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Typology of dairy goat production systems in a semiarid region of Brazil

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ABSTRACT

Socio-productive initiatives that culminated with the advent of the Food Acquisition Program in the Milk modality (PAA Milk) in 2003 boosted the development of Local Productive Arrangements for the dairy goat farming, especially in the area located between the states of Paraíba and Pernambuco, belonging to the Northeast region of Brazil. Considerable changes were performed in goat production systems with the introduction of specialized breeds, new facilities, and increased consumption of external inputs, especially concentrate feed, among other changes. This study characterized the socioeconomic, productive, and structural diversity of dairy goat production systems on 334 farms in the state of Paraíba and 220 farms in the state of Pernambuco aiming to understand the current situation of the production systems and to bring reflections on possible actions for improvement. Multiple correspondence and hierarchical cluster analyses were performed in sequence to establish the typology. Qualitative and quantitative variables were analyzed in the multiple correspondence analysis, and then the first three dimensions (coordinates) were retained for the cluster analysis, which generated three groups of farms: Group I with 216 farms (39% of the sample), Group II with 127 farms (22.9% of the sample), and Group III with 211 farms (38.1% of the sample). Group I had a lower percentage of landowners (34%), a lower presence of retired producers, lower frequencies of cactus pear areas and annual planting for forage conservation, low livestock diversity, few water facilities, and high access to PAA Milk (92%). In Group II, 80% of producers own their farms, have the smallest goat herd (18 heads), high presence of cactus pear areas and annual planting, and, consequently, a high practice of forage conservation and diversity of water facilities. Group III presented the oldest producers, larger areas of properties (41 ha), high presence of native pasture area, and higher daily milk production per farm (21 L). The results showed diversity among the identified groups, but with important similar aspects, such as the introduction of specialized breeds for milk production, the fragility of the feed security of herds, high stocking rates of ruminants, and a strong dependence on external feeds compared to those produced in the systems, particularly concentrate feeds, in addition to the high dependence on PAA Milk for production distribution and production stagnation due to few commercialization alternatives. It is necessary to implement solutions for the main identified distortions, such as improvement in the use of native and cultivated forages, adequacy of the stocking rate, reassessment of the composition strategy of the goat herd with specialized animals, and, mainly, the search for new dairy products and marketing channels to reduce the dependence on PAA Milk.

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1. Introduction

Brazil produces about 26 million liters of goat milk per year on 15,720 farms, and the Northeast region is responsible for 70% of this production, carried out on 13,053 farms. The main goat milk-producing states in this region are Paraíba and Pernambuco, which together account for 50% of the Northeast production and 35% of the Brazilian production (IBGE, 2019).

The microregions Western Cariri and Eastern Cariri in Paraíba, and Pajeú, Sertão do Moxotó, Ipojuca Valley, and Ipanema Valley in Pernambuco, are important dairy goat production areas in Brazil. These microregions are responsible for an annual production of 7.4 million liters of goat milk, accounting for 81% of the total production in Paraíba and Pernambuco, being 77% of this production commercialized, generating an annual income of R$ 10.4 million (IBGE, 2019).

Socio-productive governmental and non-governmental initiatives implemented between the late 1990 s and early 2000 s positively affected dairy goat farming in Northeast Brazil, promoting an organized process of milk collection, processing, and distribution, which structured dairy goat farming in that region to a level beyond family or local consumption, aimed at a more structured market (Gonçalves Junior, 2010). The Food Acquisition Program (Programa de Aquisição de Alimentos – PAA) in the Milk modality – PAA Milk, a federal program implemented in 2003 in partnership with state governments of the semiarid region of Brazil intended for the purchase of cow and goat milk from family farmers, stands out among these initiatives (Gonçalves Junior and Braga Martes, 2015).

Fourteen goat milk processing units managed by Producer organizations currently existing in the mentioned area have been structured since the PAA Milk implementation, with an installed processing capacity estimated at 25,000–30,000 liters/day. Record levels of goat milk production and processing in the states of Paraíba and Pernambuco reached 19,735 liters/day in 2015 and benefited approximately 39,000 people at food risk who received the milk distributed by the social program, in addition to encouraging the productive insertion of thousands of farmers and shifting 19 million reais in a region that has a medium to low human development index (HDI) status (Atlas Brasil, 2013).

The increase in the number of farmers, not accompanied by the significant increase in the volume of resources allocated to the program, led to the introduction of financial quotas for farmers and a limitation of the milk volume sold daily from 11 to 13, depending on the price paid per liter of milk in each state. In this scenario, the estimated average daily milk production of a modal farm in Cariri in Paraíba was 20 liters (Lucena et al., 2020), reaching up to 45% of excess production volume compared to the quota established by the government program. Law No. 13,789 (Brasil, 2019) was enacted in 2019, providing for the limit for the purchase of goat milk under PAA, modifying the financial quota from R$ 4500 per semester (11 liters/day for the state of Pernambuco) to a maximum of 35 liters/day, but it was only recently implemented by the states participating in PAA. This fact improves the income perspective of families but does not reduce the need to expand marketing channels for the milk and dairy products, given that the sale of milk is mostly supported by a single buyer market, that is, the governmental market.

Together with these changes, production systems in the semiarid region of the states of Paraíba and Pernambuco that explored various agricultural and livestock activities without prioritizing the commercial exploitation of dairy goats have started to explore it and commercialize milk, which led to changes in dairy goat production systems (Meneses, 2015; Sampaio et al., 2010; Souza Neto et al., 1987). Moreover, an important factor is that these systems are mostly located in the Caatinga area (native forest), which has low stocking capacity due to the seasonal characteristics of plants, adverse climate and soil conditions, and, above all, the vegetation, which is mostly composed of non-forage plants (Santos et al., 2010), thus interfering with the historically low dairy productivity (Oliveira et al., 2011).

Therefore, studies that allow the knowledge of this new productive reality, revealing the diversity of the production systems regarding socioeconomic, productive, and structural aspects, aiming at the identification of strengths and weaknesses to support the development of improvement strategies, are needed.

The typology of production systems is a tool that classifies production systems with high heterogeneity among each other into groups, but with high homogeneity within each established group (Köbrich et al., 2003). The identification of diversities between production systems through groups allows us to know and understand their reality and collaborate on the development of solid policies and technologies adapted to the reality of the different production systems existing in a region (Haileslassie et al., 2016; Kostrowicki, 1977; Pacini et al., 2014).

This study aimed to characterize the socioeconomic, productive, and structural diversity of dairy goat production systems in the main goat milk production area of the Northeast region of Brazil through the establishment of typologies and identify opportunities for improvement or future perspective for the identified groups.

2. Material and methods

2.1. Study area

This study was carried out in the main dairy goat production area of the Northeast region of Brazil, located in the states of Paraíba and Pernambuco, covering 35 municipalities in the microregions Western Cariri and Eastern Cariri in Paraíba, and Pajeú, Sertão do Moxotó, Ipojuca Valley, and Ipanema Valley in Pernambuco, totaling an area of 17,473 km^2 (Fig. 1). These microregions account for 85% and 76% of the goat milk production, respectively (IBGE, 2019), and have 14 plants to process goat milk.

According to the Köppen classification (Alvares et al., 2013), the climate of the microregions of Cariri in Paraíba and Sertão in Pernambuco (Pajeú and Sertão do Moxotó) is BSh, i.e., a dry semiarid climate with mean annual precipitation between 400 and 500 mm and mean annual temperature between 22 and 24 °C. The climate classification in the microregions of Ipanema and Ipojuca valleys, located in the Agreste of Pernambuco, is As, i.e., a tropical climate with winter rains, mean annual precipitation of 700 mm, and mean annual temperature from 20° to 22°C. The mean annual precipitations by region in the years of field collections (2017 and 2018) were 420 mm in Western Cariri, 281 mm in Eastern Cariri (AESA, 2021), 479 mm in Sertão do Moxotó, 688 mm in Pajeú, 743 mm in Ipanema Valley, and 499 mm in Ipojuca Valley (IPA, 2021).

The predominant vegetation in these microregions is the Caatinga, which is composed of shrubs and small trees, usually thorny and deciduous, which lose their leaves at the beginning of the dry season, normally from August to December. Annual plants, cacti, bromeliads, and herbaceous components, composed of grasses and dicots, are additional complements to the botanical composition of this biome (IBGE, 2004; Santos et al., 2010).

2.2. Data collection

A survey of dairy goat farms was carried out in both states through consultations with farmer registries in technical assistance and rural extension companies – ATER and goat milk processing companies to form the sampling frame by state, with 1146 farms listed in Paraíba and 726 farms in Pernambuco.

In the state of Paraíba, secondary data were obtained from the questionnaire "Diagnosis of the Family Production Unit – UFP" applied by the Technical Assistance and Rural Extension Corporation of Paraíba – EMATER-PB within the scope of the "Public Call SAF/ATER number 07/2012 of the Ministry of Agrarian Development – MDA, Lot 06″ (Brasil, 2014) for technical assistance to dairy goat farms, while primary

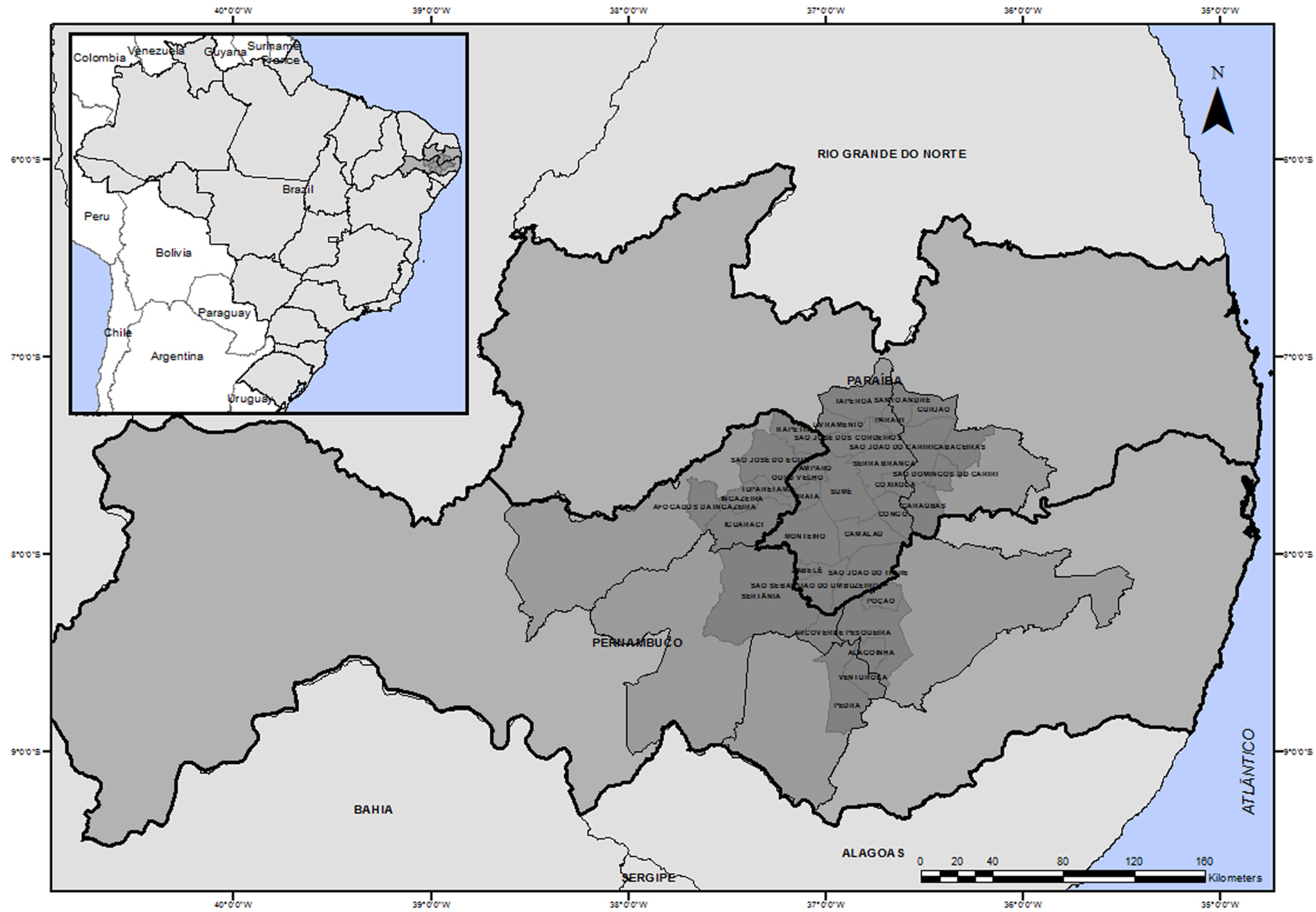

Fig. 1. Map of the municipalities in the states of Paraíba and Pernambuco that participated in the study (shades of gray from lightest to darkest: Northeast, Paraíba and Pernambuco, microregions, and municipalities).

data were obtained using a complementary questionnaire through direct interviews (face to face) carried out from April to August 2017, gathering information from 349 farms. In the state of Pernambuco, the data were obtained through a questionnaire constructed from the combination of the mentioned questionnaires, applied between December 2017 and March 2018 by direct interviews in selected farms within each municipality, with the collaboration of the technical assistance and rural extension company of the state of Pernambuco, Agronomic Institute of Pernambuco – IPA, Diocesan Center for Support Small Food Producers – CEDAPP, and the Brazilian Agricultural Research Corporation – Embrapa, totaling 239 visited farms. The participation of farmers in the interviews using these questionnaires was voluntary.

The data were organized in a spreadsheet (Microsoft Excel®), eliminating observations (farms) with missing, duplicate, and/or atypical data. Thus, a database with 554 farms was used, that is, 334 from Paraíba and 220 from Pernambuco, which represented, respectively, 29.1% and 30.3% of the farms surveyed in the sampling frames in the respective states.

2.3. Data analysis

Two exploratory multivariate analysis techniques were used in sequence to characterize the typology of farms: the multiple correspondence analysis was used to reduce the dimensionality of the data into a low number of dimensions and the cluster analysis was used to group farms with similar characteristics according to the selected variables. These analyses were performed in the R environment (R Core Team, 2021).

Eleven qualitative and eleven non-correlated quantitative variables, considered important in discriminating the farms were selected to characterize the overall socioeconomic aspects of the family, overall characteristics of farms, management and feeding and sanitary practices in the goat herd, and commercialization of products of dairy goat farming. Quantitative variables were categorized by frequencies of observations within quartile ranges (the presence of zero in the variables not necessarily defined an exclusive quartile range), analyzed together with qualitative variables in the multiple correspondence analysis using the package FactoMineR (Lê et al., 2008).

The multiple correspondence analysis was performed in two steps. The first step used the 22 pre-selected variables (Table 1), considered active, to select those most representative through the criterion of cosine^2 ($\cos^2$) (Lê et al., 2008). The variables of any category with $\cos^2 > 0.2$ in at least one of the first three dimensions remained to be used in a new multiple correspondence analysis (second step) to perform the calculation of inertia and principal coordinates of rows and columns. The selection of the first dimensions to reduce the dimensionality of the data mass was carried out based on the scree plot method (Cattell, 1966; Sourial et al., 2010), and their coordinates were used as "new" quantitative variables to perform the cluster analysis.

The cluster analysis, carried out with the package factoextra (Kassambara and Mundt, 2020), used the Euclidean distance as a similarity measure and Ward's method as a clustering method, which allows minimizing the internal sum of squared distances, promoting less variance between grouped objects (Hair et al., 2006). The number of clusters was established using the package NbClust (Charrad et al., 2014), which has up to 30 indices, and the indication with the highest number of

Table 1
Variables used in the multiple correspondence analysis.

Variable	Class*	Observation
Farmer's age (FA) (years)		
FA 1	21 – 36	135
FA 2	37 – 44	136
FA 3	45 – 52	133
FA 4	53 – 82	150
Family size (FS) (number of individuals in the family)		
FS 1	1	47
FS 2	2	166
FS 3	3	121
FS 4	4 – 9	220
Head of household's education (HHE)		
HHE 1	Illiterate, literate, and incomplete elementary school	104
HHE 2	Incomplete elementary and high school	352
HHE 3	High school and university education	98
Land tenure condition (LTC)		
LTC 1	Landowner or agrarian reform settlement	335
LTC 2	Lessee, lender, sharecropper, or partner	150
LTC 3	Squatter	69
Income from other economic activities (IEA)		
IEA	Yes	171
IEA	No	383
Retiree in the family (RF)		
RF	Yes	99
RF	No	455
Bolsa-Família (BF)[a]		
BF	Yes	303
BF	No	251
Farm credit (FC)		
FC	Yes	336
FC	No	218
Farm size (FS) (ha)		
FS 1	0.07 – < 5	115
FS 2	5 – < 15	159
FS 3	15 – < 32.5	140
FS 4	32.5 – 340	140
Cultivated pasture area (PA) (ha)		
PA 1	0 – < 0.5	295
PA 2	0.5 – < 2.1	121
PA 3	21 – 34	138
Forage cactus pear area (FPa) (ha)		
FPa 1	0 – < 0.5	219
FPa 2	0.5 – < 1.5	184
FPa 3	1.5 – 10.8	151
Annual planting area (APA) (ha)		
APA 1	0 – < 0.95	277
APA 2	0.95 – < 2	122
APA 3	2 – 10	155
Number of goats (NG) (head)		
NG 1	1 – 17	128
NG 2	18 – 30	136
NG 3	31 – 50	148
NG 4	51 – 202	142
Number of cattle (NC) (head)		
NC 1	0	273
NC 2	1 a 6	131
NC 3	7 a 52	150
Number of sheep (NS) (head)		
NS 1	0	354
NS 2	1 – 9	55
NS 3	10 – 90	145
Number of poultry (NP) (head)		
NP 1	0	233
NP 2	1 – 9	39
NP 3	10 – 24	142
NP 4	25 – 120	140
Forage conservation (FC)[b]		
FC	Yes	235
FC	No	319
Concentrate supplementation throughout the year (CS)		
CS	Yes	374
CS	No	180
Use of forage machine (FM)		
FM	Yes	284
FM	No	270
Presence of milking parlor (MP)		
MP	Yes	254
MP	No	300
Water sources		
WS 1	0 – 1	222
WS 2	2	172
WS 3	3	117
WS 4	4 – 5	43
Sale of goats for replacement (SGR)		
SGR	Yes	234
SGR	No	320

*Priority was given to the ranges
Variables in bold having any category with a cos2 > 0.2 in at least one of the first three dimensions remained to be used in the second multiple correspondence analysis.
[a] Cash transfer program.
[b] Silage or hay.

indices was chosen.

The means and standard deviations (quantitative variables) of formed clusters were analyzed using the Kruskal-Wallis and Nemenyi tests, according to the non-normal distribution of the variables. Frequencies (qualitative variables) were analyzed using the chi-square or Fisher test (when the frequency in the contingency table was lower than five).

3. Results

The variables farmer's age, land tenure condition, farm size, number of goats, cattle, and poultry, forage conservation, and water sources were selected using the cos^2 criterion, which was used in the second multiple correspondence analysis, which generated 22 dimensions (components), retaining 100% of the total inertia (variance) of the data so that the first three dimensions accumulated 24.9% of the total inertia. The coordinates of the first three dimensions were used to perform the cluster analysis, which resulted in three groups of farms (Fig. 2): Group I with 216 farms (39%), Group II with 127 farms (22.9%), and Group III with 211 farms (38.1%). The state of Paraíba concentrated farms of

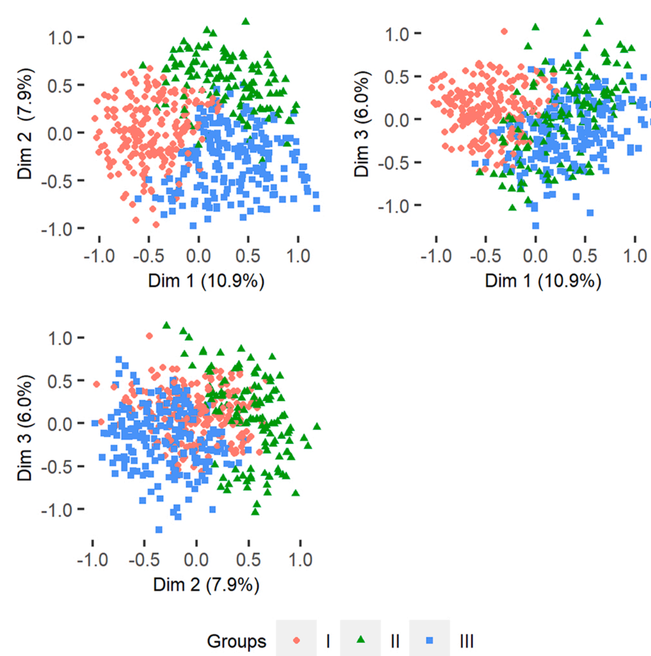

Fig. 2. Clusters of farms dispersed in the first three dimensions of the multiple correspondence analysis.

Group I with 53%, followed by Group III with 38% of the total, while the state of Pernambuco concentrated farms of Groups II and III, with 45% and 38% of the total per state, respectively.

Farmers in Group III were the oldest, with a mean of 53 years old, while those in Group II were the youngest, with a mean of 40 years old (Table 2). Group II had the highest family size, with 3.7 members. The educational level of farmers in the three groups was concentrated in the range between complete elementary school and incomplete high school. Group I was formed by 55% of farmers, who were lessees, lenders, sharecroppers, or land partners, whereas Groups II and III were mostly formed by land-owning farmers.

Group I had the lowest frequency of income from other non-agricultural economic activities (informal, public service, trader, and/or entrepreneur) among groups, with only 20% (Table 2). Groups I and II had more access to the Bolsa Família[1] program than Group III.

Group I and Group II had the smallest production structure, with a mean farm size of 21.5 and 13.6 ha, respectively (Table 3). Group II and Group III showed the highest diversity of livestock production, as 67% and 68% of the farms had at least three out of four livestock activities (goats, cattle, sheep, and poultry), respectively, while Group I had a low livestock diversity, as 44% of the farms presented only the goat herd, and only 6% of the farms raised animals of the four species (goats, cattle, sheep, and poultry). The average stock rate for all groups was 1.4 AU/ha (Table 3).

Only 18% and 59% of the farms in Group I adopted forage conservation practices and concentrate supplementation throughout the year for the goat herd, respectively, with the lowest values between groups (Table 4).

Table 2
Socioeconomic aspects of the three groups of farms.

Variable	Group			p-value
	I	II	III	
Mean farmer's age (year) (mean and standard deviation)	41.2 ± 9.9^{b}	40.5 ± 9.7^{b}	53.3 ± 11.7^{a}	< 0.001
Mean family size (members) (mean and standard deviation)	2.9 ± 1.3^{b}	3.7 ± 1.4^{a}	3.2 ± 1.5^{b}	< 0.001
Head of household's education				< 0.001
Illiterate, literate and incomplete elementary school (%)	25.0^{a}	7.9^{c}	19.0^{b}	< 0.001
Complete elementary school and incomplete high school (%)	58.3	66.9	66.8	0070
High school and university education (%)	16.7	25.2	14.2	0056
Farmer condition				
Landowner (%)	34.3^{b}	80.3^{a}	75.4^{a}	< 0.001
Lessee, lender, sharecropper, or partner (%)	55.1^{a}	9.4^{b}	9.0^{b}	< 0.001
Squatter (%)	10.6	10.2	15.6	0127
Income from other economic activity (%)^{d}	20.4^{b}	43.3^{a}	34.1^{a}	< 0.001
Retirement (%)^{d}	7.4^{c}	14.2^{b}	30.8^{a}	< 0.001
Bolsa-Família (%)^{d}	62.5a	71.7^{a}	36.5^{b}	< 0.001
Farm credit (%)	62.0	66.9	55.5	0097
Participation in social organizations (%)	94.9	94.5	96.2	0722

$^{a-c}$ Means and frequencies with different letters in the row differ from each other ($p < 0.05$).
^{d} Non-agricultural income

Table 3
Characteristics of farm size, forage areas, and herds for the three groups of farms.

Variable	Group			p-value
	I	II	III	
Farm size (ha)	21.5 ± 39.8^{b}	13.6 ± 18.4^{b}	40.5 ± 38.1^{a}	< 0.001
Presence of feed production areas and herds				
Native forest area (Caatinga) (%)	81.5^{a}	74.8^{b}	94.8^{a}	< 0.001
Cultivated pasture area (%)	56.9	61.4	67.8	0069
Cactus pear area (%)	48.1^{c}	92.9^{a}	80.1^{b}	< 0.001
Annual planting area (%)	59.3^{c}	80.3^{a}	70.6^{b}	< 0.001
Goat (%)	100.0	100.0	100.0	–
Cattle (%)	25.5^{b}	63.8^{a}	68.7^{a}	< 0.001
Sheep (%)	26.4^{b}	30.7^{b}	49.3^{a}	< 0.001
Poultry (%)	31.5^{c}	82.7^{a}	70.1^{b}	< 0.001
Mean size of feed production areas and present herds				
Native pasture (Caatinga) (ha)	14.6 ± 33.1^{b}	9.8 ± 16.4^{c}	25.9 ± 31.6^{a}	< 0.001
Cultivated pasture (ha)	2.8 ± 3.3^{a}	2.0 ± 4.0^{b}	3.8 ± 4.6^{a}	< 0.001
Cactus pear (ha)	0.9 ± 0.9^{c}	1.4 ± 1.4^{b}	2.2 ± 2.1^{a}	< 0.001
Annual planting (ha)	1.6 ± 1.6^{b}	1.4 ± 1.0^{b}	2.2 ± 2.0^{a}	< 0.001
Goat (head)	34.4 ± 25.5^{b}	17.8 ± 13.3^{c}	58.9 ± 36.9^{a}	< 0.001
Cattle (head)	9.4 ± 8.9	8.3 ± 8.4	10.8 ± 10.1	0077
Sheep (head)	20.9 ± 18.5^{b}	12.5 ± 10.8^{c}	27.1 ± 20.0^{a}	< 0.001
Poultry (head)	20 ± 12.8^{b}	19.1 ± 11.4^{b}	30.9 ± 23.0^{a}	< 0.001
Stocking rate (AU/ha)^{d}	1.8 ± 6.0	1.39 ± 2.48	0.88 ± 1.16	0050

$^{a-c}$ Means and frequencies with different letters in the row differ from each other ($p < 0.05$).
^{d} Animal unit (cattle: 0.7; goat: 0.1; and sheep: 0.1) (Food and Agriculture Organization - FAO, 2011)/total forage production areas.

Table 4
Feed, sanitary, and reproductive management and genetic composition of the goat herd of the three groups of farms.

Variable	Group			p-value
	I	II	III	
Forage conservation (silage or hay) (%)	18,1^{c}	74,8^{a}	47,9^{b}	< 0.001
Concentrate supplementation				
Throughout the year (%)	58.8^{b}	80.3^{a}	62.1^{b}	< 0.001
Rainy season (%)	56.9^{c}	89.0^{a}	67.3^{b}	< 0.001
Dry season (%)	98.6	97.6	98.1	0.786
Sanitary and productive practice				
Deworming (%)	95.8	94.5	95.7	0.825
Vaccination against clostridiosis and/or rabies (%)	94.4^{a}	78.7^{b}	93.4^{a}	< 0.001
Disbudding (%)	28.2^{b}	58.3^{a}	49.8^{a}	< 0.001
Trimming (%)	27.3^{b}	49.6a	41.7a	< 0.001
Burning and/or burial of carcasses (%)	17.6	27.6	19.4	0.077
Reproductive practices				
Separation of males from females (%)	57.4^{b}	68.5^{a}	70.1^{a}	0.014
Controlled mating (%)	57.4^{b}	69.3^{a}	56.9^{b}	0.049
Castration (%)	28.2^{b}	40.2^{a}	44.1a	0.002
Breeding season (%)	17.1^{b}	19.7b	27.5a	0.028
Ram effect (%)	16.2^{a}	4.7b	13.7a	0.007
Main introduced goat breeds				
Saanen (%)	80.1^{b}	92.9a	89.1a	0.001
Alpine (%)	51.4	48.0	58.8	0.119
Toggenburg (%)	44.9^{b}	51.2^{ab}	57.3^{a}	0.037
Anglo-Nubian (%)	12.0^{b}	10.2^{b}	19.9^{a}	0.020
Boer (%)	7.4^{a}	5.5^{b}	12.8^{a}	0.044

$^{a-c}$ Means and frequencies with different letters in the row differ from each other ($p < 0.05$).

[1] A federal government program that contributes to the fight against poverty and inequality in Brazil. It has three main axes: 1 – Income supplement, in which families served by the program receive a monthly cash benefit; 2 – Access to rights, reinforcing access to education, health, and social assistance; and 3 – Articulation with other political-social actions to stimulate family development to overcome the situation of vulnerability and poverty (Ministério da Cidadania, 2021).

Deworming was the declared sanitary practice that presented the same behavior for the three groups, with a frequency of 95% for all the surveyed farms. Vaccination against clostridiosis and/or rabies, with a minimum adoption of 78% of the farms in Group II and above 93% for the other groups, also stood out.

The Alpine breed was equally present in the three groups, whereas the Saanen breed was the most frequent in all groups, but with a lower frequency for Group I (Table 4).

The sheepfold was the most present structure for the goat herd, showing equal frequencies between groups, with values above 73% (Table 5). The forage machine was the most present in farms of Group III. Group II had the lowest presence of milking parlor among farms, with a frequency of 28%, while Groups II and III had 47% and 55%, respectively.

The most common water source among groups was the concrete cistern, a reservoir with a mean capacity of 16 thousand liters used to collect the rainwater used only for family consumption, with emphasis on Group II, which showed a frequency of more than 90%. Group II stood out from the other groups regarding the surface dam, with a frequency of 70%.

The mean goat milk production in Group III was the highest among the three groups, with a mean production of 21 L/day. Group I was that most accessed the sale of milk for the PPA Milk, with 92% of farmers using this marketing channel. The sale of animals for slaughter was another important source of income from goat farming, in which 92% of all farms accessed this market and sold animals for replacement in other herds, standing out Groups II and III. In this case, more than half of the farms practiced this type of trade (Table 5).

4. Discussion

This discussion was structured into five topics: 1 – Social characteristics of the household; 2 – Characteristics of areas and herds on farms; 3 – Feed, health, and reproductive management and genetic composition of the goat herd; 4 – Structure, milk production, and commercialization of dairy goat farming; and 5 – Suggestions to improve farms.

Table 5
Facilities, equipment, water sources, production, and sales for the three groups of farms.

Variable	Group			p-value
	I	II	III	
Equipment and facilities				
Forage machine (%)	34.3[c]	48.0[b]	70.6[a]	< 0.001
Milking parlor (%)	47.2[a]	28.3[b]	55.0[a]	< 0.001
Sheepfold (%)	73.1[b]	85.0[a]	75.8[b]	0.037
Deposit (%)	33.8[b]	52.8[a]	61.6[a]	< 0.001
Water sources				
Concrete cistern[a] (%)	64.4[c]	90.6[a]	80.6[b]	< 0.001
Surface dam (%)	17.1[c]	70.1[a]	52.6[b]	< 0.001
Artesian well (%)	19.9[b]	44.1[a]	53.6[a]	< 0.001
Terrace cistern[b] (%)	5.1[b]	22.0[a]	20.9[a]	< 0.001
Stream (%)	7.4[b]	18.9[a]	17.1[a]	0.002
Goat milk production/farm (liter/day) (mean and standard deviation)	13.3[b] ± 13.6	14.1[b] ± 10.1	21.2[a] ± 19.8	< 0.001
Commercialization				
Sale of goat milk to PAA Milk[c] (%)	91.7[a]	76.4[b]	82.5[b]	< 0.001
Sale of goat milk out of the PAA Milk (%)	15.3	15.7	10.9	0.316
Processing and sale of goat dairy products (%)	2.3[b]	10.2[a]	9.0[b]	0.004
Sale of goats for slaughter (%)	94.9	90.6	91.0	0.207
Sale of goats for replacement (%)	31.9[b]	42.5[a]	52.6[a]	< 0.001

a - c Means and frequencies with different letters in the row differ from each other ($p < 0.05$).

[a] Concrete cistern – cylindrical. closed. and buried or semi-buried reservoir with the capacity to store 16 thousand liters of water. coupled to the gutters on the roof of the house to catch rainwater.

[b] Terrace cistern – cylindrical. closed. and buried reservoir with the capacity to store up to 52 thousand liters of water. connected to a 200-m^2 terrace. which serves as an area for catching rainwater.

[c] Food Acquisition Program in the Milk modality – PAA Milk

4.1. Social characteristics of the household

The mean age of 46 years of the heads of household pointed to farmers of middle age, as 63% of them were over 40 years old, which is in line with the results of other typologies of dairy goat systems in Greece, Italy, Turkey, and Algeria (Gelasakis et al., 2017; Gökdai et al., 2020; Ouchene-Khelifi et al., 2021). The mean number of three members per family showed shrinkage in the rural household, which is compatible with the behavior observed between the 1991 and 2010 censuses, in which the number of people per rural household dropped from 4.7 to 3.6 (Maia and Buainain, 2018). The reduction in fertility levels and migration of young people from rural to urban areas are among the factors that justify these results (Anríquez and Stloukal, 2008).

The last three demographic censuses conducted in Brazil (1991, 2000, and 2010) pointed to a rapid decrease in fertility levels, particularly from the 2000 s onwards, contributing to the aging of the Brazilian population, both in urban and rural areas (IBGE, 2011). The migration of more educated and female youths to urban centers contributes to aging and, consequently, to a reduction of the household, as this phenomenon compromises family reproduction (Maia and Buainain, 2018).

The educational level of farmers in the three groups was concentrated between illiterate, literate and incomplete high school, considered a low and medium educational level. Knowledge of the educational level of farmers is of paramount importance, as it affects the form of access to information related to production and, therefore, the adoption of technologies. Higher educated farmers search for more modern information and communication technologies, such as cell phones and the internet (Mittal and Mehar, 2016).

Land tenure, more frequent in Groups II and III, may have occurred by inheritance, with intense land fractionation over generations due to conjunctural rules according to internal and external circumstances to the family – in most cases, without formalization, being defined and demarcated by the family work (parents and siblings) (Galizoni, 2002). Income is another factor that may have favored the highest number of landowning farmers for Groups II and III, as these groups had more other non-agricultural incomes compared to Group I.

The presence of income from other non-agricultural economic activities, which are higher for Groups II and III than for Group I, is probably related to the family size of both groups. Families with income from other economic activities had an additional member compared to families without this source of income ($p < 0.001$). The positive contribution of family size was expected because having more members in the family means more possibilities to obtain higher income from other activities (Ahmed et al., 2018).

Other reasons that probably have collaborated in the search for other non-agricultural economic activities are the risks and uncertainties inherent in agriculture, especially those related to the climate conditions of Northeast Brazil and low economic returns, which are insufficient to meet the growing needs of families in the purchase of consumer goods and services (Odoh and Nwibo, 2017; Shirai et al., 2017).

The higher presence of retirees in the families of Group III was due to the higher mean age of farmers in this group, as the mean age of farmers among those with and without retirement were, respectively, 55 and 44 years ($p < 0.001$). Rural workers in Brazil (family farmer, artisanal fisher, and indigenous) are entitled to retirement 5 years earlier than other workers – men aged at least 60 years old and women aged 55 years old, provided that the minimum age of 15 years in rural activity is proven (Instituto Nacional do Seguro Social – INSS, 2021).

Another important source of income was the Bolsa Família, present in more than half of the surveyed farms, but more frequent in Groups I and II. It indirectly demonstrates that farmers of these two groups have less favorable economic conditions and investment capacity than those of Group III because families must have an income per person of up to R$ 89.00 or up to R$ 178 per month to be eligible, as long as they have children and adolescents from 0 to 17 years old (Ministério da Cidadania, 2021).

The information on the surveyed non-agricultural income showed that 79% of all farms have at least one non-agricultural income, which indicates fragility, as the main source, in addition to agricultural income, is originated from a public policy of income distribution aimed at families in poverty and extreme poverty. Initially, the purpose was to provide a temporary condition for families, who would then have to break free and find other sources of income and employment.

4.2. Characteristics of areas and herds on farms

The native dry forest area, that is, the Caatinga, was the main source of feed for ruminant herds in the studied systems, as occurs in other regions with low rainfall and unfavorable areas for agriculture, such as the mountainous regions of Greece, Spain, Italy, and France (Gelasakis et al., 2017; Ruiz et al., 2009). The size of these areas of native pasture was influenced by farm size, presenting a strong positive correlation ($r = 0.88$, $p < 0.001$) and indicating the superiority of Group III compared to Groups I and II, with larger areas of native vegetation.

The implanted areas of cactus pear and annual planting for silage production were more frequent in farms of Group II, with a higher diversity of forage production than areas in Group I. The low percentage of landowning farmers in this group may be one of the reasons for the low frequencies in the implanted areas of cactus pear and cultivated pasture, which require high investments for their implementations.

Research and technical assistance institutions and non-governmental organizations have evaluated the combination of plants, such as cacti, perennial legumes, and grasses, with different growth characteristics and degrees of adaptation to the semiarid environment with good production potentials in small rural properties to reduce the climate risk in the expansion of forage production areas and bring them closer to the nutritional requirements of animals.

Cactus pear, supplied as a forage supplement during drought periods in several semiarid regions of countries such as Morocco, Mexico, South Africa, and Tunisia (Andrade-Montemayor et al., 2011) was present in more than half of all the studied systems. This finding is considered positive after two decades of the attack of the pest carmine cochineal (*Dactylopius opuntiae*), which practically destroyed areas of cactus pear in the states of Paraíba and Pernambuco. Government programs have been established to recover areas and replace affected species with resistant ones (Almeida et al., 2019), considering this crop for animal feed as a strategic measure of lower risk in the face of climate variables.

The annual planting area for forage production, which is more present in Group III, is characterized by the intercropping between corn (*Zea mays* L.) and bean (*Phaseolus vulgaris* or *Vigna unguiculata*), the first used for animals and the second used exclusively for human food. Besides these two crops, there is an increasing adherence to sorghum (*Sorghum bicolor* L.) planting.

The abandonment of annual planting under rainfed conditions by farmers was noticeable. It has occurred due to the frequent droughts recorded in recent years, especially from 2011 to 2016, when it was more intense in terms of duration, severity, and recurrence over the Brazilian Northeast region, reaching 10 million people and direct losses in agriculture and livestock of R$ 6.8 billion (Brito et al., 2018). Although government drought relief programs have evolved, rainfed agriculture has remained vulnerable since drought policies were formulated (Campos, 2015). The surveyed properties had livestock diversity, that is, 76% of them presented two or more combinations between goats, cattle, sheep, and poultry. Similar to what happens in other semiarid regions of other developing countries, such as African countries (Monau et al., 2020; Wodajo et al., 2020), livestock, especially small ruminants, is one of the main factors that guarantee food and nutrition security and income generation for rural families in the Northeast semiarid due to the high animal resistance to drought compared to the agricultural cultivation (Coutinho et al., 2013).

Goat herd had a mean size of 40 animals per farm, a value higher than that obtained in the 2017 Agricultural Census, which recorded a mean of 27 animals per farm in the studied municipalities (IBGE, 2019). This difference between the mean of the present study and that of the census may be attributed to the target audience of this research, composed of 100% of goat milk farms, whose activity may or may not be exclusive.

The associated rearing of sheep and goats was present in only 36% of the farms. Goats and sheep have the same crucial role in the production systems of Northeast Brazil because they provide revenue, food (meat and/or milk), and input (manure), also working as a savings for times of financial or climate difficulties, such as during drought periods, being highly liquid in the market (Bosman et al., 1997; Kuivanen et al., 2016; Oluwatayo and Oluwatayo, 2018).

Poultry produced on these farms is often free-range chickens, being raised near the homes of families and managed by women and children with the production destined for the own household consumption and sale of eggs and animals for slaughter, which is also an additional source of income. A review of socioeconomic aspects of hen production in communities in the tropics of developing countries showed that chicken production was the main livelihood of rural families, with the potential to increase family income, improve food security, and contribute to poverty alleviation, being carried out by women with the help of children (Alemayehu et al., 2018).

The high stocking rates of the three groups indicate attention and concern since farms are small-sized, have a deficit in forage production, intensified by irregular and long periods of drought, which negatively affect the availability and quality of the main feed source for the ruminant herd, the Caatinga (Santos et al., 2010). Studies have indicated that inadequate grazing in intensity and frequency significantly reduces the diversity of trees and shrubs of native pasture and modifies soil physical attributes (Batista et al., 2018; Schulz et al., 2019).

The lowest stocking rate in the present study was 1 AU for 1 ha of the farm, indicating a high rate in all farms when considering that slight to moderate stocking rates consist of 1 AU for 10–13 ha of Caatinga (Albuquerque, 1999; Araújo-Filho, 1987). It justifies the frequent supply of concentrate supplementation almost every year and the frequent purchase of roughage for supplementation, especially silage, increasing the cost of production.

4.3. Feed, sanitary, and reproductive management, and genetic composition of the goat herd

Forage conservation , which was practically carried out as silage usually made with corn, sorghum, elephant grass, or native pasture, or even different combinations of them, was adopted in less than 45% of the farms, being an essential factor for ruminant production in this region, which has gone through several drought periods (Brito et al., 2018). Several factors may be associated with this low adoption such as frequent droughts in the region, which discourage the farmer to carry out the annual planting; the need for machinery for the ensilage process, as farmers need tractors and silage machines from the city hall, associations, or unions on many occasions; and the planted material, which is often not adapted to the region.

The low adoption of forage conservation practices by farms of Group I (82% of the farms belonging to both Western and Eastern Cariri of Paraíba) is justified by the adverse climate for annual plantings, with mean annual precipitation from 400 to 500 mm (Alvares et al., 2013), and frequent years of drought (Brito et al., 2018), which is one of the critical factors for dairy goat production in this region (Costa et al., 2010, 2008).

Practically 75% of the farms in Group II carried out forage conservation, probably due to the tradition of dairy cattle farming in the state of Pernambuco, as 78% of the farms of Group II belonged to this state and used this practice (IBGE, 1990). Ensilage of small amounts of forage into 30–50 kg plastic bags may have contributed to the high adoption of this practice in these groups, facilitating the process because it does not depend on heavy machinery and a lot of labor, besides reducing losses after opening and making transport to more strategic locations on the farm easier.

The lower frequencies of use of concentrate supplementation in the rainy season in Group I and III may be related to an increase in the quantity and quality of native pasture during this period, which allows for the minimum meeting of the nutritional requirements of goats with production level (Oliveira et al., 2016; Santos et al., 2010).

The two main sanitary practices adopted in the three groups were monthly deworming and vaccination against clostridiosis (infections and toxinfections caused by anaerobic bacteria of the genus *Clostridium*) and/or rabies. Both practices are quite consolidated among goat and sheep farms (Alencar et al., 2010; Bandeira et al., 2007; Souza Neto et al., 1987), but there is evidence from field visits and previous reports that these practices have been carried out in many cases erroneously.

The immunization against clostridiosis has no specific calendar, poor vaccine conservation, repetition of immunization in shorter periods than recommended, and absence of booster for animals vaccinated for the first time. Prevention and fight against worms showed a lack of a specific calendar, use of non-specific vermifuge, underdoses, and weekly deworming repetition, favoring parasite resistance and, consequently, the continuation of the disease in the herds (Alencar et al., 2010; Riet-Correa et al., 2013). Rabies vaccination in herbivores is not mandatory but recommended for susceptible animals in outbreaks and peri-outbreaks, according to local geographic conditions (MAPA, 2020), not being systematically carried out by producers.

In general, goats of the surveyed farms are crossbred animals with outstanding characteristics for milk production due to the introduction of dairy breeds three decades ago, mainly from the Southeast region of Brazil (Costa et al., 2010; Neumaier, 1984). However, a genetic non-structuring of herds based on the climate conditions of this region is observed (Riet-Correa et al., 2013). Consequently, a large part of the productive capacity of the introduced breeds is wasted with production limited by available resources and the quota imposed by the PAA Milk. Similar behavior is observed in Eastern European countries, where dairy herds are small and local breeds have been replaced by more productive exotic breeds, such as Saanen and Alpine (Ruiz Morales et al., 2018).

4.4. Structure, milk production, and commercialization of dairy goat farming

The most common structure in farms intended for goat production was the sheepfold, which is usually built with wood mostly taken from the Caatinga, ceramic roof, and earthen floor (Guilherme et al., 2017; Riet-Correa et al., 2013).

The presence of the milking parlor, an essential structure in the dairy activity that provides better hygienic conditions at the time of milking, was less frequent in Group II. This group was composed of 78% of farms located in Pernambuco, whose production incentive policies are more recent, but less intense in the state of Paraíba, which had actions to improve goat milk production under the Pacto Novo Cariri program (Costa and Ferreira, 2010). The presence of the milking parlor on goat milk-producing farms is essential for obtaining safe milk, according to current regulations (MAPA, 2000).

The concrete cistern, a structure for capturing and storing rainwater and meeting the family's water demand, was the most frequent water source in all groups. It is mainly from a public policy of the federal government created in 2003 and called the "One Million of Cisterns Program" (Passador and Passador, 2010), being effective in serving the farms, regardless of the identified groups.

Regarding the water structure for animal and agricultural production, Group II and III showed the highest diversity of water sources compared to Group I. More than 50% of the farms of this group had an artesian well or surface dam, structures that require investment for installation.

The highest daily milk production presented by Group III is probably due to the size of the herd and, consequently, the number of milked goats, unlike Group II, which had similar production to Group I, but with half of the goat herd, showing higher productivity per animal. The mean milk production of the studied farms was 16 liters/day (Table 5), which is the volume limited by the financial quota imposed by PAA Milk, the main and only destination of the produced milk in most cases.

The greatest access to the PAA Milk program was from Group I (92%), but the other groups (higher than 76%) also had strong access, demonstrating the importance and dependence of goat milk farmers in the studied area on the government market.

The guaranteed purchase of almost all goat milk produced in the Northeast by PAA Milk, with the subsequent sale to processing plants, made several family-based diversified livestock systems start to explore dairy goat farming as the main commercial activity in Paraíba and Pernambuco from 2000, leveraging their production systems (Meneses, 2015; Sampaio et al., 2010).

Despite the apparent advance of dairy goat farming with the guarantee of government purchase and the intensification of production systems, this sector has been experiencing difficulties, pointing out the restricted market (dependence on PAA Milk) as the main challenge, followed by the financial quota for milk purchase of the program, limited to R$ 4500.00 per family unit/semester, which, consequently, limits an increase in milk production.

As in other countries, the sale of animals for slaughter is another source of income for dairy goats, with males destined for sale, as meat is a quick source of income for owners to purchase agricultural and feed inputs, and payment for medical, school, and marital expenses, among others (Ouchene-Khelifi et al., 2021). Male goats are usually slaughtered with a mean age of 9 months and 18–20 kg, and this source of income is very important in the goat production system even before the dairy vocation is implemented after government incentives.

Another source of income for goat farming was the commercialization of dams and sires for replacement in other herds, standing out Groups II and III possibly due to the high availability of animals and the genetic composition of the herd for milk production. The commercialization of animals for reproductive purposes adds value to the animal, allowing selling them for twice or more the value of the animal that would be destined for slaughter. Also, no farms in these regions commercialize genetics only and exclusively. This function seems to be more distributed among farms of Groups II and III, as 43% and 53% of them commercialize animals for this purpose, respectively.

4.5. Suggestions to improve farms

As a premise for suggestions for improvement, we consider that more important than discussing ways for an individual farmer to migrate to another group is to identify potential alternatives to increase the sustainability of production units that fit the different profiles. However, it is worth mentioning that the determining variable for cluster formation was the farm size, an element that brings with it the complexity of land issue in Brazil. Moreover, the absence of data and models that prove the ideal farm size to present better results and performance, especially in the case of a semiarid region, does not allow any suggestions to be made in this regard.

The production systems targeted in this study belong primarily to family-based production on small rural properties, with a strong trend to multifunctionality, but low investment power, signaling the need for a systemic and integrated view of its components to point out more effective actions. Actions aimed at increasing autonomy over production processes, and even processing and marketing, with a view to productive insertion, income expansion, fixation of young people in the countryside, higher efficiency in production and use of inputs, and the balance of production and cycling of nutrients for the maintenance of natural resources are intended to contribute to the reproduction strategies of these people in the field.

Aging, low educational level, and household reduction, transversal to the three groups, can be circumvented with actions that value the knowledge of older farmers, according to their education and customs, favoring a more stable, healthy, and productive economic life (Anríquez and Stloukal, 2008). Actions aimed at young people are also needed, identifying the reasons for their migration to urban areas and promoting policies that offer better economic and educational opportunities and social connectivity with other groups and regions (Ei Chew et al., 2011).

Actions that promote the diversification of agricultural income sources, reduce the cost of inputs, and guarantee the purchase of products at fair prices to enable the maintenance or increase of activities can be initiatives to generate income for families (Petrini et al., 2016), which would consequently reduce the need for income from government cash transfer programs.

Considering the most frequent feed production area (Caatinga), the numbers of ruminant herds, the high stocking rates, and the constant concentrate supplementation observed in goat herds, it is suggested to improve the forage support of farms through the adequacy of the stocking rate (Salem, 2010); the increase in the support capacity of the Caatinga through manipulation techniques that provide an increase in forage mass and, consequently, animal performance (Santos et al., 2010); and the implementation and/or expansion of cactus pear areas intercropped or not with annual crops more adapted to the semiarid region, such as sorghum and millet, for forage production and conservation (Ramos et al., 2016).

Stock rate adjustments are an important strategy for ruminant management in semiarid areas, such as those in Northeast Brazil (Salem, 2010). Stocking rate adjustment based on a comparison of current year precipitation and historical series average resulted in improved cattle production, maintaining or improving pasture conditions in a semiarid region of Mexico (Díaz-Solís et al., 2009).

Caatinga management practices, such as thinning, lowering, and enrichment, are suggested to farms of Group I and III to increase forage yield and, consequently, ruminant productivity (Pinheiro and Nair, 2018). Cattle, goats, and sheep can reach annual gains of 172, 120, and 180 kg/ha, respectively, in enriched Caatinga areas, values much higher than those found in unmanaged Caatinga areas, with gains reaching only 5.6, 11.9, and 9.7 kg/ha, respectively (Araújo-Filho, 2013).

These actions may increase the degree of grazing on farms of Groups I and III, enabling a reduction in the amount of purchased concentrate. A study carried out on goat farms in the region of Andalusia (Spain), practicing different degrees of grazing, showed that it is possible to obtain satisfactory productivity and profitability levels (Mena et al., 2017).

The expansion of areas with integrated food production systems (crop-livestock-forest and agroforestry systems, among others) from the combination of several plants with different characteristics, growth cycles, and potential for adaptation considering water scarcity has shown to be of great importance to make up the diet of animals, in addition to ensuring higher ecological balance and reducing the risk of climate variations and the cost of purchasing external inputs.

Evaluations of intercropped systems of cactus pear and sorghum in the Brazilian semiarid region have shown to be viable alternatives for the feed security of ruminant herds. Sorghum as a secondary crop in intercropped systems can promote more resilient and stable crops due to its high adaptive capacity, especially in low-fertility environments and under water deficit conditions, increasing forage yield with no impact on its nutritional quality (Diniz et al., 2017; Jardim et al., 2021). The increase in perennial and annual cultivated forage areas may be a viable alternative for farms of Group II, which have the presence and smaller Caatinga areas.

The points that deserve attention regarding the sanitary aspects are the need for training to guide farmers on correct immunization practices against clostridiosis (Tizard, 2021) and implementation and training for integrated management of parasites, with the introduction of effective methods, such as FAMACHA©, which has been viable to control gastrointestinal helminths of dairy goats in a semiarid region of Northeast Brazil (Vilela et al., 2012). Integrated management training, including FAMACHA©, for goat and sheep farmers, was successful on farms in the US, resulting in fewer gastrointestinal parasite problems and economic benefits reported after training (Whitley et al., 2014).

Participatory approaches for the implementation of genetic breeding programs for goats that consider the productive and edaphoclimatic characteristics of the region, defining objectives and criteria considering the wishes and needs of local farmers, could be a way to be followed (de Aguiar et al., 2020; Gebre et al., 2020; Ramzan et al., 2020). Studies with this objective have been carried out with goat farmers from the state of Ceará, also in the Northeast region of Brazil, and developing countries such as Kenya, pointing out that the use of a participatory methodology was efficient in capturing the perception of farmers and holistic analysis of the production system to define objectives and selection criteria for the establishment of a breeding program based on local demands, with personal fulfillment, the family's food source, income generation, savings, and cultural traditions being the main objectives (de Aguiar et al., 2020; Kosgey et al., 2008). Considering the studied systems, especially the main source of forage (native pasture), milk production and sale of animals for slaughter, an alternative for crossing and/or breed would be the use of animals with lower nutritional requirements, medium production, and dual purpose for milk and meat. The Anglo-Nubian breed would be one of these alternatives because it has good body conformation and good milking capacity (Sousa et al., 2011).

One way to boost the increase and sale of goat milk in the Paraíba and Pernambuco region is to encourage the valorization of local resources and the implementation of certifications, such as the indication of origin, which considers the method of preparation and sale of traditional products. This path, adopted by small cheese producers in the mountains of the state of Minas Gerais (Canastra, Salitre, and Serro), strengthened by the political-institutional support of various governmental and non-governmental organizations, managed to boost production chains and regions (Wilkinson et al., 2017). Other examples for inspiration are goat cheeses from various regions of Spain that are produced and protected by Protected Designation of Origin, such as Camero, Ibores, Majorero, Murcia, and Palmero (Martínez et al., 2011), especially Ibores, as it is produced in a mountainous area located in the Southwest of the Iberian Peninsula (Cáceres, Spain), characterized by a very harsh climate, with low rates of income and population density (Gaspar et al., 2011), similar to the studied semiarid region.

In general, considering that dairy goat systems are in a semiarid region with native pasture being an important and present factor, with an evident redirection of production to a semi-intensive model with more concentrate supplementation and introduction of exotic breeds, it is necessary to revise production bottlenecks that have hampered the sustainability of the systems, such as the high cost of production due to the high use of inputs, low efficiency in the use of natural resources, in addition to the milk market limited by PAA Milk.

A future path may be the agroecological transition with a higher appreciation of local resources, creation of distinctive signs for products, use of techniques for coexistence with the semiarid region, higher use of pasture with diverse feed resources is sought, with an adapted stocking rate and a lower amount of external inputs (concentrate), use of breeds adapted to environmental conditions, heritage preservation, and other social contributions (Dubeuf et al., 2018; Dumont et al., 2018).

The world production of goat cheese totaled 569,832 tons between 2010 and 2019, showing a 30% growth in production volume in the period compared to cow's milk, whose growth was 14.6% (FAO, 2019). Sepe and Argüello (2019) indicate that, gradually, consumers of dairy products have opted for goat dairy products instead of cow dairy products due to commercial appeals related to the appreciation of artisanal products or even products with greater functional potential. In this sense, considering that the tradition of fluid milk consumption in Brazil is very low (Alves et al., 2020), the opportunities to open channels with the private market follow in two directions: producers who can verticalize production, adding value to milk by producing cheeses via family agro-industry with artisanal appeal, whose frequency of profiles in the present study ranged from 1% to 5% of producers; and the other producers, who can simply supply the surplus milk not destined for PAA Milk to small dairies in the region for the processing and commercialization of industrialized products.

5. Conclusions

Dairy goat production systems in the main milk production area of Brazil are diversified and can be classified into three distinct groups based on the analysis of typologies, standing out the importance of the variable farm size to establish the groups:

Group I – Extensive systems with low input – Lower tenure relationship with the land, low agricultural and livestock diversity, lower frequency of income from other non-agricultural activities, higher fragility in the production and conservation of feed for animals, and less equipped farms regarding production and water supply facilities.

Group II – Semi-intensive systems with high input – Smaller production area and higher tenure relationship with the land, moderate presence of income from other non-agricultural activities, higher livestock diversity and feed production for the herds, higher use of forage conservation and concentrate feed for the goat herd in the dry season, and higher presence of production and water supply facilities.

Group III – Semi-intensive systems with moderate input – Larger production area and strong tenure relationship with the land, presence of income from other non-agricultural activities, livestock diversity, moderate production of feed for the herds and forage conservation, and higher presence of production facilities and moderate water supply facilities.

Similar points were observed despite the specific characteristics of the groups, standing out the high dependence of the groups on the PAA Milk program and low access to other marketing channels for goat milk and dairy products, high use of concentrate supplementation in the dry period, the introduction of exotic breeds specialized in milk production, and sale of goats for slaughter as an important source of income.

The diversification of livestock activities, goat breed composition most suitable for the edaphoclimatic conditions, increase in water support for animal and plant production, adequate planning of forage support (budget, implementation and/or expansion of areas with cactus pear, annual crops and legumes more adapted to the semiarid region, and use of integrated systems and diversified practices of feed conservation), adequacy of the Caatinga stocking rate (with the expansion of support capacity), and the search for new markets for goat milk and dairy products indicate the main ways to provide economic gains associated with higher sustainability of the systems identified in this study.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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