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Original

Hygienic and sanitary characterization of bovine milk from the Nariño province

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ABSTRACT

Objective. The aim of this study is to evaluate the hygienic and sanitary quality of bovine milk from dairy farms of Nariño, Colombia by determining the presence of environmental microorganisms of public health importance such as *Salmonella* spp., *Escherichia coli* O157, *Listeria monocytogenes*, *Staphylococcus aureus* and *Yersinia enterocolitica* and to evaluate the impact that the rainy seasons have on milk quality **Materials and methods**. Milk samples were taken in 180 farms located in four natural subregions, both in the high rainfall season and in the low rainfall season. Mesophilic aerobic count, a somatic cell count by automated methods, and a total coliform count in 3M Petrifilm® plates were done to each milk sample. Detection of Salmonella spp., *Escherichia coli* O157:H7 and *Listeria monocytogenes* was done by the 3M MDS system, *Staphylococcus aureus* and *Yersinia enterocolitica* were isolated by conventional microbiology techniques. **Results**. The highest somatic cell counts were found during the high rain season. The median of the mesophilic, total coliform and somatic cell counts were 20,085 CFU/ml, 265 CFU/ml and 219,170 cells/ml, respectively, with no significant differences in the two rainy periods. Neither *Salmonella* spp. nor *E. coli* O157/H7 were detected. There was no significant difference among the presence of *Listeria* sp., *L. monocytogenes*, *Y. enterocolitica*, *Staphylococcus aureus* and coagulase negative *Staphylococcus* between the two rainy seasons. **Conclusions**. 80% of the milk samples met the hygienic and sanitary quality standards and no influence of the sampling period on the hygienic quality of the milk was observed.

Keywords: Cow's milk; food safety; food pathogens; foodborne illness (*Source: Tesauro y Glosario de la National Agricultural Library*).

RESUMEN

Objetivo. Evaluar la calidad higiénico-sanitaria de la leche bovina de Nariño mediante los recuentos de mesófilos aerobios y de células somáticas y determinar presencia de microorganismos ambientales importantes en salud pública como *Salmonella* spp., *Escherichia coli* O157, *Listeria monocytogenes*, *Staphylococcus aureus* y *Yersinia enterocolítica* y evaluar las variaciones de los parámetros de calidad

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en dos periodos lluviosos diferentes. **Materiales y métodos**. Se tomaron muestras de leche en 180 predios de cuatro subregiones naturales, en épocas de diferente precipitación. A cada muestra se le realizó recuento de aerobios mesófilos, y el recuento de células somáticas por citometría de flujo, y el de Coliformes totales mediante lectura en placa. La detección de *Salmonella* spp., *Escherichia coli* O157:H7 y *Listeria monocytogenes* por el sistema de detección molecular MDS 3M, *Staphylococcus aureus* y *Yersinia enterocolitica* por microbiología convencional. **Resultados**. Los recuentos de células somáticas fueron superiores en la época de altas precipitaciones. La mediana de los recuentos de mesófilos y coliformes totales fue de 20.085 UFC/ml, 265 UFC/ml respectivamente sin diferencias significativas en los dos periodos. No se detectó *Salmonella* spp. ni *E. coli* O157/H7. No se observaron diferencias significativas en la frecuencia de presentación de *Listeria* sp., *L. monocytogenes, Y. enterocolítica*, *Staphylococcus aureus* y *Staphylococcus* coagulasa negativa entre los dos periodos de lluvia evaluados". **Conclusiones**. Se observó que el 80% de las muestras de leche analizadas en este estudio cumplen con los estándares de calidad higiénico-sanitaria y no se observó influencia de la época de muestreo sobre la calidad higiénica de la leche.

Palabras clave: Leche de vaca; inocuidad alimentaria; bacterias patógenas; enfermedades transmitidas por alimentos (*Fuente: Tesauro y Glosario de la National Agricultural Library*).

INTRODUCTION

The dairy sector is one of the most critical production segments of the Nariño province, Colombia. It contributes about 27% to the country's Gross Domestic Product (GDP) and creates more than 90.000 direct jobs and 160.000 jobs linked to the dairy farming business (1). The primary production link involves 40 thousand producers, and 80% of them are peasants and indigenous smallholders (2,3).

In 2017, the province's milk produced was 327.6 million liters, 5.7% of the national total (3). The Altiplano Nariñense dairy basin is located mainly in the Centro, Exprovincia de Obando, and La Sabana subregions, where the municipalities of Pasto, Ipiales, Guachucal, Cumbal, and Túquerres concentrate more than 55% of the province's production (3). In recent years, Buesaco in the Juanambú subregion has shown significant development in the dairy production system (4).

The province's dairy value chain includes producer associations, intermediaries, the processing industry, and marketers. The Nariño and Valle del Cauca provinces are the main markets for the production obtained. Formal and artisan companies participate in milk processing, the former supplying wholesale supermarkets nationwide and neighborhood stores. In contrast, artisan companies directly supply the market with direct sales to consumers, stores, neighborhoods, and marketplaces. The latter is also characterized by lacking a trademark and not being subject to expiration control (4).

For milk quality control, producers and the industry are guided by Resolution 0017/2012 issued by the Ministry of Agriculture and Rural Development (MADR, for its acronym in Spanish). It establishes quality indicators and, according to their characterization, provides a bonus or penalty in calculating the payment to the producer (5,6). The main parameters to estimate the hygienic quality in producer payment systems are the total bacteria count (TBC) or aerobic plate count (APC), which is an indicator of milk harvesting, conservation, and collection, and the somatic cell count (SCC), as an indicator of udder health (5,6).

Several microorganisms and their toxins adversely affect the quality of milk, whose presence is directly related to different factors, including inadequate handling conditions (7), storage temperature (8,9), the degree of exposure of milk to light and oxygen, cleanliness of utensils and equipment used in milk harvesting, seasonal changes (10), soil condition and animal health (9,11,12). The bacteria that reach the milk may or may not be pathogenic, adversely affecting consumers' health or deteriorating the milk quality necessary to prepare by-products (13,14).

This study assessed the hygienic-sanitary quality of bovine milk from associated producers in 11 municipalities in four natural subregions of Nariño during two rainy periods of different intensity using APC, SCC, and the presence of pathogens considered environmental microorganisms of public health importance, such as *Salmonella* spp., *Escherichia coli* O157,

Listeria monocytogenes, *Staphylococcus aureus*, and *Yersinia enterocolitica*.

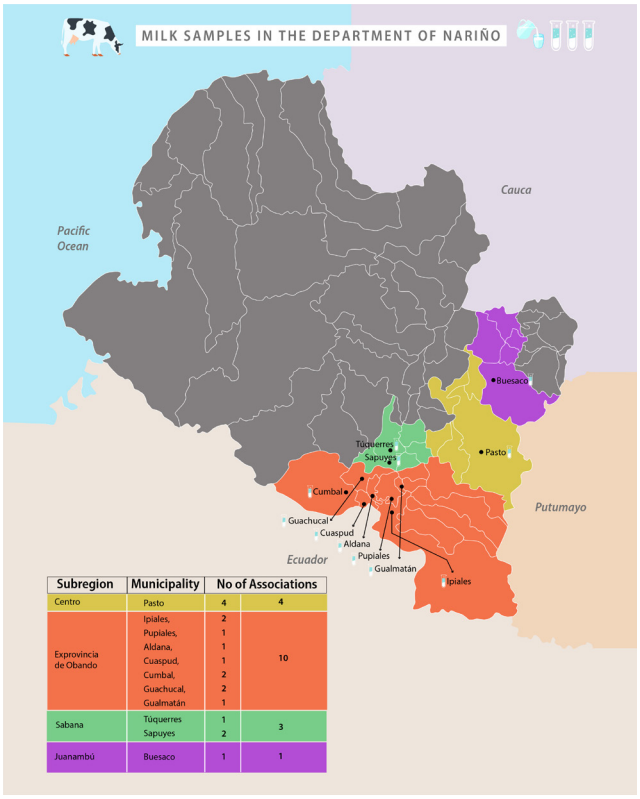
MATERIALS AND METHODS

Type of study. A prospective longitudinal cohort study was designed, whose experimental units were farms producing raw milk in the Andean dairy region of Nariño, with two seasons of different rainfall intensities (high and low). According to the Institute of Hydrology, Meteorology, and Environmental Studies (IDEAM, for its acronym in Spanish), Nariño has two well-defined rainfall patterns; the first occurs from March to April and the second from October to December, with rainfall from 1.000 to 1.500 mm.

Selection of producer associations. The choice of farms, municipalities, and associations was a consensus of public and private institutions, such as the collection and processing industry, producer associations, the Society of Nariño Farmers and Ranchers (SAGAN, for its acronym in Spanish), the University of Nariño, the Nariño governor's office, and the Colombian Corporation for Agricultural Research (AGROSAVIA). One hundred ninety farms were randomly selected from the Nariño Governor's office and SAGAN's database, distributed proportionally among 18 associations in 11 municipalities, and categorized by geographic subregion (Figure 1).

Milk sampling. Three hundred eighty samples of tank milk were collected in farms or collection centers, of which 190 were collected in the high rainfall season between April and June and the same number in the low rainfall season between September and October 2017. The milk samples were collected according to ISO 707:2008: Milk and milk products – Guidance on sampling. The refrigerated samples (1-6°C) were taken to the milk analysis laboratory of the Obonuco Research Center and the Tibaitatá Research Center and processed in the first 24 hours after collection.

Aerobic plate count and somatic cell count. The SCC/ml and APC expressed in colony-forming units per milliliter of milk (CFU/ml) were performed by flow cytometry (Fossomatic® and BactoScan FOSS FC+® equipment, respectively). The sample treatment, equipment operation, and reagent preparation followed the laboratory protocols and manufacturer instructions. The total coliform count (CFU/ml) used the plate method (Petrifilm 3M®).



Subregion	Municipality	No of Associations	
Centro	Pasto	4	4
Exprovincia de Obando	Ipiales,	2	10
	Pupiales,	1	
	Aldana,	1	
	Cuaspud,	1	
	Cumbal,	2	
	Guachucal,	2	
	Gualmatán	1	
Sabana	Túquerres	1	3
	Sapuyes	2	
Juanambú	Buesaco	1	1

Figure 1. Geographical distribution of dairy farmers associations and municipalities. Source: Prepared based on information from Gobernación de Nariño (15).

Detection of pathogens in milk. The 3M™ Molecular Detection System (MDS) was used to detect *Salmonella* sp., *Listeria* sp., *L. monocytogenes*, and *E. coli* O157:H7. *S. aureus*, coagulase-negative *Staphylococcus* (CNS), and *Y. enterocolitica* were detected according to the Food and Drug Administration (FDA) recommendations that are available in the Bacteriological Analytical Manual (BAM). The genus and species of bacteria were identified with the automated system Vitek® using cards for Gram-positive and Gram-negative.

Statistical analysis. The Kolmogorov-Smirnov test determined whether the numerical variables had a normal distribution, inducing the application of the t-test for samples related to a normal distribution and the Wilcoxon test in non-normal distributions for APC and SCC. The within-season numerical variables were analyzed with Mann-Whitney paired tests between subregions. Frequency analysis for repeated measures was performed with McNemar's χ^2 test. Within-season comparisons of proportions by subregion were made with paired Z tests for independent

proportions. The confidence intervals of the proportions were achieved using the Wilson method. The statistical significance was 0.05. The software used was IBM-SPSS-26 AND EPIDAT 3.1.

RESULTS

SCC, APC, and TBC. Of the 190 scheduled farms, repeated sampling could be obtained in 189 (99.4%), and not all microbiological tests were performed on all farms. The Kolmogorov-Smirnov test indicated that the SCC, APC, and TBC variables in raw milk did not have a normal distribution ($p<0.001$).

The general medians of SCCs in high and low rainfall seasons were 244.129 and 201.443 cells/ml of milk, respectively. The significance of equal counts was 6%, and of different counts was 94%; they are statistically different. The count of the high rainfall season was significantly higher than that of the low rainfall season. No differences were found in the SCC between seasons for the subregions ($p>0.05$)(Table 1).

The within-season observation differed for low rainfall, where La Sabana denoted significantly higher counts than the other subregions (Table 1).

Table 1. Wilcoxon test and medians of SCCs in raw milk between rainfall seasons by subregion in Nariño.

Subregion	Farms	HRC	LRC	Wilcoxon	
				Z	*p*
Centro	44	191.233[a]	132.302 [a]	-1.132	0.258
Ex Obando	103	221.274[a]	200.242 [a]	-1.599	0.110
La Sabana	21	345.431[a]	341.806 [b]	-0.052	0.958
Juanambú	10	236.323[a]	127.659 [a]	-0.866	0.386
General	178	244.129	201.443	-1.854	0.064

HRC: High rainfall Cells/ml of milk; LRC: Low rainfall Cells/ml of milk.
Columns with different letters are statistically different within the season. Whitney paired tests within the season for subregions.

Of the total farms analyzed for the SCC variable, 44.4 and 48.9% correspond to good quality milk, with counts below 200.000 cells/ml; 30.9 and 33.1% to fair quality milk, with 200.000 to 500.000 cells/ml, and 24.7 and 18.0% to poor quality milk, with counts higher than 500.000 cells/ml in the high and low rainfall seasons, respectively.

The general median of APC or CFU/ml of milk in high and low rainfall seasons was 25.696 and 19.832, respectively; however, there were no statistical differences between them. In the assessment by subregions for APC, Centro and Exprovincia de Obando showed significant differences between seasons, the former being higher for the high rainfall season and the latter for the low rainfall season. La Sabana and Juanambú did not have different APC values between seasons (Table 2). The results for the within-season APC were significantly higher in La Sabana for both seasons, while the other subregions were alike (Table 2).

Concerning TBC in CFU/ml of milk, the general median for high and low rainfall seasons was 258 and 168 CFU/ml, respectively, but without statistical differences. The count did not show differences between seasons for the subregions; however, La Sabana had significantly higher counts than the other subregions (Table 2).

Table 2. Wilcoxon test and median APC and TBC in raw milk between rainfall seasons by subregion in Nariño.

Subregion	No. of farms	CFUM-H	CFUM-L	Wilcoxon	
				Z	*p*
Centro	44	25.452 [a]	5.615[a]	-4.586	*0.000*
Ex Obando	102	19.402 [a]	34.007[a]	-2.259	*0.024*
La Sabana	25	138.799 [b]	219.536[b]	-1.117	0.264
Juanambú	10	38.360 [ab]	18.826[a]	-0.561	0.575
General	181	25.696	19.832	-0.373	0.709
CFU of coliforms/ml of milk					
Centro	44	170[a]	123[a]	-0.048	0.961
Ex Obando	103	358[ab]	190[a]	-0.909	0.363
La Sabana	21	3.400[b]	2.610[b]	-0.295	0.768
Juanambú	10	100[a]	40 [a]	-0.889	0.374
General	178	258	168	-0.607	0.544

CFUM-H: CFU of mesophiles/ml of milk (high rainfall); CFUM-L: CFU of mesophiles/ml of milk. (low rainfall).
Columns with different letters are statistically different medians within the season. Whitney paired tests within seasons for subregions.

In the hygienic quality classification, the percentage of farms with good milk (≤100.000 CFU/ml) was 75.1 and 72.9%, with standard milk (>100.000 to 200.000 CFU/m) 8.8 and 6.6%, and with poor quality milk (>200.000 CFU/ml) 16.0 and 20.4% in high and low rainfall seasons, respectively.

Pathogenic microorganisms. In the milk of the two samples, neither *Salmonella* spp. nor *E. coli* O157/H7 was detected, but *Listeria* sp, *L. monocytogenes*, and *Y. enterocolitica* were. *Listeria* sp. and *L. monocytogenes* were found in Centro, Exprovincia de Obando, and La Sabana, noting statistically equal proportions between seasons (Table 3).

In the two seasons evaluated, *L. monocytogenes* was isolated in the farms of Centro (5.5%), followed by La Sabana (3.8%) and Exprovincia de Obando (2.7%). *Y. enterocolitica* was found during the two sampling seasons in Centro (1.66%) and Exprovincia de Obando (4.44%).

In the high rainfall season, there was a significantly higher proportion of farms with *Listeria* in La Sabana and Centro. In the low rainfall season, the proportions of milk contaminated with *Listeria* were similar between subregions (Table 4).

Table 3. Frequency of bacteria of public health interest in raw milk from Nariño farms in different rainfall seasons.

Species	High rainfall		Low rainfall		Significance between seasons*	95% CI Wilson proportion**
	N farms	% farms	N Farms	%farms		
Salmonella sp	0/180	0.0	0/189	0.0	NC	0.00 – 1.00
E. coli O157H7	0/180	0.0	0/189	0.0	NC	0.00 – 1.00
Listeria sp	22/180	12.2	7/180	3.9	0.003	5.70 -11.3
L. monocytogenes	13/180	7.2	7/180	3.9	0.180	3.62 – 8.42
Yersinia enterocolítica	8/180	4.4	3/180	1.7	0.227	1.71 – 5.39

*McNemar farms related between seasons. NC: Not calculable. **Wilson method for CI of proportions in the two seasons.

Table 4. Frequency and percentage distribution of farms with *Listeria* sp in raw milk in different rainfall seasons by subregion in Nariño

Subregion	High rainfall		Low rainfall		Significance between seasons*	95% CI Wilson proportion**
	Nfarms	% farms	Nfarms	% farms		
Centro	7/44	15.9 ^{ab}	4/44	9.1 ^{a}	0.453	7.1 – 21.0
Ex Obando	8/101	7.9 ^{b}	1/101	1.0 ^{b}	0.039	2.4 – 8.30
La Sabana	7/25	28.0 ^{a}	2/25	8.0 ^{a}	0.125	9.8 – 30.8
Juanambú	0/10	0.0 ^{b}	0/10	0.0 ^{a}	NC	0.0 – 16.1

*McNemar paired farms between seasons. NC: Not calculable. **Wilson method for IC of proportions in the two seasons. Columns with different letters are statistically different proportions. Source: The authors

S. aureus was isolated in milk samples from all subregions; however, no statistically significant differences were found between seasons or within subregions (Table 5).

Twelve CNS species were identified in the primary production sector. The most prevalent species were *Staphylococcus warneri*, *Staphylococcus hominis*, *Staphylococcus haemolyticus*, *Staphylococcus epidermidis*, and *Staphylococcus chromogenes* (Table 6).

Table 5. Frequency and percentage distribution of farms with *S. aureus* in raw milk in different rainfall seasons by subregion in Nariño

Subregión	HR		LR		SBS*	ICP**
	NP	%P	NP	%P		
Centro	7/44	15.9 ^{a}	7/44	15.9 ^{a}	1.000	9.7–25.0
Ex Obando	6/101	5.9 ^{a}	11/101	10.9 ^{a}	0.332	5.3–13.1
La Sabana	1/25	4.0 ^{a}	1/25	4.0 ^{a}	1.000	1.1–13.5
Juanambú	2/10	20.0 ^{a}	4/10	40.0 ^{a}	0.625	14.6–51.9
Total	16/180	8.9	23/180	12.8	0.289	8.0–14.5

HR: High rainfall; BP: Low rainfall; NF: N farms; %P: %Farms; SBS: Significance between seasons; ICP: 5% CI Wilson proportion.
*McNemar paired farms between seasons. **Wilson method for IC of proportions in the two seasons. Columns with different letters are statistically different. Source: The authors

CNS was isolated in all four subregions; 13.6 and 29.0% of the properties had CNS in high and low rainfall seasons, respectively, being significantly different proportions. In the Exprovincia de Obando, the proportion of farms with CNS in raw milk was significantly higher in the low rainfall season. Juanambú and Centro showed equal and significantly higher proportions within the high rainfall season variable than the Exprovincia de Obando. In contrast, within the low rainfall season, no differences were found between subregions (Table 7).

Table 6. Frequency and percentage distribution of farms with CNS in raw milk in different rainfall seasons in Nariño

Species	High rainfall		Low rainfall		Significance between seasons*	95% CI Wilson proportion**
	N farms	% farms	N farms	% Farms		
S. warneri	10/180	5.6	15/180	8.3	0.405	4.8–10.1 *a*
S. hominis	2/180	1.1	10/180	5.6	*0.021*	1.9–5.7 *b*
S. haemolyticus	5/180	2.8	6/180	3.3	1.000	1.7–5.4 *b*
S. epidermidis	3/180	1.7	6/180	3.3	0.508	1.3–4.7 *b*
S. chromogenes	3/180	1.7	4/180	2.2	1.000	0.9–4.0 *bc*
S. simulans	0/180	0.0	6/180	3.3	NC	0.8–3.6 *bc*
S. lentus	0/180	0.0	5/180	2.8	NC	0.6–3.2 *bc*
S. sciuri	2/180	1.1	0/180	0.0	NC	0.2–2.0 *c*
S. vitulinus	0/180	0.0	2/180	1.1	NC	0.2–2.0 *c*
S. cohnii	1/180	0.6	0/180	0.0	NC	0.1–1.6 *c*
S. xylosus	1/180	0.6	0/180	0.0	NC	0.1–1.6 *c*
S. auricularis	0/180	0.0	1/180	0.6	NC	0.1–1.6 *c*

Table 7. Frequency and percentage distribution of farms with CNS in raw milk in different rainfall seasons by subregion in Nariño.

Subregión	High rainfall		Low rainfall		Significance between seasons*	95% CI Wilson proportion**
	N farms	% farms	N farms	% farms		
Centro	10/40	25.0 [a]	16/40	40.0 a	0.180	23.2 – 43.4
Ex Obando	8/110	7.2 [b]	29/110	26.4 a	0.000	12.5 – 22.3
La Sabana	5/25	20.0 [ab]	7/25	28.0 a	0.625	14.3 – 37.4
Juanambú	2/8	25.0 [a]	1/8	12.5 a	1.000	6.6 – 43.0
Total	25/183	13.6	53/183	29.0	0.000	17.4 – 25.8

*McNemar paired farms between seasons. **Wilson method for IC of proportions in the two seasons. Columns with different letters are statistically different.

DISCUSSION

Globally, the consumption of bovine milk increases yearly, mainly in the infant population. Therefore, its production must guarantee quality conditions that allow the consumption of a safe product.

According to the SCC results, about 45% of the farms analyzed had milk that meets the quality parameters of leading markets such as the European Union, the United States, and New Zealand (6). As an indicator of mammary gland health, an SCC of 200.000 cells/ml or less in a tank is a target to improve milk quality and processing.

In Colombia, technical standard 399 of 2002 specifies that milk with less than 700.000 cells/ml is required for industrial processes so that it

does not affect transformation and processing (16). Accordingly, 70% of the milk analyzed in the study can be used for industrial processes. Still, 30% does not meet the parameters and requires attention since high SCCs can be associated with mastitis problems; however, it must be taken into account that several non-infectious factors can increase the SCC, such as the age of the cow, lactation period, time of year, interval between milkings, and stress (16).

Concerning the time of year, this study reflects that during the periods of higher rainfall, the SCC was higher; humidity and rain can cause mud to accumulate in the udder, predisposing cows to mastitis (16) with the increased SCC; however, no differences were observed between the seasons for the subregions. In La Sabana (17), values from 100,000 to just over 1.000.000 cells/ml were found, which could be associated with management conditions and the prevailing rainfall during the sampling period.

In Colombia, according to technical standard 399 of 2002, milk suitable for the industry must contain less than 700.000 somatic cells/ml since high SCCs affect milk transformation and processing (17). In the present study, the milk of about 70% of the producers meets this parameter for industrial processing. Although the SCC is not contemplated for the payment for milk quality, the industry uses it as a parameter to evaluate milk quality.

Regarding hygienic quality, 73% of the evaluated farms meet the quality standards based on the APC, as outlined in Resolution 017/2012 issued by the MADR for quality payment, and 50% have APCs below 25.000 CFU/ml at the time of marketing for the two seasons studies. Nonetheless, a group of producers (27%) have not yet obtained milk with good sanitary quality, probably due to contamination during the milk harvest process and the poor adoption of good milking practices.

The CFU/ml values did not have significant differences for the high and low rainfall seasons, a result similar to the values found by Vásquez (6) in milk samples from 11 collection centers of various milk production systems in Colombia. In contrast, Martínez and Gómez (10) found high values of aerobic mesophiles in the summer season with statistically significant differences $p<0.05$ (1.0×10^8 CFU/ml in summer and 1.2×10^7 CFU/ml in winter) (10).

Moreover, in the two seasons evaluated in all subregions, coliforms were detected. Although this analysis does not determine bacterial species, it is considered a guide for contamination and suggests fecal contamination of milk. Milk can be contaminated by poor hygienic conditions in facilities, utensils, and handling processes during harvest (13,18).

Regarding pathogenic microorganisms, *Listeria* sp. was detected in 12 and 7.8% of arms in the high and low rainfall seasons, respectively. In La Sabana, the highest number of samples with *Listeria* sp. was found, with 28 and 12% of the samples for the high and low rainfall seasons, respectively, without significant statistical differences. This study detected *L. monocytogenes* in 6.11% of the samples evaluated (22/360) on farms in Centro, Exprovincia de Obando, and La Sabana. These values are different from those in the "National Sanitary Profile of Raw Milk for Direct Human Consumption" drawn up by the Ministry of Health, where a prevalence of 13.45% (19/141) was found for *L. monocytogenes,* and the data reported by Jurado (19) for *Listeria* sp. in La Sabana in 2019, with 4.6% of 70 samples. This group of pathogens in raw milk is hazardous to human health since these agents potentially cause food poisoning. Despite pasteurization and other industrialization processes being capable of destroying them, their presence and other environmental contaminants can lead to the detriment of nutritional components, which would reduce the nutritional value of milk and adversely affect yields in the industry.

L. monocytogenes occurs due to exogenous contamination of milking equipment and storage containers; its persistence is associated with failures in washing and disinfection of utensils for milk harvesting. An essential factor that should be mentioned is that this bacterium tends to be present in highly humid areas, explaining its presence in the samples from the sub-regions of Nariño in this study.

Studies conducted in the United States have shown that the prevalence of *L. monocytogenes* varies depending on the geographical area, being higher in states with colder temperatures and lower in places with warm temperatures (14,20,21), which could explain the findings of this study. So, *L. monocytogenes* was present in milk samples from farms above 2.900 masl in Centro, La Sabana, and Exprovincia de Obando and not in farms in Juanambú located between 1.900 and 2.300 masl.

Concerning *Y. enterocolitica*, this study constitutes the first record of this pathogen in raw bovine milk in Colombia. Milk samples contaminated with *Y. enterocolitica* (Table 3) came from farms in Centro (Pasto) and Exprovincia de Obando (Ipiales, Aldana, Pupiales, Gualmatán, Cuaspud, and Guachucal) located above 2.900 masl. This location corresponds to the cold and páramo altitudinal zones with temperatures between 0 and 12°C, favoring the survival and permanence of *Y. enterocolitica*, which can multiply at low temperatures (22).

Y. enterocolitica is a zoonotic pathogen that causes Yersiniosis in humans and animals. Contaminated feed, reservoir animals, and the contaminated environment are potential sources of human infection (23). Its presence in the milk of sick or healthy animals, feces, and preserved fodder increases human infection probability. In addition, *Yersinia* produces enterotoxins, a significant factor that can impact food safety (24,25).

The presence of *S. aureus* ranged from 8.9 to 12.8%; CNS ranged from 14.3 to 28.6%. Although the epidemiological dynamics of these microorganisms depend on several factors, such as the production system, the geographical region, and animal management practices, the frequency with which these microorganisms were isolated was relatively high in the milk samples analyzed.

S. aureus and CNS have been detected in raw milk samples from various dairy regions of Colombia, such as Córdoba, Caldas, Antioquia, Tolima, Cundinamarca, Boyacá, and Valle del Cauca, with prevalence ranging between 8.3 and 47 % for *S. aureus* and 0.46 and 49.3 % for CNS (18,21,26,27). These findings were common for specialized and dual-purpose milk production systems. *Staphylococcus* was found to be related to bovine mastitis (27), making it necessary to increase the control of this pathology and avoid its adverse impact on public health (21).

From the group of CNS, the species *S. chromogenes*, *S. simulans*, *S. haemolyticus*, *S. xylosus*, and *S. epidermidis* were found, which have been identified as causing bovine mastitis (Table 6), although it is accepted that the effect on SCC and milk production is generally limited or non-existent for this group of microorganisms (28).

CNS are common opportunistic pathogens, ubiquitous commensals in humans and animals, and are associated with infections in which strains are resistant to antimicrobials, including methicillin and other antibiotics (29); thus, attention should be paid to this bacterial group. It can be a source of transmission of resistance to other bacterial populations and cause significant public and animal health problems.

In conclusion, this study demonstrates the particularities of the dairy subregions of Nariño concerning milk quality, which can be affected by the greater or lesser intensity of rainfall. While some producers obtain excellent quality milk suitable for industrial processes, it is necessary to continue improving animal management processes to guarantee better udder health and harvest, handling, and conservation processes.

Conflict of interests

The authors of this article state no conflict of interest.

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