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Exploring the non-genetic factors that affect reproductive traits of Saanen goats in Indonesia

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Abstract

Adjustment of trait records for different non-genetic factors increases the accuracy of genetic parameters and enables more accurate selection. This study aimed to investigate the non-genetic factors affecting reproductive traits in Saanen goats at the Baturraden breeding centre, Indonesia. Data from 71 Saanen does from 2015 to 2021 included reproductive traits, namely, total birth weight (TBW), age at first kidding (AFK), kidding interval (KI), litter size (LS), multiple birth rate (MBR), and kidding failure rate (KFR). Non-genetic factors explored included parity, season of kidding (SK), and year of kidding (YK). The data was analysed using STATISTICA statistical package version 8.0. First, the descriptive statistics of reproductive traits were analysed; second, the effect of non-genetic factors on reproductive traits was analysed using one-way ANOVA. The mean ± SE values for the descriptive analysis were LS (1.28 ± 0.41), TBW (6.35 ± 0.24 kg), KI (9.46 ± 0.28 months), AFK (15.63 ± 0.64 months), MBR (29 %) and KFR (17 %). The one-way ANOVA results indicated significant effects of parity ($p < 0.05$) on TBW and LS, while SK had a significant effect on AFK ($p < 0.0001$), and YK had significant effects on TBW, AFK ($p < 0.0001$), and LS ($p < 0.001$). The TBW, LS and MBR increased as parity advanced, while KI declined with parity. The AFK was higher in dry season (19.3 ± 3.58 months) than in wet season (13.3 ± 3.05 months). Therefore, the study concluded that non-genetic factors have a significant effect on reproductive traits. Adjusting reproductive traits for significant non-genetic factors increases the accuracy of estimated genetic parameters and selection programs for these traits in Saanen goats.

Keywords: small ruminants, animal breeding, parity, prolificacy, reproductive performance

1 Introduction

Worldwide, Saanen goats are considered as one of the most productive milk goat breeds (Akar, 2013; Sadjadian *et al.*, 2013). Consequently, the goats are introduced as pure breeds or crossbreds in dairy goat breeding programs to improve milk production (Massender, 2022). Goat milk plays an important role in the nutrition of both young and elderly people due to its low cholesterol content, which helps to reduce blood cholesterol and the risk of hypertension-related diseases. Moreover, its low acidity promotes easy digestion and offers medicinal benefits (Kumar *et al.*, 2021). The growing awareness of the benefits of goat milk has driven a substantial rise in its global demand (Luo *et al.*, 2019; Liang & Paengkoum, 2019).

The escalating global demand for goat milk is compelling the dairy goat industry to undertake substantial efforts towards enhancing milk production (Luo *et al.*, 2019). Consequently, breeders have intensified their focus on the genetic selection of milk yield. Nevertheless, this heightened emphasis on milk yield selection has inadvertently contributed to a reduction in reproductive performance, attributed to the unfavourable genetic correlation between milk yield and reproduction (Berglund, 2008; Ziadi *et al.*, 2021). This phenomenon raises a notable area of concern, given the economic significance of reproduction trait (Ziadi *et al.*, 2021).

Reproductive performance is an important key factor of efficiency, productivity, and economic viability in dairy goats. Optimal reproduction performance enables an increase of surplus animals for production purposes and a lower culling rate (Mellado *et al.*, 2006). Furthermore,

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multi-births lead to a greater amount of placenta tissue, promoting mammary gland development and resulting in higher milk yield compared to single births (Ferreira *et al.*, 2017). Conversely, poor reproduction performance results in reduced milk production per individual per day, reduction in replacement stock and an increase in voluntary and involuntary culling (Britt, 1985; Sadjadian *et al.*, 2013; Snyman, 2010). Moreover, low reproductive performance results in high input costs due to repeated inseminations, additional hormonal treatments for does that fail to conceive, extended days open, and longer kidding intervals (Kgari *et al.*, 2022). As a result, it is imperative for dairy goat selection programs to emphasise reproductive traits, despite milk being the primary product of these animals (Kgari *et al.*, 2022).

Incorporating reproduction as a selection criterion necessitates breeders to thoroughly evaluate various reproductive traits to attain a favourable selection response. This need arises from the complex nature of the reproduction process, which comprises several biological stages such as folliculogenesis, ovarian development, ovulation, pregnancy, gestation maintenance, among others (Diskin & Morris, 2008). Notable reproductive traits include litter size, kid birth weight, age at first kidding, kidding interval, kidding success, multiple birth rate (Nitter, 1985; Berglund, 2008).

To establish a robust breeding plan and effective selection program of reproductive traits, it is essential to estimate the genetic parameters, including breeding values of animals. Nonetheless, non-genetic factors tend to mask the actual breeding value of the individuals. Thus, accurate estimation of genetic parameters necessitates appropriate trait adjustment for various non-genetic factors (Wilson *et al.*, 2010; Berglund, 2008). These non-genetic factors include, parity, year and season of birth, age of dam, among others.

The objective of this study is to investigate the effect of non-genetic factors, namely parity, year, and season of kidding on reproductive traits in Saanen goats. The information obtained from this study will be crucial in the development of effective selection models for reproductive traits in Saanen goats.

2 Materials and methods

2.1 Study area

This study used data obtained from a Saanen flock kept at Baturraden breeding centre in Indonesia (BBPTU-HPT Baturraden) located in Central Java, Indonesia at 7°18’53.3” S 109°13’59.7” E. The seasons of the study area are classified into two, i.e., rainy season (October to March) and dry season (April to September) (Santosa *et al.* 2019; Susanto *et al.*, 2023). The average temperature is 21.1 °C and the annual precipitation is approximately 3290 mm. The temperature fluctuation between the two seasons is 1.2 °C. The lowest rainfall, with a mean value of 55 mm, is recorded in August/September, while the highest rainfall, with a mean value of 507 mm, is recorded in January (Harjana *et al.*, 2022).

2.2 Animals and management

This study investigated the reproductive performance of Saanen goats. The goats were kept in confinement within designated pens, categorised according to their reproductive stages, including pregnant does, dry does, kids. The breeding buck was used for 10 does in the breeding program. The animals were fed a mixture of concentrates, maize silage and alfalfa, three times a day. Kids were fed replacement milk and gradually fed on concentrates until weaning.

2.3 Data collection and analysis

In this study, secondary data was analysed from a sample of seventy-one does that were randomly selected and had parity orders ranging from 3 to 6. These does were born to a total of twenty-six sires and sixty-four dams during the period of 2015 to 2019. The data records consisted of pedigree information, reproductive traits and non-genetic factors. The reproductive traits analysed were litter size (LS), total birth weight (TBW), age at first kidding (AFK), kidding interval (KI), multiple birth rate (MBR) and kidding failure rate (KFR) (abortion and still birth). The non-genetic factors were parity (1 to 6), season of kidding (SK) (dry and wet) and year of kidding (YK) (2015 to 2021).

In this study, LS is defined as the number of kids born per kidding or parturition, TBW is defined as the live weight of the total kids per parturition; AFK is defined as the interval (in months) from birth to first kidding of a doe, KI is defined as the period (in months) between two consecutive kidding events, multiple birth is the parturition of more than one kid, whereas, multiple birth rate is $\left(\frac{\text{no. of multiple birds}}{\text{total no. of parturations}}\right) \times 100$. Similarly, kidding failure is defined as the abortion and (or) still birth, whereas kidding failure rate is $\left(\frac{\text{no. of kidding failures}}{\text{total no. of parturations}}\right) \times 100$. On the other hand, parity is the number of times the doe has been pregnant, regardless of the kidding success, i.e., whether the kid was born alive or not; SK and YK are the season and year of parturition; respectively.

For analysis purpose, the variables were coded as follows: kidding failure (alive = 1 & abortion or still birth = 2); parity (1, 2, 3, 4, 5 & 6); YK (2015 = 2; 2016 = 3, 2017 = 4; 2018 = 5; 2019 = 6; 2020 = 7 & 2021 = 8); SK (dry = 1 & wet = 2). The data generated in this study was analysed using the software package namely: STATISTICA statistical package version 8.0 (Stasoft Inc, 2008). Two statistical methods were used to analyse the data in this study. Firstly, descriptive statistics and secondly, one-way analysis of variance (ANOVA) or univariate generalized linear model (GLM) which was used to determine the effect of non-genetic factors on reproductive traits. The model was as follows:

$$y_{ij} = \mu + \alpha_i + e_{ij}$$

Where: y_{ij} is the reproduction trait or observation; μ is the mean, α_i is the effect of non-genetic factor and e_{ij} is the random error associated with the observation. The further tests of comparison of means were done using Tukey's method. The percentages of MBR and KFR in different parities, SK and YK were determined to project the effect of non-genetic effects on these traits.

3 Results

3.1 Descriptive statistics of reproductive traits

The results of descriptive analysis of this study are shown in table 1 below.

Table 1: *Descriptive statistics of reproductive traits.*

Variable	*N*	*Mean ± SE*	*Min*	*Max*
Litter size	140	1.28 ± 0.41	1	3
Total birth weight (kg)	123	3.99 ± 0.15	1.8	9
Age at first kidding*	47	15.63 ± 0.64	10	26
Kidding interval*	111	9.46 ± 0.28	8	17
Multiple birth rate (%)	(115) 34†	28	16	40
Kidding failure rate (%)	(138) 24†	17	0	34

* in months; † The number in the parenthesis is the total number of samples analysed and the number outside the parenthesis is the number of observations.

3.2 The effect of non-genetic factors on reproductive traits

The least squares means and results from the variance analysis are shown in table 2. Firstly, the results showed that parity had a significant effect ($p < 0.05$) on TBW and LS. Both TBW and LS showed an increasing trend with parity up to number 4 and then a decline in parity 5. The records of TBW and LS for parity 1 were 3.30 ± 0.26 kg and 1.14 ± 0.07, respectively, whereas for parity 4, they were 4.98 ± 0.44 kg and 1.47 ± 0.12, respectively. Subsequently, a decline in parity 5 was observed for both traits (4.17 ± 0.50 kg and 1.27 ± 0.14). Secondly, KI showed a decreasing trend with successive parturition as parity advanced, although there was no statistical difference between the means ($p > 0.05$). The highest KI was recorded in parity 2 (10.1 ± 0.53 months), while the lowest was recorded in parity 6 (9.0 ± 1.14 months). Thirdly, a trend of increasing MBR with parity was observed where the least was recorded in parity 1 (16 %) while the highest was in parity 3 and 4 (40 %). Lastly, KFR did not show any specific trend with parity. These results indicate that TBW, LS, KI and MBR improved with successive parturitions as parity advances.

Season of kidding had a significant effect ($p < 0.0001$) on AFK. The largest and lowest AFK were recorded in dry season and the lowest, respectively (19.3 ± 0.77 and 13.3 ± 0.60). Parity did not have a significant effect ($p > 0.05$) on LS, TBW and KI. The MBR was higher in wet season (29 %) compared to wet season (22 %), while KFR was lower in wet (10 %) than dry season (26 %). These results indicate that the SK had a significant effect only on AFK.

The YK had a highly significant effect ($p < 0.0001$) on TBW and a significant effect ($p < 0.001$) on LS, which both showed the highest means in 2017, (6.12 ± 0.32 kg and 1.80 ± 0.13; respectively). Year of kidding did not have a significant effect ($p > 0.05$) on KI.

4 Discussion

4.1 Parity

The increasing trend of TBW, LS and MBR with parity has been consistently reported in previous studies (Hoque *et al.*, 2002; Sodiq *et al.*, 2003; Ince, 2010; Montaldo *et al.*, 2014; Assan, 2020). This rise in LS with parity is attributed to the improved reproduction efficiency achieved with good maternal care, enhanced uterine capacity, improved body weight, high body scoring conditions and well-developed reproductive function of reproductive tissues of does in advanced parity orders (Hong *et al.*, 2009; Bushara *et al.*, 2011; Radhika *et al.*, 2015; Harowi, 2016). On the other hand, the increase of TBW with parity is attributed to the physiological changes in female goats with increasing age (Haslin *et al.*, 2022). The decline in LS and TBW of does in parity 5, as observed in this study, has been reported in previous studies as well (Hoque *et al.*, 2002; Sodiq *et al.*, 2003; Sodiq & Tawfik, 2003). This decline in reproductive performance from parity 5 onwards is attributed to the decline of the physiological condition of older does (Haldar *et al.*, 2014). Notably, in this study, LS increased again in parity 6, which was due to the culling of poor-performing does in parity 5.

Consistent with findings of this study, previous research conducted by Awemu *et al.* (1999) and Bushara *et al.* (2011) also reported a steady decline of KI between successive parturitions as parity advanced. This decrease in KI with parity

Table 2: *Least squares mean (± SE) of reproductive traits of Saanen goats as affected by non-genetic traits.*

	Reproductive traits					
Factor	*TBW (kg)*	*KI (months)*	*AFK (months)*	*LS*	*MBR (%)*	*KFR (%)*
Parity	*	ns		*		
1st	(5) 3.30 ± 0.26^{b}			(42) 1.14 ± 0.07	(42) 16	(47) 11
2nd	(6) 3.79 ± 0.29^{ab}	(46) 10.1 ± 0.53		(34) 1.21 ± 0.08	(34) 24	(45) 29
3rd	(9) 4.48 ± 0.30^{ab}	(29) 9.6 ± 0.67		(28) 1.36 ± 0.09	(28) 40	(28) 3
4th	(5) 4.98 ± 0.44^{a}	(16) 9.5 ± 0.90		(15) 1.47 ± 0.12	(15) 40	(16) 12
5th	(3) 4.17 ± 0.50^{ab}	(12) 9.2 ± 1.04		(11) 1.27 ± 0.14	(11) 30	(12) 8
6th	(4) 4.65 ± 0.56^{ab}	(10) 9.0 ± 1.14		(10) 1.60 ± 0.15	(10) 25	(10) 20
SK	ns	ns	***	ns		
dry	(10) 3.83 ± 0.24	(54) 9.6 ± 0.49	(18) 19.3 ± 0.77^{b}	(54) 1.26 ± 0.06	(54) 22	(70) 26
wet	(22) 4.01 ± 0.19	(59) 9.9 ± 0.47	(29) 13.3 ± 0.60^{b}	(86) 1.29 ± 0.05	(86) 29	(87) 10
YK	***	ns		**		
2015			(7) 15.0 ± 1.21^{b}	(7) 1.28 ± 0.20ab	(7) 28	(7) 0
2016	(3) 3.62 ± 0.46^{b}	(5) 9.4 ± 1.62	(5) 24.4 ± 1.43^{a}	(11) 1.60 ± 0.22ab	(11) 27	(11) 0
2017	(11) 6.12 ± 0.32^{a}		(19) 9.9 ± 0.83	(19) 1.80 ± 0.13^{a}	(19) 68	(19) 5
2018	(6) 5.07 ± 0.35^{ab}		(16) 8.6 ± 0.90	(16) 1.41 ± 0.12^{ab}	(16) 37	(0) 0
2019	(6) 3.77 ± 0.75^{ab}		(16) 10.1 ± 1.14	(16) 1.40 ± 0.15^{ab}	(16) 30	(16) 9
2020	(4) 3.24 ± 0.22^{b}	(29) 10.0 ± 0.67	(32) 14.6 ± 0.56^{b}	(43) 1.62 ± 0.08^{b}	(43) 12	(61) 34
2021	(4) 3.43 ± 0.25^{b}	(34) 9.9 ± 0.62		(34) 1.57 ± 0.10^{b}	(34) 15	(33) 12

TBW: total birth weight; KI: kidding interval; AFK: age at first kidding; LS: litter size; SK and YK: season and year of parturation. Means with different superscripts in the same column differ significantly; where, $*p < 0.05$; $**p < 0.001$; $***p < 0.0001$ and ns (not significant); The number in the parenthesis is the total number of samples analysed.

is attributed to the reduced time required for the recovery of reproductive system of does as parity progresses. The females in earlier parities take longer than the older does to recover and return to favourable reproductive status (Awemu *et al.*, 1999). Moreover, the trend of decreasing KI with parity may also be indicative of culling does with lower fertility (Marai *et al.*, 2009).

Regarding the KFR, previous findings have indicated high abortion rate in primiparous does and in advanced parities (Rattner *et al.*, 1994; Mellado *et al.*, 2004; Mellado *et al.*, 2006). These results are in contrast to the findings of the current study, which showed no specific trend of KFR between parities. The inconsistent trend of KFR between parities could be attributed to individual differences between the does and variation in management practices implemented in the population (Awemu *et al.*, 1999).

4.2 Season of kidding

The AFK of the does in this study was lower in wet than in dry season. The variation in AFK across seasons may be a reflection of changing environment such as rainfall, temperature, relative humidity and available fodder. Kids born in dry season will be suckling throughout the dry season and then pastures become available when they are weaned and will have access to the forage during wet season. This implies that the kids weaned in wet season are likely to grow faster and attain sexual and breeding maturity earlier (Abanikannda & Olutogun, 2019). Moreover, the rain in the wet season can mitigate the effect of heat stress thereby stabilizing hormonal balance in the animals and ensuring a longer duration of oestrous (Abanikannda & Olutogun, 2019). According to Koketsu *et al.* (2017), high temperatures reduce GnRH secretion and impare ovarian follicle development, leading to compromised corpus lutea functions and low progesterone concentrations. Hence, the weather conditions during the wet season contribute to the early AFK observed in goats.

Similar to the findings in this research, several studies demonstrated that SK did not have a significant effect on TBW, LS and KI (Wilson *et al.*, 2010; Joshi *et al.*, 2018). There is minimal to no variation in LS between seasons, particularly in small ruminants reared under intensive management systems. This is primarily due to the consistent and constant availability of adequate feed with high nutritional value throughout the year in intensive management systems (Assan 2020; Papaloukas *et al.* 2016; Zamuner *et al.* 2020).

4.3 Year of kidding

Year of kidding had a significant effect on TBW and LS. The observed results may be attributed to the variation in dry matter of veld across different years. The fluctuation of veld is caused by variations in rainfall levels between years and the consequences of these fluctuations may be reflected in the reproduction performance of animals (de Waal *et al.*, 2000). In this context, a previous study showed that LS increased by 11 % in years with high rainfall compared to dry years (Dadi *et al.*, 2008). Apart from rainfall, other factors such as feed practices, management systems and practices, climatic conditions, health, and diseases, among others, may also contribute to the varying reproductive performance observed in different years (Caroprese *et al.*, 2009; Assan, 2020). These factors play a role in manipulating the reproductive performance in various years and should be considered when evaluating the impact of YK on TBW and LS in Saanen goats.

5 Conclusion

The present study revealed that all the non-genetic factors investigated had a significant effect on one or more reproductive traits. Therefore, the study concluded that parity, season, and year of kidding should be included in genetic evaluation models to increase the accuracy of genetic parameters of reproductive traits in Saanen goats. This will ensure effective selection of reproductive traits in breeding programs of Saanen goats.

Conflict of interest

We declare that there is no conflict of interest with any financial, personal, or other relationships with other people or organisation related to the material discussed in this manuscript.

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