Heritability of longevity in New Zealand dairy goats

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Abstract

Longevity is a trait of economic importance in dairy goat farming. Actual longevity (AL) is defined as the number of days from birth to when the animal leaves the herd, whereas functional longevity (FL) is defined as AL adjusted for first lactation energy-corrected milk yield (ECMY). This study reports the heritability (h^2) for AL and FL in New Zealand dairy goats. Records of longevity from 12,108 does born between 1993 and 2011 were analysed with a model that included the fixed effects of herd-year (does born in the same herd and year) and covariates for the proportion of Alpine, Nubian, Toggenburg and heterosis, and the random effect of animal. The model for FL was the same as AL, but included ECMY as a covariate. Average AL was 1,891 (SD=832) days. Estimates of h^2 were 0.07 for AL and FL. The estimated regression coefficient for ECMY on AL was 0.56 days/litre. There were significant differences in longevity among herds, indicating that management and feeding are important factors affecting longevity. Further research is required to estimate genetic correlations with economically important traits.

Keywords: Dairy goat; longevity; heritability; New Zealand

Introduction

Increased longevity of multi-parous animals such as dairy goats, enables an older age structure and consequently greater milk production by the herd, it also reduces replacement costs (Serradilla et al. 1997; Castañeda-Bustos et al. 2017). Until recently, improving production of milk, fat and protein per doe have been the main breeding objective traits in genetic improvement programs of dairy goats (Desire et al. 2017; Valencia-Posadas et al. 2017). Placing too much emphasis on production, whilst neglecting other traits, may result in unexpected and undesirable consequences on the health and fertility of animals, which decreases longevity (Oltenacu & Broom 2010). Either direct or indirect evaluation of longevity, if used in selection, will increase the overall economic efficiency of the dairy goat industry.

In dairy ruminants, actual longevity (AL) takes into account all reasons the animal was removed from the herd, while functional longevity (FL) takes into account all reasons except milk productivity. Adjusting for milk production results in a longevity value that reflects the animal's ability to avoid involuntary culling due to health and reproductive challenges (Castañeda-Bustos et al. 2014).

Longevity, or similar traits, such as stayability or survival, are now typically included in the breeding objective for most dairy cattle breeding programs (Miglior et al. 2005), but longevity is not yet included in dairy goat breeding programs (Castañeda-Bustos et al. 2014, 2017; Valencia-Posadas et al. 2017; Palhière et al. 2018). Only three papers report longevity of dairy goats in New Zealand (Wheeler et al. 2013, 2014; Gautam et al. 2017). The studies by Wheeler et al. (2013, 2014), provide estimates of stayability and AL in a single herd. The study by Gautam et al. (2017) is a retrospective study that analysed risk factors for the animals leaving the herd. None of these provided estimates of heritability for FL. The objective of this study was to estimate the heritability of AL and FL of dairy goats in New Zealand.

Materials and methods

Data

The dataset used in this study was obtained from Livestock Improvement Corporation and comprised 112,009 dairy goats of Alpine, Nubian, Saanen, and Toggenburg breeds as well as crossbred animals, born between 1973 and 2016. The goats were from 164 herds located throughout North Island, descending from 26,720 dams and 1,284 sires.

Individual birth dates of animals were not available for all animals; some farmers allocated a single birth date for a group of animals. Contemporary groups that had these single birth dates for a group of animals were removed from the analysis. Pedigree information was incomplete; of the does, only 18% had known sires and 44% had known dams. Therefore, only records from those few better-recorded farms were used to calculate longevity. The farms whose data were used were those that had more than 70% of does with known sires and with more than 15 does born in a specific year.

Animals were removed from the analysis if they were born before 1993 or after 2011. These dates were chosen because an exploratory analysis showed that contemporary groups (animals born in the same herd and year) typically comprised more than 15 animals. Those does born after 2011 would not yet have had an uncensored opportunity to express survival.

The number of days from birth to when the animal left the herd defined AL whereas FL was defined as longevity adjusted by the energy-corrected milk yield (ECMY) in the first lactation, calculated as, ECMY = 0.327×MY + 12.86×FY + 7.65×PY, where MY, FY and PY were estimated first lactation yields of milk, fat and protein, respectively (Flores et al. 2009).

Statistical analysis

Descriptive statistics were obtained using the MEAN procedure of Statistical Analysis System version 9.4 (SAS Institute Inc., Cary, NC, USA). The Kaplan-Meier survival curve was obtained using the LIFETEST procedure of SAS.

Contemporary group was defined as does born in the same herd and year. The original dataset included 112,009 animals in 2,058 groups and 12,108 animals in 123 groups after editing.

Analyses of AL and FL were performed using ASReml software (Gilmour et al. 2009) fitting a mixed linear animal model. The model included the fixed effects of herd-year (contemporary group), and covariates for proportion of Alpine, Nubian, Toggenburg and general heterosis, and a random animal effect. General heterosis, instead of specific two-breed heterosis, was calculated because the number of crossbred animals was insufficient to determine specific heterosis for each of the breed combinations. General heterosis assumes that first-cross heterosis is the same for all breed combinations (Olfati et al. 2012).

Analysis for FL was the same as AL, but including ECMY as a covariate. Phenotypic variance was the sum of animal and residual variances, genetic variance was the animal variance, and heritability (h^2) was calculated as the proportion of genetic variance with respect to the phenotypic variance. To explore the level of variation caused by the herd-year effect, the statistical model was run a second time, but with herd-year considered as a random effect rather than fixed effect.

Results

The main studies on different measures of longevity of dairy goats are presented in Table 1. The numbers of goats in these studies ranged from 4,910 to 1,137,793 animals and included the same breeds as in this study. The final dataset included 12,108 does from eight herds, representing descendants of 407 sires.

Descriptive statistics for first lactation MY, FY, PY, ECMY and AL are in Table 2. There was a 6 kg difference between first-lactation milk yield and ECMY for the same lactation and a reduction in the maximum milk yield from 1,538 to 1,510 kg, respectively. Average longevity of does born between 1993 and 2011 was 1,891±832 days.

Figure 1 shows the longevity of dairy goats born in the eight herds. There was large variation in mean longevity among herds, from 1,638 to 2,088 days. When herd-year was included as a random effect, it was found that herd-year effect explained 35% of the total variation.

Figure 2 shows a Kaplan-Meier survival curve that included the longevity of 12,108 does. After 1,000 days, 85% of the goats remained in the herd and by 2,000 days, only 40% of the animals remained in the herd.

The estimates of breed and heterosis effects were not significantly different from zero. The estimate of the regression coefficient of AL on ECMY was 0.56 days/kg ECMY ($P<0.0001$). Estimates of variance components and h^2 for AL and FL are in Table 3. The estimates of h^2 for AL and FL were the same at 0.07. The phenotypic and genetic coefficients of variation were 39 and 11% for AL and 38 and 10% for FL, respectively.

Table 1 Longevity traits studied in dairy goats around the world.

Country	Trait	Study
New Zealand	Survivability	Wheeler et al. 2013
	Longevity	Wheeler et al. 2014
	Risk factors associated with the length of productive life	Gautam et al. 2017
Mexico	Stayability	Pérez-Razo et al. 2004
	Productive life	Torrero 2010
France	Productive life	Palhière et al. 2018
United States	Productive life	Valencia-Posadas et al. 2010
	Functional productive life	Castañeda-Bustos et al. 2014
	Functional stayability	Castañeda-Bustos et al. 2017
		Valencia-Posadas et al. 2017

Table 2 Descriptive statistics for first-lactation milk production and longevity of New Zealand dairy goats, born between 1993 and 2011.

Trait	n	Mean	SD[1]	Min	Max	CV[2]
First lactation yields (kg)						
Milk	12,108	502.9	223.2	30.0	1,538.1	44
Fat	12,108	16.9	7.6	1.1	54.3	45
Protein	12,108	15.1	6.5	1.0	43.0	43
Energy-corrected milk	12,108	496.9	216.7	31.4	1,510.0	44
Actual longevity (days)	12,108	1,891	832	400	6,551	44

[1]SD = standard deviation. [2]CV = coefficient of variation.

Figure 1 Boxplot of the longevity of dairy goats born between 1993 and 2011, in eight herds throughout the North Island of New Zealand. Number of does in each herd were; herd 1=2,721, herd 2=1,835, herd 3=611, herd 4=1,610, herd 5=1,327, herd 6=1,208, herd 7=2,117 and herd 8=679 does.

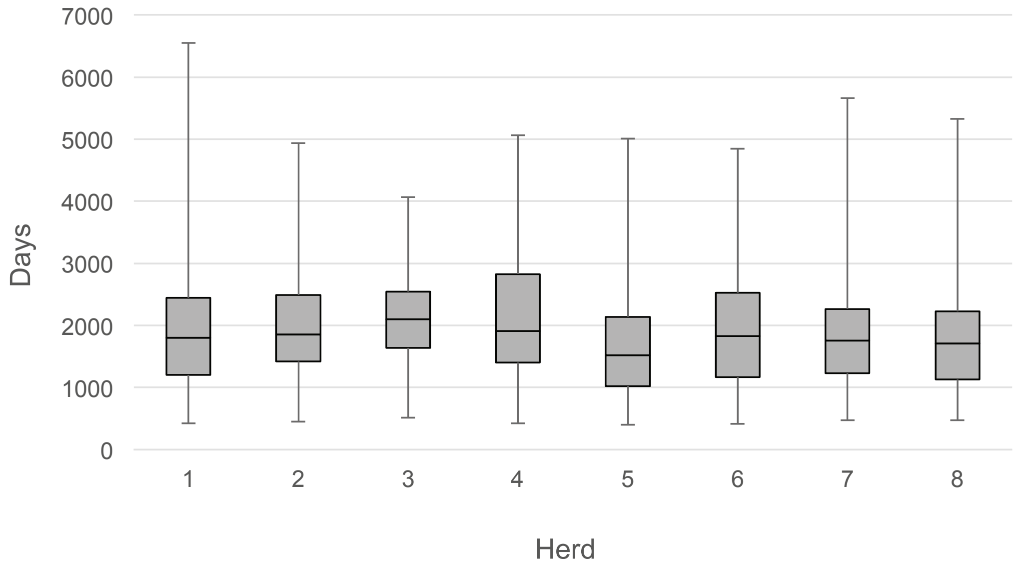

Figure 2 Kaplan-Meier survival curve for longevity of 12,108 New Zealand dairy goats born between 1993 and 2011.

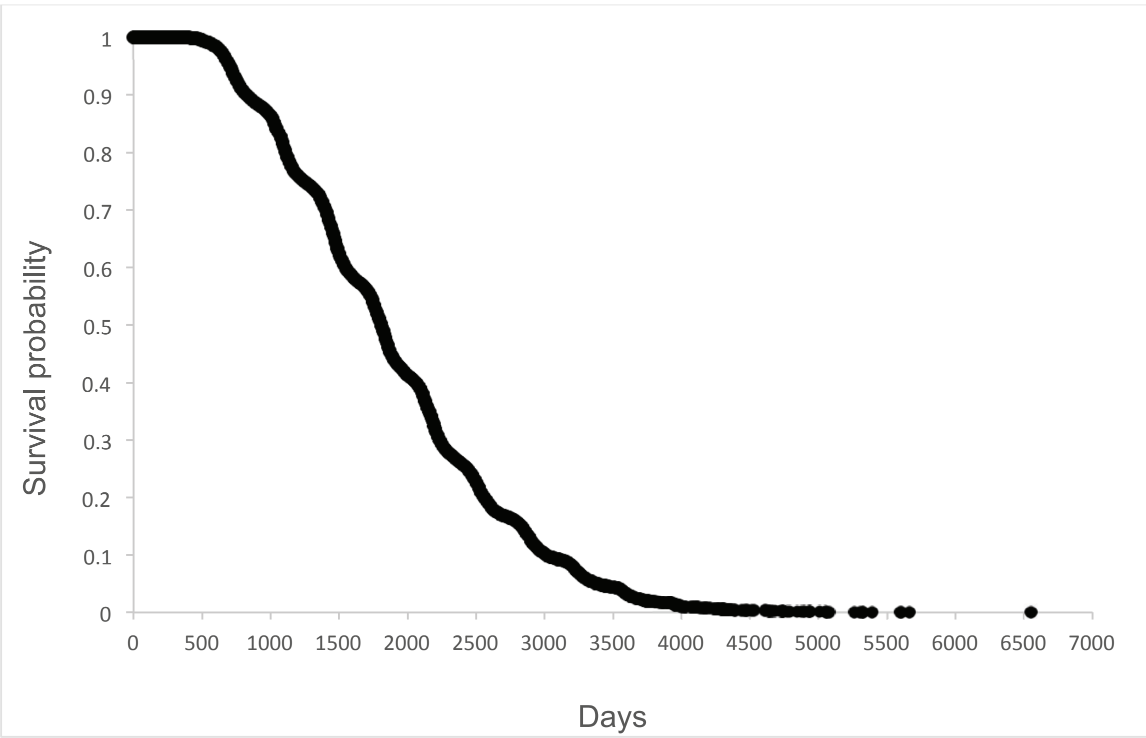

Table 3 Estimates of heritability (h^2) and additive and phenotypic variances for actual and functional longevity of New Zealand dairy goats born between 1993 and 2011, obtained using a single-trait analysis.

	Actual longevity			Functional longevity		
	Estimate	SE[1]	CV[2]	Estimate	SE[1]	CV[2]
Genetic variance	39,547	4.85	11	38,482	4.76	10
Residual variance	529,157	52.61	39	523,033	52.54	38
Total variance	568,700	7,388	40	561,520	7,294	40
Heritability	0.07	0.01		0.07	0.01	

[1]SE = standard error. [2]CV = coefficient of variation.

Discussion

Longevity is an economically important trait in production animals, with genetic parameters being published for dairy cattle, sheep, pigs and rabbits, but there are few reports of the genetics of longevity in dairy goats. The main studies found in the literature included the same breeds as in this study in addition to the La Mancha (Castañeda-Bustos et al. 2014, 2017; Valencia-Posadas et al. 2017) and Granadina (Pérez-Razo et al. 2004) breeds.

Descriptive statistics suggest that the average longevity of does in New Zealand was 1,891±832 days, which is longer than the 1,644 days previously reported (Gautam et al. 2017). Both studies used the same dataset but with different editing criteria. The dataset in this study accounted for pedigree information that limited the number of observations, whereas, Gautam et al. (2017) did not account for pedigree, so the dataset included more herds (38 herds).

Comparisons with other studies was difficult because of differences in the definition of survival. Palhière et al. (2018) reported a decline in the length of productive life in Saanen and Alpine goats born in France from 1991 to 2011. The length of productive life of animals born in 1991 were 1,150 and 1,175 days for Saanen and Alpine, respectively, whereas the length of productive life of animals born in 2011 was 800 and 850 days for the respective breeds. These values of longevity are lower than the values found in this study, assuming that first kidding for those studies was at 365 days of age.

The proportion of does surviving as they become older shows noticeable dips every 200-300 days. A similar pattern was observed by Gautam et al. (2012), who modelled the instantaneous removal hazard (expressed as a probability of removal per day) as a function of age. Their results showed a reoccurring pattern which has crests representing the dry period within a lactation cycle (low risk of being culled), followed by a large dip (high risk of being culled). Therefore, the dips in (Figure 2) represent the end of each lactation period, before the animals are dried off, as this is typically the time when a farmer will cull undesirable animals, for example, those that are not pregnant or have low production.

The regression of AL on first-lactation ECMY was significant indicating that longevity was increased by 0.56 days for each extra kilogram of ECMY, indicating that does with higher production lasted longer. However, the estimate of h^2 for FL was the same as the estimate of h^2 for AL. This result agrees with Castañeda-Bustos et al. (2014), who reported similar h^2 estimates for productive and functional productive life. Nevertheless, knowledge about genetic parameters for FL are still important, as genetic improvement of longevity would be more efficient when the effects of voluntary culling can be taken into account (Castañeda-Bustos et al. 2014).

Despite low h^2 estimates for AL and FL, the genetic coefficients of variation for AL and FL (11% and 10%, respectively) suggest there is genetic variation of longevity in this dairy goat population. These results agree with those of Valencia-Posadas et al. (2017) who reported that there was sufficient additive genetic variation to justify the inclusion of functional stayability at 24 and 36 months of age, into a breeding program.

Estimates of h^2 of longevity vary in different species with low estimates for sows, cows and sheep (0.02-0.08 VanRaden & Klaaskate 1993, Serenius & Stalder 2004, El-Saied et al. 2005) and larger estimates for rabbits (0.15 Piles et al. 2006). Comparison of the h^2 estimates from this study with other estimates from other studies of goats, warrants caution as different definitions of longevity and statistical models have been used. Estimates of h^2 for length of productive life in French dairy goats (Palhière et al. 2018), FL of US dairy goats (Valencia-Posadas et al. 2017) and stayability of New Zealand dairy goats were low (0.07 to 0.09). Whereas, estimates of h^2 for length of productive life at 72 months old of US dairy goats (Castañeda-Bustos et al. 2014, 2017) were higher (0.14 to 0.17). Overall, the h^2 estimates in this study were within the range of published values for longevity of dairy goats.

This study analysed the effect of does kidding in the same herd and year, breed, heterosis and the individual animal effect on longevity. In addition to these, the effects of birth month and dam age on survival of progeny, were also investigated. Including month of birth as a covariate was attempted, but birth date of animals was not accurately recorded in all farms, therefore, this factor could not be included in the model. Age of dam was calculated using pedigree data but the dataset containing the birth date of dams was incomplete. With many missing records, including this variable in the analysis would have required that a significant proportion of data would have been filtered out and excluded from the analysis. However, using an incomplete dataset, results showed no significant effect of dam age on longevity.

Results from this study suggest that if selection for longevity is included in a selection index, there is adequate genetic variation for longevity of New Zealand dairy goats to allow genetic improvement for this trait. Solis-Ramirez et al. (2018) estimated the economic value for longevity of \$0.04 per day, enabling the straightforward inclusion of this trait into a selection index. However, further work is required, especially in quantifying the genetic and phenotypic correlations with other traits, to enable the inclusion of longevity in the current genetic evaluation system.

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