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Genetic and phenotypic aspects of functional stayability traits in the Murciano-Granadina goats

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Abstract Data consisted of pedigree information and kidding records from 7,541 Murciano-Granadina goats collected between 2018 and 2023, from a commercial dairy farm in Ghale-Ganj City, southern Kerman province, Iran, were used. The functional stayability traits were defined as binary traits and included stayability until 24 months (Stay24), 36 months (Stay36), and 48 months (Stay48) after first kidding. The averages for the functional stayability until 24, 36, and 48 months after first parity were 81%, 52%, and 30%, respectively. Kidding year and milk yield level were statistically significant risk factors for all the investigated stayability traits ($P < 0.01$). Genetic analysis was performed by applying a Bayesian multivariate threshold animal model via Gibbs sampling. Posterior means of heritability estimates $\pm$ posterior standard deviation (PSD) were 0.08 ± 0.03 , 0.06 ± 0.02 , and 0.18 ± 0.06 , for Stay24, Stay36, and Stay48, respectively. Posterior means $\pm$ PSD for genetic correlations among the studied traits were positive estimates of 0.82 ± 0.17 (Stay24-Stay36), 0.74 ± 0.19 (Stay24-Stay48), and 0.68 ± 0.19 (Stay36-Stay48). The phenotypic correlation estimates were 0.93 ± 0.01 , 0.89 ± 0.03 , and 0.94 ± 0.01 for Stay24-Stay36, Stay24-Stay48, and Stay36-Stay48, respectively. Given the low heritability estimates, improving environmental conditions and potentially incorporating non-additive genetic effects in future breeding schemes may be more important for enhancing functional stayability of the Murciano-Granadina goat in the flock.

Keywords: Bayesian approach, dairy goat, functional stayability, genetic correlation, heritability

Introduction

Native breeds of goats make an important contribution to the livelihoods of local farmers in developing countries (Peacock, 2005). However, the production efficiency of native breeds is often low due to several factors, including low genetic potential (Jembere et al., 2017), harsh environmental conditions, and the low-input and low-output production systems (Kosgey and Okeyo, 2007) of native breeds. Odubote (2020) noted that focusing on the genetic option of crossbreeding indigenous goat breeds with high-performing exotic breeds may be an alternative

for overcoming these limitations.

The Murciano-Granadina goat breed is a famous dairy breed in Spain, holding international significance, having been exported to other countries (Martinez et al., 2010). In 1975, the Murciano-Granadina goat breed was developed through the crossbreeding of two Spanish breeds of goat, Murciana and Granadina. In dairy herds, it is important to identify not only the most productive animals but also those that combine the best production, reproduction, and longevity traits, resulting in animals that contribute to the increased profitability of the farm (De

Mello et al., 2014). Stayability may be defined as the survival rate of an animal to a given age and directly affects the economic return (Hamidi Hay and Roberts, 2017) and influences the profitability of the economically valuable traits (De Carvalho et al., 2025). Stayability can also be interpreted as an indicator of animal welfare, as high discard and mortality rates may indicate inadequate conditions of welfare, such as improper nutritional management, stressful and inappropriate handling, among others (Weigel et al., 2003).

Developing appropriate breeding schemes for genetic evaluation of animals requires accurate estimates of genetic parameters for economically important traits. It enables the selection of superior animals to be the parents of the subsequent generations. Limited information is available on the genetic and phenotypic aspects of the stayability traits in the Murciano-Granadina goat breed. As the breed is kept out of its natural habitat in Spain, there is no accurate and reliable information on the genetic parameters of stayability traits under such production and breeding conditions. There are limited published documents on the estimation of genetic parameters for stayability traits in dairy goat breeds. Valencia-Posadas et al. (2017) reported genetic estimates for functional stayability at 24 and 36 months of age traits in US dairy goats. High genetic correlations between stayability traits in dairy goats (Valencia-Posadas et al., 2017) and dairy cows (Sasaki, 2013) imply the efficiency of indirect selection based on early stayability for improving the herd life of animals.

In 2015, the private sector facilitated the import of 3,000 Murciano-Granadina goats from Spain to the southern area of Iran. This effort aimed to boost productivity in native goat farms characterized by low-input and low-output systems. The objectives of the present investigation were to investigate the genetic and phenotypic aspects of the three functional stayability traits in this population of the Murciano-Granadina goat breed in the southern tropical area of Iran.

Materials and methods

Data and flock management

In the present study, pedigree and kidding records, along with their corresponding survival, for 7,541 Murciano-Granadina goats collected between 2018 and 2023 from a commercial dairy farm in Ghale-Ganj City, southern Kerman province, Iran, were used. Animals in the flock were generally kept under an intensive management system on a single farm. They were kept in separate enclosures based on their age, sex, physiological condition, and health status (Ehsaninia et al., 2025). Maiden goats were exposed to the fertile bucks at about 11 months of age, and 25 kg live body weights in separate groups with a ratio of 15 goats per fertile buck. Dairy goats are fed commercial concentrates (1350 g/day/goat), alfalfa hay (250 g/day/goat), wheat straw (25 g/day/goat), forage corn silage (1000 g/day/goat),

and sugar beet pulp (1000 g/day/goat). The concentrate mixture contained the following ingredients: 210 g/kg of barley; 400 g/kg of corn; 225 g/kg of soybean and rapeseed meals; 85 g/kg of meat and fat powder; 77 g/kg of vitamin and mineral mixture; and 3 g/kg of common salt. The amounts of concentrate and hay were calculated based on the animals' age and production status. Water was freely available to all animals. Animals receive veterinary care and antiparasitic drugs, as well as vaccinations against diseases like enterotoxaemia, foot-and-mouth disease, goat pox, and brucellosis (Ehsaninia et al., 2025).

Pedigree information of 35,121 Murciano-Granadina goats, originating from 937 sires and 11,328 dams, was considered in the present study. The CFC program (Sargolzaei et al., 2006) was used to investigate pedigree errors, such as animals that were registered as both sire and dam, and cycling pedigree (when the identification of an animal is registered as the identification of its parents) were identified. An edited pedigree was used for genetic analyses. The pedigree structure of the studied population is shown in Table 1.

Table 1. Pedigree structure of the population of the Murciano-Granadina goat

Item	Numbers
Individuals in total	35121
Inbreds in total	2484
Sires in total	937
Dams in total	11328
Individuals with both parents known	31543
Individuals with both parents unknown	3358
Individuals with one parent unknown	220
Individuals with progeny	12265
Individuals with no progeny	22856
Average number of discrete generation equivalents	2.00
Maximum number of discrete generation equivalents	5.00
Average inbreeding coefficients in the inbreds (percent)	4.07
Maximum of inbreeding coefficients in the inbreds (percent)	31.25
Minimum of inbreeding coefficients in the inbreds (percent)	0.10

Editing protocol and the studied traits

The original dataset comprised kidding records from 7,541 Murciano-Granadina goats. For editing purposes, goats with a minimum age of 16 months at first kidding, with information available on total milk yield at the first parity, with a minimum of 60 days lactation period, and a minimum of 150 kg milk yield during the first lactation, were considered. Records of goats without a birth date were removed because it was not possible to calculate any of the stayability traits. Furthermore, records without information on the first lactation were removed, as well as those with missing information on the lactation number and their parents. Stayability until a certain age was defined as a binary trait, assigning 1 when the doe reached a certain age, or 0 when the age of the doe was less than the certain age. Three functional stayability traits, including stayability until 24 months after first kidding (Stay24), stayability until 36 months after first kidding (Stay36), and stayability until 48 months after

first kidding (Stay48), were defined. Functional stayability refers to stayability evaluated with adjustment for milk yield. Descriptive statistics for the investigated functional stayability traits are shown in Table 2.

Table 2. Descriptive statistics for the functional stayability traits in the Murciano-Granadina goat breed

Traits ¹	No. of records	Mean	S.D. ²
Stay24	2617	0.81	0.39
Stay36	2617	0.52	0.49
Stay48	2617	0.30	0.46

¹Stay24: Stayability after first parity until 24 months, Stay36: Stayability after first parity until 36 months, Stay48: Stayability after first parity until 48 months.

²S.D.: standard deviation.

Genetic analysis

Typically, an animal is evaluated for stayability, where the opportunity to survive to a certain age is recorded as a zero (0) if the animal fails to survive or as a one (1) if it survives to the given opportunity age (Everett et al., 1976). As pointed out by Famula (1981), this evaluation method of stayability has several limitations. First, due to the binomial nature of the observations, the mean and variance are not independent, unlike in the normal distribution. Second, the number of observations is limited by opportunity, and it cannot utilize those animals that fail to reach the given opportunity. To overcome these limitations, Van Vleck (1980) proposed a multiple-trait categorical stayability model where each category is a different opportunity. Thus, in the present study, the estimation of genetic parameters for the studied functional stayability traits was performed by applying a multivariate threshold animal model as follows:

$$\mathbf{y}_i = \mathbf{X}_i \mathbf{b}_i + \mathbf{Z}_i \mathbf{a}_i + \mathbf{e}_i$$

where $\mathbf{y}_i$ represents a vector with the liability for the trait i ; $\mathbf{b}_i$, $\mathbf{a}_i$, and $\mathbf{e}_i$ represent vectors of fixed, direct genetic, and residual effects for trait i , respectively. $\mathbf{X}_i$ and $\mathbf{Z}_i$ are design matrices that associate the fixed and direct additive genetic effects with the vector of $\mathbf{y}_i$, respectively. The fixed effects were included kidding year with six levels (2018 to 2023), kidding season with two levels (the first season from March to September, and the second from October to February), the birth type of the kids with two levels (single-born and twin or higher kidding born), sex of the kids with two levels (male and female), milk yield at the first parity with five categories (≤ 249 kg, 250–380 kg, 381–515 kg, 516–650 kg, ≥ 651 kg), and age at first kidding with two levels (1 year old and 2 years old). By considering a normal distribution, five categories of milk yield, including 1.5 standard deviations below the mean, between 1.5 and 0.5 standard deviations below the mean, between 0.5 standard deviation below the mean and 0.5 standard deviation above the mean, between 0.5 and 1.5 standard deviations above the mean, and 1.5 standard deviations above the mean, were defined. Logistic regression models were used to analyze the effects of the considered fixed effects on the functional stayability traits using the maximum likelihood method of the LOGISTIC procedure of SAS 9.4 software (SAS, 2010).

The genetic analyses were done via a Bayesian approach and by applying the THRGIBBS1F90 software (Misztal et al., 2002). For both genetic analyses, 200,000 iterations were run, with thinning intervals of 100 iterations, of which the first 20,000 iterations were discarded as burn-in. Finally, 1,800 samples were considered for computing features of the posterior distribution. The posterior analyses for calculating the posterior means and posterior standard deviations (PSD) of the parameters were implemented by applying the POSTGIBBSF90 program (Misztal et al., 2002).

Multivariate normal distributions were assumed, a priori, for animal effects with a null mean vector and a (co)variance matrix $\mathbf{G} \otimes \mathbf{A}$, where $\mathbf{G}$ and $\mathbf{A}$ are the genetic (co)-variance matrix and numerator relationship matrix among bulls, respectively. The vector of residual effects was assumed to follow a multivariate normal distribution with a null mean vector and (co)variance matrix $\mathbf{R} \otimes \mathbf{I}_n$, where $\mathbf{I}_n$ is an identity matrix and $\mathbf{R}$ is the residual (co)variance matrix; $\otimes$ denotes the Kronecker product. The prior distributions of the genetic and residual effects were assumed to be the inverted Wishart distribution, so that their fully conditional posterior distributions were also inverted Wishart (Sorensen and Gianola, 2002). All the investigated functional stayability traits were analyzed by applying threshold models, having two categories. For identification purposes, the first threshold for each trait was set to 0. The threshold and the residual variance cannot be estimated simultaneously for binary traits (Korsgaard et al., 2003). Therefore, residual variances for these traits were set to 1. The residual covariance between the traits at two time points is set to be zero.

Convergence for the Markov Chain Monte Carlo chains was evaluated by visual inspection of trace plots for the posterior samples of parameters. Furthermore, the effective sample size (ESS) was also considered as a diagnostic measure of convergence for MCMC samples (Burkner, 2017).

Results and discussion

General considerations

Animals with both known parents, one known parent, and both unknown parents were 89.81%, 9.56%, and 0.63% of the total registered animals, respectively, suggesting reasonable pedigree completeness for genetic analysis, though 9.56% of animals with one unknown parent may limit accuracy for some individuals. Individuals with progeny and without progeny were 34.92% and 65.08% of the total individuals, respectively. Averages for the number of discrete and complete generation equivalents were 2.00 and 5.00, respectively. The inbred individuals comprised 7.07% of all individuals, with an average inbreeding coefficient of 4.07% in inbred individuals.

In the present study, the averages for the functional stayability until 24, 36, and 48 months after first parity were 0.81, 0.52, and 0.30, respectively. Female

longevity or stayability is a trait of crucial importance, especially in dairy breeds with a high level of intensification, where females are subjected to more productive stress and their longevity is reduced (Ziadi et al., 2024). Several definitions of longevity have been proposed in the literature. For example, the number of days from first calving to death or culling as productive life (VanRaden et al., 2006) and total days in production (VanRaden and Klaaskate, 1993). Stayability is defined as a binary trait relating to survivability in a given environment and is treated as an indicator trait for longevity (Ogawa et al., 2021). Therefore, comparison of the obtained results in the present study with other studies dealing with various definitions of longevity may be partly justified.

By the same definition for stayability as in our study, Valencia-Posadas et al. (2017) reported lower averages of 0.50 and 0.24 for functional stayability until 24 and 36 months in the US dairy goat breeds, which were lower than the corresponding values in the present study. Such differences may be explained by breed differences and management practices in the population (Ogawa et al., 2021).

Associated risk factors

Risk factors associated with the investigated functional stayability traits in the Murciano-Granadina goat breed are shown in Table 3. Kidding year and milk yield level were statistically significant risk factors for all the investigated stayability traits ($P < 0.01$). In the present study, the odds ratios of the studied stayability traits across the kidding years decreased significantly ($P < 0.01$), implying lower stayability of goats kidding in the recent years than in previous ones (Table 3), which is possibly influenced by the variation of management practices or environmental conditions over the studied years. On the other hand, this trend may reflect both year effects and the fact that goats kidding in more recent years have had less opportunity to reach the ages right-censored. As shown in Table 3, the odds ratios of the investigated functional stayability traits increased significantly with the increase of milk yield in the first lactation period ($P < 0.01$). Goats that produce low milk yield in the first lactation have lower Stay24, Stay36, and Stay48 than high-producing goats. Ziadi et al. (2024) also reported higher culling risk of low-producing goats in Florida and Payoya dairy goat breeds. They pointed out that milk yield is one of the most important traits and has a strong impact on the culling decisions in dairy breeds. Vukasinovic et al. (2001) also pointed out that high-producing females are less likely to be culled than low-producing ones from the same herd.

Genetic parameters

The three investigated stayability traits (Stay24, Stay36, Stay48) are not independent observations; animals that survive to 48 months necessarily also survive to 24 and 36 months, and animals that survive to 36 months

necessarily also survive to 36 months after first kidding. In other words, these traits represent a nested structure in which repeated measures of the same underlying longevity process at different time points are considered. The multivariate threshold model appropriately handles this structure and the associated culling bias.

Posterior means of heritability estimates $\pm$ posterior standard deviation (PSD) were 0.08 ± 0.03 , 0.06 ± 0.02 , and 0.18 ± 0.06 , for Stay24, Stay36, and Stay48, respectively (Table 4). Direct additive genetic effects explain limited variation, suggesting that environmental factors (and potentially non-additive genetic effects, though not estimated here) are the primary determinants of these traits, and direct selection for improving them may not be so effective. There are limited published estimates for the heritability of functional stayability traits in dairy goats. Valencia-Posadas et al. (2017) reported values of 0.08 ± 0.01 and 0.09 ± 0.02 for heritability estimates of Stay24 and Stay36 in the US dairy goat population, respectively, which were close to the estimated values in the present study. There are various definitions for stayability traits in domestic animals. Wheeler et al. (2013) defined stayability traits in Saanen goats as survival from 1 to 2 years of age, 1 to 3 years of age, 1 to 4 years of age, and 1 to 5 years of age, with corresponding heritability estimates of 0.04, 0.05, 0.05, 0.10, respectively. Although species differences limit direct comparability, Ogawa et al. (2021) defined the stayability from a certain parity to the next parity. They reported heritability estimates of stayability from first to second, from second to third, from third to fourth, from fourth to fifth, from fifth to sixth, and from sixth to seventh in Landrace pigs as 0.200, 0.189, 0.141, 0.174, 0.136, and 0.154, respectively.

Posterior means $\pm$ PSD for genetic and phenotypic correlations among the studied traits are presented in Table 4. Genetic correlations were positive estimates of 0.88 ± 0.02 (Stay24-Stay36), 0.87 ± 0.02 (Stay24-Stay48), and 0.93 ± 0.01 (Stay36-Stay48). Phenotypic correlations among the studied traits were also positive but higher than the corresponding genetic correlations in magnitude (Table 4). As shown in Table 4, the phenotypic correlation estimates were 0.98 ± 0.01 , 0.92 ± 0.01 , and 0.96 ± 0.01 for Stay24-Stay36, Stay24-Stay48, and Stay36-Stay48, respectively. Due to high and positive genetic and phenotypic correlations among the investigated traits, it can be concluded that selecting for higher Stay24 in the Murciano-Granadina goat breed would result in higher stayability at older ages, including Stay36 and Stay48. Valencia-Posadas et al. (2017) reported genetic and phenotypic correlations between Stay24 and Stay36 in the US dairy goat population as 0.69 and 0.28, respectively, which were lower than the corresponding estimated values in the present study. Wheeler et al. (2013) also found positive and high genetic and phenotypic correlations among stayability traits in Saanen goats. They reported that genetic correlations ranged from 0.29 between survival from 1 to 2 years of age and survival from 1 to 5 years of age to 0.74 between survival from 1 to 4 years of age and

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survival from 1 to 5 years of age. The corresponding phenotypic correlations ranged from 0.44 between survival from 1 to 2 years of age and survival from 1 to 5

years of age to 0.96 between survival from 1 to 4 years of age and survival from 1 to 5 years of age.

Table 3. Risk factors associated with the stayability traits in the Murciano-Granadina goat breed

Variable	Level	Traits ¹					
		Stay24		Stay36		Stay48	
		Odd Ratio (95% CI)	P-value	Odd Ratio (95% CI)	P-value	Odd Ratio (95% CI)	P-value
Kidding yr	-	-	0.01	-	0.01	-	0.01
	2018	Reference	-	Reference	-	Reference	-
	2019	0.61 (0.40-0.92)	-	0.63 (0.47-0.85)	-	0.87 (0.66-1.15)	-
	2020	0.49 (0.33-0.74)	-	0.62 (0.46-0.84)	-	0.27 (0.19-0.39)	-
	2021	0.43 (0.31-0.60)	-	0.17 (0.13-0.21)	-	0.24 (0.12-0.49)	-
	2022	0.47 (0.33-0.67)	-	0.15 (0.09-0.22)	-	0.05 (0.03-0.08)	-
	2023	0.03 (0.02-0.06)	-	0.13 (0.09-0.19)	-	0.03 (0.02-0.05)	-
Milk yield	-	-	0.01	-	0.01	-	0.01
	< 249 kg	Reference	-	Reference	-	Reference	-
	250 kg-380 kg	3.78 (2.57-5.57)	-	2.99 (1.87-4.79)	-	2.05 (1.15-3.65)	-
	381 kg-515 kg	6.47 (4.47-9.38)	-	3.81 (2.43-5.97)	-	2.48 (1.43-4.33)	-
	516 kg-650 kg	6.90 (4.58-10.41)	-	4.14 (2.61-6.56)	-	2.69 (1.54-4.72)	-
	> 650 kg	6.06 (3.31-11.08)	-	3.00 (1.74-5.17)	-	1.90 (1.00-3.62)	-
	-	-	0.11	-	0.61	-	0.14
Kidding season	First	Reference	-	Reference	-	Reference	-
	Second	0.81 (0.62-1.05)	-	0.95 (0.76-1.17)	-	0.88 (0.68-1.15)	-
The birth type of the kid	-	-	0.20	-	0.84	-	0.60
	Single-born	Reference	-	Reference	-	Reference	-
Sex of the kid	Twin or higher kidding born	0.86 (0.68-1.09)	-	0.98 (0.82-1.18)	-	1.05 (0.87-1.27)	-
	-	-	0.16	-	0.59	-	0.86
Age at first kidding	Male	Reference	-	Reference	-	Reference	-
	Female	0.84 (0.67-1.08)	-	0.95 (0.79-1.14)	-	0.98 (0.81-1.19)	-
Age at first kidding	-	-	0.06	-	0.89	-	0.56
	1-yr	Reference	-	Reference	-	Reference	-
	2-yr	1.30 (0.99-1.70)	-	1.01 (0.82-1.18)	-	1.07 (0.86-1.33)	-

¹Stay24: Stayability after first parity until 24 months, Stay36: Stayability after first parity until 36 months, Stay48: Stayability after first parity until 48 months

Reference categories for kidding year, milk yield, kidding season, sex of the kid, and age at first kidding were 2018, < 249 kg, first season (from March to September), male kids, and 1-yr, respectively.

Table 4. Posterior means $\pm$ posterior standard deviation for heritability estimates (on diagonal), genetic (above diagonal), and phenotypic (lower diagonal) correlations of functional stayability traits in the Murciano-Granadina goats from multivariate analyses

Trait ¹	Stay24	Stay36	Stay48
Stay24	0.08 $\pm$ 0.03	0.88 $\pm$ 0.02	0.87 $\pm$ 0.02
Stay36	0.98 $\pm$ 0.01	0.06 $\pm$ 0.02	0.93 $\pm$ 0.01
Stay48	0.92 $\pm$ 0.01	0.96 $\pm$ 0.01	0.18 $\pm$ 0.06

¹Stay24: Stayability after first parity until 24 months, Stay36: Stayability after first parity until 36 months, Stay48: Stayability after first parity until 48 months

Conclusion

Genetic aspects of three functional stayability traits in the Murciano-Granadina goat breed under intensive production conditions were investigated. Low additive genetic variation was found for the investigated

stayability traits. Therefore, it may be concluded that future studies should consider estimating non-additive genetic effects, and breeding programs should focus on environmental improvements, given the low heritability estimates in developing a breeding scheme aimed at enhancing functional stayability of the Murciano-Granadina goat in the flock.

Conflicts of Interest

The authors declare no conflicts of interest.

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