Systematic factors and individual variation affecting litter size of Boer and Jawarandu goat cross

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Abstract. We studied the systematic factors and individual variation affecting litter size in the crossbreds between Boer and Jawarandu goat. The data were obtained from the records of litter size of Boerja goats from 2012 to 2015. The systematic factors consisted of season and year of birth, doe breeds and the kid’s sex; along with individual data including pedigree, date of birth, and parental breeds. The data consisted of 107 Boer does, 687 Jawarandu does, and 495 Boerja does with a total of 3804 kids. A linear model was developed to account the effect of systematic factors on litter size of Boerja goats. Later, a mixed model was solved with Restricted Maximum Likelihood (REML) method to estimate the individual variations on litter size. The results showed that litter size trait in goat was influenced by doe breed (P<0.05). Individual variation of this trait was also high (46%). Based on this research, it can be concluded that litter size of Boer goats and their crosses were affected by the doe’s breed with high individual variation. Doe’s selection is potential to improve litter size in goat crossbred population in the future.

1. Introduction

Goats are small ruminants that widely reared in Indonesia. The population of goats in Indonesia is reached 19,608,181 in 2016 and expected to grow in the future [1]. There were various indigenous goat breeds in Indonesia such as Kacang, Jawarandu and Etawa Grades goats. Local goat productivity can be improved through breeding programs including selection and crossbreeding between exotic superior males with local females [2]. Borja goat is the result of crossbreeding between Boer and Jawarandu goats that conducted in Indonesia.

Boer buck and Jawarandu doe cross were made to increase genetic quality of local goats. Boer goat is an exotic goat with high meat production [3], while Jawarandu goat is known with superior prolific reproductive traits [4]. The prolific trait of goats to give birth more than one kid was expected to be increased because it can provide economic benefits for farmers. The litter size of a boer doe was determined by three genetic factors, consisted of the number of eggs produced each time of ovulation rate, fertility and the condition during pregnancy, and embryonic death [5]. These three factors are affected by systematic factors such as doe’s age, doe’s weight, type of birth, buck’s influence, season, and levels of feed nutrients.

Evaluation of the Borja goat breeding program can be observed from the litter size which described the level of reproducibility. Single or multiple birth of kid can affect the total reproductive value of doe which can then be used for evaluating the reproducibility. This study aims to determine the effect of
systematic factors such as season and year of birth, breed doe, and kid’s sex as well as individual variation factors on litter size trait of Boer and Jawarandu goat cross.

2. Materials and methods

2.1. Data collection and does rearing

This retrospective study use data that was obtained from the records of litter size of Boerja goats from 2012 to 2015 in CV. Kambing Burja, East Java, Indonesia. The data consisted of systematic factors including season and year of birth of kids, breed doe, and the kid’s sex. Season and year of birth of kids was obtained from the difference in rainfall each year from the birth of kid in 2012-2015. The records of litter size were equipped with pedigree, date of birth, and parental breeds. The goat population consisted of 26 male Boer goats, 107 female Boer goats, 687 female Jawarandu goats, and 495 female Boerja goats.

Boer bucks and does are purebreed that were imported from Australia with selection program, but some Boer doe were born in Indonesia. Jawarandu does are crossbred of Etawa Grade buck with Kacang doe. Jawarandu doe was obtained from local market without any information of parity and age. A total of 3,804 offsprings with three different compositions of breed was produced.

The does were kept intensively in colony without breed separation, containing 20-25 goats in each flock. There was no different in farm management including feed management. Mating process was performed by joining a Boer buck into a flock for 45 days. The Boerja F1 was produced by mating Boer bucks with Jawarandu does. Mating was performed while minimizing inbreeding.

2.2. Data analysis

Litter size and systematic factors data were statistically analyzed by a linear model at α=0.05. The fixed effect of this study such as season and year of birth of kids, breed doe, and the kid’s sex were analysed according to the following basic model [6]:

\[ y_{ijk} = \mu + SYB_i + B_j + Sex_k + e_{ijk} \]

Where,

- \( y \): response (litter size)
- \( \mu \): general mean
- \( SYB_i \): season and year of birth effect
- \( B_j \): breed doe effect (j= 1,2,3)
- \( Sex_k \): offspring sex effect (k= 1,2)
- \( e_{ijk} \): residuals

Variance component analysis of litter size on the individual goat doe was preliminary analysed by a linear model to check the significance of season and year of birth of kids, breed doe, and the kid’s sex factors affecting the litter size trait. Later, we employed a mixed model procedure including the significant fixed effect(s) and individual does as random effect to estimate the variance components as in the following equation:

\[ y = Xb + Ia + e \]

where \( y \) is a vector of observed variables, \( b \) is a vector of fixed effects accounted for season and year of birth of kids, breed doe, and the kid’s sex and \( X \) is the incidence matrix corresponded to the fixed effects. \( I \) is an identity matrix corresponding to the random individual effect (a) where \( a \sim MVN(0, \sigma_a^2) \). Random residual vector is \( e \) with \( e \sim MVN(0, \sigma_e^2) \). The equation was solved with maximum likelihood estimator in R programming language [7].
3. Results and discussions

3.1. The effect of systematic factors on doe’s litter size
A total of 3,804 offsprings with three different compositions of breed was produced by does. The result showed that breed doe was the only systematic factor in this study that gave a significant effect of litter size (p<0.05), whereas season and birth of year and sex’s kids didn’t give any effect (p>0.05) on litter size of doe observed (Table 1).

Table 1. Number of records (n), mean and standard deviation of litter size of does in various season and year of birth, doe breed, and kid’s sex.

| Variable                | Level    | N   | Mean ± sd |
|-------------------------|----------|-----|-----------|
| Season and year of birth| Rainy 2012| 280 | 1.50±0.51 |
|                         | Dry 2012 | 221 | 1.46±0.54 |
|                         | Rainy 2013| 538 | 1.52±0.53 |
|                         | Dry 2013 | 272 | 1.54±0.53 |
|                         | Rainy 2014| 598 | 1.48±0.52 |
|                         | Dry 2014 | 390 | 1.52±0.52 |
|                         | Rainy 2015| 420 | 1.54±0.53 |
|                         | Dry 2015 | 125 | 1.57±0.59 |
|                         |          |     | 3.81x10⁻¹ |
| Breed Doe               | Boer     | 321 | 1.62±0.51a |
|                         | Jawarandu| 1585| 1.52±0.53b |
|                         | F1       | 938 | 1.46±0.52c |
|                         |          |     | 2.60x10⁻⁷ |
| Kid’s Sex               | Male     | 1915| 1.63±0.52 |
|                         | Female   | 1889| 1.65±0.51 |
|                         |          |     | 3.51x10⁻¹ |

Note: Different superscripts show significantly different (P < 0.05).

Breed doe in this study shows a significant effect on doe’s litter size and have a different result between Boer, Boerja, and F1. In the present study, we found Boer does produce more kids (p<0.05) compared to Jawarandu and F1 doe. Prolific trait in goats can be inherited by the parent to the offspring [8]. Previous study confirmed that litter size was influenced by body size especially body length and hip width [9]. Boer does have bigger body size than Jawarandu and F1. Body length and hip width are related to the area of the abdomen and uterus, which could be useful indicator to estimate the number of offspring in female goat [10].

Boer doe in this study had a low summary of litter size compared to previous studies [11-13]. Boer doe was assumed to have difficulty adapting due to differences in environmental factors such as weather and feed availability in Australia compared to Indonesia. The result of previous study by Nugroho [14] using the same data reported that Boer doe had tend to decrease litter size start from 2012 to 2015, strengthened the result of this study.

Jawarandu and F1 doe produces less kids compared to Boer. Jawarandu doe was obtained from local market without any information of parity and age. These two factors did not state in the recording, so they could not be selected before. According to the earlier study, small litter sizes in Jawarandu doe could be affected by several factors: doe was giving birth for the first time and doe has not yet reached sexual maturity or doe has giving birth more than 6 parities [15].

Season and year of birth and kid’s sex had no significant effect (P>0.05) on doe’s litter size of Boerja, same with the previous study [16]. The weather changes outside the barn every year could not affect...
doe’s performance because the doe reared intensively inside the flock and doe was maintained under the same management system in every season. Different kid’s sex also did not affect doe’s litter size. Kid’s sex was influenced by genetic factors related to the activity of sex chromosomes that occur during prenatal period and carried by the spermatozoa; the sex chromosomes X and Y in the process of fertilization [17].

### Table 2. Variance components of Boerja goat’s litter size trait

| Variable  | Residual variance | Individual variance |
|-----------|-------------------|---------------------|
|           | 0.1600±0.011      | 0.1354±0.016        | 46%      |

3.2. Variance component of doe’s litter size

Based on the result of observed variable, individual variation contributes 46% to the litter size of does (Table 2). All the systematic factors in this study consisting of season and year of birth, breed doe and kid’s sex have been corrected. The difference or variation presumably due to genetic variation between the doe and environment [18], because Jawarandu doe was obtained from local market without any recording, although they reared under the same cage and same feed in CV. Kambing Boerja. According to the earlier study, interaction between genetic and environment factor could affect individual variation [19].

Environmental factor that could affect litter size was nutritional level of feed given at the prenatal period and goat growth [20]. Lack of information on the feed management condition of breeding does during the prepubertal period was the reason that could affected the high percentage of individual variation. To the best of our knowledge, doe’s selection was performed at smallholder farm, then selected and reared after puberty in the same flock. Difference in environmental management, especially during prepubertal, can lead to variation in ovum production and reproductive organ maturity. Feed given at prepubertal or at weaning age was a factor that determined the growth, reproduction, and health of does [21]. Previous study confirmed that deficiency or imbalance nutrition during pre-pubertal period could affect the reproductive process and late of puberty [22].

Litter size variation also can be influenced by genetic factors of does in producing ovum. Genetic factors that affected litter size were the doe’s ability to produce ovum, the number of fertilized ova, the ability of the fertilized ovum to implant itself and able to survive in each doe [23]. Hormonal activity could be one of the reasons that effected those genetic factors. The ovulation rate of each parent was controlled by the hypothalamus through the pituitary gland in brain. Gonadotrophin Releasing Hormone (GnRH) from hypothalamus stimulates the pituitary gland to secrete Follicle Stimulating Hormone (FSH) and Luteinizing Hormone (LH) [24]. Previous study reported that these two hormones play an important role in the process of folliculogenesis and ovulation that affected follicle growth and maturation [25].

In the molecular perspective, the variation of genes controlling ovum production could explain the difference litter size between does. Difference expression of genes lead to the difference litter size and ovum production. For example, the difference of BMP15 expression in antral follicle is associated with goat fertility [26]. Research by Moore and Shimasaki [27] reported that this gene is able to increase the sensitivity of granulosa cells to FSH (Follicle stimulating Hormone) which will accelerate the development of follicles and premature ovulation of small follicles so doe’s prolificacy could be increase.

In doe’s selection, careful selection, and the application of genetic standard need to be concerned. Selection can be done traditionally by looking at the doe’s performance or using molecular sciences. By intense selection accompanied with maintain the environment, doe individual variation could be reduced. A high number of litter size followed by a low number of individual variations indicates a good doe reproductive performance and expected to improve the performance of local goats in the future.
4. Conclusions

Based on this study, the doe breed is one of the systemic factors that can affect litter size of Boer goats and their crosses. This study also shows that there is a wide variation of litter size resulted due to variation between individual Boerja doe. Especially in doe’s selection, careful selection and the application based on doe source, age, and parity of genetic standard need to be concerned in order to maximizing litter size and reduce the number of individual variations, so that the reproductive quality of local goats in the future can be improved.

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