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Comparison of selection indexes for dairy goats in the tropics

Fernando Brito Lopes[1*], Marcelo Corrêa da Silva[1], Eliane Sayuri Miyagi[1], Maria Clorinda Soares Fioravanti[1], Olivardo Facó[2] and Concepta McManus[3]

*[1]Programa de Pós-graduação em Ciência Animal, Escola de Veterinária e Zootecnia, Universidade Federal de Goiás, Cx. Postal 131, 74001-970, Campus II, Goiânia, Goiás, Brazil. [2]Embrapa Caprinos e Ovinos, Sobral, Ceará, Brazil. [3]Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil. *Author for correspondence. E-mail: camult@gmail.com*

ABSTRACT. The selection process in dairy goat was evaluated by selection indexes. Basal population of 1,000 does, randomly mated by 50 unselected and unrelated bucks, was simulated. Eight selection indexes in two production systems (intensive - indexes I-IV and semi-intensive - indexes V-XIII) were compared. Three groups of dairy goats (A, B and C) were simulated with a respective intensity of 10, 25 and 50%. Each group was composed of five generations and each generation was replicated 20 times. All traits were simulated using matrices of direct additive genetic and the residual (co)variance and the effect of Mendelian segregation. Statistical analyses were performed by repeated measurements in time. Selection using the suggested indexes improved all traits. Selection indexes III and VII are suggested due to simultaneous production and reproduction trait improvement. Indexes IV and VIII are recommended when higher rates of total solids and somatic cell count occur and would correspond to differentiated payment for the milk.

Keywords: first calving, milk, breeding goals, selection criteria, total solids.

Comparação de índices de seleção de caprinos leiteiros em regiões tropicais

RESUMO. Objetivou-se avaliar o processo de seleção de caprinos leiteiros utilizando-se índices de seleção. Foi simulada população a base composta por 1.000 fêmeas, acasaladas aleatoriamente com 50 reprodutores, não selecionados e não aparentados. Foram comparados oito índices de seleção em cada sistema de criação: intensivo (índices I-IV) e semi-intensivo (índices V-VIII). Foram simulados três grupos de caprinos leiteiros (A, B e C), utilizando-se intensidade de seleção de 10, 25 e 50%, respectivamente. Cada grupo foi composto por cinco gerações e cada geração foi replicada 20 vezes. Todas as características foram simuladas utilizando-se as matrizes de (co) variância genética aditiva direta, residual e o efeito da segregação Mendeliana. As análises estatísticas foram realizadas por meio de medidas repetidas no tempo. A seleção realizada por meio dos índices propostos promoveu melhorias em todas as características. Sugere-se a utilização dos índices III e VII, por promoverem melhorias simultâneas nas características produtivas e reprodutivas. Da mesma forma, sugere-se a utilização dos índices IV e VIII havendo pagamento diferenciado por maiores teores de sólidos totais e à contagem de células somáticas.

Palavras-chave: primeiro parto, leite, objetivo de seleção, critério de seleção, sólidos totais.

Introduction

Increasing food demand in tropical regions is a consequence of rapid human population growth. Milk production of dairy goats is on the increase in the tropics (FAO, 2009) and it is estimated that total milk production will double in the next twenty years (FAO, 2007). Due to increasing buying power in many countries (such as Brazil), the pressure on systems to produce more without an increase in farming area is growing. Consequently, selection indexes may increase dairy goat production and help decrease food demand in tropical regions owing to the simultaneous improving of production and reproduction traits.

Besides being a meat, milk and clothing supply source in domestic markets, goat farming in the tropics is important for household income in many rural homesteads (KOSGEY et al., 2006). The relative importance of milk varies from one region to another due to ecological, economic and cultural factors. In the wake of intensification in land use and high population pressure, goat farming is gaining importance in small farmstead systems lying in favorable locations (BETT et al., 2007).

Although in Brazil several goat breeds have been imported to improve production and reproduction efficiency, selection methods may only be defined if their genetic resource availability is properly and fully understood. The determination of breeding goals has been pointed out as the first and crucial step to develop successful breeding programs (DUBEUF; BOYAZOGLU, 2009; LÔBO et al., 2010).

In 2005 the EMBRAPA Goat and Sheep created the Dairy Goat Breeding Program. The program aimed to structure the dairy goat national data bank and to conduct progeny tests for the main dairy breeds raised in the country. Supported by the Brazilian Ministry of Agriculture, the Goat and Sheep Breeders Association of the state of Minas Gerais (ACCOMIG – CAPRILEITE) and by EMBRAPA Goat and Sheep, the Official Dairy Control Test has been carried out by technicians of the Brazilian Association of Holstein Breeders (ABCBRH) with an average of 45 days between tests. Some breeders have been carrying out several analyses for milk protein, fat, lactose, total solids contents and somatic cell count. The Official Dairy Control Test has been carried out in eleven herds in the states of Minas Gerais, Rio de Janeiro and São Paulo (the southeastern region of Brazil) (LÔBO et al., 2010). Descriptions of the national breeding program may be found in Facó et al. (2011) who state that current selection criteria were mainly designed to respond to market demands. They are focused on milk yields, length of lactation period and reproductive traits, without any formal use of selection index theory.

According with Miglior et al. (2005), most selection indexes worldwide focus on increasing milk production. Brazilian selection indexes are based on improving milk yield with a gradual shift towards improvements of protein yield and, with the exception of North America, towards increasing fat and especially protein rates. This is true for most countries with the exception of Scandinavia, whose selection indexes also included health and reproduction, and North American countries, whose selection indexes included conformation and production. According to these authors, there has been a growing interest in broadening selection indexes to include functional traits such as reproduction and health. The main reasons for such a shift include quota-based milk marketing systems, price constraints, or both, increasing producer and consumer concerns associated with reported deterioration of the dairy systems' health and reproduction.

Selection indexes, including the economic weights of important traits for dairy goat, may be promoting the simultaneously improvement of group traits. Many authors (CUNNINGHAM; TAUEBERT, 2009; LAMBE et al., 2008; NIELSEN et al., 2005; ŠAFUS et al., 2006) working with selection indexes have shown that the selection index is a highly precise manner for animal selection with regard to several traits, since the relationship between all traits, comprising breeding value and economic weight, is taken into account. The use of selection indexes is an important implement for dairy goat systems, because the use of these indexes may improve trait groups simultaneously (HAZEL, 1943). Current investigation simulates and analyzes the selection process of dairy goat herds by selection indexes.

Material and methods

Current analysis reports on Brazilian literature and data on the production and economic weights for intensive and semi-intensive dairy goat system in Brazil (BARROS et al., 2005; GONÇALVES et al., 2008; MEDEIROS et al., 2006; QUEIROGA et al., 2007; RODRIGUES et al., 2006; VIEIRA et al., 2009). A deterministic and static bio-economic model was used in herd simulation and Microsoft Excel spreadsheets were employed to estimate production and reproduction performances, costs and income. The economic values (EV) for the traits were obtained by the difference between average profits (AP) before and after improvement (EV = AP' – AP), where AP' is the average profit after 1% increase in the traits, keeping other traits unchanged.

Hazel (1943) defined the aggregate genotype H for a given individual as the sum of its genotypes for several traits (assuming a distinct genotype for each economic trait), with each genotype weighted by their predicted contribution to the increase in the overall objective. This contribution is determined by the so-called cumulative discounted expressions and economic rates. The cumulative discounted expression of a trait reflects time and frequency of the future expression of a superior genotype originating from the use of a selected individual in a breeding program (BRASCAMP, 1975). Multiplying the economic value by the cumulative discounted expression provides the discounted economic value. The following equations illustrate the principles above:

$$H = a_1BV_1 + a_2BV_2 + \ldots + a_iBV_i$$

where BV_i is the breeding value for trait; a_i is the discounted economic value for trait i. The discounted economic value is $a_i = c_i \times v_i$, where, c_i is a cumulative discounted expression for trait i; and v_i is the economic value of trait i.

Once a linear breeding goal has been developed and the economic rates of economic traits have been estimated, the selection index theory (HAZEL, 1943) is used to derive a linear selection index, which predicts the breeding goal as accurately as possible, from the information available in the form of EBV for individual traits:

$$I = b_1EBV_1 + b_2EBV_2 + ... + b_iEBV_i$$

where EBV_i is the estimated breeding rate for trait i; b_i is the index weight on EBV_i.

Index weight was estimated by the MTINDEX program (VAN DER WERF, 1999) (Table 1). The gene flow discounted was given by GFLOW program (BRASCAMP, 1975; HILL, 1974).

Basal population (which represents founder parents) was composed of 1,000 goats, randomly mated with 50 unselected and unrelated bucks. In each new generation, new bucks were simulated and mated with the selected females. This was necessary to avoid mating of inbred animals. Females with low genetic rates, predicted by selection indexes (Table 1), were discarded.

The evolution of milk production (MP), lactation length (LL), age at first calving (AFC), calving interval (CI), somatic cell count (SCC) and total solids (TS) in three herds (A, B and C) was performed by Monte Carlo simulation for five generations, with each generation repeated 20 times. Simulation comprised the three herds with the same basal population and the females selected at 10, 25 and 50% intensity, respectively. Eight selection lines were used with different selection indexes and production systems (intensive or semi-intensive; Figure 1), defined in Lopes et al. (2012).

The mathematical model $Y_i = \mu + a_i + e_{ij}$ simulated the traits, where *Yij* is the trait (MP, LL, AFC, CI, SCC and TS); a_i is the direct additive genetic effect; e_{ij} is the residual effect. All traits were simulated with matrixes of direct additive genetic and residual (co) variance (Table 2) and the effect of Mendelian segregation. Breeding rates for the direct additive genetic and residual effects for the basal population were taken randomly from a multinormal distribution with mean zero and variance σ^2a (a~N - 0, σ^2a) and σ^2e (e~N - 0, σ^2e), respectively.

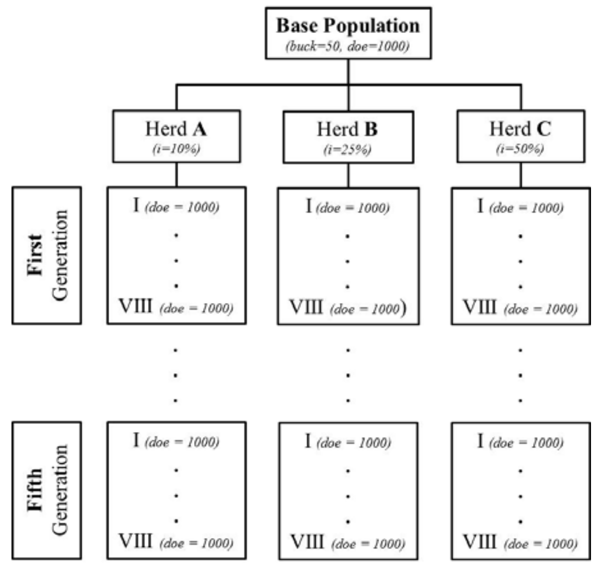

Figure 1. Simulation steps of herd structure.
i: percentage of selected animal (10, 25 and 50%); I to VIII: sub-groups.

The residual and genetic (co)variance matrix (Table 2), positively defined (VAN DER WERF, 1999), was estimated using the phenotypic and genetic parameters from Brazilian and international literature (AFOLAYAN et al., 2009; AHUYA et al., 2009; ANDRADE et al., 2007; BAGNICKA et al., 2007; BARILLET, 2007; BARILLET; BONAÏTI, 1992; BERRY et al., 2003; BUTCHER et al., 1966; CORBET et al., 2006; EKNÆS et al., 2006; LEGARRA; UGARTE, 2005; LÔBO; SILVA, 2005; PIMENTA FILHO et al., 2004; PIMENTA FILHO et al., 2009; QUEIROGA et al., 2007; RIGGIO et al., 2007; SOARES FILHO et al., 2001; TORRES-VÁSQUEZ et al., 2009; TOSHNIWAL et al., 2008; VALENCIA et al., 2007; ZHANG et al., 2009).

Table 1. Selection indexes for intensive and semi-intensive dairy goat systems in Brazil.

System	Index	Traits					
		MP	LL	AFC	CI	SCC	TS
Intensive	I	11.23	7.92				
	II	9.88	7.01	1.37			
	III	6.91	7.35	-2.46	-1.11		
	IV	3.40	7.89	-2.99	-1.94	-17.67	46.96
Semi-intensive	V	8.44	6.97				
	VI	8.83	5.83	1.09			
	VII	7.99	6.77	-1.99	-0.63		
	VIII	3.21	6.94	-2.17	-1.15	-14.99	44.22

MP: milk production; LL: lactation length; AFC: age at first calving; CI: calving interval; SCC: somatic cell count; TS: total solids; r_{HI}: accuracy of selection index.

Table 2. Positive matrix of covariance (above diagonal) and variance (in diagonal) for the direct additive genetic and residual effects.

Trait	MP	LL	AFC	CI	SCC	TS
	Direct additive genetic (co)variance					
MP	1019.466	211.497	-470.017	-649.490	-3.715	552.573
LL		691.421	-237.439	-1.622	-0.292	1.800
AFC			1407.563	-835.111	2.145	-13.229
CI				2154.358	1.842	-11.363
SCC					1.616	-2.044
TS						854.282
	Residual (co)variance					
MP	5015.153	1126.296	2286.597	2862.682	-23.406	2267.077
LL		2869.994	1769.785	0.003	-0.061	-0.010
AFC			5889.316	5465.974	0.030	0.005
CI				12859.004	-0.037	-0.006
SCC					5.642	0.135
TS						3299.502

MP: milk production; LL: lactation length; AFC: age at first calving; CI: calving interval; SCC: somatic cell count; TS: total solids.

All traits were simultaneously simulated by the positive defined genetic and residual (co)variance matrix (Table 2). Thus, the direct additive genetic effects between two traits were considered genetically correlated. This process refers to Cholesky decomposition of the G Matrix of genetic (co)variance:

$$G = \begin{pmatrix} \sigma_{a1}^2 & \sigma_{a1a2} \\ \sigma_{a1a2} & \sigma_{a2}^2 \end{pmatrix} = \begin{pmatrix} C_{11} & 0 \\ C_{21} & C_{22} \end{pmatrix} \times \begin{pmatrix} C_{11} & C_{12} \\ 0 & C_{22} \end{pmatrix},$$

where C is a lower triangular matrix with rates C_{11}, C_{12} and C_{22} which corresponds respectively to the σ_{a1}^2, σ_{a1a2}^2 and σ_{a2}^2 components.

Next generations were then simulated taking into account that the rate of an individual (g_n) is equal to the average rate of the parents (g_d and g_b), plus deviation due to Mendelian segregation, or rather, $g_n = ((g_d + g_b) \div 2) + SM_a$ (ANALLA et al., 1995; CLÉMENT et al., 2001). Mendelian segregation rates (SM_a) were simulated by $SM_a = z_n \times C_{ij}$, where SM_a is the random Mendelian segregation due to direct additive genetic effects; z_n represents normally distributed random deviations; C_{ij} is the terms of Cholesky decomposition of the G matrix. Mendelian segregation rates were independently estimated from direct additive genetics (BULMER, 1971). The Cholesky decomposition was obtained by *ROOT* function of procedure Interactive Matrix Language - PROC IML (SAS, 2002).

The model used in repeated measure was $Y_{ijk} = \mu\mu +_i + Y_j + (TY)_{ij} + e_{ijk}$, where Y_{ij} is the traits of j[th] generation and of i[th] index; μ is a constant; T_i is the effect of i[th] index (I, II, III, IV, V, VI, VII andVIII); Y_j is the effect of j[th] generation; $(TY)_{ij}$ is the effect of interaction between the index and generation; e_{ij} is the error.

The Mauchly sphericity test was carried out to analyze whether covariance matrix sums were in accordance with HUYNH-FELDT (H-F) conditions (MAUCHLY, 1940). The test evaluates whether a multivariate normal population presents equal variance and null (zero) correlations. The criteria for the test's interpretation were reported by Fernández (1991).

The following hypothesis was tested in the multivariate analysis: H_{01} – no effect of the generation; H_{02} – no interaction effect between the index and generation; H_{03} – no effect of index. The Lambda-Wilks test was used to analyze these hypotheses ($p < 0.01$).

Comparisons were made between the basal population and the fifth generation by Tukey's test and 20 repetitions per simulation. The repeated measures of variance procedures (PROC GLM) tested the effects of generation, index and interactions among them (SAS, 2002).

Results and discussion

The Maunchly sphericity test shows that sphericity condition was not violated ($p > 0.05$). The (co)variance matrix may be considered a Huynh-Feldt type and the analysis may be uni- or multivariate (VIEIRA et al., 2007). As the traits could be analyzed and discussed individually or combined, a repeated measure analysis was carried out.

Since there was no statistical difference ($p > 0.05$) between generation or any interaction between the index and the generation (Lambda-Wilks), selection indexes show similar results between indexes over the generations. However, there was a difference ($p < 0.01$) among the animals' traits (MP, LL, AFC, CI, SCC and TS) in the basal population and those of the fifth generation (Table 3). It may be stated that selection indexes may improve the selection criteria used in the dairy goat system (MP, LL, AFC, CI, SCC and TS).

Only milk production presented statistical differences ($p < 0.01$) between intensive and semi-intensive systems. Minor selection intensity resulted in a greater variability of selection criteria (Table 3). This is due to the number of animals used per selection intensity (10, 25 or 50%). When a smaller fraction of superior genotypes is selected (PEIXOTO et al., 2005; SIMONELLI et al., 2004), better animals contribute towards the improvement of selection criteria.

Milk yield average was similar ($p > 0.01$) among the selection indexes (Table 3). Since the lactation length is a criterion that cannot be evaluated alone, the most accurate way to determine the best index for this selection criterion is using the ratio of MP and LL. In fact, a higher ratio between LL and MP indicates a more efficient and productive animal. There was no difference in milk production and better results were obtained with LL rates from III and VII indexes. These indexes showed better results for age at first calving and calving interval.

For somatic cell count and total solids, indexes IV and VIII had the best results, regardless of the selection intensity of the latter. This was due to criteria inclusion in the selection indexes that improved simultaneously the production and reproduction traits.

Traits related to milk quality (total solids) and udder health (somatic cell count) are important in dairy production. In fact, several authors have proposed the use of somatic cell count as an indicator of mastitis (HERINGSTAD et al., 2008; KOIVULA et al., 2005; RUPP et al., 2009; SØRENSEN et al., 2009; VALLIMONT et al., 2009).

In dairy goat production, milk quality has an essential and fundamental importance so that the systems would remain competitive. Indexes IV and VIII in intensive and semi-intensive systems respectively promoted improvements in milk quality by increasing the amount of total solids. They also selected animals with lower susceptibility to mastitis, due to a decrease in somatic cells (Table 3).

Several studies have reported variability among dairy goats systems in Brazil. There are distinctions related to technology input, geographic region and use of specialized animals for the same intensive or semi-intensive system (BARROS et al., 2005; GONÇALVES et al., 2002; GONÇALVES et al., 2008; MEDEIROS et al., 2006; RODRIGUES et al., 2006; QUEIROGA et al., 2007; VIEIRA et al., 2009). Current study registered difference only for milk production ($p < 0.01$) among the dairy goat systems. In fact, the intensive system showed more production than that of the semi-intensive system.

Table 3. Average milk production (MP), lactation length (LL), age at first calving (AFC), calving interval (CI), somatic cell count (SCC) and total solids (TS).

Selection Intensity	Index	Trait					
		MP*	LL	AFC	CI	SCC	TS
10%	I	785.99^{aA}	369.18^{aA}	17.21^{aD}	8.59^{aD}	5.07^{aD}	14.39^{bA}
	II	776.10^{aA}	368.66^{aA}	17.14^{bD}	8.58^{aD}	5.06^{aD}	14.40^{bA}
	III	778.35^{aA}	358.87^{bA}	16.24^{cD}	8.01^{bD}	4.85^{aD}	14.41^{bA}
	IV	773.31^{aA}	368.90^{aA}	17.09^{aD}	8.53^{aD}	4.04^{bD}	14.97^{aA}
	V	787.11^{aA}	369.64^{aA}	17.14^{bD}	8.56^{aD}	5.08^{aD}	14.48^{bA}
	VI	781.57^{aA}	367.04^{aA}	16.21^{cD}	8.02^{bD}	5.08^{aD}	14.38^{bA}
	VII	774.92^{aA}	359.42^{bA}	17.14^{bD}	8.60^{aD}	4.89^{aD}	14.37^{bA}
	VIII	779.06^{aA}	368.98^{aA}	17.10^{bD}	8.56^{aD}	4.06^{bD}	14.91^{aA}
	R^2	0.76	0.87	0.96	0.96	0.91	0.95
25%	I	637.94^{aB}	329.91^{aB}	18.94^{aC}	8.99^{aC}	5.18^{abC}	12.89^{bB}
	II	629.74^{aB}	326.30^{aB}	18.37^{bC}	8.97^{aC}	5.17^{abC}	12.81^{bB}
	III	633.56^{aB}	309.00^{bB}	18.37^{bC}	8.83^{bC}	5.16^{bC}	12.82^{bB}
	IV	629.88^{aB}	325.88^{aB}	18.30^{bC}	8.81^{bC}	5.04^{cC}	13.01^{aB}
	V	627.75^{aB}	328.11^{aB}	18.99^{aC}	8.97^{aC}	5.14^{bC}	12.86^{bB}
	VI	627.03^{aB}	327.10^{aB}	18.31^{bC}	8.99^{aC}	5.19^{aC}	12.88^{bB}
	VII	631.85^{aB}	311.63^{bB}	18.39^{bC}	8.85^{bC}	5.17^{abC}	12.80^{bB}
	VIII	625.47^{aB}	326.96^{aB}	18.38^{bC}	8.84^{bC}	5.05^{cC}	12.99^{aB}
	R^2	0.75	0.79	0.93	0.92	0.93	0.87
50%	I	488.30^{aC}	290.16^{aC}	21.48^{aB}	9.87^{aB}	5.45^{aB}	12.09^{bC}
	II	485.93^{aC}	287.39^{aC}	20.65^{bB}	9.89^{aB}	5.41^{bB}	12.08^{bC}
	III	485.81^{aC}	287.31^{aC}	20.66^{bB}	9.33^{cB}	5.41^{bB}	12.07^{bC}
	IV	486.92^{aC}	291.24^{aC}	20.65^{bB}	9.50^{bB}	5.28^{cB}	12.27^{aC}
	V	482.86^{aC}	288.11^{aC}	21.49^{aB}	9.84^{aB}	5.49^{bB}	12.08^{bC}
	VI	484.72^{aC}	286.92^{aC}	20.66^{bB}	9.87^{aB}	5.46^{aB}	12.08^{bC}
	VII	485.34^{aC}	286.49^{aC}	20.66^{bB}	9.31^{cB}	5.41^{bB}	12.09^{bC}
	VIII	485.66^{aC}	288.42^{aC}	20.59^{bB}	9.51^{bB}	5.20^{cB}	12.23^{aC}
	R^2	0.81	0.79	0.92	0.93	0.94	0.98
Basal herd		$380,51^{D}$	222.29^{D}	23.29^{A}	11.93^{A}	6.99^{A}	10.49^{D}

R^2: coefficient of determination; ^{abc}Different lowercase superscripts in the column, for each selected fraction, indicate statistically significant differences ($p < 0.01$) by Tukey's test; ^{ABC}Different uppercase superscripts in the column indicate statistically significant differences ($p < 0.01$) by Tukey's test between fractions selected; *Difference ($p < 0.01$) existed between intensive and semi-intensive systems only for milk production.

Due to differences among dairy goat systems, the selection indexes were established to suit the most varied farm profiles (LOPES et al., 2012). Since breeding goals and selection criteria may vary among dairy goat farmers, the choice and use of each index must be established for each goat system.

For instance, if a farmer assesses only milk volume and lactation length, indexes I and IV should be used respectively for intensive and semi-intensive systems. On the other hand, if the farmer also assesses reproduction traits, such as age at first calving and calving interval, the animals may be simultaneously selected for production and reproduction traits (Indexes II, III, IV, VI, VII and VIII). It is thus possible to improve reproduction efficiency using early developing animals selected by the indexes proposed in current study.

The dairy goat market in Brazil is based on volume production. Few dairy industries have a differential payment for milk quality (somatic cell count and total solids). Dairy products such as cheese, butter, milk candy or drinks are of significant importance in terms of nutritional and economic rates (AL-TABBAA; AL-ATIYAT, 2009; LINDSAY; SKERRITT, 2003).

The selection of superior animals for milk composition through criteria such as total solids is therefore possible and improves milk-derived products (cheese, butter, milk candy or drinks). Thus, if there were differential payments for the production of goat milk with higher quality (total solids, protein and fat), indexes IV and VIII may be a future goal in Brazilian dairy goat production. On the other hand, goat milk is mainly used in Europe to produce several types of cheese and other dairy products, featuring protein and fat contents as an important breeding goal (LINDSAY; SKERRITT, 2003). Contrastingly, since fluid and raw milk is the major dairy goat product on the Brazilian market, different breeding goals, such as total milk volume, are highlighted.

The selection of multiple traits using selection indexes is the fastest way to improve production and reproduction efficiency coupled to the health of the herd. This occurs because information from many traits is used to produce a single rate that predicts the economic genetic merit of the animal to be selected (CUNNINGHAM; TAAUEBERT, 2009; LAMBE et al., 2008).

Conclusion

Improvement in all traits was reported when the indexes proposed were used. Indexes that include milk production, lactation length, age at first calving and calving interval should be used as selection criteria. In situations where differential payment for milk quality occurs, such as total solids and somatic cell count, the indexes with traits IV and VIII are suggested. The choice and use of indexes depend on the definition of selection objectives and on the measurability of the selection criteria to be used in dairy goats systems.

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