rccp Revista Colombiana de Ciencias Pecuarias

Raw milk quality in Northwestern Colombia¤

Calidad de leche cruda en el noroeste de Colombia

Qualidade do leite cru no noroeste da Colômbia

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(Received: November 29, 2014; accepted: March 31, 2016)

doi: 10.17533/udea.rccp.v29n3a06

Summary

Background: the worldwide trend in agro industries is to optimize food quality and obtain safe products for human consumption. It is important to produce milk with excellent physicochemical and microbiological quality to reduce public health risks. **Objective:** to evaluate the physicochemical and microbiological quality of milk and udder health in northwest Colombia, through the raw milk received at a leading dairy plant in Valledupar (Colombia). **Methods:** a non-probability sampling and a cross-sectional study were conducted. Raw milk samples from 186 beef and milk (dual purpose) farms were collected. Physicochemical parameters, mesophilic and somatic cell counts were determined. Data were analyzed by descriptive statistics using SAS software. **Results:** physicochemical parameters were within the normal range in accordance with Colombian Decree No. 616 of 2006. The average mesophilic and somatic cell count was 305,279 colony forming units (CFU)/mL, and 523,207 somatic cells (SC)/mL, respectively. Sixty-eight percent of the farms had somatic cell counts greater than 200,000 SC/mL, which is the threshold for bovine mastitis. **Conclusion:** physicochemical quality of milk was good, but there were shortcomings in microbiological quality and udder health. Therefore, efforts are required to prevent this problems and to implement excellent management practices in the farms.

Keywords: *composition, mesophilic, protein, quality, somatic cells*.

¤ To cite this article: Suàrez GJ, Pomarez JV, Rangel AC, Rodrìguez VR, Angulo LM, Garay OV. Raw milk quality in Northwestern Colombia. Rev Colomb Cienc Pecu 2016; 29:210-217.

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Resumen

Antecedentes: la tendencia mundial en prácticas agroindustriales es la obtención de alimentos de excelente calidad e inocuidad para el consumo humano. Es importante producir leche de excelente calidad fisicoquímica y microbiológica para disminuir los riesgos en salud pública. **Objetivo:** evaluar la calidad fisicoquímica y microbiológica de la leche asi como la salud de la ubre en el noroeste de Colombia, a traves de la leche cruda recibida en una planta procesadora de Valledupar (Colombia). **Métodos:** se utilizó un muestreo no probabilístico por conveniencia y un estudio de corte transversal. Muestras de leche cruda de 186 fincas doble propósito fueron recolectadas. Se determinaron parámetros fisicoquímicos, conteo de células somáticas y mesófilos. Los datos obtenidos se analizaron por estadística descriptiva mediante el programa estadístico SAS. **Resultados:** los parámetros fisicoquímicos se encontraron dentro de los valores normales de acuerdo al decreto 616 de 2006. El promedio del recuento de mesófilos fue de 305.279 unidades formadoras de colonia (UFC)/mL y 523.207 células somáticas (CS)/mL. En el 68% de las empresas ganaderas, el conteo de células somáticas fue mayor a 200.000 CS/mL, lo cual, es un indicio de mastitis bovina. **Conclusión:** la calidad fisicoquímica es buena, pero hay deficiencias en la calidad microbiológica y sanidad de la ubre, por lo cual se deben implementar excelentes prácticas de manejo y de prevención.

Palabras claves: *calidad, células somáticas, composición, mesófilos, proteína*.

Resumo

Antecedentes: a obtenção de alimentos de excelente qualidade e segurança para o consumo humano é uma tendência mundial. É importante produzir leite de excelente qualidade físico-química e microbiológica para reduzir os riscos na saúde pública. **Objetivo:** avaliar a qualidade físico-química e microbiológica do leite cru produzido no noroeste da Colômbia, recebeu em um laticínio líder em Valledupar (Colômbia). **Métodos:** foi utilizada uma amostragem não probabilística e um estudo transversal. Amostras de leite cru foram coletadas em 186 fazendas de dupla aptidão. Foram determinados parâmetros físico-químicos, mesófilos e contagem de celulas somanticas. Os dados obtidos foram analisados pela estatística descritiva mediante a utilizacao do programa estadistico SAS. **Resultados:** os parâmetros físico-químicos foram encontrados dentro da normalidade de acordo com o decreto 616 de 2006, a média da contagem de mesólitos foi de 305.279 unidades formadoras de colónias (UFC)/mL e a contagem de células somáticas (CS) foi 523.207 CS/mL. Em 68% das empresas produtoras de gado, a contagem de células somáticas foi maior do que 200.000 CS/mL. **Conclusão:** a qualidade físico-química é boa, mas há falhas na qualidade microbiológica e a saúde do úbere, por isso os esforços nas fazendas devem procurar a implementação de excelentes práticas de gestão e prevenção.

Palavras chave: *células somáticas, composição, mesófilos, proteína, qualidade*.

Introduction

A global trend in agriculture consists in producing safe foods for human consumption. It is an ongoing concern to all parts of the dairy industry -and farms are not an exception- to guarantee milk quality (Calderón *et al*., 2006). Excellent milk should conform to food safety and quality regulations (Minprotección, Colombia, 2006). To succeed on this, the following parameters should be obtained: protein >3.2%, fat >3.5%, total solids >12.2%, mesophilic count <50,000 CFU/mL, somatic cell count (SCC) <100,000 SC/mL (Calderón *et al.,* 2006), and absence of foreign substances or inhibitors. Prior to pasteurization, high counts of mesophilic and somatic cells favor the release of proteolytic enzymes, which decrease the shelf life of the product (Calderón *et al*., 2006) affecting milk yield and physicochemical parameters during milk coagulation processes (Calderón *et al.*, 2012).

In regard to public health, there are obvious risks related to the consumption of raw milk. The Colombian government has issued a regulatory framework to rule the market and consumption of raw milk in order to minimize health risks for humans (Calderón *et al*., 2006; Minprotección, 2006; Minprotección, 2011).

Mesophilic bacterial count, which grow between 20 and 40 ºC is an indicator of the microbiological quality of raw milk (Chacón, 2004). Nevertheless, a lower number of mesophilic counts do not assure the lack of pathogens or their toxins.

Somatic cells count is indicative of inflammation of the mammary gland, which results from the attack of pathogens or other factors, such as trauma. SCC consist of epithelial cells or desquamation cells (2%) and leukocyte migration to the epithelium. When infection develops, the diapedesis phenomenon increases, which is also a non-specific immune response. This phagocytic response against infectious agents helps repairing the alveolar epithelium and return to normal function. The former action is mediated by proteases, lipases and phospholipases. These enzymes and bacterial inhibitors are incorporated into the milk and accelerate the decomposition of proteins and fats. Consequently, somatic cells counts increase with the severity of the infection. Hence, somatic cells quantification is a key parameter to evaluate udder health and milk quality (Cerón *et al.,* 2007; Calderón *et al*., 2012). According to the above, the general objective of this study was to assess somatic cell count, physicochemical and microbiological quality of raw milk produced in northwestern Colombia.

Materials and methods

Location

This study comprised five areas in northwestern Colombia, including the following municipalities: Zone 1: Agustin Codazzi, San Diego, La Paz, and Valledupar. Zone 2: Betania, Bosconia and El Copey. Zone 3: Curumaní and Becerril. Zone 4: Nueva Granada and Santa Ana. Zone 5: Urumita and Villanueva. Zones 1, 2, and 3 are located in Cesar Province, Zone 4 in Magdalena province, and Zone 5 in La Guajira Province.

Sample size

A convenience non-probability sampling method was used to take 186 milk samples from a farm devoted to milk and beef production (dual-purpose system).

Selection criteria

The farms were providers of raw milk for a well-known dairy processing company. They were managed under a dual-purpose system and used cooling tanks to preserve milk in individual or collective tanks from daily milking until dispatch to the milk processing plant.

Sampling

Each tank (individual and collective) was stirred for 10 minutes. Then, samples were manually collected with a sterile stainless steel sampler. 20 mL of raw milk was transferred to a labeled sterile bottle, which was then stored under refrigeration (4 ^{o}C).

Physicochemical parameters

Determination of the percentages of protein, fat, and total solids was done in an equipment with infrared technology (MilkoScan^{TM} FT 120; Foss, Hillerød, Denmark).

Microbiological parameters

Count of mesophilic bacteria in milk was performed in an equipment with flow cytometry technology (BactoScan^{TM} FC; Foss, Hillerød, Denmark).

Somatic cell count (SCC)

SCC was performed by fluorescence using an optical cell counter (DeLaval, 2005. Tumba, Sweden).

Statistical analysis

A descriptive analysis of SCC, physicochemical and microbiological variables was performed. Comparisons were made between types of milk storage tanks (individual and collective) and areas of study, using the test of Kruskal Wallis. The SAS software (SAS Institute Inc, Cary, NC, USA) was used.

Results

Table 1 shows the number of farms by area and Table 2 shows the descriptive statistics analysis of SCC, physicochemical and microbiological parameters of raw milk.

Table 1. Number of farms by area of study in Northwestern Colombia.

Area	Province	Municipality	Number of farms	Milk collected (L)
1	Cesar	Vallledupar	84	57,654
2	Cesar	Betania-Copey	28	13,671
3	Cesar	Becerril-Curumaní	40	26,242
4	Magdalena	Granada y Santana	18	13,307
5	Guajira	San Juan	16	8,157
Total			186	119,031

Table 2. Overall quality of raw milk in Northwestern Colombia.

Variable	n	Mean	SD	Min. V.	Max. V.
Protein (%)	185	3.43	0.13	3.13	3.92
Fat (%)	185	4.17	0.34	2.75	5.34
NFS (%)	185	8.70	0.14	8.15	9.01
TS (%)	185	13.16	0.39	11.90	14.55
Mesophilic CFU/mL	186	305,276	698,206	8,000	6,796,000
Somatic cell (SC)/mL	176	523,207	209,191	180,000	1,701,5000
Volume	186	119,031	-	50.00	2,780

n: number of samples; SD: standard deviation; Min. V: minimum value; Max. V: Maximum value; NFS: non-fat solid; TS: total solids; CFU: colony forming units; SC: somatic cells.

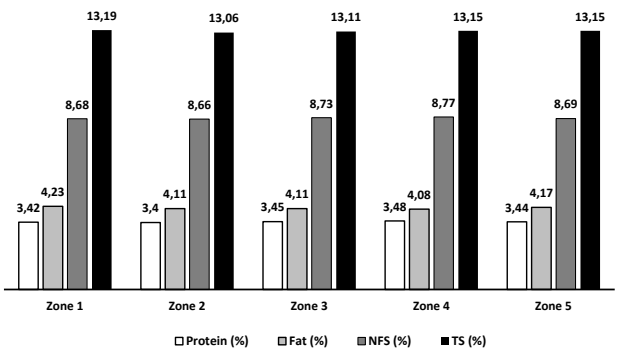

Figure 1. Physicochemical quality of raw milk in Northwestern Colombia.

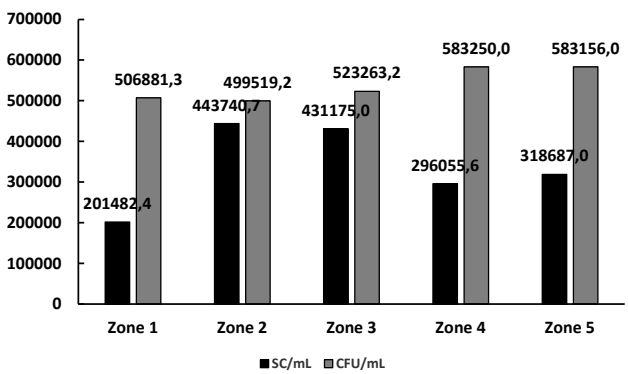

Figure 2. Mesophilic (CFU/mL) and somatic cell count (SC/mL) in raw milk in Northwestern Colombia .

Physicochemical quality of raw milk in each geographic region is shown in Figure 1.

Microbiological quality and SCC of raw milk in each geographic region are shown in Figure 2.

Table 3 shows the distribution of mesophilic count of raw milk in the dairy processing plant.

Table 4 shows the distribution of somatic cell count, which is an indicator of udder health and mastitis in cattle from farms located in Northwestern Colombia.

Table 3. Distribution of mesophilic count in raw milk received by a dairy processing plant in nNorthwestern Colombia.

Category (CFU/mL)	Frecuency	%	Volume	%
<25,000	19	10.22	19,376	16.27
25,001 to 50,000	18	9.68	7,886	6.62
50,001 to 100,000	28	15.05	12,226	10.27
100,001 to 150,000	34	18.28	18,566	15.60
150,001 to 200,000	33	17.74	22,925	19.26
200,001 to 300,000	16	8.60	8,149	6.85
300,001 to 500,000	14	7.53	9,402	7.90
500,001 to 700,000	11	5.91	9,885	8.30
>700,000	13	6-99	10,616	8.90
Total	186	100	119,031	100

Table 4. Distribution of somatic cell count in raw milk from farms in Northwestern Colombia.

Category	Frecuency	%	Volume	%
< 100,000 SC/mL	0	0	0	0,0
100,001 to 200,000 SC/mL	2	1.14	1,392	1.17
200,001 to 300,000 SC/mL	12	6.82	5,458	4.58
300,001 to 500,000 SC/mL	75	42.61	48,862	41.05
500,001 to 700,000 SC/mL	68	38.64	54,149	45.49
700,001 to 1,000,000 SC/mL	11	6.25	5,155	4.33
1,000,001 to 2,000,000 SC/mL	8	4.55	4,015	3,37
Total	176	100	119,031	100

Table 5 shows the distribution of SCC, physicochemical and microbiological quality of raw milk by type of storage tank (individual or collective) collected at a dairy processing plant in Valledupar (Colombia).

Discussion

The average percentage of protein was 3.43 ± 0.13%, with a minimum of 3.13 and maximum of 3.92% (Table 2). This is lower than the value reported by Calderón *et al*. (2007), which was 3.6 ± 0.42%, and greater than 3.22 ± 0.09 and 3.28 ± 0.23% determined by Calderón *et al.* (2011) and Calderón *et al*. (2012), respectively. Álvarez *et al.* (2012) in Mexico found

Tabla 5. Distribution of somatic cell count, physicochemical and microbiological quality of raw milk collected at a dairy processing plant in Valledupar (Colombia), depending on the type of storage tank (individual or collective) .

Variable	Type of tank	n	Media	SD	P-Value
Protein (%)	1	66	3.46	0.13	0.1013
	2	119	4.42	0.14	
Fat (%)	1	66	4.13	0.36	0.1971
	2	119	4.20	0.33	
NFS (%)	1	66	8.73	0.13	0.066
	2	119	8.69	0.15	
TS (%)	1	66	13.16	13.12	0.7634
	2	119	13.16	13.18	
Mesophilic CFU/mL	1	67	152,537	270,570	<0.0001
	2	113	391,277	838,234	
Somatic cell (SC)/ mL	1	63	544,571	262,209	0.9508
	2	113	391,277	836,234	

1= individual tank 2= collective tank.

n: number of samples; CFU: colony forming units; NFS: non-fat solids; TS: total solids.

a lower value (3.29%), and García *et al*. (2013) in Venezuela reported a similar percentage (3.49%) under comparable management conditions. Sandoval *et al*. (2011) in Paraguay concluded that high SCC decreases the percentage of protein, and Barbosa *et al*., (2013) found that high SCC is associated with protein reduction in Gyr cattle (although, this situation did not occur in this study, since correlation was low and not significant, r: 0.06; p>0.05).

Average percentage of fat determined in this study was of 4.17 ± 0.34%, with a minimum of 2.75% and a maximum of 5.4% (Table 2). According to Decree 617 (Ministry of Social Protection, Colombia, 2006), raw milk must contain at least 3% fat. This average is higher than the 3.64 ± 0.46 and 3.70 ± 0.23% reported by Calderon *et al*. (2011) and Calderon *et al*. (2012), respectively, in milk from cows without subclinical mastitis. These values could be due to racial types (*Bos indicus* x *Bos taurus*), which were adapted to the environmental conditions of the area (Briñez *et al*., 2008). Barbosa *et al*. (2013) reported a high SCC value not associated with the reduction in fat percentage of Gyr cattle in Brazil. Cervantes *et al*. (2013) concluded that cow nutrition has an important effect on milk composition, mainly on fat content.

The average NFS was 8.70 ± 0.14%, with a minimum value of 8.15% and a maximum of 9.01% (Table 2). This value is higher than the minimum established by law in Colombian (Ministry of Social Protection, 2006) and the reported by Calderón *et al*. (2007) and Calderon *et al*. (2011) (8.38 ± 0.48 and 8.59 ± 0.16%, respectively) for cows without subclinical mastitis. Higher values (9.56%) have been reported in Venezuela (Briñez *et al*., 2003). In Brazil, in semi-specialized milk production systems a value of 8.58 ± 0.25% was obtained for NFS percentage (Rosa *et al*., 2012). Alvarez *et al*. (2012) determined that NFS percentage does not significantly change during the year. Moreover, Barbosa *et al*. (2013) determined that high SCC was associated with a reduction of NFS in Gyr cattle.

The average TS percentage was 13.16 ± 0.39%, with a minimum of 11.90% and maximum of 14.55% (Table 2). This value classifies as ordinary milk (Calderón *et al*., 2006) and is higher than the current rule accepted in Colombia (11.30%; Ministry of Social Protection, 2006), and higher than 12.06 ± 0.87% reported by Calderón *et al*. (2007) and 11.45 ± 0.75% found by Calderon *et al*. (2012). A smaller percentage of TS has been reported in Brazil (12.37%; Ribas *et al*, 2004.). Barbosa *et al*. (2013) found that SCC was associated with reduced milk protein percentage in Gyr cattle. Sandoval *et al*. (2011) showed that high SCC are related to reduced TS content.

Mesophilic count, SCC, and physicochemical parameters are shown in Figures 2 and 3, for each of the areas sampled. Average mesophilic count was 305,276 ± 698,206 CFU/mL, with a minimum of 8,000 and maximum of 6,796,000 CFU/mL (Table 2). This average is higher than 235,450 CFU/mL reported by Calderon *et al*. (2012) from a farm equipped with a cooling tank in Monteria (Colombia). A high mesophilic count could be due to hygienic conditions of the stables and milking sites, lack of proper teat sanitation practices, inadequate cleaning routine, improper teat disinfection, poor disinfecting containers used in milking conditions, which were not evaluated in this study. In these situations, good manufacturing practices are required (Villoch, 2010). Ruiz *et al*. (2012) determined that mesophilic count ranged between 4,500 and 2,103,500 CFU/mL in eastern Antioquia (Colombia), with an average of 115,932 CFU/mL. They proposed to improve the former variables to enhance the bacteriological quality of milk. In different Colombian regions, Vásquez *et al*. (2012) established that 93.9 % showed mesophilic count up to 200,000 CFU/mL and out of these, 84.49% had values under 100,000 CFU/mL, as required by the European Community and the United States. The 47.53% of samples in the above report displayed mesophilic count below 25,000 CFU/mL, which inferred an excellent microbiological quality. Cervantes *et al*. (2013) in Hidalgo (Mexico) suggested that reducing the exposure time of the milk to environmental factors such as temperature, humidity, dust, and other pollutants will improve its bacteriological quality.

In agreement with the Colombian resolution # 000017 of 2012, only 68% (132/186) of milk producers in this study should receive bonus for mesophilic counts lower than 200,000 CFU/mL (Table 3). In a study regarding temperature and spread of bacteria, Ruiz *et al*. (2012) reported milk of excellent quality from San Pedro de los Milagros in northern Antioquia, with a mesophilic count of 4,500 CFU/mL. Calderon *et al*. (2012) estimated an average of 160,346 ± 213,354 CFU/mL and found differences between non-refrigerated (235,450 ± 252,559 CFU/mL) and refrigerated milk (74,514 ± 125,222 CFU/mL). The reason for these differences was the use of cooling systems, which inhibit bacterial growth, extends the storage time in the farm and reduces transportation costs (DeLaval, 2006).

On the other hand, high bacteria load in milk decreases the shelf time of the product and deteriorates its organoleptic and nutritional quality. In addition, it interferes with lactic acid fermentation, enzymatic degradation or coagulation and promotes casein proteolysis (Signorini *et al*., 2008). Silanikove *et al*. (2010) admitted that high counts of aerobic mesophilic bacteria (AMB), total coliform bacteria (TCB) and psychrophilic bacteria could be a source of transmission of foodborne diseases.

Table 5 shows the distribution of physicochemical quality of mesophilic and somatic cell counts by tank type (individual or collective). There was a significant difference between individual and collective tanks. Probably, these were due to the material used to build

the collective tanks, which may not be suitable for the food industry. Besides, other factors such as the container itself and prolonged milk transportation could be reasons for those differences, although they were not evaluated in this study.

The average SCC in this study was 523,207 ± 209,191 SC/mL with minimum and maximum values of 180,000 and 1,7015,000 SC/mL, respectively (Table 2). Calderón *et al.* (2011) obtained a SCC of 230,000 ± 5,650 SC/mL, which was assumed as low for cows without subclinical mastitis. It was determined that high SCC values greatly affect the physicochemical quality of milk and diminish the production of coastal cheese by 5.58%. Additionally, Calderon *et al*. (2012) reported a SCC of 345,133 ± 302,241 in northwestern Colombia. In other regions, such as northern Antioquia, SCC less than or equal to 400,000 SC/mL have been reported (Posada *et al*., 2010). This parameter has been accepted by the dairy industry; nonetheless, it is still an evidence of subclinical mastitis, loss of quality, and low milk yield. Vásquez *et al*. (2012) established an average SCC of 642,000 SC/mL and 39.54% of the milk samples did not exceed international standards for SCC. Finally, those authors concluded that these numbers should be reduced in order to compete in international markets. Noro *et al*. (2006) obtained an average SCC of 390,000 SC/mL in Brazil. While Ortiz and Vera (2006) (Peru) concluded that the best technological levels for processed milk result in lower SCC. Moreover, Revelli *et al*. (2011) reported an average SCC of 407,000 ± 230,000 SC/mL. Meanwhile, Sandoval *et al*. (2011) in Paraguay established that 47.5% of their samples had less than 200,000 SC/mL.

Only 1.14% (2/176) of the studied farms in this work had SCC less than or equal to 200,000 SC/mL (Table 4). SCC less than or equal to 200,000 SCC can be considered as good, although with subclinical mastitis; SCC greater than 400,000 SC/mL are denotative of subclinical and clinical mastitis. Therefore, it is necessary to implement preventative measures to control bovine mastitis. Sears and Mc Carnthy (2003) concluded that SCC below 400,000 SC/mL is indicative of farms with good management practices, but they do not emphasize on mastitis control.

The physicochemical variables in raw milk presented an excellent compositional quality. However, its microbiological quality is deficient in spite of the fact that milk was kept in cold conditions. Farms should implement quality assurance programs, which allow production of excellent quality milk.

Conflicts of interest

The authors declare that they have no conflicts of interest with regard to the work presented in this report.

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