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Small-scale milk production systems in Colombia: a regional analysis of a potential strategy for providing food security

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Colombia has an agro-ecological diversity that favours the implementation of milk production systems. Dairy farming is an integral part of the rural economy and makes a positive contribution to the nutrition and income of families. The objective of this study was to classify milk production systems in the community of El Peñon (Municipality of Sibate, Colombia), and analyse the results in connection to the concept of food security. The study evaluated components related to production levels and administration using variables such as (i) location, biophysical aspects, use and management of land (ii) forage resources and feed (iii) animal resources (iv) animal reproduction and health (v) milk production and marketing, and business management (vi) labour, infrastructure and equipment and (g) owner information. Eighteen dairy farms located in the study area were analysed and thereby classified using multiple correspondence analysis and descriptive study. The information was obtained from the milk production systems using a questionnaire. The analysis of conglomerates allowed us to identify heterogeneous production models due to their diverse production conditions and the different sizes of productive units. Milk producers were typified in 4 groups as specialised dairy (33%), semi-specialised dairy (17%), small-scale dairy (28%), and family-owned dairy farms (22%). The dairy systems represent a productive potential to support food security, especially small-scale systems. For this reason, it is important to implement efficient technological models in small-scale dairy systems to contribute to the improvement of food security for the population.

1. Introduction

Food is one of the basic needs of human beings, and according to the FAO, the size of the global population and its accelerated growth is the biggest problem and the most serious threat to humanity (FAO 2002; 2014; 2019a). One of the current problems of the worldwide population is malnutrition due to a lack of nutrients, protein, and micronutrients to meet the basic needs to maintain normal functions, growth, and development (Latham, 2002; Pinstrup-Andersen, 2009). Malnutrition promotes the development of diseases and undesirable physical conditions (FAO, 2009a; Weiler et al., 2015). FAO reports for the years 2015 and 2016 the prevalence of malnutrition in the world, and the values are 794 (10.8%) and 815 (11.0%) million people, respectively. These figures show an increase in the number of undernourished and hungry people, principally a result of the following causes: natural disasters, armed conflicts, population growth, and poverty (FAO, 2009b).

It is estimated that the growth of the population could soon overtake food production and supply (Burchi & De Muro, 2016). This estimate is mainly due to an increase in the population of urban areas due to high fertility rates, migration from rural areas to cities, and inequality in the distribution of food, which is gradually affecting a global financial crisis. In this regard, studies have been conducted at a global level for the development of policies that would help mitigate the dynamics of poverty and solve the problems connected to the challenge of hunger (Borch & Kjærnes, 2016; Gohar & Cashman, 2016; Myers & Caruso, 2016; Martin et al., 2016; Lipton & Saghai, 2017; Moragues-Faus, 2017; Leventon & Laudan, 2017). According to FAO (2002), milk is considered one of the most nutritious food types, because it provides proteins, carbohydrates, fat, minerals, and vitamins of high biological value.

Based on the previous considerations, agricultural producers have the challenge of increasing productivity to meet the needs of the population. Livestock plays an important role in the livelihoods of millions of milk producers in developing countries. Livestock farming provides approximately 26% of protein and 13% of the total calories consumed by people (FIDA, 2016). The dairy sector has been recognised for its leadership role in sustainable practices for several years. In 2019, world milk production was 852 Mt (OECD-FAO, 2020). The expansion of production originates mainly from India, Pakistan, China, the European Union and Brazil and on a smaller scale in countries such as Australia, Colombia and Argentina (FAO, 2019b). Colombia reported total production of 7,301 million litres of milk for 2019 (FEDEGAN, 2020).

In the livestock sector, it has been determined that Colombian cattle production is made up of a variety of production models within a heterogeneity of systems, mainly of dairy cattle. Authors have classified worldwide milk production systems and contributions to food security in several ways: as tropical or dual-purpose cattle, intensive dairy, and small-scale dairy (García et al., 2012; Castillo et al., 2012; Hernández et al., 2013); specialised dairy systems located in high or low altitudes and dual-purpose cattle (González, 2012; Vargas-Leitón et al., 2013); and specialised dairy, semi-specialised dairy, family-owned dairy farms and dual-purpose cattle (Cortez-Arriola et al., 2015). According to FEDEGAN (2017), the figure for milk production in Colombia is reported to be 7,094 million litres per year, obtained from different production systems. These figures have been increasing over the last few years with a total of 7,257 and 7,301 million litres in the years 2018 and 2019, respectively (FEDEGAN, 2019). Therefore, the objective of this study was to carry out the classification and analysis of milk production systems in El Peñon.

2. Materials and Methods

2.1. Study area

The study was conducted with milk producers in the farming area El Peñon (Municipality of Sibate, Cundinamarca, Colombia), geographically located at coordinates 4° 30'12 "N and 74° 20'47W, at 2,767 metres above sea level (Figure 1). A cold climate, an average temperature of 13.5 ° C, and a rainfall of 723 mm characterise the region. The region's economy is predominantly built on agriculture, and for this reason, it was chosen for the study.

2.2. Data collection

This study was carried out between November 2018 and July 2019. Information regarding the producers and milk production systems was collected through a series of both semi-structured and open interviews using the survey method. For the survey, the study region was selected given the high heterogeneity and variability of the farming and livestock production systems, to provide adequate representation of the technical, socioeconomic, and biophysical diversity of the region. The selection of respondents was made through non-probabilistic snowball sampling, where the sample of producers obtained corresponded to the entire population under study.

The participants were active milk producers, and the focus group was comprised of 18 producers, which is the total population of producers in the studied region. The study evaluated components related to the product levels and administration of these systems using variables such as (i) location, biophysical aspects, use and management of land (ii) forage resources and

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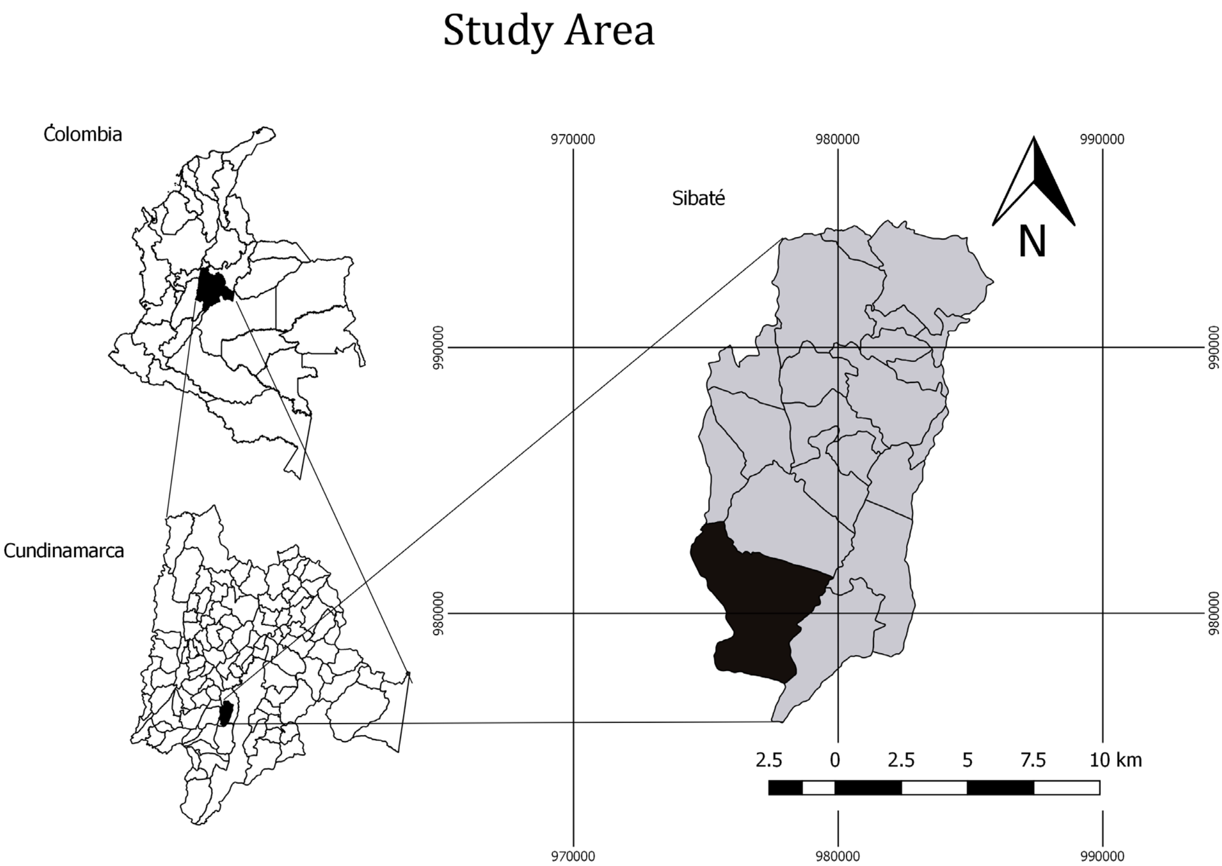

Figure 1. Study area: Map of El Peñon, highlighted. Cundinamarca State, Colombia.

food (iii) animal resources (iv) animal reproduction and health (v) production of milk, marketing, and business management (vi) labour, infrastructure and equipment and (g) owner information.

2.3. Statistical analysis

The analysis of the data collected was carried out through the evaluation of quantitative and qualitative variables, through multiple correspondence analysis (MCA) and descriptive studies using the statistical package SAS (Statistical analysis system, version 9.4).

3. Results

The information obtained in this study allowed the identification of different types of milk production systems according to structural, technical, and production characteristics.
Figure 2 shows the results of the cluster analysis of milk producers. Results were classified into four groups of milk production systems, according to the similarities of the variables. The groups identified were classified as specialised dairy (33%), semi-specialised dairy (17%), small-scale dairy (28%), and family-owned dairy farms (22%). It was evidenced that dairy cattle and milk production is one of the traditional trades for the majority of families living in the region studied. Half of the current production systems correspond to small producers, which represent productive potential and food security.

There are diverse dairy production systems in the study region that incorporate different technological models for obtaining dairy products. One of the main components of these systems is the introduction of different breeds. However, the Holstein breed is used at a proportionately high level due to its productivity and adaptability to existing environmental conditions. Pastoral systems dominate dairy production in the study region. All production systems also presented a similar proportion of grassland established with improved pastures (80%). The Pennisetum clandestinum was more common in dairy systems.

The diversity found among the systems reflects the implementation of productive models with different levels of several factors, such as the use of technology,

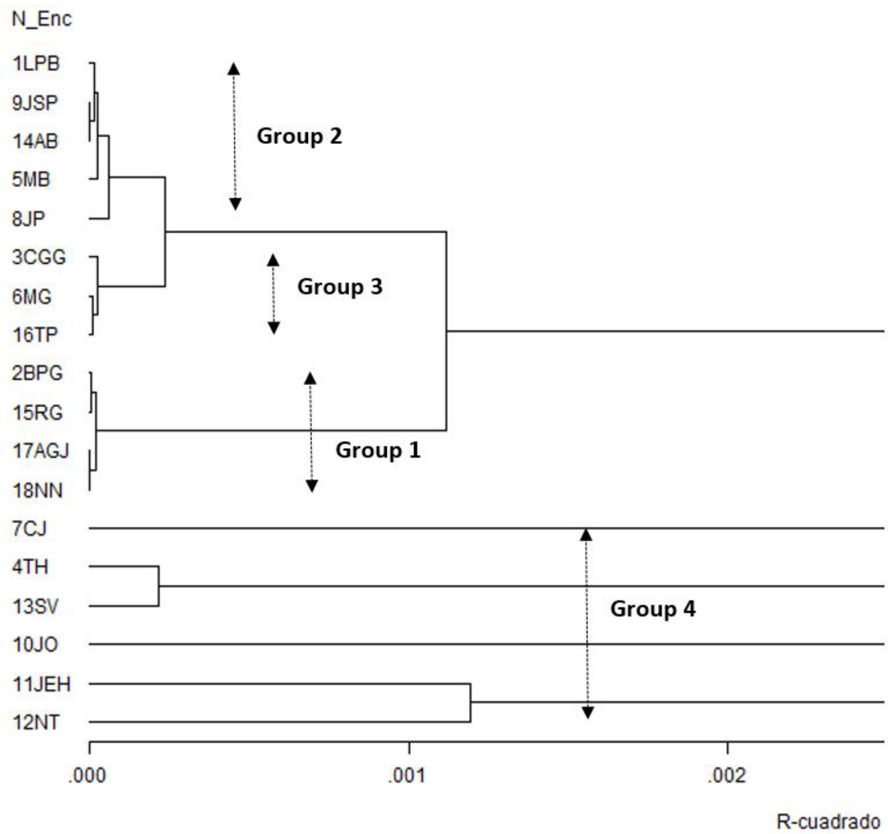

Figure 2. Dendrogram of milk production system conglomerates in El Peñon. Arrows indicate the grouping of dairy farmers classified. Group 1. Family-owned dairy farms Group 2. Small-scale dairy Group 3. Semi-specialised dairy Group 4. Specialised dairy

inclusion of productive strategies related to the management of forage resources, supplements and food by-products, use of animal resources of high genetics, infrastructure, and manpower. It should be noted that these cattle production systems are developed in different micro-ecosystems with different degrees of intensification of variables and heterogeneous socio-economic strata.

Table 1 shows the average values of the production parameters for milk production systems in the region of study.

Family-owned dairy farms (Group 1) correspond to 22% of the studied populations and are characterised by having on average less land (1.8 + 1.1 ha) and fewer animals (3.5 + 2.7). The lack of productive technology use characterises these systems and the mean values of milk production/cow/day and total are 6.7 + 2.8 and 8 + 6.8 litres, respectively. In terms of applying labour to livestock development, work is mainly limited to the owner and their spouse. This study reveals that milk producers in these systems are among the least educated people in the region, and this can be a problem when it comes to incorporating new technologies. In regards to small-scale dairy (Group 2), which corresponds to 28% of the population, it was found that the characteristics of the production model analysed were similar to those of Group 1. However, it reported higher values for land size (14 + 3.2 ha), number of animals (17.9 + 4.3), milk production/cow/day (10 + 3.1 litres) and milk production/day (82 + 7.9 litres). Another key characteristic of family-owned dairy farms and small-scale dairy groups is the lack of technical assistance, access to extension services, and the high costs of inputs.

On the other hand, semi-specialised dairy systems (Group 3) correspond to only 17% and are characterised by the inclusion of production technologies that focus on improving nutritional and genetic components. These production technologies are done by pro-

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viding supplements to animals, and crossing breeds with high genetic value. These systems have more land (22.4 + 6.1 ha) which holds a larger number of animals (28.3 + 5.5) with higher levels of milk production/cow per day (13.3 + 3.2 litres).

Regarding the characteristics of Group 4, specialised dairy systems correspond to 33% and have the most land (118.4 + 60.4 ha) and the largest number of animals (124.7 + 29.6). This typology reports the highest level of milk production/cow per day compared with the other systems, as well as the higher insertion of labour to carry out activities related to production. Furthermore, they employ the most productive strategies, including rotational grazing systems with improved foraged grasses and alternative animal supplementation. Besides, this group also works to improve nutritional, genetic, and sanitary components. To this end, the group uses soil fertilisation practices to increase biomass production, as well as reproductive biotechnologies like artificial insemination using animals with high-value genetics. They also use biosecurity and vaccination plans.

Another factor is that while small-scale dairy system producers only have access to information via radio and television, semi-specialised and specialised dairy producers used mobile phones to obtain up-to-date information and access professional technical support.

Table 1. Parameters of milk production systems in the area of El Peñon.

	Productive system			
Parameter	**Group 1**	**Group 2**	**Group 3**	**Group 4**
	Family-owned dairy farms	**Small-scale dairy**	**Semi-specialised dairy**	**Specialised dairy**
Number of dairy farmers	4	5	3	6
% of the sample	22	28	17	33
Farm size (ha)*	1.8 ± 1.1	14 ± 3.2	22.4 ± 6.1	118.4 ± 60.4
Animals				
Numbers of animals *	3.5 ± 2.7	17.9 ± 4.3	28.3 ± 5.5	124.7 ± 29.6
Production cows *	1.2 ± 0.9	8.2 ± 2.7	13.6 ± 2.1	61.9 ± 12.5
Dry cows *	0.8 ± 1.1	2.9 ± 1.3	4.6 ± 1.2	20.2 ± 7.9
Heifers *	0.6 ± 0.9	2.8 ± 0.7	4.5 ± 1.1	26.1 ± 7.7
Calves *	0.7 ± 0.3	3.4 ± 0.6	4.7 ± 0.9	15.1 ± 3.9
Bulls*	0.3 ± 0.5	0.4 ± 0.5	0.6 ± 1.1	1.6 ± 1.3
Production				
Milk production/cow/day (litres)*	6.7 ± 2.8	10 ± 3.1	13.3 ± 3.2	16.5 ± 3.7
Milk production/day (litres)*	8 ± 6.8	82 ± 7.9	180.9 ± 6.6	1021.4 ± 83.2
Labour				
Owner	1	1	0.6	0.3
Spouse	0.2	0.2	0.1	0.2
Administrator	0	0	0.2	0.7
Milking staff	0	0	1	3
Day labourers	0	0	1	1.8
Commercialisation				
Self-consumption (litres)*	1.5 ± 0.5	3 ± 1.4	2.6 ± 0.6	9.8 ± 1.7
Sale (litres)*	6.5 ± 2.2	79 ± 6.4	178.3 ± 5.9	1011.6 ± 30.1

(%) Percentage of dairy farmers that belong to the milk production system.
* Values represented in average ± standard deviation

4. Discussion

Milk production systems are concentrated around the main cities and municipalities where the demand for milk is highest. Farms in the region were grouped based on multivariate analysis, taking the production system into account, to identify them according to their use of technology.

In general, all the systems studied performed milking twice a day and marketed their milk locally. As described above, milk production systems have a high degree of variability in their productive indicators, given the number of technologies that could directly affect the productivity, profitability, and competitiveness. Therefore, the productivity of these systems has an indirect relationship with the size of the herd and the technological model implemented. According to Holmann et al. (2003), the improvement of competitiveness is associated with the size of the herd.

The diversity within the different systems is due to technological and economic factors and organisational issues that have allowed the adoption of uneven technological innovations within dairy systems, resulting in different levels of productivity and profitability (Sraïri & Lyoubi, 2003; Köbrich et al., 2003; Gaspar et al., 2007; Giorgis et al., 2011; García et al., 2012; Gelasakis et al., 2012; Nivia et al., 2018).

On the other hand, dairy farming is a basic part of the rural economy. This study has shown that as milk producers have made technological changes and investments, their competitiveness and productivity have improved, and this has increased net income per hectare. Thus, the specialised dairy producers report the highest values in the production of milk/cow per day. Dairy farming is a highly labour-intensive industry, and small-scale dairy and family-owned dairy farms rely greatly on family labour.

Furthermore, the typification of milk production systems showed that half of the systems are distributed between family-owned dairy farms and small-scale dairy. These categories contribute significantly to the total milk production in the region. For this reason, small-scale dairy producers can contribute a remarkable share to the total milk production of the country and can be a viable instrument to stimulate economic growth and reducing poverty (Bennett et al., 2006).
A general analysis of milk production systems in Colombia has allowed us to identify which systems have begun to use technology to advance milk production, specifically in areas such as genetic improvement and food and nutrition programs. To a large extent, this explains the production growth during the past few years. However, the preceding is mainly due to specialised dairy systems, which have been able to deploy new technologies.

Despite these factors, the dairy industry in Colombia has shown a lack of profitability. One of the main problems in the milk production sector is the lack of technical assistance and the high costs of inputs. The limited access to extension services has been a limiting factor for the improvement of producer productivity and dairy product supply. Therefore, the results showed that small-scale dairy system producers only have access to information via radio and television. In contrast, semi-specialised and specialised dairy producers used mobile phones to obtain up-to-date information and to access professional technical support. Small-scale production systems represent a productive potential in the region and therefore require the implementation of efficient technological models. This study has concluded that small milk production systems can contribute to high levels of food security by offering safe and nutritious products to the population. Moreover, a growing demand for livestock products over the next 20 years, which could more than double, are mainly related to factors such as urbanisation, economic growth and changing consumption patterns in developing countries. In this way, they can meet the population's dietary needs and food preferences for an active and healthy life, as described by the FAO (2002). This analysis supports the fact that the adoption of technology by family-owned dairy farms, small-scale dairy, and semi-specialised dairy (corresponding to 75% of the studied population) is essential to intensify milk production and thus ensure greater performance and productivity. Also, a market-oriented dairy enterprise approach is proposed as a strategy to increase the income of small producers (Bennett et al., 2006). On the other hand, small-scale livestock production is mainly based on family farms and is crucial for the livelihoods of the rural poor, food security and the creation of employment.

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The dairy industry has experienced enormous changes over the last few decades due to the implementation of economic policies and the use of new technology. World milk production grew by 1.3% in 2019 to around 852 Mt of which 81% corresponds to cow's milk. This growth is attributed to increased production and not to herd growth. Strategies as performance growth drivers include optimising milk production systems, introducing better genetics, improving animal health, and improving efficiency in feeding (OECD-FAO, 2020).

Milk production in Colombia grew 2.3% in 2018, with a total of 7,257 million litres, of which only 47.06% were collected. In 2019, a total of 7,301 million litres of milk was produced, with a low increase of 0.6% compared to the previous year, related to the climatic factor, primarily due to the rainy seasons (FEDEGAN, 2020).

Milk production systems are mainly classified as specialised, dual-purpose, and small-scale, which contribute to the volume of national production in different proportions. However, small-scale dairy producers contribute a remarkable share to the total milk production of the country. Finally, the Colombian State must adapt technical assistance policies focused on this type of producer.
In general, the greatest global challenge facing cattle production systems is linked to changes in the availability of food for animals, both in terms of quantity and quality (specifically concerning protein levels). For this reason, from a development perspective, it is appropriate to adapt research areas. Studies should focus on milk production systems in rural areas that incorporate models of feeding intended to increase the availability and quality of forage, as well as the animal population per hectare (Tapasco et al., 2019).

The genotypes present in production systems are a constraint for productivity, particularly in rural areas based on small-scale. However, the genetic resources in the region studied reflect the considerable size of the population and the biodiversity that exists between them.

5. Conclusion

In conclusion, the proposed methodology identified four groups of milk production systems based on their productive and administrative characteristics, starting with the analysis of conglomerates. This diversity reflects the variability of the productive model, in keeping with the level of adoption and use of technology and the inclusion of productive strategies. This study identified that the perception of the milk producers of the new technologies was the main limitation to adopt new technologies. Biophysical, agronomic, and socioeconomic factors that affect milk producers are all attributed to the yield gap. The adoption of technology is affected by factors such as farm size, availability of capital and labour, education, and land ownership. Our findings showed that Small-scale and Family-owned dairy farms represent a productive potential for food security, given the number of existing producers and the ability to implement efficient technological models. Training is, therefore, essential to contribute to the decrease of the starving population and to achieve an effective impact on sustainable rural development in areas where milk production can be competitive.

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Conflict of Interests

The authors hereby declare that there is no conflict of interest. Besides, the funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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