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Proportional hazard models associated with the survival of dairy goats reared in a tropical environment

Talita A. Ferreira[a,b], Paulo G.M.A. Martins[a,*], Gabriela C. Gouveia[b], Luíza R.A. Abreu[b], Aurora M.G. Gouveia[c], Olivardo Facó[d], Enrico A. Colosimo[e], Iraides F. Furusho-Garcia[f], Idalmo G. Pereira[b]

[a] Federal University of Jequitinhonha and Mucuri Valleys, Department of Animal Science, Diamantina, MG 39100-000, Brazil
[b] Federal University of Minas Gerais, School of Veterinary, Department of Animal Science, Belo Horizonte, MG 31270-901, Brazil
[c] Federal University of Minas Gerais, School of Veterinary, Department of Veterinary Preventive Medicine, Belo Horizonte, MG 31270-901, Brazil
[d] Embrapa Goats and Sheep, Sobral, CE 62010-970, Brazil
[e] Federal University of Minas Gerais, Department of Statistics, Belo Horizonte, MG 31270-901, Brazil
[f] Federal University of Lavras, Department of Animal Science, Lavras, MG 37200-901, Brazil

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ABSTRACT

Increasing the functional life of a doe in order to keep the most productive females in the herd as long as possible can result in a reduction of replacement costs because of the better utilization of the animal in the production system. Thus, the objective was to evaluate the influence of environment effect, and morphometric and type traits on the culling that limits the stay of a doe of an exotic dairy goat breed reared in a tropical climate in the herd (stayability). The data utilized in the present study had information of 1439 Saanen does, born between 2000 and 2015, from 17 herds. The stay in the herd for longer than 28 months of age (STAY28), that is lack of culling, was defined as successful; the does' records were then not censored (C = 1). On the other hand, does kept in the herd for less than 28 months had their records censored (C = 0), once we considered that she still would kid. Does sold to other farmers were considered censored. Information regarding birth year, birth season, herd, six morphometric traits, and 12 visual appraisal-scored traits were evaluated. The Cox proportional hazard rate and the Kaplan-Meier models were fitted to analyze the data. Birth year, body length, rump width, feet and legs soundness, udder, and teat conformation were the traits that affected STAY28. For each birth year, body length, and rump width, reductions of 4 %, 2 %, and 5 % were observed on the culling hazard of a doe, respectively. Does with great scores for traits related to the mammary system were prematurely culled from the herd. In conclusion, STAY28 can be used as a selection criterion based on the aforementioned morphological and type traits, since it is effective to early detect individuals that will stay longer and more productive in a herd. Therefore, these traits should be considered in breeding programs.

1. Introduction

The functionality of an animal in a herd is defined as its capacity to stay healthy and productive, regardless of its level of production (Ducrocq, 1987). In dairy production systems, it is interesting to keep the most productive females as long as possible. Thus, studies evaluating the length that animals stay in herds (longevity or stayability) are being developed to identify those that will remain longer and producing more.

The increase in the functional life of females can result in a decrease in the replacement costs because of the better utilization of the animal in the system. The association of stayability and profitability increases the importance of a doe staying longer in dairy production systems (Galeazzi et al., 2010; Sewalem et al., 2010). The criteria for dairy cow culling are based on milk production, pregnancy, lactation stage, age, health and animal conformation (Ducrocq et al., 1988). For dairy goats, the same criteria are utilized, thus, quantifying and determining how these factors influence the stayability of does in herds are extremely relevant. In addition to those traits, kidding number, litter size, birth weight, and kidding month are important factors affecting culling, thus defining stayability. Several previous reports of studies evaluating these traits are available in the literature (Pérez-Razo et al., 2004; Pellerin

* Corresponding author.
E-mail address: paulo.martins@ufvjm.edu.br (P.G.M.A. Martins).

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Table 1
Descriptive statistics of data analysis of censored (C = 0) and uncensored (C = 1) covariates of Saanen dairy goats reared in tropical environment considering the ability to not being culled (stayability) before 28 months of age.

Item	C = 0					C = 1				
	n	$\overline{X}$	SD	Minimum	Maximum	n	$\overline{X}$	SD	Minimum	Maximum
Body measurements, cm										
Withers height	235	75.19	4.03	65.00	86.00	1204	74.39	4.80	61.00	104.00
Thoracic perimeter	235	85.99	6.35	71.00	104.00	1204	88.21	6.72	65.00	115.00
Body length	235	77.85	5.77	64.00	98.00	1204	78.32	6.33	58.00	107.00
Rump height	235	74.55	4.31	62.50	92.00	1204	73.87	4.60	62.00	108.00
Rump width	235	19.39	4.51	9.00	37.00	1204	17.86	4.16	8.00	30.00
Rump length	235	22.81	3.13	12.00	29.00	1204	23.46	2.59	10.00	30.00
Visual appraisal scores, points										
Breed characteristic	235	4.96	0.23	3.00	5.00	1204	4.93	0.29	3.00	5.00
Head	235	4.94	0.25	3.00	5.00	1204	4.91	0.34	2.00	5.00
Shoulders and top line	235	6.26	0.80	4.00	8.00	1204	6.40	0.86	4.00	8.00
Feet and legs soundness	235	9.25	1.15	6.00	12.00	1204	9.11	1.22	2.00	12.00
Dairy type	235	16.10	1.88	11.00	20.00	1204	16.54	1.55	10.00	20.00
Body capacity	235	16.25	1.59	12.00	20.00	1204	16.36	1.68	9.00	20.00
Udder	235	6.65	1.46	1.00	10.00	1204	6.90	1.25	1.00	10.00
Rear udder ligament	235	3.61	1.30	1.00	5.00	1204	4.15	0.96	1.00	5.00
Front udder ligament	235	3.33	1.24	1.00	6.00	1204	3.90	1.09	1.00	6.00
Udder texture	235	3.52	1.14	1.00	5.00	1204	4.07	0.97	1.00	5.00
Teats conformation	235	2.67	0.82	1.00	4.00	1204	2.83	0.80	1.00	4.00
Final score	235	77.38	7.61	60.00	97.00	1204	80.13	6.68	60.00	98.00

n = number of observations; $\overline{X}$ = average; SD = standard deviation.

and Browning, 2012; Castañeda-Busto et al., 2014; Castañeda-Bustos et al., 2017; Valencia-Posadas et al., 2017). In these cases, the survival analysis methodology is indicated.

Survival analysis using proportional hazard models may provide useful information for stayability studies. These analyses allow the use of non-normal distributions and censored data, that is, those which the end of the event may be unknown (Colosimo and Giolo, 2006). It is desirable to determine culling criteria based on measurements that can be obtained earlier in a doe's life, avoiding the animal reaching two lactation cycles. Since morphometric and type traits are frequently collected during the first lactation, these traits could be an alternative to predict the longevity of a doe in the herd. The advantage of using these traits as selection criteria is related to the easiness of measurement after the first parturition and because they are associated with animal stayability, especially those related to the udder and animal size such as body depth and chest width. These variables were widely utilized as selection criteria in dairy cows (Boettcher et al., 1997; Vollema et al., 2000; Larroque and Ducrocq, 2001; Sewalem et al., 2005). However, studies evaluating the influence of these morphometric and type traits on the longevity of dairy goats are scarce.

The use of stayability in selection programs has been highlighted because allows the reduction of non-productive females in the herd. In this manner, the stayability in survival analyses allows predicting how long the animal will remain productive in a certain herd, besides knowing the factors that affect this permanence. Considering the abovementioned, the objective was to evaluate if the environment effect and the morphometric and type traits would affect the culling from the herd of does of an exotic dairy breed reared in a tropical environment before completing 28 months of age.

2. Materials and methods

2.1. Data

Institutional animal care and use committee approval was not requested for the present study because data were provided by the Association of Goats and Sheep Breeders of Minas Gerais ('Associação dos Criadores de Caprinos e Ovinos de Minas Gerais'; ACCOMIG), a subdelegate branch of the Brazilian Association of Goats Breeders ('Associação Brasileira de Criadores de Caprinos'; ABCC), from an existing database. The dataset had records of 1439 Saanen does from 17 different herds, reared in feedlots, born between 2000 and the beginning of 2015, with a definitive genealogical record. Does born in this time period had the opportunity to kid twice within 28 months of age. Does were kept in the herd at least for two years, in feedlot facilities, and weaned at approximately two months of age. These does were subjected to artificial insemination or controlled natural mating.

The database had information regarding birth year, birth season (1: March; 2: April; 3: May to July; and 4: August to February), herd, morphometric and type traits. The measurement and recording of the morphometric and type traits were performed after the first kidding by technicians accredited by the ACCOMIG. The type evaluations are carried out obligatorily for the registration of the animals, a practice approved by the Brazilian Ministry of Agriculture, Livestock, and Supply. Thoracic perimeter, body length, withers height, rump height, rump width, and rump length were considered as morphometric traits (all registered in centimeters); and type traits (determined by score) were breed characteristics (0–5 scale), head (0–5 scale),shoulders and top line (0–8 scale), feet and legs soundness (0–12 scale), dairy type (0–20 scale), body capacity (0–20 scale), udder (0–10 scale); rear (0–5 scale) and front (0–6 scale) udder ligaments, udder texture (0–4 scale), teats conformation (0–4 scale), and final score (0–100 scale). Only animals with all these parameters were considered in the analyses. Data organization and consistency checking were performed using the SAS (version 9.1; SAS Institute Inc., Cary, NC, USA) statistical software.

The ability of a doe not being culled before 28 months of age (STAY28) and to stay in the herd was considered as successful. This time period (28 months) was determined based on the lactation curve of dairy goats. Until 28 months of age, the does will be at the maximum starting their third lactation, since the age at first kidding ranges between 12 and 15 months and the kidding interval is 8 months (Sarmento et al., 2003; Gonçalves et al., 2008). Until the third lactation, milk production of the goats remains high, decreasing sharply from the fourth lactation onwards (Cabrita, 2013; Arnal et al., 2018). Censorship was considered when does were not successful and were culled from the herd. If this variable was greater than 28 months, we considered that the doe was successful and its registry was not censored (C = 1). On the other hand, does that stayed for less than 28 months in the herd had their registry censored (C = 0), that is, they did not have their observation completed in the study since it was considered the doe would kid in the future. Does sold to other producers were also considered censored; when the exact slaughtering date was missing, the last

registered kidding date was utilized as the slaughtering date. Does presenting more than 85 months of age were also censored. The descriptive statistic of the database is presented in Table 1.

2.2. Cox model analysis

Stayability of does in the herd was evaluated by survival analysis, using Cox's proportional hazard model (Cox, 1972). All independent variables in the model were treated as covariates to evaluate the covariates in a parametric context (Colosimo and Giolo, 2006). The Cox model can be described as:

$$\lambda(tx) = \lambda_0(t) \times \exp\{\beta x\}$$

in which $\lambda(t)$ is the hazard function for a doe to fail; t is the time of permanence of the doe in the herd; $\lambda_0(t)$ is the baseline hazard function that represents the aging process related to the survival time; β is a vector of unknown parameters; and x is the vector of covariates. Each of the regression coefficients of (β), estimated by the model, can be interpreted as an effect that accelerates ($\beta > 0$) or slows down ($\beta < 0$) the hazard function. A covariate selection strategy was adopted and only the effects that were statistically significant ($P < 0.05$) by the Wald (1939) test were kept in the model.

The proportional hazard model analyses were performed using the Survival package of the R software (R Development Core Team, 2014). The model fitness was evaluated through the Cox-Snell residuals (Cox and Snell, 1968), which allowed verifying if no violation of the model assumptions occurred.

The relationships between STAY28 and birth year, birth season, herd, morphometric, and type traits were expressed as the hazard rate ratio (HRR), defined as the ratio between the estimated likelihood of a doe be culled from the herd or the last parturition in the herd per goat that survived, keeping the other covariates fixed. The covariates selected to be included in the model were defined on the stepwise methods, through a model selection strategy derived from the methodology described by Collett (2003).

2.3. Kaplan-Meier analysis

The Kaplan-Meier is an estimator that can be used to estimate the survival function ($\hat{S}(t)$; Kaplan and Meier, 1958). This method allows evaluating the rate at which a failure event occurs in the different studied groups since it calculates the survival each time that a failure occurs. The Kaplan-Meier estimator can be defined as:

$$\hat{S}(t) = \prod_{j:t_j<t} \left(1 - \frac{d_j}{n_j}\right)$$

in which $t_1 < t < t_k$, assuming that there are k distinct times of stay in the herd with $t_1 < t_2 < \ldots < t_k$; dj is the number of does that were successful at tj, in which j = 1,… k; and nj is the number of does present at hazard at tj (i.e., does that did not fail or have not been censored before the time tj; if the censure occurred exactly at tj, does were at hazard at tj).

The Kaplan-Meier estimator was used to plot the survival function, considering only significant covariates ($P < 0.05$) by the Wald (1939) test. For type covariates, does were grouped into four categories for each variable, according to their score. This grouping was performed according to the Official Regulation of the Genealogical Registry of Goats ('Regulamento Oficial do Serviço de Registro Genealógico de Caprinos') from the ABCC. In this system, the animal can be ranked as regular, good, great or excellent (Table 2). This ranking was performed to facilitate the graphic visualization of the data. According to the breed pattern regarding type traits, morphometric measurements were also classified into four categories. For better graphic depiction, the covariate birth year was also divided into three groups, according to Facó et al. (2011): (1) animals that were born before the beginning of the official dairy control program (from 2000 to 2005); (2) animals born after the beginning of the program and the record of the first controlled lactations (from 2006 to 2010); and (3) animals born after the record of the other controlled lactations and the first summary of dairy goats (2011–2015). The classification into categories of the morphometric traits was performed by organizing the sorting the observations in ascending order, considering the standard interval for each category. Then, each covariate was analyzed individually regarding the doe's length of stay in the herd. Data analyses using the Kaplan-Meier estimator were carried out using the Survival package of the R software (R Development Core Team, 2014).

3. Results

Does with censored stayability records represented 19.52 % of the total database analyzed (Table 1). The averages of traits for the censored group were similar to those of the uncensored group (Table 1), indicating that the censorship occurred homogeneously in the database.

The model analyzed all covariates and weighted them according to their degree of influence on STAY28. The traits that influenced ($P < 0.05$) STAY28 were birth year, body length, rump width, feet and legs soundness, and udder and teat conformations (Table 3). An annual reduction of 4 % on the culling hazard was observed, that is, younger animals have a decrease in the culling hazard of 4 %. By means of the solutions of the regression coefficients of the significant morphometric covariates, we observed that the increase of one unit in body length and rump width leads to a reduction of 2 and 5 %, respectively, in the culling hazard for STAY28 (Table 3). In practical terms, for these traits, the increase of one centimeter reduces the risk of the animal being culled from the herd by 2 and 5 %, respectively. Conversely, for feet and legs soundness, and for teat conformation, a 1-point increase leads to an increase of 7 and 15 % in the culling hazard, respectively. Udder was the only type trait that decreased the hazard of culling by 6 %.

No violation ($P > 0.05$) of Cox's proportional hazard model was observed when testing each covariate that significantly affected the STAY28 (Table 4). Furthermore, no violation was observed when the model with six covariates was considered. The proportional contribution of each covariate that significantly influenced herd survival was evaluated for the occurrence of the failure, from the HRR obtained for each covariate. Based on HRR, teats conformation was the trait with the greatest effect on STAY28. Its contribution to the culling event was 15 %, followed by feet and legs soundness (7 %). A decrease in the culling hazard was observed over the birth years in relation to STAY28 (Fig. 1). Does from group 2 (born between 2006 and 2010) were more likely to continue breeding in the herd when compared with does born in the previous years. For does born in 2013 (group 3), a sudden decrease in stayability was observed.

The behavior of the survival functions regarding morphometric and type traits was obtained through the Kaplan-Meier estimators after the separation of the animals into categories according to their measurements or scores (Table 2 and Figs. 1b, 1c, 1d, and 1e). Those covariates influenced the STAY28 distinctively. The difference observed in the behavior of the curves between the different categories is not very expressive for body length (Fig. 1b) and can be better visualized in does that remained in the herds for more than 1000 days. In these circumstances, does pertaining to the good, great and excellent groups that stayed in the herd more than 1800 days had greater chances of survival compared with does from the regular group. Similar behavior can be observed for rump width (Fig. 1c). Regarding feet and legs soundness, and udder (Figs. 1d and 1e), does from the good and great groups, which presented score values around the average score, showed the lowest culling hazard, increasing the hazard for goats that had very high or low scores for these covariates. For teats conformation, analyzing the survival curves, we observed that does from the excellent group were kept for less time in the herd (Fig. 1f).

Table 2
Descriptive statistics for significant ($P < 0.05$) covariates to describe the ability of Saanen dairy goats reared in the tropics to not being culled (stayability) before 28 months of age.

Covariate	Regular					Good					Great					Excellent				
	n	$\overline{X}$	SD	Min	Max	n	$\overline{X}$	SD	Min	Max	n	$\overline{X}$	SD	Min	Max	n	$\overline{X}$	SD	Min	Max
Body length	148	67.80	2.08	58.00	70.00	805	76.06	2.71	71.00	80.00	460	84.49	2.85	81.00	91.00	26	95.23	3.81	92.00	107.00
Rump width	214	10.20	0.94	8.00	12.00	288	15.99	1.18	13.00	17.80	868	20.10	1.76	18.00	24.00	69	26.06	1.80	25.00	37.00
Feet and legs soundness	3	3.33	1.16	2.00	4.00	422	7.73	0.60	5.00	8.50	477	9.02	0.10	9.00	9.50	537	10.36	0.61	10.00	14.00
Udder	12	2.17	0.84	1.00	3.00	190	4.90	0.35	4.00	5.50	1089	6.97	0.78	6.00	8.00	148	8.99	0.29	8.50	10.00
Teats conformation	79	1.00	0	1.00	1.00	365	1.98	0.1	1.50	2.00	712	2.97	0.11	2.50	3.00	283	3.98	0.11	3.50	4.00

n = number of observations; $\overline{X}$ = average; SD = standard deviation; Min = minimum value; Max = maximum value.

Table 3
Statistics obtained by the Cox model for the covariates used to explain the ability of Saanen dairy goats reared in the tropics to not being culled (stayability) before 28 months of age and the corresponding hazard rate ratio (HRR) and their confidence intervals (CI) at 95 %.

Covariate	β	Standard error	$P < 0.05$	HRR	CI95 % (HRR)
Birth year	−0.039	0.0091	4.95e-06	0.96	0.95; 0.99
Body length	−0.016	0.0049	0.00152	0.98	0.98; 0.99
Rump width	−0.046	0.0085	8.98e-08	0.95	0.94; 0.97
Feet and legs soundness	0.068	0.0272	0.01213	1.07	1.02; 1.13
Udder	−0.059	0.0286	0.03773	0.94	0.89; 0.99
Teats conformation	0.145	0.0457	0.00152	1.15	1.06; 1.26

β = the vector of regression coefficients for fixed effects.

Table 4
Proportionality test of the culling hazard rates in the adjusted model.

Covariate	ρ	Chi-square	*P*-value
Birth year	−0.0350	1.457	0.23
Body length	−0.0220	0.647	0.42
Rump width	0.0388	1.879	0.17
Feet and legs soundness	−0.0424	2.149	0.14
Udder	0.0213	0.539	0.46
Teats conformation	−0.0125	0.191	0.66
GLOBAL[1]	–	6.712	0.35

[1]GLOBAL = model with the six adjusted covariates; ρ = Schoenfeld residual (Schoenfeld, 1982).

4. Discussion

The average values of morphometric and type traits observed in the present study are in agreement with the results previously reported (Valencia-Posadas et al., 2010; Ferreira et al., 2014), demonstrating that selection of animals is occurring to preserve the pattern of these traits. In dairy cattle, morphometric and type traits have been used as an appropriate predictor in defining how long a cow stays in the herd (Vollema and Groen, 1997; Sewalem et al., 2010; Zavadilová et al., 2011; Kern et al., 2014a, 2014b, 2015). On the other hand, in dairy goats, these variables are easily measured at the time of the inspection to obtain the definitive genealogical record; thus, it is possible to use this information in a similar way of what is performed in survival studies using cattle. Differences between herds were not detected in the present study. This result was expected because morphological and type data are measured at the beginning of the productive life and these parameters are evaluated only in animals presenting the pattern established by the breed association. Thus, all registered animals will be homogeneous.

Birthdate, birth weight (although not evaluated in the present study), as well as the age and the month of occurrence of the first parturition, affected the survival of Saanen goats, which presented the lowest survival when compared to other dairy breeds (Pérez-Razo et al., 2004). These researchers observed a maximum lifetime of four years and an average of 2.58 parturitions for Saanen goats. Valencia-Posadas et al. (2017), evaluating stayability in goats in the United States, reported that only 50 % of goats reached 24 months of age. It is noteworthy to highlight that in the present study we choose to evaluate the effect of the traits on the stayability of Saanen does before reaching 28 months of age.

The survival analysis is an interesting approach to study the length of the permanence of the animals in a herd. The culling hazard can also be evaluated by the survival functions behavior. The Cox regression model is indicated for this statistical study. The results obtained by the adjusted Cox regression provided similar estimates to those found by Valencia-Posadas et al. (2010) for birth year and rump width (Table 3). These authors, evaluating the stayability up to 36 months of age of Saanen goats from the USA, reported a 2 % decrease in the culling hazard for each year increase on birth year, but this effect was not significant. For rump width, Valencia-Posadas et al. (2010) reported that this trait affected significantly the stayabilityon the herd, similarly of what was observed in the present study. In other words, for each additional centimeter in rump width, the risk of culling is decreased by 5 %.

When a negative coefficient ($\beta < 0$) is found, the hazard function decrease as obtained for rump width (Table 3). It can be related to the correlation between this variable and reproductive efficiency (Silva et al., 2015). Rump width has a low phenotypic correlation with productive life at 72 months in dairy goats (0.13 ± 0.01; Castañeda-Bustos et al., 2017). Genetic correlations, however, were moderate to high, which can be explained by the fact that variables related to prolificacy and parturition easiness are related to increases in the productive life of females in the herds (Castañeda-Bustos et al., 2017). In goat herds, the twin kidding trait of females is often used as a selection criterion in breeding programs because it is related to prolificacy. As well as rump width, other morphometric and type traits of dairy goats have been studied and are combined as selection criteria (Luo et al., 1997; Wiggans and Hubbard, 2001; Ferreira et al., 2014). The covariates associated with udder and teats conformation combined with milk production has shown significant genetic gains (Manfredi et al., 2001; Rupp et al., 2011). Selection of animals presenting great scores for traits that affect the hazard function in the herd could increase female culling.

Proportionally, teats conformation was the variable that most affected the culling hazard of the does, while the udder, along with rump width and birth year influenced approximately 20 % less on STAY28. However, it should be considered that teats conformation is in a certain way strongly associated with udder.

The association of the best scores for udder texture, udder itself, and teats conformation directly influence the decisions of voluntary culling of females. On the other hand, the increased likelihood of injuries and mastitis infection increases the involuntary culling in the herd. Furthermore, that association has an influence on health during the lactation period which guarantees the quality of milk, and production efficiency (Sewalem et al., 2010; Zavadilová et al., 2011). Castañeda-

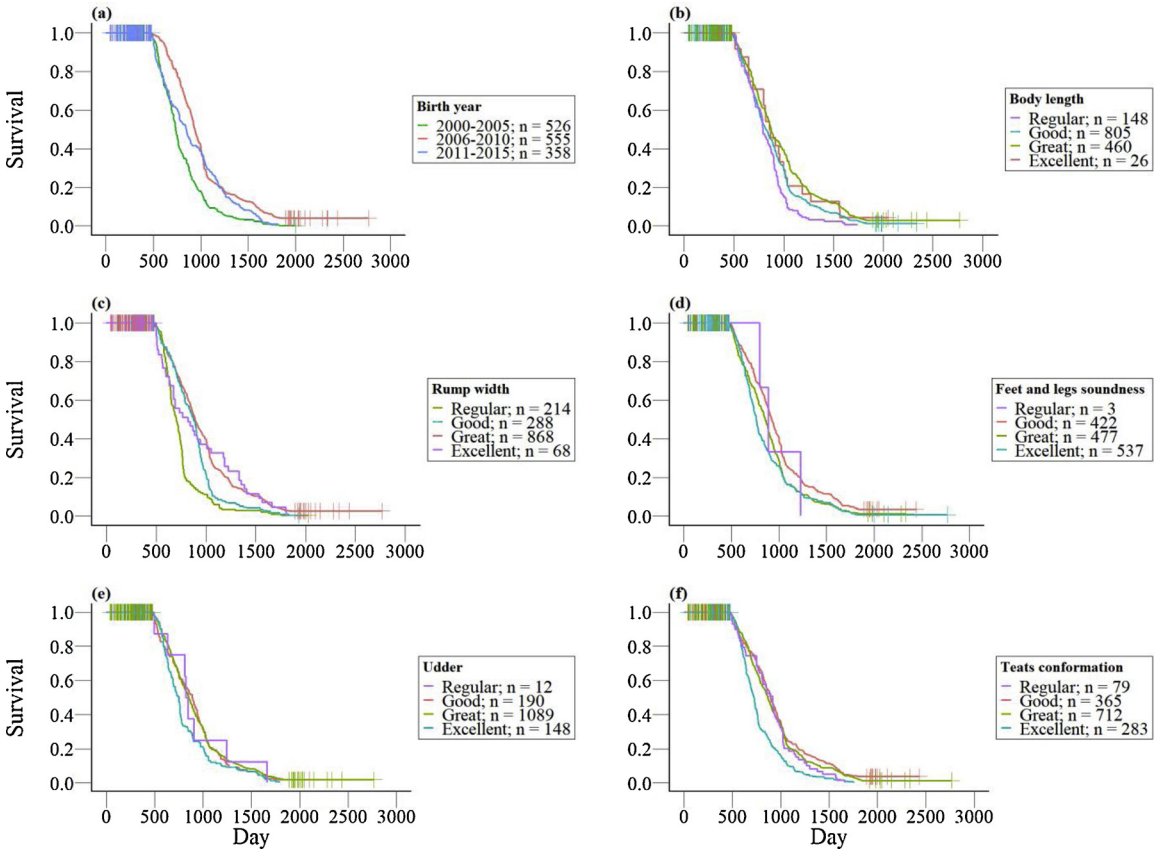

Fig. 1. Effect of birth year, body length, rump width, feet and legs soundness, and udder and teats conformation on the ability of dairy Saanen goats reared in the tropics to not being culled before 28 months of age (STAY28).

Bustos et al. (2017) suggested selecting animals with intermediate to high values for udder intentionally to indirect select for longevity in dairy goats. The preference for does with intermediate scores for these traits was also demonstrated in the present study (Fig. 1f); these does were the ones that stayed longer in the herd.

In the present study, does born before the beginning of the official dairy control program (group 1) presented a shorter survival length (with peak culling occurring approximately 1000 days of age) if compared with does born between 2006 and 2010 (group 2), which were culled only after 1000 days of age. This period coincides with the consolidation of the Genetic Improvement Program for Milk Goats (Capragene®) in Brazil (Facó et al., 2011). However, does born between 2012 and 2015 (group 3) stayed for less time in the herds, reflecting in the lower survival rates (1500 days of age). This fact can be attributed to market opportunities during that time as selling does were favorable because of the great demand for high genetic potential animals. In addition, in 2014 (group 3; Fig. 1a), the first Brazilian summary of dairy production and progeny testing of goats was published (Facó et al., 2014). In this year, the observed culling rates and the number of censored records on the database were greater than those of the previous years, which contributed to the observed behavior of the survival function. The reason why does from group 3 stayed less time in the herd is that the evaluation of these does through the Genetic Improvement Program for Milk Goats dairy control had already occurred allowing an increase in voluntary culling rates in the herd (Fig. 1a).

Regarding morphometric and type traits, the survival of the animals was observed according to the category in which they were classified (Table 2). The preference for animals with increased body length and rump width scores (great and excellent groups) happens possibly because of the correlation between these variables and the parturition easiness (Castañeda-Bustos et al., 2017) and their relation with the reduction of reproductive problems. This fact reflects the higher survival rates observed for these groups (Figs. 1b and 1c). The association between ease of kidding and longevity is important to avoid the occurrence of animals that will have reproductive problems. But these results expose a condition that deserves attention; when larger does are selected to stay longer in the herd, the maintenance and production requirements also increase (Seal and Reynolds, 1993; Agricultural and Food Research Council (AFRC), 1998). In addition to this observation, does need a wide rump for larger kids and those with wider rump stayed longer in the herd. The increase of rump width is a reflex of an intense selection for high-milk producing does since the increase of milk production also requires adequate udder and increased body structure to accommodate the size of the mammary gland that has been selected.

The decreased survival observed for does with higher udder and teats conformation scores is possibly because the selection based on increased milk production also select does with lower udder and teats conformation scores. These high-milk producing does are more susceptible to problems that affect teats conformation and the mammary gland, which increase the risk of early culling (Rupp et al., 2011; McLaren et al., 2016). For the other traits evaluated in the present study, does from the regular group were culled more frequently when compared to other groups. However, for feet and legs soundness, the behavior of the survival curve is questionable for the regular group (Fig. 1d). This fact may have occurred because of the reduced number of does in this group (Table 2). Because selection in the last years was focused only on milk production with a low priority for body capacity, does with better scores for feet and legs soundness were early culled from the herds, especially because these animals are reared in feedlot facilities (i.e., they do not need to walk long distances to consume feed). Therefore, the Brazilian Association of Goats Breeders should utilize not

only milk production attributes, but also consider type traits as selection criteria. Unfortunately, the association is not requiring morphometric measurements, but the results obtained in the present study indicate that these traits are important and should be kept as selection criteria.

In conclusion, body length, rump width, and udder reduce the risk of culling whereas feet and legs soundness and teats conformation increase the culling hazard of Saanen does reared in a tropical environment. In practice, selection of Saanen does reared in a tropical environment is being directed to the increase of body size and the feet and legs soundness are becoming compromised. Producers should be aware of these changes on those traits since the demand for bigger animals reflects on offspring and on worst teats conformation, leading to an early culling. Those traits (i.e., morphometric, type and environmental) should be considered in breeding programs to obtain does that would stay longer and more productive in the herd. Therefore, goat producers can obtain more revenue from their production systems.

Declaration of Competing Interest

The authors declare no conflict of interest.

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