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Physicochemical characterization and correlation of raw cow's milk according to classification assigned in Panama[1]

Caracterización físico-química y correlación de la leche cruda de vaca según la clasificación asignada en Panamá

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Abstract

Introduction. Currently, there are no bibliographic or statistical records that allow establishing a correlation between the physical-chemical quality characteristics of raw cow's milk produced in the Republic of Panama and the classification it receives. **Objective.** To characterize and quantify the physical-chemical parameters of the quality of raw cow's milk and correlate these characteristics with the classification that milk receives in Panama. **Materials and methods.** A stratified sampling was carried out according to the classification of raw cow´s milk (grade A, B, and C), 48 of grade A, 71 of grade B, and 393 of grade C. Random samples were taken in Cocle, Veraguas, Herrera and Los Santos during the rainy season from June to September 2018. In the Chiriquí province, the sampling was conducted during the dry season, from January to March 2019. In addition, it was necessary to have at least 512 producers or farms, so that the analysis reached a confidence level of 95 %, a standard deviation of 5 %, and a limit of error of 5 %. **Results.** The values found allow us to consider that the milk produced in Panama has the physical-chemical characteristics according to international standards. The correlation analysis indicated that the protein had a high relationship with solids non-fat (SNF), density (D), and lactose (L) (0.93, 0.91, and 0.96, respectively); also L is strongly related to SNF and D (0.94 and 0, 91, respectively). **Conclusions.** The analysis of variance did not allow to establish significant differences between the three existing classifications in the country, which allow a distribution of milk according to the grades of these parameters. However, it was possible to establish the existing correlation between some of these parameters.

Keywords: unprocessed milk, dairy herd, physic-chemical parameters, milk production, grade.

Resumen

Introducción. Actualmente, no existen registros bibliográficos o estadísticos que permitan establecer una correlación entre las características de calidad físico-químicas de la leche cruda de vaca producida en la República de Panamá y la clasificación que recibe. **Objetivo.** Caracterizar y cuantificar los parámetros físico-químicos de la calidad de la leche cruda de vaca y correlacionar estas características con la clasificación que recibe la leche en Panamá.

Materiales y métodos. Se realizó un muestreo estratificado según la clasificación de la leche cruda de vaca (tipos A, B y C), 48 del grado A, 71 del grado B y 393 del grado C. Se tomaron muestras aleatorias en las provincias de Coclé, Veraguas, Herrera y Los Santos durante la época lluviosa, de junio a septiembre de 2018. En la provincia de Chiriquí, el muestreo se realizó durante la época seca, de enero a marzo de 2019. Además, fue necesario contar con 512 productores o fincas, para que el análisis alcanzara un nivel de confianza del 95 %, una desviación estándar del 5 % y un límite de error del 5 %. **Resultados.** Los valores encontrados permiten considerar que la leche producida en Panamá tiene las características físico-químicas acordes a normas internacionales. El análisis de correlación indicó que la proteína tuvo una alta relación con los sólidos no grasos (SNF), la densidad (D) y la lactosa (L) (0,93, 0,91 y 0,96, respectivamente); también L está fuertemente relacionada con SNF y D (0,94 y 0, 91, respectivamente). **Conclusiones.** El análisis de varianza no permitió establecer diferencias significativas entre las tres clasificaciones existentes en el país, que permiten una distribución de la leche de acuerdo a los grados de estos parámetros. Sin embargo, fue posible establecer la correlación existente entre algunos de estos parámetros.

Palabras claves: leche no procesada, hato lechero, parámetros físico-químicos, producción láctea.

Introduction

Considering that milk is the only material produced by nature to function exclusively as a food source, since it constitutes a nutritional source complete, not surpassed by any other known to humans (Jay, 2009).

This food consumption may represent differences in the quality of diets of people without access to adequate nutrition, especially among children. In this sense, in recent years, world milk production exceeds 600 million tons per year according to the Food and Agriculture Organization Statistics Division (Food and Agriculture Organization, 2020). The main producers are the countries of the European Union, the United States and the Russian Federation, contributing around 45 %.

In the last 10 years, the production of fresh milk has suffered negative fluctuations, in 2015, the Republic of Panama reached a production of 125 million liters, reflecting a 12 % increase in production (Instituto Nacional de Estadística y Censo, 2020). With this increase, the capacity to satisfy local consumption is far from being achieved as approximately 50 % of the demand is generated.

In Panama, milk production occurs mainly on small farms, mostly carried as a form of family income. According to current regulations, the milk production receives a classification based on the quality of this, milk grade A, grade B and grade C or Industrial. This classification (A, B and C) is mainly related to the bacterial load that the milk has: a) grade A milk <200,000 bacteria ml^{-1}, b) grade B milk with <500,000 bacteria ml^{-1}, and c) grade C milk, milk that does not meet the parameters required by grade A and B milk (Ministerio de Gobierno y Justicia, 1970).

Actually, there are approximately 5,000 milk producers. Around the 8 % of them, generate grade A milk, while 12 and 80 % provide grade B and C, respectively. Of the total milk production, the Centrals provinces (Cocle, Los Santos, Herrera and Veraguas) and Chiriquí contribute about 85 % of national production (Cadena Agroalimentaria de Leche, 2017).

Currently, there is no type of publication or reference at the national grades that indicates a physical-chemical characterization of the quality of the raw cow´s milk (RCM), which allows it to be correlated with the classification it receives according to current regulations. Actually, the concept of milk quality involves, among others, physicochemical variables such as density (D), pH, fat (F), solids not-fat (SNF), total solids (TS), lactose (L) and protein (P).

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Milk has a wide variety of components such as minerals, vitamins, etc. These components can vary even in different milkings of the same cow, mainly due to natural causes such as: genetic factors, lactation stage, health status of the cow, diet, etc. In addition to these factors, it is possible that the exposure of the milk to the environment, an inadequate management of the cold chain, hygiene of the facilities and storage time, can influence the characteristics of raw milk (Bernabucci et al., 2015; Hogenboom et al., 2019; Linn, 1988; Walstra et al., 2006).

There is the possibility of correlating the classification that RCM currently receives with the physicochemical profile of some of the characteristics considered important in milk. Given that in Panama there are no bibliographic or statistical records that allow the traceability and characterization of these quality characteristics of the milk produced in the country to be established, which incidentally, are carried out only in some cases and only by the receiving companies of milk for processing. The objective of this work was characterize and quantify the physical-chemical parameters of the quality of raw cow's milk and correlate these characteristics with the classification that milk receives in Panama.

Materials and methods

Sample Selection

In order to maintain a true representation of the diversity of existing producers, the minimum representative sample necessary was calculated through stratified sampling, considering the classification of milk grade A, grade B and grade C or Industrial, according to the presence or not of bacteria: a) grade A milk with <200,000 bacteria ml^{-1}, b) grade B milk with <500,000 bacteria ml^{-1}, and c) grade C milk, milk that does not meet the parameters required by grade A and B milks (Ministerio de Gobierno y Justicia, 1970) as a stratum. With a confidence level of 95 %, a standard deviation of 5 % and a limit of error of 5 %. These considerations identified the need to have a minimum of 359 samples, 30 from grade A, 44 from grade B and 285 from grade C. However, a total of 512 milk samples were collecgted, distributed as follows: 48 grade A, 71 grade B, and 393 grade C. These samples were randomly selected in the provinces of Cocle (A = 1, B = 3, C = 14), Veraguas (A = 3, B = 4, C = 57), Herrera (A = 3, B = 7, C = 110) and Los Santos (A = 3, B = 12, C = 97), during the rainy season corresponding to the months of June to September 2018. In the Chiriqui province (A = 38, B = 45, C = 115), the sampling was carried out during the dry season, corresponding to the months from January to March 2019. This selection was made through a call to existing producers and processing companies in the different Provinces. The type of milk produced (A, B and C) was previously classified by the collection centers of the raw milk processing companies. If samples were obtained through tours of various farms or at collection points for processing plants. It is necessary to point out that the majority of dairy producers that have a great diversity of breeds in their herds, so this aspect was not considered. They were collected and kept preserved in coolers prepared for this purpose, at temperatures between 4 and 6 degrees Celsius (Martínez et al., 2007) in 30 ml sterile plastic bottles.

Analysis of the samples

Once the interested producers have been identified, visits will be made to the producing farms in order to carry out the specific analyzes, these measurements contemplate evaluating the following variables: density (D), pH, fat (F), solids not-fat (SNF), total solids (TS), lactose (L), and protein (P).

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The physico-chemical parameters under study were measured using the Speedy Lab analyzer, based on ultrasonic technique, sensitivity, specificity (Astori Tecnica snc, Brescia, Italy). It only requires conditioning the sample temperature (35 to 40 C°) for its measurement. The pH measurement was performed with the Oakton Instruments pH 11 meter, Vernon Hills, USA.

Data processing

The data obtained was subjected to various statistical processes to obtain the best interpretation, among them, analysis of variance (ANOVA), correlation test, individually and cluster evaluation using the milk grade and geographic origin as differential parameters. For this, the statistical software such as:Statistical Package for the Social Sciences 15.0 (SPSS) and with the software XLSTAT 2019.2.1 were used.

Results

The samples were obtained in two ways, collected directly from the production farms and from collection centers of milk processing companies. A total of 512 milk samples were collected, distributed as follows: 48 samples grade A, 71 samples grade B and 393 samples grade C.

There is a wide variety of works and publications that deal with the quality of RCM, but, they do not show standardized values that indicate specific ranges that producers must meet to consider that the milk produced can be considered or not as quality milk. It was possible to generate a table of ranges of suggested values for each of the physical-chemical characteristics evaluated (Table 1).

The descriptive analysis of the data obtained, allowed to establish ranges of indicative values for each one of the studied physico-chemical parameters. As can be seen in Table 1, the values of solids non-fat, total solids and proteins were very close to the minimum reference values established. As expected, these grades influence the density results, which changes with a tendency towards minimum values. On the other hand, fats and lactose showed values with a tendency towards the upper limits considered in the bibliography. Considering that Panama does not have an official standard that establishes adequate ranges for these milk parameters, ranges of values identified from a previous bibliographic review were pre-established and based on standards from other countries and regions.

For all the physical-chemical parameters, it was possible to observe a tendency for these values to decrease as the grades of raw milk decreases. In the case of FAT, the values vary from 4.61 %, 4.12 %, and 4.08 % for grade A, B, and C, respectively. For the SNF, 9.19 %, 8.32 %, and 7.92 %, respectively for A, B and C. In respective order of A, B, and C, the TS was 13.80 %, 12.44 %, and 12.0 %. The D showed values in the same order, respectively for A, B, and C, 1032, 1029 and 1028 kg m^3. The P was 3.36 %, 3.04 %, and 2.90 % for milk A, B, and C. Finally, the L presented the same behavior, 5.05 %, 4.57 %, and 4.36 %. The pH maintains constant values, of 6.56, 6.58, and 6.55. This indicates that the grades of the physico-chemical conditions influence the quality of the RCM.

The measurements of the parameters studied reflect very close values between the classes of raw milk produced, for which an evaluation of the means (ANOVA) was carried out with the combined effect of the class of milk produced. As can be seen in Table 2, in all cases the F statistic and its level of significance ($p<0.05$) that accepts the validity of the hypothesis of equality of the means, that is, under the conditions of this study, no significant differences were found between the milk grades considered. This condition may be due to the high percentage of diversity of breeds and crosses existing in a large part of the dairy herds involved.

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Table 1. Mean values of the parameters studied in raw milk according to the class of raw cow's milk (A, B and C) and the global average (mean). The samples were collected in the provinces of Cocle, Herrera, Los Santos, Veraguas, from June to September 2018 and in the province of Chiriqui, from January to March 2019. Panama Republic. Range of values of the physical-chemical parameters to be evaluated according to the bibliography.

Cuadro 1. Valores medios de los parámetros estudiados en la leche cruda según la clase de leche cruda de vaca (A, B y C) y el promedio global (mean). Las muestras se recolectaron en la provincia de Coclé, Herrera, Los Santos, Veraguas, de junio a septiembre 2018 y en la provincia de Chiriquí, de enero a marzo de 2019. República de Panamá. Rango de valores de los parámetros físico-químicos a evaluar según la bibliografía.

Grade	A*			B*			C*			Total			References values[a]	
	mean	N	SD	mean	N	SD	mean	N	SD	mean	N	SD	Lower	Higher
FAT	4.61	48	1.430	4.12	71	0.922	4.08	393	0.911	4.14	512	0.983	3.3	4.43
SNF	9.19	48	1.247	8.32	71	0.807	7.92	393	0.477	8.10	512	0.741	7.84	9.19
TS	13.80	48	2.346	12.44	71	1.366	12.00	393	1.001	12.23	512	1.344	11.62	14.72
D	1032	48	4.306	1029	71	3.047	1028	393	1.983	1028	512	2.806	1026	1034
P	3.36	48	0.455	3.04	71	0.296	2.90	393	0.172	2.96	512	0.270	3.02	5.74
L	5.05	48	0.684	4.57	71	0.443	4.36	393	0.261	4.45	512	0.405	2.26	4.3
pH	6.56	48	0.167	6.58	71	0.162	6.55	393	0.162	6.56	512	0.162	6.25	7.18

*Milk level A, level B and level C or Industrial, according to the presence or not of bacteria a) grade A milk with <200,000 bacteria ml^{-1}, b) grade B milk with <500,000 bacteria ml^{-1}, c) grade C milk, milk that does not meet the parameters required by grade A and B milks (Ministerio de Gobierno y Justicia, 1970). / *Leche de nivel A, nivel B y nivel C o Industrial, según la presencia o no de bacterias a) grado A con <200 000 bacterias ml^{-1}, b) grado B con <500 000 bacterias ml^{-1}, c) grado C, leche que no cumple los parámetros exigidos por las leches de grado A y B (Ministerio de Gobierno y Justicia, 1970).

N: total number of observations in the sample; SD: standard deviation; SNF: non-fat solids; TS: total solids; D: density; P: protein; L: lactose/ N: número total de observaciones en la muestra; SD: desviación estándar; SNF: sólidos no grasos; TS: sólidos totales; D: densidad; P: proteína; L: lactosa.

[a] Source / Fuente: Bondan et al. (2019); Closa et al. (2003); Comunidad Andina (2009); East African Community (2006); European Economic Community (1992); Food and Agriculture Organization of the United Nations (2013); Franzoi et al. (2019); Gallardo et al. (1996); Linn (1988); Ocampo et al. (2016); Oliszewski et al. (2002); Ponce (2009).

Given the result of the absence of significant between variables regarding grade classification, the data was subjected to Pearson correlation analysis. In the Table 3, shows the grades resulting similarities, the P has a high level of correlation with the SNF, with the D and L (0.93, 0.91, and 0.96, respectively), and a positive relationship intermediate with TS (0.65), conditions to be expected in this type of matrix.

L was very strongly related to SNF and D (0.94, and 0.91, respectively. A positive intermediate relationship can also be observed between the TS with SNF, D, P, and L (0.70; 0.43; 0.65, and 0.67, respectively). In all cases, it can be seen that the pH values and the grades to which belong the samples of milk reflected almost no interaction.

A negative intermediate relationship showed that relates the grades with SNF (-0.50), D (-0.48), P (-0.50), and L (-0.50). Under the conditions carried out in this work, it is not possible to establish significant correlations between the physical-chemical characteristics evaluated that can differentiate the classes of milk, or the place where the samples come from.

Table 2. Analysis of variance with the combined effect of the class of raw cow's milk produced. Milk grade A, grade B, and grade C or Industrial, according to the presence or not of bacteria a) grade A milk with <200,000 bacteria ml^{-1}, b) grade B milk with <500,000 bacteria ml^{-1}, c) grade C milk, milk that does not meet the parameters required by grade A and B milks (Ministerio de Gobierno y Justicia, 1970). The samples were collected in the provinces of Cocle, Herrera, Los Santos, Veraguas, from June to September 2018 and in the province of Chiriqui, from January to March 2019. Panama Republic.

Cuadro 2. Análisis de varianza con el efecto combinado de la clase de la leche cruda de vaca producida. Leche grado A, grado B y grado C o industrial, de acuerdo con la presencia o no de bacterias a) grado A <200 000 bacterias ml^{-1}, b) grado B con <500 000 bacterias ml^{-1}, c) grado C, la leche que no reúne los parámetros requeridos por los grados A y B (Ministerio de Gobierno y Justicia, 1970). Las muestras se recolectaron en la provincia de Coclé, Herrera, Los Santos, Veraguas, de junio a septiembre 2018 y en la provincia de Chiriquí, de enero a marzo de 2019. República de Panamá.

			Sum of squares	gl	Mean square	F	Sig.
FAT	Inter Groups	(Combined)	.631	2	.316	.842	.431
	Intra groups		190.783	509	.375		
	Total		191.414	511			
SNF	Inter Groups	(Combined)	.081	2	.041	1.483	.228
	Intra groups		13.913	509	.027		
	Total		13.994	511			
TS	Inter Groups	(Combined)	1.071	2	.535	1.244	.289
	Intra groups		219.053	509	.430		
	Total		220.124	511			
D	Inter Groups	(Combined)	.993	2	.497	.337	.714
	Intra groups		749.026	509	1.472		
	Total		750.019	511			
P	Inter Groups	(Combined)	.002	2	.001	.076	.926
	Intra groups		6.549	509	.013		
	Total		6.551	511			
L	Inter Groups	(Combined)	.004	2	.002	.063	.939
	Intra groups		14.973	509	.029		
	Total		14.976	511			
pH	Inter Groups	(Combined)	.006	2	.003	.131	.877
	Intra groups		10.974	509	.022		
	Total		10.980	511			

gl: degrees of freedom; F: Snedecor F statistic; Sig: significance level; SNF: non-fat solids; TS: total solids; D: density; P: protein; L: lactose. / gl: grados de libertad; F: estadístico F de Snedecor; Sig: nivel de significancia; SNF: sólidos no grasos; TS: sólidos totales; D: densidad; P: proteína; L: lactosa.

Discussion

It is necessary to consider that due to the notable complexity of the sample and the large number of variables that may intervene in the characteristics of milk production (species, diet, climate, geographic location, animal health, etc.) (Allore et al., 1997; Dominguez-Salas et al., 2019; Food and Agriculture Organization, 2013; Manterola, 2011). Much of the objective of the study was achieved, to characterize and quantify the physical-chemical parameters of the quality of raw cow's milk in the different provinces studied.

The results obtained were consistent with what was observed by Hogenboom et al. (2019), where he points out that compared milk samples obtained with automatic milking system and traditional milking systems in herds

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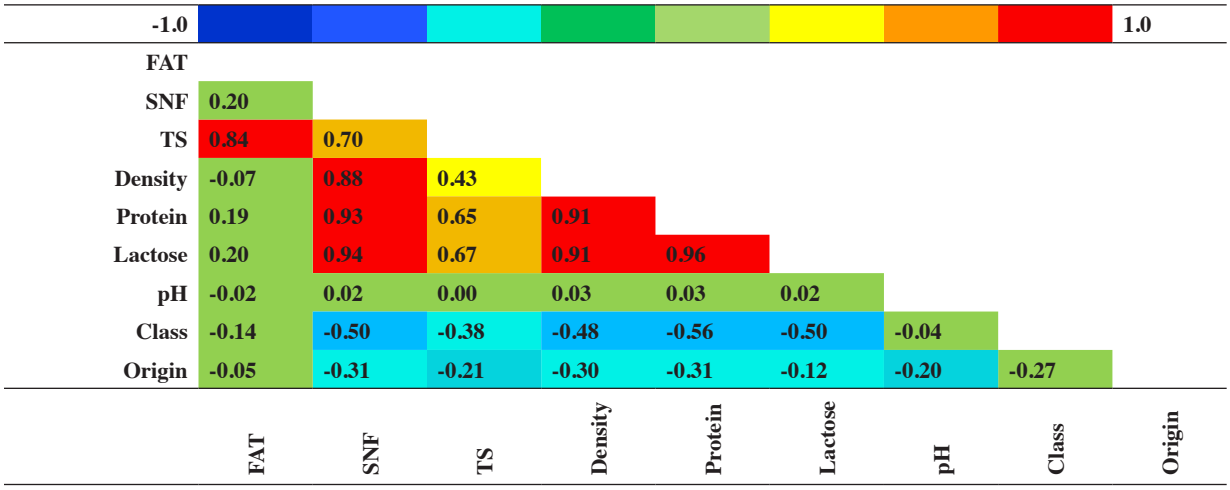
Table 3. Pearson Correlation Matrix of the parameters obtained from the samples of raw cow's milk analyzed. Provinces of Cocle, Herrera, Los Santos, Veraguas, from June to September 2018 and in the Province of Chiriquí, from January to March 2019. Panama Republic.

Cuadro 3. Matriz de correlación de Pearson de los parámetros obtenidos de las muestras analizadas de leche cruda de vaca analizadas. Provincias de Coclé, Herrera, Los Santos, Veraguas, de junio a septiembre 2018 y en la Provincia de Chiriquí, de enero a marzo de 2019. República de Panamá.



SNF: non-fat solid; TS: total solids / SNF: sólidos no grasos; TS: sólidos totales.

of different sizes, in different lactation stages and in different periods of year, found that the milking system did not significantly affected the F, P, L, SNF, and casein. This indicates that what was found in the study is possible, considering that the samples used represented a homogenization of the milk of the herds, possibly involving animals of different breeds, lactation states, health, diet, factors already defined as those responsible for the conditions. physical-chemical and microbiological quality of raw cow's milk.

The behavior of the results obteined from fat, SNF, TS, density, P, L and pH not present significant differences between the different grades of raw milk, it did represented an indication of the possible impact that the different variables studied represent on the quality grade of raw cow's milk. Condition mentioned in different studies carried out (Bernabucci et al., 2015; Hogenboom et al., 2019; Linn, 1988; Walstra et al., 2006).

Additionally, according to the values found in the present study, it was possible to affirm that RCM in the regions under study have the profile that adjusts to the wide variety of studies carried out and regulations used by different countries (Comunidad Andina, 2009; East African Community, 2006; European Economic Community, 1992). Since, it was not possible to consider that a cross-sectional analysis collects enough information to discriminate the quality of the RCM within a specific classification.

The current regulations require deepening the microbiological aspect and consider novel aspects such as the presence of somatic cells as an interpretation of the health status of the cow's udder, without neglecting the physical-chemical condition of the same, such as tools to establish the quality grades of the milk produced.

Conclusions

All the values of the different variables analyzed were within the ranges of values pre-established as satisfactory within the bibliographic review and existing regulations in other countries.

In the conditions carried out in this study, the values found, showed a slight tendency that agrees with the quality grade of the RCM, did not present significant differences that allow them to be considered as descriptors of the quality. The correlation analysis showed that there are strong positive relationship between the parameters studied.

Having carried out a sample greater than the minimum suggested according to the methodology, the results do not yield conclusive information to significantly validate the distribution of each sample in the respective current classification. It is advisable to carry out a broaders studies to establish standardized indicators that allow identifying and locating national milk as a quality product, considering sampling in consecutive periods to establish statistical significance for different climatic seasons (rainy and dry), genetic characteristics, health states herds, geographical areas, etc.

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