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Breeding programs for dairy goats generate profits in Brazil

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ABSTRACT

This work aims to evaluate the economic feasibility of a breeding program for dairy goats in developing countries. A traditional scheme was compared with a scheme using a progeny test. In the traditional scheme, farm records are used and the selection of bucks is based on reproduction and milk yield of their dams, while the selection of does is based on their own performance and on their dam's performance. Analyses were performed using the ZPLAN software, which uses a deterministic approach to estimate genetic and economic gains in breeding programs. The traditional selection scheme showed no economic viability and did not cover the costs for maintenance of the breeding program. The scheme using progeny tests of young bucks was viable, with considerable genetic profits for the objectives of selection and individual traits. The economic returns of this program exceeded its costs, with a return on investment of approximately 3%. In this scheme, somatic cell count was the trait with the largest economic impact, followed by milk yield. The intensity of use of young bucks in progeny testing should not exceed 10%. Above this value, no substantial monetary gains were obtained for the objective of selection, besides the reduction of the net present value of the breeding program.

1. Introduction

Breeding programs are essential for the efficiency of animal production systems because they promote positive changes in the traits of economic interest. However, running a breeding program has costs. According to Lôbo et al. (2000), a breeding program's efficiency is measured in terms of the profits it provides, and furthermore, it is essential to combine economic and genetic evaluations for rational and cost effective results. Thus, it is necessary to assess whether the genetic changes in selected traits and the subsequent increased productivity of the production system outweigh the costs of running it, making the investment feasible.

According to Prakash (2009), in countries with large herd sizes, progeny test stations are much more expensive than using farms records. However, in countries with small herds, progeny test stations or special nucleus recording herds may be the only effective means of male selection. Most genetic evaluations of dairy animals in the world use the progeny test. However, in developing countries, there are many financial and logistical difficulties in running a progeny test for goats, such as the lack of specific public policies, the lack of companies for semen collection and distribution, a reduced number of flocks with milk control, and a low efficiency of the insemination technique. These issues are especially true in regions with territorial dimensions such as Brazil. In this country, there are a significant number of goat herds, and traditional selection in which bucks are selected based only on their dam's phenotypic information prevails. Recently, the country began implementing a progeny test for flocks in the Southeast region. However, the relative efficiency of adopting one scheme or another in developing countries is not clear. Thus, it is necessary to assess whether progeny testing young bucks (based on database information, with subsequent collection and distribution of semen among the breeders) or simply using farm records as in traditional selection is more viable and whether running a breeding program generates enough profit to justify its implementation. It is important to question whether the costs involved in a breeding program, anywhere in the world, are viable and promote return on investment. Therefore, the aim of this study was to evaluate the economic feasibility of a breeding program using two selection

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schemes to provide a reference for optimizing the choice of future strategies for dairy goats in developing countries.

2. Materials and methods

2.1. Panel of experts from Embrapa Goats and Sheep/Embrapa Dairy Cattle

A panel of experts was proposed, due to the relative lack of publications in Brazil regarding dairy goats. The aim was to discuss issues related to the dairy goat industry in Brazil, and researchers, technicians, farmers and producers, covering information on population structure, market, production systems and selection were gathered. The discussions served to support the analyses pertaining to this study, which will be highlighted throughout the text. The meeting was realized on 03/30/2011 by video conference, with the participation of two research units of the Embrapa Sheep and Goats, located in Sobral-CE, and the Dairy Cattle, located in Juiz de Fora-MG.

2.2. ZPLAN

Economic and genetic evaluations of the selection schemes were performed using the software ZPLAN 2008 (Willam et al., 2008). ZPLAN is designed to optimize selection strategies in livestock breeding. The program requires the population structure, the transmission matrix of gene flow, and other technical and biological parameters in order to calculate results such as the annual genetic gain for the breeding objective, genetic gain for single traits and return on investment adjusted for costs. The total profit for the population is estimated as the sum of the genetic profit per animal of each selection group, with costs subtracted. The program is based on a pure deterministic approach, using the theory of selection indices and methodology of discounted gene flow (Hill, 1974; McClintock and Cunningham, 1974).

The subroutine NBILD was written to specify relationships among the parameters used in the simulations.

2.3. Population structure

Information that allowed specification of the population structure is shown in Table 1. The total population was estimated as 600,000 animals specialized for milk yield. However, the population structure of dairy goats in Brazil consists only of the breeding nucleus and commercial flocks without a clear definition of the multiplier flocks.

The breeding nucleus consisted of purebred and controlled pedigree animals. Because approximately 10,000 young animals are registered in the Brazilian Goat Breeders Association per year, half of which are male, and the average herd life of a doe is eight years, the total number of animals in the breeding nucleus was estimated to be 40,000 (10,000*8/2). Thus, the remainder (560,000) composed the commercial stratum (no registered purebred, crossbred and unknown breed animals) in this study.

Table 1
Population structure of dairy goats in Brazil.

Parameters	Number	Source
Kidding interval in breeding nucleus	350.4 days	Vieira et al. (2009)
Kidding interval in commercial flocks	292 days	Sarmento et al. (2003)
Does registered in the association/ year in the breeding nucleus	10,000	Panel of experts (see item 2.1 in text)
Average for parity rate	1.15	Vieira et al. (2009), Sarmento et al. (2003)
Total number of does	600,000	Panel of experts (see item 2.1 in text)
Does in breeding nucleus	40,000	
Does in commercial flocks	560,000	
Does per buck	40	

2.4. Breeding objective

The following traits were considered: milk yield in kg (MY), lactation length (LL), age at first kidding in days (AFK), kidding interval in days (KI), somatic cell count (SCC/ml) and total solids in g/100 g (TS). These parameters were proposed by Lopes et al. (2012).

2.5. Selection schemes

Two selection schemes were evaluated: the traditional selection (I), which sought to portray the current reality of the general system of goat production in Brazil, and the progeny test (II), as proposed by the Dairy Goats Breeding Program (CAPRAGENE; Lôbo et al., 2010; Facó et al., 2011). CAPRAGENE started in 2005 with the support of the Embrapa Goats and Sheep and was implemented specifically in the Southeast region of Brazil. In this program, each year, a group of young bucks has semen collected, codified and distributed among breeder participants, with herds located in three states of this region (Minas Gerais, Rio de Janeiro, São Paulo and Espírito Santo).

The comparison aims to contrast the reality of the two schemes, which are running independently in Brazil. They are the same in breeding structure (two-tiered schemes with nucleus and commercial flocks), but differ in selection criteria and source of information (scheme 2 uses information of grandparents and progeny) and in buck use (scheme 2 uses AI and both young and proven bucks). More details are given below.

2.5.1. Scheme of traditional selection (I)

In this traditional scheme, 10 groups of selection were considered, corresponding to gene-flow between the different groups of bucks and does in the two strata of the population (Fig. 1). Only the use of natural mating was considered, without the adoption of artificial insemination. In the breeding nucleus, the gene-flow occurred between and within four groups of selection (1–4). The direct gene-flow from nucleus does to commercial stratum was not considered.

The traits milk yield in kg, lactation length in days, age at first kidding in days and kidding interval in days were considered as selection criteria. In all steps, the selection was carried out based on the best index for the criteria considered. The number of relatives with records in the various groups of selection was based on population parameters such as kidding and survival rates, among others. Two indices have been proposed: (i) Index 1-Selection of bucks from the breeding nucleus (groups 1, 3, 5 and 6; Fig. 1) and (ii) Index 2-Selection of does from the breeding nucleus (groups 2 and 4; Fig. 1). The information used in Index 1 was one record of the dam of the buck for each one of the traits MY, LL, AFK and KI. One record of the dam of the doe for each one of these same traits was used in Index 2.

During the assessment of genetic and economic gains for a breeding program, only the selection practiced in the breeding strata, the nucleus in this case, is considered. This is because the benefits are shared by all strata. The selection practiced in commercial flocks does not spread to the entire population, unless it is an open system, where animals from commercial flocks can be incorporated into the breeding nucleus, which is not the case analyzed in this study. Thus, the selection practiced in the commercial stratum for groups 7, 8, 9 and 10 would not influence the impacts of selection. For these groups, a selection index

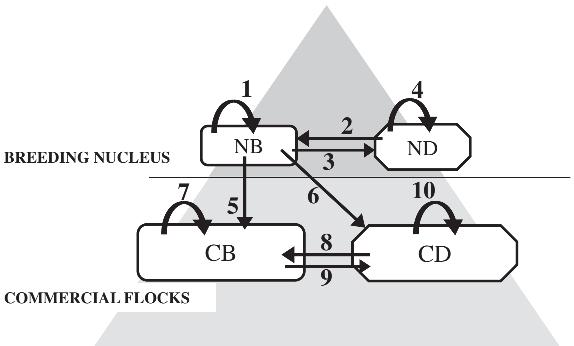

Fig. 1. Gene-flow, selection groups (1–10) and structure population in the traditional selection scheme (NB – nucleus bucks; CB – commercial bucks; ND – nucleus does; CD – commercial does). It was considered that the breeding nucleus consisted of purebred and registered animals. This nucleus had 40,000 does since 10,000 animals were registered by year according information of association's technicians. 560,000 does formed the commercial stratum. In this traditional scheme, ten groups were considered for selection, corresponding to the gene-flow among different groups of bucks and does in the two strata of the population. It was considered only the use of natural mating, without the adoption of artificial insemination (AI). In the breeding nucleus, the gene-flow occurred between and within four groups of selection (1–4). For example, the first step (1) corresponded to the genes from the fathers of the bucks of the nucleus, while the second step (2) corresponded to genes from mothers of these bucks, and so on. The gene-flow between nucleus and commercial flocks occurred from the bucks of the nucleus to bucks (5) and does (6) of the commercial stratum, but the reverse was not considered. The direct gene-flow from nucleus does to commercial stratum was not considered.

uncorrelated with the objective was developed because ZPLAN considers all groups of selection for defining the overall flow of genes, even if some of them do not contribute to the improvement.

2.5.2. *Scheme of selection using progeny test (II)*

As described previously, this scheme was evaluated using CAPRAGENE. In this scheme, the population structure in Table 1 was used, and artificial insemination (AI) was considered, with an estimate of 1.18 services per conception (Brito et al., 2009). The use of AI was estimated at 50% and 10% in breeding nucleus and commercial flocks, respectively. Twelve groups of selection were considered, corresponding to gene-flow in this scheme (Fig. 2).

wThe traits in the selection criteria were the same as the breeding objectives (*item 2.4*), with total solids represented by dry milk solids (DS; g/100 g), fat (FAT; g/100 g) and protein (PROT; g/100 g).

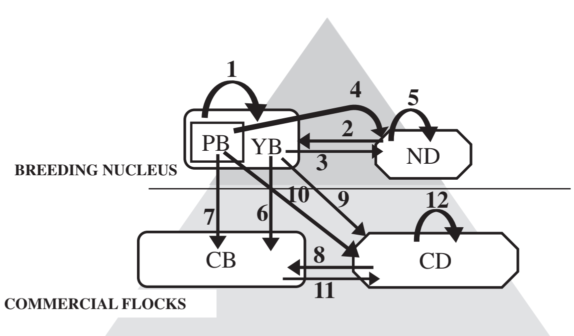

Fig. 2. Gene-flow, selection groups (1–12) and structure population in the progeny testing of young bucks (PB – proved bucks; YB – young bucks; CB – commercial bucks; ND – nucleus does; CD – commercial does). In this scheme was not considered the direct gene-flow from nucleus does to commercial stratum or upward gene-flow from the commercial to the nucleus stratum. The first step of selection (1) corresponded to gene-flow of the proved bucks as fathers of young bucks, while the second (2) referred to the gene-flow from the nucleus does, mothers of these bucks. Importantly, the proved bucks were young bucks which were selected after progeny testing. Thus, these animals were evaluated in two steps of selection. The commercial flocks only received gene through nucleus bucks (groups 6, 7, 9 and 10).

Table 2
Biological and technical parameters used in the simulation for the goat breeding program.

Trait	Nucleus		Commercial
	Traditional Scheme	Progeny Test Scheme	
Herd life of bucks (year)	7	–	6
Herd life of proved bucks (year)	–	5	
Herd life of young bucks (year)	–	4	
Herd life of does (year)	8	8	6
ABF[a] of bucks (year)	1.5	–	2.5
ABF of proved bucks (year)	–	4	
ABF of young bucks (year)	–	1.5	
ABF of does (year)	1	1	1
Survival (%)	96	96	93
Kidding interval (year)	0.80	0.80	0.90
Parity rate (%)	87	87	85
Litter size	1.49	1.49	1.49
Availability[b] (%)	87	87	87
Does per buck	40	40	40
Artificial insemination (%)	–	50	10[c]
Number of doses semen buck/year	–	1,200	–
Number services per conception	–	1.18	–

[a] ABF: age when born first kid.
[b] Availability: young does available for selection among those which are born.
[c] Only for progeny testing.

Similarly to the traditional scheme, the selection was made based on the best index for the criteria considered. The number of relatives with records in the various groups of selection was based on the population parameters, such as kidding and survival rates, among others, according to Table 2. Two indices were proposed: (1) selection of bucks from the breeding nucleus (groups 1, 3, 4, 6, 7, 9 and 10) and (2) selection of does from breeding nucleus (groups 2 and 5). The number of the information in Index 1 for the traits cited above corresponds to the performances of the dam of the father and dam of the mother of the buck (two lactations), dam of the buck (one lactation) and 30 daughters of the buck (one lactation), with selection in two pathways (young and proven bucks). The information about traits in Index 2 consisted of one lactation of the doe and two lactations of its dam. As stated earlier, the selection practiced in the commercial sector would not influence the objective of selection, and it was therefore disregarded (groups 8, 11 and 12).

2.6. *Technical and biological parameters*

The technical and biological parameters used in this study are described in Table 2. The following information was used to build the transmission matrix: estimates of survival rates, age at first kidding, kidding interval and herd life for each selection group evaluated. Other information was necessary for the calculation of proportions of animals selected and selection intensity. This information was obtained from various sources. The number of daughters per young buck tested was cited as a goal by Facó et al. (2011). Other information was obtained from the panel of experts (*item 2.1*).

Table 3
Economic value (*V*), trait average, standard deviation (s_p), repeatability (*r*) and heritability (h^2) used in the breeding program.

	V, US$[a]	Average	s_p	*r*	h^2
Milk yield (kg)	0.0134	511.70	351.67	0.36	0.19
Lactation length (day)	0.0105	211.40	73.20	0.43	0.07
Age at first kidding (day)	0.0029	376.89	80.57		0.21
Kidding interval (day)	0.0034	312.06	148.68	0.06	0.06
Somatic cell count (cell/ml)	−0.0094	1,340,000	700	–	0.24
Dry milk solids (%)	0.0076	11.4	2.36	0.18	0.16
Milk protein content (%)	–	3.1	0.44	0.63	0.54
Milk fat content (%)	–	3.7	0.78	0.60	0.52

[a] The values presented here (Lopes at al., 2012) were converted to United States dollar (US$ 1=R$ 2.35/July 03, 2013).

2.7. Economic values and genetic and phenotypic parameters

The economic values used in this study (Table 3) for the unitary change in each trait were derived by Lopes et al. (2012) for semi-intensive systems. The values were weighted by the number of goats (100) used to estimate these weights because ZPLAN requires economic values relating to a dam without considering the time and amount of expression in later generations. Mean values of traits and their standard deviations (Table 3) were calculated by Irano et al. (2012), except for AFK and KI, which was reported by Lôbo and Silva (2005). The values for somatic cell count, dry milk solids, protein and fat content were estimated from the CAPRAGENE databank.

The heritability and repeatability for MY and KI (Table 3) were obtained from Sarmento et al. (2006) and Lôbo and Silva (2005), respectively. In the latter, the value of repeatability for LL and the heritability for AFK were further verified. The heritability for LL was estimated by Soares Filho et al. (2001). Other studies provided some phenotypic parameters as well (Queiroga et al., 2007; Brito et al., 2009; Garcia-Peniche et al., 2012).

From the studies of Park and Humphrey (1986), Belichon et al. (1999), McManus et al. (2003), Lôbo and Silva (2005), Montaldo et al. (2010), Rupp et al. (2011) and Lopes et al. (2012), most of the genetic and phenotypic correlations were obtained (Table 4). For some correlations, the averages of the values found in the literature were used. Correlations not found in the literature for goats were supplemented with information from dairy cattle (Harder et al., 2004). The genetic correlation between MY and AFK used here was estimated from dairy cattle (Vercesi Filho et al., 2007). Some phenotypic correlations were estimated from the CAPRAGENE databank. The correlation was considered zero when no value was found in the literature for goats or for cattle, and it was not possible to estimate it from the CAPRAGENE databank.

2.8. Parameters of investment and costs

These parameters were estimated according to the market prices in Brazil in the years 2013–2014. The investment period considered was 20 years long, using 8% and 6% of discount rates for returns and costs, respectively. The annual fixed costs of the program were estimated in US dollars to be $196,042.98 (average time to occurrence-1.5 years to the traditional scheme and 2 years to the progeny test). The fixed costs referred to the outlay of a breeders association.

The variable costs considered were the following: (a) monitoring the flocks and pedigree recording per animal – US$ 15.38 (average time to occurrence 1.5 years); (b) official milk record per animal – US$ 5.53; (c) measurement of total milk yield per lactation – US$ 37.49 (average time to occurrence 1.84 years); (d) measurement of lactation length – US$ 0.85 (average time to occurrence 1.84 years); (e) measurement of age at first kidding/animal – US$ 0.42 (average time to occurrence 1.0 year); (f) measurement of kidding interval/animal – US$ 0.42 (average time to occurrence 1.80 years); (g) measurement of milk quality/record/animal – US$ 8.36 (average time to occurrence 1.84 years); (h) collecting semen dose – US$ 2.00 (average time to occurrence 0.8 years); (i) semen storage – US$ 0.21 (average time to occurrence 0.8 years); (j) annual semen collection for proven bucks – US $ 1,276.59 (average time to occurrence 3.5 years); (k) semen collection of young bucks – US$ 297.87 (average time to occurrence 0.8 years).

2.9. Level of bucks used in the schemes evaluated

The impact of using 20–100% of bucks from the breeding nucleus on the commercial flocks in the scheme of traditional selection was simulated. For the progeny test scheme, using 10%, 15% and 20% of the young bucks were evaluated. There was no increase in the number of young bucks in test, but there was an increase in the percentage of females inseminated with these bucks and a consequent reduction in the number of those inseminated with proven bucks because the total percentage of use of artificial insemination was not changed.

3. Results

3.1. Total profit and annual genetic response in the traditional and progeny test schemes

The annual genetic response for selection (Table 5) in the traditional scheme (US$ 0.26) was lower than that estimated for the progeny test scheme (US$ 0.99). The progeny test was more

Table 4
Genetic (above diagonal) and phenotypic (below diagonal) correlations used in the simulation for the goat breeding program.

	MY	LL	AFK	KI	SCC	DS	PROT	FAT
MY	–	0.760	−0.392	−0.044	0.060	0.592	−0.286	−0.138
LL	0.289	–	−0.241	−0.001	−0.009	0.002	0.000[a]	0.000[a]
AFK	−0.140	0.301	–	−0.183	0.045	−0.012	0.000[a]	0.000[a]
KI	0.094	0.000	−0.170	–	0.031	−0.305	0.000[a]	0.000[a]
SCC	0.010	−0.002	0.009	0.005	–	−0.055	−0.130	−0.190
DS	−0.040[b]	0.090[b]	0.186[b]	0.127[b]	−0.011	–	0.000[a]	0.000[a]
PROT	−0.391	0.060[b]	0.000[b]	0.000[b]	0.336	0.689[b]	–	0.563
FAT	−0.141	0.090[b]	0.179[b]	0.137[b]	0.317	0.870[b]	0.010	–

MY: milk yield; LL: lactation length; AFK: age at first kidding; KI: kidding interval; SCC: somatic cell count; DS: dry milk solids; PROT: milk protein content; FAT: milk fat content.

[a] When no value was found in the literature it was considered as zero.
[b] Estimated from CAPRAGENE databank.

Table 5
Results for the two selection schemes evaluated to Brazilian goat breeding program concerning all population of 600,000 goats, with 10% of use of the bucks from the breeding nucleus on the commercial flocks and 10% of young bucks in the scheme of progeny testing.

Variable	Traditional		Progeny test	
	Δ*G*	**GP (US$)**	**Δ*G***	**GP (US$)**
Breeding goal	US$ 0.26	0.315	US$ 0.99	7.458
Milk yield	19.31 kg	0.306	31.00 kg	3.130
Lactation length	1.98 days	0.025	4.12 days	0.326
Age at first kidding	−3.33 days	−0.007	−4.52 days	−0.067
Kidding interval	−0.13 days	0.000	−0.52 days	−0.009
Somatic cell count	0.72 cell/ml	−0.008	−58.48 cell/ml	4.072
Dry milk solids	0.05%	0.000	0.11%	0.006
Generation interval	5.63 years		5.73 years	
Fixed costs/doe	US$ 0.08		US$ 0.08	
Variable costs/doe	US$ 2.46		US$ 6.15	
Total costs/doe	US$ 3.53		US$ 7.21	
Total genetic profit/doe	US$ 0.31		US$ 7.46	
Net present value/doe	US$ −3.22		US$ 0.24	

Δ*G*: annual genetic response; GP: genetic profit/doe.

profitable (US$ 7.46) than traditional selection (US$ 0.31) when analyzing the genetic profit/doe. It is important to emphasize that genetic profit according to ZPLAN is the genetic response in the breeding objective (for all traits). The selection groups with higher contribution for total genetic profit/doe in the traditional scheme were those that involved the selection for nucleus does (Table 6), while the selection of proven bucks to mate commercial does presented a higher contribution to progeny testing (49.2%). The indices for the traditional scheme presented a low correlation with the breeding goal, with values below 0.3, in contrast to the progeny test scheme in which indices presented accuracies higher than 0.58 (Table 6).

The genetic response for MY in the traditional scheme (19.31 kg/year) was lower than in the progeny test (31.00 kg/year). The annual genetic response and genetic profit/doe for LL were positive for both schemes (1.98 days/year and US$ 0.025 for the traditional selection, and 4.12 days/year and US$ 0.326 for the progeny test).

The selections made in the two schemes reduced the AFK (−3.33 days/year in the traditional selection and −4.52 days/year in the progeny test) and KI (-0.13 days/year in the traditional selection and -0.52 days/year in the progeny test). However, both schemes had negative impacts on the genetic profit per doe for these traits. The profit for AFK was US$ -0.007 in the traditional selection and US$ -0.067 in progeny test. The profit for KI was US$ 0.000 and US$ -0.009 in the traditional selection and the progeny test, respectively (Table 5).

The genetic change in the trait SCC was positive in the traditional selection scheme (0.72/year) and negative in the progeny test (−58.48/year). The genetic profit/doe for DS was null in the traditional selection and low (US$ 0.006) in the progeny test.

Obviously, the variable costs in the progeny test were higher than in the scheme of traditional selection, due to the inclusion of expenses such as the measurement of milk quality, cost of a semen dose, cost of semen storage, annual collection of semen of proven and young bucks, plus a 2% increase in wages (changing to 12%) for data processing and communication.

The net present value was obtained by subtracting the full costs from the total genetic profit. The traditional scheme showed negative net present value (US$-3.22; Table 5), meaning that even having shown positive total genetic profit, the scheme has failed to cover the costs for its implementation. In turn, the scheme that performed progeny testing of young bucks showed positive net present value (US$ 0.24; Table 5).

3.2. Economic impact of the change in percentage of use of bucks from the breeding nucleus on commercial stratum in the traditional scheme

The increase in usage of bucks from the breeding nucleus on commercial flocks reduced economic losses in the traditional scheme; however, even with 100% use of nucleus bucks on commercial flocks, the plan was not profitable (Table 7). This higher use increased the genetic change for MY, LL, AFK and SCC but did not generate changes for KI and DS.

3.3. Intensity effects of using young bucks for the scheme with progeny test

The increase in use of young bucks consequently reduced the use of proven bucks because the total use of bucks (young or proven) was not altered. Thus, the increased use of young bucks, between 10% and 20%, showed a small improvement in monetary genetic profit per year for the purpose of selection (from US$ 0.99/year to US$ 1.02/year), although the net present value per doe reduced with this increase (from US$ 0.24/year to US$ 0.15/year; Table 8). There were reductions in the genetic profits of all traits in the breeding goal, except KI and DS.

Table 6
Selection intensity, accuracy of the selection index, and genetic profit according each selection group for the two selection schemes evaluated to goat breeding program.

	Traditional					
	NB > NB	ND > NB	NB > ND	ND > ND	NB > CB	NB > CD
Selection intensity	2.890	1.443	2.890	1.443	2.539	1.792
Accuracy (r_{ai})	0.133	0.284	0.133	0.284	0.133	0.133
Genetic profit/doe (% from total)	0.053 (17%)	0.062 (20%)	0.064 (20%)	0.074 (23%)	0.018 (6%)	0.044 (14%)

	Progeny test								
	PB > YB	ND > NB	YB > ND	PB > ND	ND > ND	YB > CB	PB > CB	PB > CD	YB > CD
Selection intensity	2.663	1.443	2.792	2.663	1.443	2.792	0.381	2.792	0.381
Accuracy (r_{ai})	0.692	0.581	0.692	0.692	0.581	0.692	0.692	0.692	0.692
Genetic profit/doe (% from total)	1.655 (22.2%)	0.861 (11.5%)	0.121 (2%)	0.693 (9%)	0.415 (5.6%)	0.000 (0%)	0.000 (0%)	3.670 (49.2%)	0.043 (0.5%)

NB – nucleus buck; ND – nucleus does; CB – commercial bucks; CD – commercial does; PB – proved bucks; YB – young bucks.

Table 7
Economic impact of the percentage of use of the bucks from the breeding nucleus on the commercial flocks in the traditional scheme.

	Breeding Goal (US$)	Net present value/doe (US $)	Genetic profit / doe (US$)					
			MY	LL	AFK	KI	SCC	DS
20%	0.26	−3.07	0.45	0.04	−0.01	0.00	−0.01	0.00
30%	0.26	−2.94	0.58	0.05	−0.01	0.00	−0.01	0.00
40%	0.26	−2.81	0.70	0.06	−0.02	0.00	−0.02	0.00
50%	0.26	−2.69	0.82	0.07	−0.02	0.00	−0.02	0.00
60%	0.26	−2.58	0.92	0.07	−0.02	0.00	−0.02	0.00
70%	0.26	−2.48	1.02	0.08	−0.02	0.00	−0.03	0.00
80%	0.26	−2.38	1.12	0.09	−0.03	0.00	−0.03	0.00
90%	0.26	−2.29	1.20	0.10	−0.03	0.00	−0.03	0.00
100%	0.26	−2.21	1.28	0.10	−0.03	0.00	−0.03	0.00

MY: milk yield; LL: lactation length; AFK: age at first kidding; KI: kidding interval; SCC: somatic cell count; DS: dry milk solids. Fixed costs = US$ 0.08.

Table 8
Economic impact of the percentage of use of young bucks in progeny testing.

	Breeding goal (US$)	Net present value/doe (US$)	Cost /doe (US$)	Genetic profit/doe (US$)					
				MY	LL	AFK	KI	SCC	DS
10%	0.99	0.24	7.21	3.13	0.33	−0.07	−0.01	4.07	0.01
15%	1.01	0.19	7.10	3.09	0.31	−0.06	−0.01	3.96	0.01
20%	1.02	0.15	6.99	2.99	0.29	−0.06	−0.01	3.93	0.01

MY: milk yield; LL: lactation length; AFK: age at first kidding; KI: kidding interval; SCC: somatic cell count; DS: dry milk solids.

4. Discussion

4.1. Considerations about simulation models

The results of this study are dependent upon the set of input parameters and represent two points in the parameter space, which is one of the limitations of simulation. In the deterministic approach, there are insufficiencies due to the lack of accounting for reduced genetic variance due to selection and inbreeding and risks inherent in the selection scheme, which are important in small populations and small groups. Compared to stochastic simulation models, its advantages are multi-trait modeling, including return and costs over a given time horizon and fast time for running (Willam et al., 2008). The stochastic models are limited by their high computational requirement. Nevertheless, our results, despite possible overestimation secondary to the available parameters, are realistic and could be extrapolated to similar situations. Most importantly, this research proved that different schemes can produce important genetic gains, but some do not compensate for the costs of the investments.

4.2. Genetic gain for the breeding goal and its traits

The greatest genetic profit for breeding goals in the progeny test was due to the highest correlations (r_{ai}) between the indices used in the optimization and the breeding objective (in the traditional scheme, the r_{ai} were 0.13 and 0.28 for the indices used in the selection of bucks and does, respectively, while the r_{ai} were 0.69 and 0.58 for bucks and does in the progeny test). The higher accuracy in the selection of the does than expected in the selection of the bucks limits the efficiency of the traditional scheme because males tend to have a higher contribution in breeding programs. The difference between the traditional scheme and the progeny test is much higher in genetic profit (2267%) than in the annual genetic response (281%). This was a function of factors such as the selection of proven bucks for commercial does (49.2% of the genetic profit/doe in the progeny test came from this selection group), faster genetic dissemination with higher selection intensity due to AI and inclusion of more selection criteria, mainly the trait somatic cell count. In the progeny scheme, there were more gains in other traits as well. We evaluated a third scheme (the traditional scheme with the same selection criteria, especially SCC, as the progeny test) and observed loss in genetic gain and negative economic impact for MY but higher genetic gain and economic profit for SCC. The phenotypic and genetic correlations between SCC and milk yield are positive, and the first has a negative economic value. In the traditional scheme, there was an increase in annual genetic response, and its contribution to the genetic profit was low. Nevertheless, in the progeny test, there was a decrease in the genetic response with a consequent high contribution to genetic profit.

An increase in somatic cell count can be caused by mastitis and can cause reductions in milk yield and changes in its composition (Andrade et al. 2001). The reduction in SCC in the progeny test promoted a high genetic profit (US$ 4.07). This value ranked this trait as the first in importance in the progeny test scheme. These results may be related to its economic negative weight, where selection would act to reduce the trait, and its heritability as superior to that for milk yield, the second trait of importance for progeny test and the first in the traditional scheme. De Cremoux et al. (1999) observed that lactations with SCC of more than 1.6 million cells/mL produced 21.2% less milk than those with counts less than 200,000 cells/ml. Decreased fat and protein produced was also observed.

The genetic gain for milk yield in both schemes outperformed the genetic trends observed by Lôbo and Silva (2005) for Anglo-Nubian (1.05 kg/year) and Saanen (0.65 kg/year) goats. In turn, Gonçalves et al. (2002) reported negative values (-0.8109 kg/year), indicating that in practice, selection for milk yield in Brazil is lower than the expected. Importantly, the estimates in this study refer to a deterministic simulation, which does not predict variations, assuming constant conditions and explaining the differences in the values observed in real situations. However, it is possible to assess the trend and demonstrate the possibility of significant gains. Comparisons among studies are not precise due to differences among their objectives, criteria of selection, population structure and parameters used. Abegaz et al. (2014) reported genetic gains ranging from 0.0066 to 0.0114 kg of daily milk yield for Abergelle goats when evaluating one tier community-based breeding schemes with four different scenarios in Ethiopia. These authors used the daily milk yield, which is different from our study, which considered total milk yield in lactation.

Milk yield represented approximately 97% and 42% of genetic profit per doe for the purpose of selection of the traditional and progeny test schemes, respectively. This result was expected because this is the main trait in any system of goat milk yield in Brazil, and it has high economic value. In dairy cattle, Balaine et al. (1981), Harder et al. (2004) and Kahi et al. (2004) also reported that the highest genetic profit is related to milk yield.

The positive genetic response and genetic profit for lactation length were expected as a function of their correlations with milk yield. Regarding the reproductive traits of age at first kidding and kidding interval, the genetic responses were in the expected direction (decreasing) in both schemes. However, this contributed to the genetic profit negatively because these traits have positive economic values. Generally, breeders ensure that their animals have lactations as long as possible. This promotes increased KI, hence the positive economic value for this trait. These results may be related to negative genetic correlations between these traits and milk yield. In one real life situation for one flock in Brazil, Lôbo and Silva (2005) reported a positive genetic trend (1.78 day/year) for age at first kidding in Anglo-Nubian goats and no genetic trend in the Saanen breed.

The genetic responses for dry milk solids were low but positive in both schemes, although it had not been considered as a selection criteria in the traditional scheme. The positive genetic correlation of this trait with milk yield explains this result. However, the genetic change in the traditional scheme was not sufficient for a significant contribution to genetic profit. Its contribution to the genetic profit of the breeding objective was also low in the progeny test. Its economic value is low, especially when compared to milk yield and lactation length. In Brazil, there is no differential payment for milk quality, as there is in other countries. In France, the selection performed does not aim at increasing the milk yield but at increasing its components, particularly protein and fat (Barillet, 2007).

4.3. Net present values for the schemes

The negative net present value for the traditional scheme was related to the low correlation between the criteria and the objective of selection and the low accuracies of the optimized indices. Therefore, this scheme does not justify the maintenance of physical and human infrastructure to run a program of animal breeding. This highlights the importance of economic evaluation of a breeding program because when considering only the genetic response, the traditional scheme was suitable. In Jordan, Al-Atiyat et al. (2010) reported a net present value of 0.264 € per doe for a two closed tier scheme in which bucks were only disseminating from nucleus to commercial farms. This value corresponded to US$ 0.32 in the period that this study was performed and was superior to that observed here for progeny testing.

The net present value for the progeny test represented approximately 3% of the genetic response to the selection objective (net present value per doe/total genetic profit per doe). This return on investment shows that the breeding program using progeny testing of young bucks is feasible but could be improved. Nitter et al. (1994), when evaluating a selection scheme for cattle in Australia, reported investment returns from a breeding program of approximately 20%. König et al. (2009) reported a genetic response for the purpose of selection equal to 48%, while Harder et al. (2004) and Chen et al. (2011) found genetic responses of 57% and 54%, respectively. Higher results (70%) were verified by Lôbo et al. (2000) when evaluating dual-purpose cattle in Brazil, with a greater emphasis on milk yield. According to these last authors, this total genetic profit is expressed by the monetary value of genetic changes observed in the animals selected during the investment period. Considering the somatic cell count in the selection also favored the increase in total genetic profit for the progeny test because there was high profit for this trait in all selection groups.

4.4. Use of nucleus bucks on commercial stratum in the traditional scheme

With respect to the economic impact of the change in percentage of nucleus bucks used in commercial stratum in the traditional scheme, genetic profit overall for traits almost tripled during the analyzed interval, except for kidding interval and dry milk solids. However, this was not sufficient to modify the annual genetic response for the breeding goal and to make the scheme profitable. This occurred because even with more use of selected bucks, the indices present low correlation with the breeding aim. This evaluation confirmed that the traditional scheme has low viability.

4.5. Level of use of young bucks in testing

In practical terms, there is no advantage to promoting increased use of young bucks in the progeny test because the changes in genetic responses for the breeding goal were not compensated for due to the reduction in the net present value. The high percentage of use of young bucks represents a higher number of does available for testing, as they are not mated with the proven bucks that present a higher contribution in profit/doe. As a consequence, there was a reduction in the genetic gain for some traits and reduction in economic gains for the population as a whole, due to increased costs from the highest number of young bucks in testing.

4.6. General considerations

The results obtained here are applicable only to the selection schemes considered, and they may differ when biological and economic parameters are different. Thus, it becomes essential to evaluate a wider range of schemes, taking into account the specific conditions of each region. It is necessary to obtain specific parameters in each situation evaluated. Before the deployment of large breeding programs, pilot studies should be performed to verify their economic viability. During all phases of establishment, the needs and interests of the breeders, as well as the system sustainability must be taken into consideration.

The results (genetic gains and profit) of this study proved that the progeny testing scheme is feasible under conditions in developing countries. However, policy makers have a detached role. Because there are needs for infrastructure for research, the use of AI, performing of official milk records, etc., the stimulus to establish companies providing such services is necessary. This can be reached with specific policies for the goat producer sector, such as particular legislation (primarily health and on reproductive aspects), tax incentives, investment plans for the acquisition of proven genetic material (semen and animals) with affordable interest rates, establishment of public–private partnerships, etc.

5. Conclusion

It is worth running a progeny test in developing countries, despite the difficulties in performing it. The execution of a breeding program with this selection scheme is justified because it generates profit. The traditional selection scheme has no economic viability and does not cover the costs of physical and human infrastructure to maintain it. The economic return from the progeny testing scheme outweighs the costs, with an investment return of approximately 3%. In this scheme, the trait of greater economic impact was somatic cell count, followed by milk yield.

The intensity of use of young bucks should not exceed 10% because higher use does not promote considerable increases in monetary gains to the selection objective, and it will reduce the net present value of the program.

Conflict of interest

There is no conflict of interest in this study.

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