heads of goats. Goat milk derivatives (cheese, manjar and yoghurt) are marketed within the province, similar to another report which shows that the marketing of products.[28] 86% of the establishments dedicated to the production and marketing of fresh cheeses in Sullana lack basic services, making the intervention of the provincial government of Sullana and the Piura region essential to improve cheeses production and improve product competitiveness in the market. These findings aligns with the need to restructure services and regulate public policies so that the artisanal cheese production chain recovers after Covid-19 pandemic.[31]

Cheese producers who sell their products directly to consumers strive to comply with good manufacturing practices and health and hygiene standards, despite the limited infrastructure available to them.[32,33]

Therefore, it is demanded for the goat producer associations in the province of Sullana to comply with the regulations of the artisanal cheese production process. Although they may be family-owned and locally-based businesses in rural areas, it is pertinent that milk storage on the farm be refrigerated at 12°C for 12 hours to prevent bacterial growth.[34]

The associates reported a significant decrease in the number of livestock in recent years, which may be due to the presence of certain diseases and a deficit of livestock feed. Previous studies suggest that the dietary combination of *Chlorella vulgaris* and/or vitamin C on goat growth could be safely used as a supplement to improve antioxidant defenses, enhance male reproductive activities under normal conditions, and eliminate free radicals.[35] For this reason, it is possible that some producers in the province of Sullana may provide medications and vitamins for goat. Although the concentrations of vitamins and carotenoids in goat milk and its color vary significantly due to factors such as diet, breed, and seasonality of the goats.[36]

During the cheese characterization process, data on moisture, dry extract, ashes, acidity, pH, and brix were collected. According to the Milk and Dairy Products Regulation (NTP. 202.193), the moisture content for fresh cheese must be equal to or greater than 46 percent (≥46%),[37] The evaluated samples had an average of 52.96%. Therefore, in relation to these parameters, all samples fall within the values established in the technical standard. These results were compared with previous studies,[38] that evaluated goat cheeses with moisture values in a high range between 50.24 to 55.03%. Also, moisture findings have been reported in goat cheese with lower values, in a range of 38.56 to 48.12%.[39] Low humidity values may be related to high syneresis rates. Additionally, the amount of carbohydrates and minerals can also influence the moisture content in the cheese under the action of polysaccharides.[40]

Regarding the ash content, the cheese under evaluation exhibited an average of 4.0%, which differs from other studies that reported an average of 2% ash content for fresh goat cheese[41] and 6.9% ash for cottage cheese from cow's milk20 which show that cheese contains minerals that favor nutritional composition.

The acidity of cheese was found to be within the allowable range (not exceeding 2%). A low level of acidity results in a weak curd, while excessive acidity can lead to a sour cheese.[42] Acidity is an indicator of proper cheese production.[38]

The pH values of the studied samples had an overall average of 5.7, apparently within the allowed range. The low pH may be related to lactic acid fermentation. However, it is important to control this parameter in cheese manufacturing to guarantee food safety. Other reports suggest that changes in

pH can also cause the loss of certain soluble ions such as Ca^{2+}, Mg^{2+} and K+.[43]

The growth of bacteria is often attributed to inadequate pasteurization, improper handling during the manufacturing process, or a abruption in the cold chain, which can lead to a decrease in pH.[44] Figure 1 displays the mesophilic count at 24 hours. Samples M1, M4, M11, and M13 exhibited the highest number of CFU/g, reaching values ≥ 2.51 x 10^6 CFU/g, which represents 29% of the total count. According to the Venezuelan standard COVENIN 3338:1997, this exceeds the maximum limit of colonies allowed for dairy products.[38] However, in Peru, the microbiological criteria standard RM 591-2008 does not establish a limit for mesophilic evaluation. Samples M3, M5, M6, M7, M8, and M14 exhibited values ≤ 0.09 x10^6 CFU/g, indicating their suitability for human consumption. Despite their presence in the evaluated cheeses, a low mesophilic count does not guarantee the absence of toxins or pathogens, while a high count may indicate excessive contamination of the raw material.[12]

Food containing more than 6 log CFU/g of this bacteria are prone to spoilage, which often alter their sensory characteristics and aspects such as odor, flavor, or appearance, acting as an indicator of hygienic treatment in the cheese producing process, as reported in the literature, cheese due to its conditions may contain high concentrations of aerobic mesophiles.[43] Research referring to fresh cheese reported values of 3.80 log CFU/g to 8.92 log CFU/g[45] values that were also found in the present investigation.

The mesophile counts at 48 hours showed that sample M1, M2, M4, M9, M11, M12 and M13 had the highest number of CFU/g, reaching values ≥ 2.34 x 10^6 CFU/g, representing 50% of the total. These values exceed the recommended limits set by COVENIN 3338: 1997.[38] However, samples M3, M5, M7, M8, and M14 exhibited values ≤ 0.31 x106 CFU/g, indicating their suitability for consumption. Additionally, it is observed that 97.4% of artisanal fresh cheese sold in Lima, Peru had the presence of mesophilic aerobic bacteria.[46] Furthermore, when evaluating fresh cheese from Florida-Pomacochas, Leymebamba, and Molinopampa in the Amazonas region, it was observed that 81.25% of the samples had mesophilic aerobic counts exceeding 10^4 CFU/g evidencing the deficiency in hygienic-sanitary quality of fresh cheese.[47] Another study demonstrated that the addition of nisin and oregano oil can reduce the presence of mesophilic bacteria during the storage of fresh cheese, without affecting the physicochemical and sensory characteristics.[48] The application of essential oils and other natural antioxidants in cheese has been extensively studied, providing good outcomes in the prevention of microbial contamination, and even providing cheese with enhanced properties.[49–52]

The enumeration of total and fecal coliforms revealed that the analyzed samples do not comply with the standards established in D.S N° 007-2021-MINAGRI, with values ranging from 2.06 - 3.48x10^6 CFU/g, exceeding the parameters established in the aforementioned regulation (5x10^2 CFU/g). However, the presence of total coliform bacteria is not always related to fecal origin, as other genera from other sources such as water, vegetation, and soil may exist without representing a health risk.[53] No growth of total and fecal coliform colonies was observed in samples M7, M8, and M14. Compliance with regulations enables the regulation of the commercialization of high-risk food products in terms of health, hygiene, safety, and consumer protection, in accordance with the requirements established by the Peruvian government and in accordance with the provisions of the Codex Alimentarius. In Table 6, it can be observed that the samples (M2, M4, M11, and M13) from the Marcavelica district, (M7, M8, and M12) belonging to Lancones, and the sample (M14) from the Salitral district exhibit values <3.0 (MPN/g), which represents 57% of the analyzed samples falling within the limits established in the D.S N°007-2017-MINAGRI.[54] However, the samples (M1, M3, M5, M6, M9, and M10) belonging to the Marcavelica district, which represent 43% of the surveyed population, obtained values >3.6 NMP/g. These data may pose a health risk as they exceed the limits established by the D.S.[54] When analyzing the sanitary and hygienic quality of fresh cheese marketed in the province of Callao - Cercado, the presence of *E. coli* was also identified, with an average of 4.6 ≥ 102 NMP/g. These results indicate that the establishments do not comply with Peruvian legislation, specifically NTP 202.195:2004 and NTS N°071 - MINSA/DIGESA.[55] Other studies also report the presence of *E. coli* in 97.4% of artisanal samples marketed in various

markets.[46] Without distinguishing between formal and informal microenterprises, it was identified that between 98 and 100% of the cheese samples (n = 48 samples) presented populations of total and fecal coliforms and Staphylococcus sp. above the limits established by Colombian regulations.[56] The presence of fecal coliforms and *E. coli* in retail cheese samples was reported at rates of 50% and 40%, respectively, which could be an indicator of poor hygiene practices.[57] Similar findings were observed in markets in Mexico City where the presence of fecal coliforms in cheeses ranged from 33% to 54%.[58]

The fecal contamination of fresh cheeses occurs due to hygienic deficiencies, improper handling of artisanal fresh cheese, and the presence of *E. coli* in these analyses, which raises concerns as it serves as an indicator of potential risk for Foodborne Diseases (FBDs).

Table 3 shows the results of the *S. aureu*s count, where the obtained values <10 are within the established parameters by the DS N°007-2021-MINAGRI.[54] These findings differ from those of another study which detected *S. aureu*s as the sole pathogen in samples of raw milk cheese and various points on the surface in contact with food.[12] It is necessary not to neglect the good manufacturing practices and hygiene throughout the entire cheese production chain, from the microbiological quality of raw milk to the final product ready for consumption, especially with regard to the presence of *S. aureu*s. No presence of *Salmonella* spp was identified, which is favorable when complying with the provisions of D.S N°007-2021-MINAGRI (Absence/25g de *Salmonella* spp.).[54] The research findings align with those obtained in previous studies, wherein *Salmonella* spp. was not detected in the cheese samples studied.[23,47]

It has been described that pathogenic bacterium such as *Salmonella*, *L. monocytogenes*, *E. coli*, produce harmful metabolites that contribute to inflammation and alteration of the intestinal microbiota, helping its rapid growth and dispersion to different organs of the body, affecting the homeostasis of the organism.[59]

The absence of *L. monocytogenes* (in 25g) in artisanal fresh cheese from Sullana is an encouraging result, as it complies with the provisions of D.S N°007-2021-MINAGRI, which requires the absence of *L. monocytogenes* in 25g of the sampled food. Therefore, from a consumer health perspective, these cheeses are deemed suitable (R.M. N°591- 2008- MINSA).[54]

It is important to conduct further studies of the presence of microorganisms,[60] or demonstrate their ability to produce enterotoxins,[61] in order to ensure the safety of products, and prevent the proliferation these microorganisms during the distribution and commercialization of cheese.[62] Furthermore, there is a necessity for effective inspection by competent authorities,[63] considering that these foods constitute a risk associated with consumption for the population,[64] due to the presence of mesophilic bacteria, total coliforms, and fecal coliforms in the majority of the samples may lead to the emergence of foodborne diseases.[63] Furthermore, it is pertinent to conduct new studies that enable the sanitary surveillance of food, as well as studies that extend the shelf life of fresh goat cheese.

Future Perspectives

The future prospects are oriented towards the need to invest in projects that allow access to basic services such as water, sewage, roads, and productive projects that improve the productivity of goat farming associations, enabling greater competitiveness. Similarly, the intervention of the Ministries of Agriculture through INIA and SENASA, the Ministry of Production through its programs for competitiveness, the Ministry of Education through universities, technological centers, CITEs, and the Ministry of Health through regulatory bodies such as DIGESA is pertinent. There should be a greater commitment to training producers in milk production, processing, storage, transportation, and cheese trade, as the majority lack specialized technical training in the various links of the production chain.

Conclusion

The majority of cheese producers in the province of Sullana are family businesses and do not have specialized education. The limited basic sanitation infrastructure in the home as well as in establishments for goat milking, cheese production, storage, transportation and trade, in addition to the training of producers in good manufacturing practices (GMP), are the aspects that most influence the physicochemical and microbiological

characteristics. The cheeses analyzed have a high ash content, which suggests the need to carry out more studies to determine their detailed mineral composition, which may contain minerals beneficial to human health. In the microbiological aspect, most of the samples analyzed did not comply with the limits established in D.S N°007-2021-MINAGRI for total coliforms, and also presented high values for *E. coli*. While *S. aureu*s was within the permitted limits, *Salmonella* spp. and *L. monocytogenes* were absent. These values suggest the need to generate projects that improve basic sanitation, the infrastructure for cheese production and GMP training in the different links of the dairy food chain in the province of Sullana.

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Conflict of Interest

All authors declare that they have no conflicts of interest.

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