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The dairy cow: Understanding
the sustainable production

Quality of raw milk and payment system for quality in Ecuador

Calidad de la leche cruda y sistema de pago por calidad en el Ecuador

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Abstract

States legislate quality to maintain the health of the population, safety and nutritional properties of food, regulations that apply on the production and industrialization, thus Ecuador implemented a policy to improve the quality of raw milk through price. This study aimed to determine the compliance of the parameters established in the regulation of payment for quality of raw bovine milk (RPQM) in Ecuador during the period 2009-2018. Total data (n= 103204) were obtained by the milk quality laboratory of the Salesian Polytechnic University from 3 regions of the country. The parameters of fat, protein, total solids, total bacteria count (TBC) and somatic cell count (SCC), and the Ecuadorian regulations that promoted the quality and productivity of milk in this study period were analyzed. The general averages were: fat $3{,}80 \pm 0{,}05\,\%$; protein $3{,}12 \pm 0{,}10\,\%$; total solids $12{,}36 \pm 0{,}16\,\%$. SCC and TBC decreased between 2009 and 2018: SCC from 460×10^3 to 447×10^3 cells/mL and TBC from 1 million CFU/mL to averages around 200×10^3 CFU/mL, respectively. In conclusion the RPQM was positive for the chemical parameters with values above the limits established. The hygienic quality (TBC and SSC) showing improvements over time although, the SCC does not within the maximum permissible because it implies a multifactorial action for improvement being necessary to concentrate efforts on health and GMP.

Keywords: Milk composition, milk quality, payment system, bacteria count, somatic cells

Resumen

Para mantener la salud de la población los Estados legislan la calidad, inocuidad y propiedades nutricionales de los alimentos, regulaciones que se aplican en la producción e industrialización, así, Ecuador implementó una política de mejora de la calidad de la leche cruda a través del precio. .El objetivo del estudio fue determinar el cumplimiento de los parámetros establecidos en el reglamento de pago por calidad de leche (RPCL) cruda bovina vigente en el Ecuador durante el periodo 2009-2018. Se utilizaron (n =103 204) datos obtenidos por el Laboratorio de Calidad de Leche de la Universidad Politécnica Salesiana provenientes de 3 regiones del país. Fueron analizados los parámetros de: grasa, proteína, sólidos totales, contaje de bacterias totales (CBT), conteo de células somáticas (CCS) y se revisaron las diferentes regulaciones ecuatorianas que impulsaron la calidad y productividad de la leche en el periodo de estudio. Los promedios generales fueron: $3,80 \pm 0,05\,\%$; proteína $3,12 \pm 0,10\,\%$; sólidos totales $12,36 \pm 0,16\,\%$. CCS y CBT disminuyeron entre el 2009 y 2018: CCS de 460×10^3 a 447×10^3 células/mL y el CBT de 1 millón UFC/mL a promedios entorno a los 200×10^3 UFC/mL, respectivamente. Se concluye que el RPCL fue positivo para los parámetros de composición con valores sobre los límites establecidos. La calidad higiénica y sanitaria muestran mejoras en el tiempo, aunque CCS no entra en los límites máximos permisibles debido a que implica un abordaje multifactorial de acciones para la mejora.

Palabras clave: Composición de leche, calidad de leche, sistema de pago, contaje de bacterias, células somáticas

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1 Introduction

Because of the importance of nurturing the body and maintaining a healthy life, states have created laws to guarantee the quality, safety and nutritional properties of food (Hoyos and D'Agostini, 2017). Since the industrial revolution, there is the need to control products and services, but from 1960 the Food Law emerged in Europe. This law along with regulations have guided the construction of methods to improve national and international trade relations. These regulations were imposed for the production, industrialization and collection of innocuous food with consumer health protection.

Agricultural policies in Ecuador began with agrarian reforms (1950-1978) by peasant struggles, which modified the structure of land ownership and distribution. The Agricultural Development Act of 1979 promoted Integral Rural Development, where the first policies were generated to carry out agricultural research, technical assistance, supply of inputs and regulations for processed products (García et al., 2019; Madrid, 2019).

Since 2000, policies focused on promoting small and medium-sized industries, and standardized protocols for the packaging and labeling of agricultural products. In post-neoliberal period, the concept of food security and food sovereignty, arose the inclusive business of traditional and non-traditional products, was promoted the export, requiring compliance the regulations in whole production chain (Madrid, 2019). From 2007, policies and regulations were aimed at guaranteeing the consumers rights, quality and competitiveness in production areas.

Under the 2008 Ecuadorian constitution of 2015-2025 agricultural policy was generated, promoting sustainable rural development, eradicating hunger and malnutrition. At the same time, other related laws were generated, and the institutional component necessary for the implementation (Lasso and Clark, 2016).

The milk production in Ecuador is the most important livestock activities, since its production represents around 5.1 million L/day from the three regions of the country: Costa, Sierra and Amazonia (INEC, 2018). A high-quality milk is defined as a food with an enjoyable taste, without odor, with adequate chemical composition, without pathogens or contaminants (Pereira, 2014; Sah et al., 2018). The milk parameters for determining the quality are evaluated through physical, chemical and microbiological analyzes. These parameters are regulated in all countries with slight variations in compliance limits and methods used (Dürr et al., 2004).

Until 2008, the price of milk in Ecuador did not influence on the composition or other parameters, was it determined directly between the industries and the producers (MAGAP, 2008). Know the quality of milk is important for allows to make decisions on the management of industrial production. Under the quality policy in 2013, the Ministry of Agriculture of Ecuador (MAGAP) issued the milk quality payment regulation (RPCL), the Regulation 394, defined the payment per liter on farm, demanding compliance of quality parameters, hygienic and sanitary quality. Other related regulations and changes in state institutions were established for their implementation.

In this context, the objective of this research was to determine the compliance with the requirements established in the RPCL in the parameters of fat, protein, total solids, total bacterial count and somatic cell count during the period 2009-2018, comparing the information available for each region. Besides to analyze the regulations issued around the RPCL their impact on producers, production and productivity.

2 Materials and methods

2.1 Study area

Ecuador is divided into 3 regions: Coast, Sierra and Amazonia due to factors environmental such as the presence of the Andes mountain, the vegetation of the Amazon, and the currents of El Niño and Humboldt (IGM, 2017). In each region the climate varies according to the altitude, humidity, precipitation and temperature. According to the National Institute of Statistics and Census (INEC, 2018), these factors also affect the volume production, reporting 23 %, 72 % and 5 % for the Coast, Sierra and Amazonia, respectively.

2.2 Data, sample collection and analysis methodology of quality parameters

The data was provided from the milk quality laboratory database of the Salesian Polytechnic University (UPS). There was a total of 99271 (n) analyzes requested between 2009 and 2018 by milk storage facilities (CA) of associated producers, community farms and farms with a frequency of 1-2 times/month. The data correspond to 12 provinces in the 3 regions of Ecuador. The Sierra region was divided into 2 by its importance in the production, North Sierra: Carchi, Imbabura, Pichincha with 78.9% (n = 81431) and Central Sierra: Chimborazo and Tungurahua with 4.7% (n= 4835). The Coast: El Oro, Esmeraldas, Guayas, Manabí and Santo Domingo de los Tsatchílas with 9.8% (n= 10066). The Amazon region: Napo with 6.7% (n= 6872).

The samples were collected followed standard procedures (Cassoli et al., 2007, 2010), were used 40 mL sterile bottles containing Bronopol for the composition and somatic cells, and Azidiol for TBC. The milk samples were stored at 4-7°C. The composition minimum limit allows fat, protein and total solids of: 3.0%, 2.9%, and 11.2%, respectively (INEN, 2012). Both for total bacteria count (TBC) allows an upper limit of300 $\times 10^3$ UFC/mL (MAGAP, 2013) and for somatic cell count (SCC) an upper limit of 400 $\times 10^3$ cells/mL (Cerón-Muñoz et al., 2007).

Fat, protein and solids were analyzed by Fourier transformed infrared spectrophotometry (FTIR) with the MilkoScan FT 6000 (Foss Analytical Instruments, Denmark) and the results were expressed as percentage values (g/mL) (Takahashi, 2011). The Fossomatic minor FC (Foss- Analytical, Denmark), an electronic counter based on cytometry, was used for SCC, where a colored milk sample emits light pulses that are expanded by a photomultiplier (Ramos, 2019).

The flow cytometry method was used to determine TBC with the BactoScan FC 50H (Foss Analytical Instruments, Denmark), an analytical principle based on injecting a colored sample through a flow chamber, the optical system detects fluorescence-stained particles. The results are expressed as CFU/mL and represent the amount of mesophilic aerobic bacteria (Cassoli et al., 2007; Numthuam et al., 2017).

All analysis were subjected to quality controls in accordance with ISO-17025, 2017. The equipment and methods remained unchanged during the study period.

2.3 Statistical analysis

A descriptive analysis was analyzed using the statistical software Infostat version 2018, for variables according to limits allows and the information between the regions.

2.4 Review of Regulations

According to the information available in MAGAP, the regulations, instructions and procedures, and other documents that supported the execution of RPCL.

2.5 Analysis of producers, production and productivity

Milk producers required modifications to their production practices and infrastructure to comply with the indications of RPCL. Small producers (<200 L/day) were grouped in CA and farms, and between 2009-2018 many had agreement with the UPS for milk analysis, monitoring and training in good milking practices (GMP), and good agricultural practices (GAP). Production and productivity information was analyzed according to INEC data for the same years.

3 Results and discussion

3.1 Evolution of compositional quality

Composition parameters are influenced by different factors such as diet, genetics, breed, lactation period, season, frequency and milking moment (Belage et al., 2017). When milk has higher concentration of total solids, essentially protein and fat, more nutrients are provided, the yield and quality of dairy products are improved (Barbano et al., 2006; Pereira, 2014). However, the relationship between its components is stable and variation can be used as indicator. Continuous monitoring of chemical and microbiological factors is essential for the establishment of quality control program ((Dürr et al., 2004; Johnson, 2017; Takahashi, 2011).

3.1.1 Fat

This parameter tends to vary more than other milk components. The main influencing factors are breed, age, diet, lactation, bacterial activity in the rumen, mastitis and environmental effects (Ramírez-Rivera et al., 2019). In addition to dietary concentrates, type, quantity and size of the fiber particle also contribute to the variation of fat percentages in milk.

Fat is composed of 98 % triglycerides and 2 % diglycerides, cholesterol, phospholipids and free fatty acids. Bovine milk fat is one of the most complex, having more than 400 different fatty acids that form triglycerides, of which 70 % are saturated fatty acids and 30 % unsaturated fatty acids (García et al., 2014; Pereira, 2014; Sah et al., 2018).

The overall average fat content was 3.80 $\pm$ 0.05 %, higher than the limit for all years analyzed (Figure 1a). The highest values were reported for the Coast and Amazon region (3.82 $\pm$ 0.10 %) where there are dual-purpose cows (meat and milk) (INEN, 2012; Oñate, 2018). These values correspond to those reported in similar works in Hidalgo- Mexico, where 1416 samples were analyzed, obtaining 3.46 $\pm$ 0.26 % of butyric fat by classifying milk as type A, indicating excellent quality in this parameter (Cervantes et al., 2013). Guevara-Freire et al. (2019), working with producers in the Ecuadorian Sierra, reported that feeding of herds based on grains and forage legumes, as well as the use of concentrates increased the percentages of fat. Another influential factor was the breed, mainly of Holstein and creole dairy cows (Creole x Holstein), which maintained fat values between 3.4 % and 3.7 %.

3.1.2 Protein

The protein content in dairy cows is important in the human diet as it provides between 30-32 g/L. Soluble proteins are serum proteins such as lactoalbumin, lactoglobulin and other non-nitrogenous proteins such as urea that represent 20 %, and insoluble proteins known as casein that represent 78-80 % (Pereira, 2014). Since casein forms a stable colloidal system with calcium, phosphorus and magnesium, it helps to digestibility and transportation of minerals. Due to the high biological quality of bioactive peptides, milk proteins contribute to the human health by favoring the absorption of other nutrients (García et al., 2014; Sah et al., 2018).

In the industry the protein percentage influences the yield of processed products, mainly cheese and yogurt, and in Ecuador it accounts for 41 % of the most consumed dairies (Alvarado, 2017; Oñate, 2018). Several factors that influence fat content also influence the protein composition of milk such as nutrition, disease management, lactation, and cow´s age, as well as climate (García et al., 2014; Johnson, 2017). The pasturelands used in the Coast region and improved pasturelands in the Sierra region (Requelme and Bonifaz, 2012) allow protein to be maintained at values from 3.01 to 3.25 %, for 70 % of producers reported by Valladares (2016).

The overall average for this parameter (Figure 1b) was between 3.12 $\pm$ 0.10 % and it was higher than the allowable limit in all regions. The lowest values in the Amazon region (3.04 $\pm$ 0.09 %) are due to the different food patterns, energy levels and animal breeds that determine the milk composition in this parameter (García et al., 2014). Another study carried out to evaluate the physical-chemical, microbiological and toxicological properties in seven dairy farms in the Puno region of Peru that produce 7.5% of the country's production found values of 2.81-3.20 %, which could vary by the type of food provided, showing higher percentages by the use of protein concentrates derived from fishmeal, soybeans, alfalfa and corn versus grazing (Brousett-Minaya et al., 2015).

In countries that produce yogurt, cheese and powdered milk, the payment system prefers the protein content, as Spain and Costa Rica (Dürr et al., 2004; Martinez and Gomez, 2013).

3.1.3 Total Solids

In food where water is the dominant component (83-84 %), total solids extract (EST) corresponding to the total of fat, true protein, lactose and minerals (Ramírez-Rivera et al., 2019). In the international market, the EST is the most important benchmarks of dairy quality, it represents lower costs of dehydration and greater conversion of final product

(Barbano et al., 2006). Production systems, instead of increasing the volume, should to obtain milk with more total solids. The criteria for maximizing the EST should be based on efficient balance of nutrients, maximization of food consumption, monitoring diet and periodic corrections for quantitative and qualitative changes in the resources used. For some authors, the increase in milk production is observed in the concentration of total solids, fats, proteins and non-fatty solids (Ramírez-Rivera et al., 2019).

EST values in all regions were $12.36 \pm 0.16\%$ above the limit corresponding to good quality milk (Figure 1c). The Central Sierra, compared to North Sierra, the lowest averages ($12.27 \pm 0.22\%$) are highlighted, because the northern region initiated technical training programs promoted by the government and private institutions (Vinueza, 2015).

These values are similar to those presented in Sucre state- Colombia in 12 municipalities, where the compositional and hygienic quality of the milk was evaluated during summer and winter, obtaining average values of 12.79 and 13.11%, respectively and indicating a high-quality milk. This trend can be explained by the predominant presence of Zebu breeds with crosses between *Bos taurus* and *Bos indicus*, concentrate a lot more the solids present (Martinez and Gomez, 2013). Zebu cattle are also reported on the Coast of Ecuador, but there are also crosses with Brahman, Charolaise and Holstein. In Sierra, most of the cattle have been improved with Holstein, Brown Swiss and Jersey (Requelme and Bonifaz, 2012).

3.2 Evolution of sanitary and hygienic quality

3.2.1 Somatic cell count

Somatic cells (leukocytes, especially neutrophils and epithelial cells) indicate the health of the mammary gland, therefore, the quality of the milk. An increase in somatic cells may be an indicator of inflammatory processes due to the response of phagocytosis. Factors that increase CCS may be postpartum periods, the number of lactations, physical agents or irritant chemicals in udders, among others, therefore early detection of the increase in these values is essential for the control (Carloni et al., 2016; Gonçalves et al., 2018).

CCS values in cases of absence of breast infection range from $200 - 300 \times 10^3$ cells/mL, while counts $> 800 \times 10^3$ cells/mL are usually associated with persistent inflammatory processes. Although CCS is not included in the current RPCL of Ecuador, a limit of 400×10^3 cells/mL will be considered for this study, since it is a standardized value in several countries, especially in Europe and Brazil, associated with herds containing GAP (Cerón-Muñoz et al., 2007; MAPA, 2011).

The results of this study (Figure 2a) show a reduction continual of SCC in all regions based on an average value of $460 \times 10^3 \pm 118$ to $447 \times 10^3 \pm 32$ cells/mL for 2009 and 2018, respectively. North Sierra, Central Sierra and the Amazon region showed values <400 x 103 cells/mL and the Coast region showed a value higher than 500×10^3 cells/mL.

A study carried out in 7 provinces of Ecuador, 90% of producers reported the importance of conducting udder cleaning prior to milking and drying, but only 65% of respondents applied a routine test for mastitis control (Bonifaz and Requelme, 2011; Guevara-Freire et al., 2019). It was necessary to define the conditions of management, production and nutrition of livestock for the compliance of RPCL in Ecuador.

3.2.2 Total bacteria count

Milk quality is essential to obtain quality products, with TBC being the most frequently used parameter as a reference (Martinez and Gomez, 2013). Ecuador as in other Latin American countries, the titratable acidity and reductase (methylene blue) tests were used until 2008 for the indirect determination of bacterial. For this reason, it was necessary to incorporate faster systems with modern technologies.

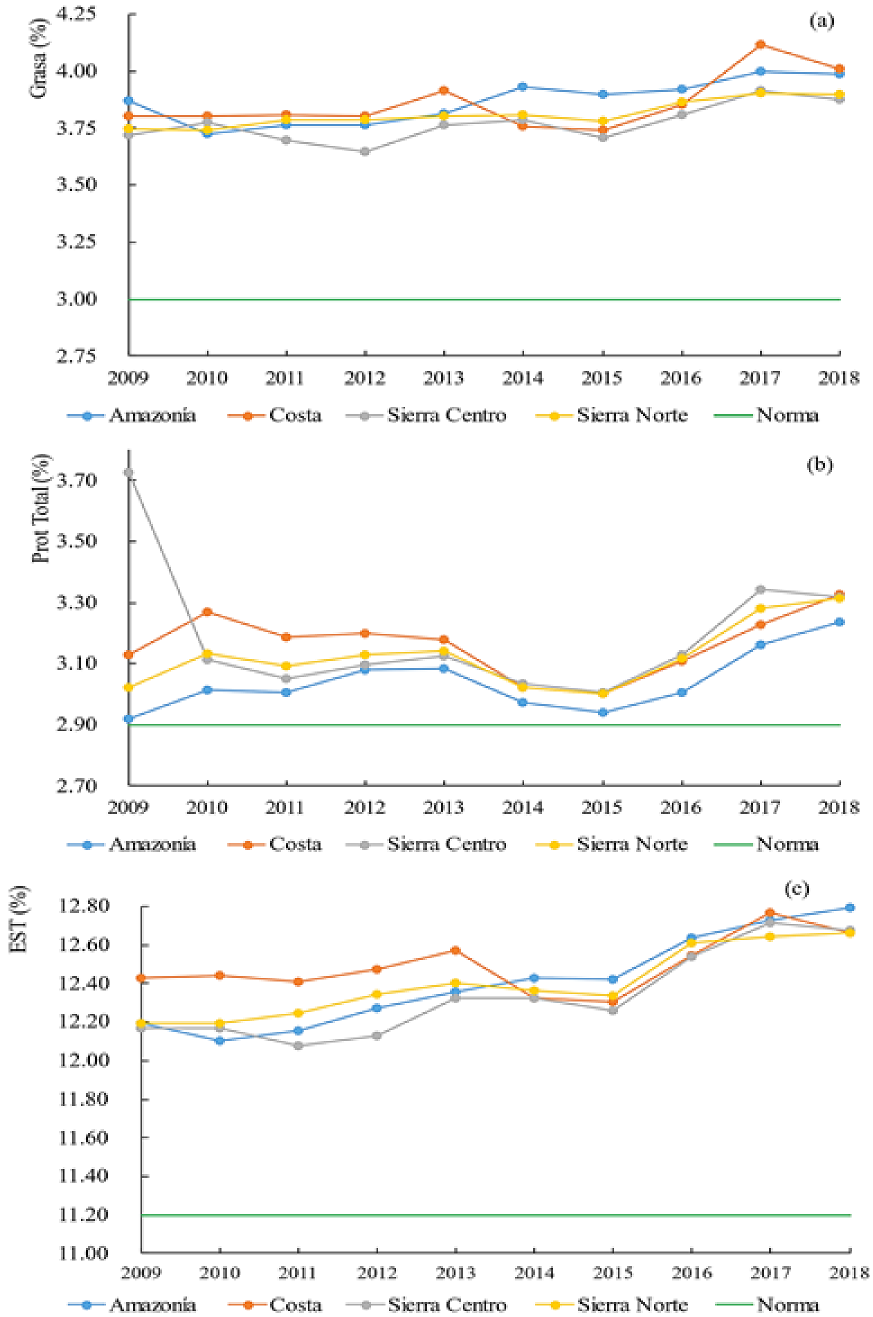

Figure 1. Milk composition parameters presented in percentages during the study period: (A) fat (b) protein (c) total solids.

International requirements are increasing, for CBT Europe and USA accept a maximum value of 1100×10^3 UFC/mL and 300×10^3 UFC/mL, respectively. The RPCL for 2008 defined a limit of 600×10^3 UFC/mL, which was likely to influence producers in the reduction of averages, from about 1 million UFC/mL to 800×10^3 UFC/mL for 2011 and 2012. The Central Sierra maintained average values of 1.5 million UFC/mL until 2013, qualifying milk as poor-quality milk; but from 2014 the averages decreased and from 2015 they were $< 400 \times 10^3$ UFC/mL. Although in 2016 and 2017, the CBT increased in the overall average ($> 500 \times 10^3$ UFC/mL), in 2018 they decreased again to 200×10^3 CFU/mL, qualifying it as of good quality milk. Is important to mention that these data correspond to formal producers (98.6 %) with contractual commitments of industries (Figure 2b).

These results are similar to those reported when analyzing 10 704 milk samples collected between 1993 and 2009 in the northwestern area of Santa Fe and southern Santiago del Estero in Argentina, showing TBC averages $< 100 \times 10^3$ UFC/mL, noting a significant improvement by the training of the producer and management processes included in the program for the integral improvement of milk quality among producers, entrepreneurs and the government (Revelli et al., 2011).

3.3 Public regulations around the RPCL

When establishing a quality payment system, it is important to have a prior diagnosis (Dürr et al., 2004). However, the first RPCL issued in Ecuador by Regulation 1042 (MAGAP, 2008) was defined on the basis of adapted international standards. The initiative to regulate the marketing of milk production with a focus on quality was a strategy to establish it. In this decree, the price of the liter of milk was increased and set at USD 0.35 if meeting the limits described in INEN 009 for the physical–chemical and microbiological requirements of raw milk. In addition, bonus criteria for meeting livestock health requirements (vaccination and GMP) were also incorporated.

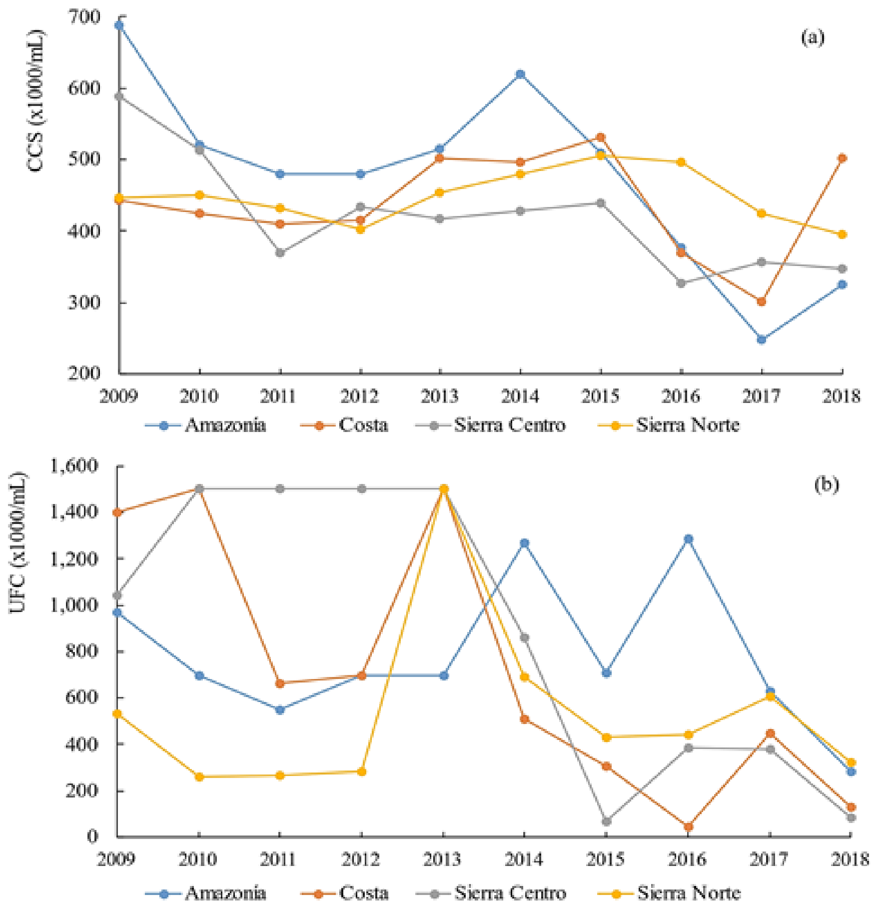

Figure 2. Microbiological milk parameters during the study period: (A) somatic cell counts (cells/10^3 cells/mL); (b) Total bacteria count ($\times 10^3$ UFC/mL).

In 2010 (Table 1), an amendment is made to the Ministerial Agreement 394 (MAGAP, 2010), which includes the price of liter of milk on farm to 52.4 % on the price of UHT milk. In 2013, the current RPCL (MAGAP, 2013) set the base price of a liter of milk (USD 0.42) and included the health-quality on BPA.

The implementation of the RPCL was accompanied by the reorganization of government institutions, like Agrocalidad along with MAGAP, was responsible for monitoring and evaluating the system of agricultural production chains (Agrocalidad, 2017). As the nutritional management of livestock and the health of the udders are influential factors in quality indicators, the BPP Guide and health surveillance procedures were established. These resolutions were disseminated between 2010-2013 in training processes such as the Agricultural Revolution Schools (ERA's) and other processes promoted by private entities such as universities and agricultural input distributors (Derks et al., 2014; FAO, 2011; Vinueza, 2015).

Another important contribution to establishing the RPCL was the certification of laboratories for the verification of quality parameters, which until 2008 were performed by the same industries (Alvarado, 2017; MAGAP, 2008). Having specialized laboratories for these services has several advantages because it centralizes investment in the personnel, infrastructure and technology, and it optimizes the use of equipment capable of performing a high number of samples (Dürr et al., 2004).

Table 1. Regulations supporting the establishment of the RPCL in Ecuador.

Date of issued	Description	Bases on
23/04/2008	Agreement *N*°077-MAG. Executive decree 1042	Law to rule the payment for milk quality and animal health
21/04/2010	Ministerial agreement MAGAP*N*° 136	Minimum price for the liter of milk to the producer, incorporated to 52.4 % at the retail price (PVP) of UHT of liquid milk in a bag
04/09/2013	Ministerial agreement MAGAP *N*° 394	Regulate and control the price of the liter of raw milk paid on farm and/or collection center and promote the quality and safety of raw milk
30/06/2015	Regulation *N*° 16. It modifies the regulation *N*° DAJ-2013461-0201.0213	Technical specifications for the collection and transportation of milk
29/02/2016	Regulation *N*° 19. It modifies the regulation *N*° 217	Guidelines for milk production. An annual health management plan is required
15/04/2016	Regulation *N*° 71	Instructions for the registration and control of raw milk analysis laboratories
15/08/2016	Regulation *N*° 154. It modifies the regulation *N*° DAJ-2013461-0201.0213	Guidelines for the monitoring and control of milk safety
30/01/2017	Regulation *N*° 276	Guidelines to good livestock practices in milk farming for small producers. It establishes monitoring and evaluation systems in the agricultural milk production chain
30/08/2017	Regulation *N*° 95. It modifies the regulation *N*° DAJ-2013461-0201.0213	Guidelines of procedures for the monitoring and control of milk safety

3.4 Impact on producers, production and productivity

From 2001, the CA formation was an important event in Ecuador, since it marked the beginning of the commercialization with cooling milk by small producers and the reduction of milk sale by informal sellers (Oñate, 2018). Public and private entities channeled offers of credit and technical assistance programs, investment in infrastructure for the pur-chase of cooling equipment, fertilizers, milking implements, vaccines, among others (Valladares, 2016). Since 2013, several programs and projects have been implemented to support CA, reduce production costs and promote a cleaner pro-duction (Valladares, 2016).

In 2009 milk production in Ecuador was 6 249 785.0 L/day (INEC, 2019). There were increments and reductions in the following years, and a negative trend was observed from 2013 to 2018 (Figure 3a). However, productivity increased at the national level (6.12 to 7.03 L/cow/day), with the Sierra region being the highest with 7.2 to 8.3 L/cow/day (Figure 3b). It can be assumed that production decreased due to difficulties of small producers when implementing and complying with RPCL. In 2017, the number of members in the CA decreased (36%) from those registered in 2008, fact can be explained because some producers abandoned the CA and others started working again with an intermediary to avoid the relationship with the CA and quality requirements (Alvarado, 2017).

The analysis should mention that 18% of the producers were people >61 years old, meaning a negative scenario for the adoption of "new" procedures such as the use of disinfectants for pre- and post-milking, use of paper to clean udders, and others (Nuñez, 2017; Oñate, 2018; Valladares, 2016).

To improve productivity during the study period, there were strong investments in the installation of irrigation systems, improving the efficient use of water increasing dry matter in livestock feeding (Cachipuendo et al., 2017), as well as the use of improved seeds adapted to local technology and livestock genetic improvement (Requelme and Bonifaz, 2012).

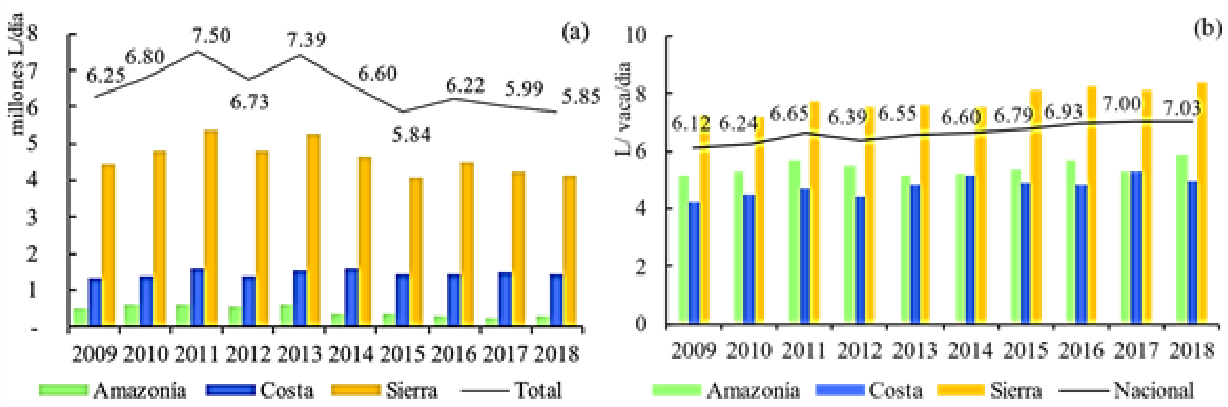

Figure 3. Production and productivity of milk by regions of Ecuador: (a) production in millions of L/ day and (b) productivity L x cow x day (INEC, 2019).

4 Conclusions

The establishment of the RPCL and the policies applied during 2009-2018 had a positive effect on the quality parameters, which meet the established limits not so on production that has a downward tendency.

The total fat, protein, and solid composition parameters are remained on limits with trend to improvement over the years. Sanitary and hygienic parameters (SCC and TBC) also show improvements over time, with SCC still not falling within the maximum allowable limits, it involves a multifactorial action for its improvement; therefore, it is necessary to concentrate efforts on the health and application of GMP dairy farms.

The establishment of milk quality payment systems should be accompanied by training and management programs between the producers, industries and the government.

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