Post-Natal Indonesian Garut Sheep Performance Fed with Sorghum-Indigofera-Mixed Feed and Stimulated with Pregnant Mare Serum Gonadotropin Hormone

Rachmat Somanjaya[1]*, Asnath Maria Fuah[2], Sri Rahayu[2], Luki Abdullah[3]*, Mohamad Agus Setiadi[4]

[1]Study Program of Animal Husbandry, Faculty of Agriculture, Universitas Majalengka, West Java 45418, Indonesia, [2]Department of Animal Production and Technology, Faculty of Animal Science, IPB University, Bogor 16680, Indonesia, [3]Department of Nutrition and Feed Technology, Faculty of Animal Science, IPB University, Bogor 16680, Indonesia, [4]Division of Reproduction and Obstetrics, School of Veterinary Medicine and Biomedical Sciences, IPB University, Bogor 16680, Indonesia.
*Corresponding author: rachmat.somanjaya@unma.ac.id, labdull@apps.ipb.ac.id

Abstract

This study aimed to determine the effect of sorghum-indigofera (SI) mixed feed and pregnant mare serum gonadotropin (PMSG) hormone stimulation on ewe's reproductive performance and Garut lamb's pre-weaning growth. Twenty-eight multiparous Garut ewes were included into four treatment groups (2 × 2) with a factorial-Completely Randomized Design (CRD). The first factors were the types of feed local forage (LF) and SI, while the second factor was PMSG hormone stimulations (with and without PMSG stimulation). Synchronized estrous used twice injections with PGF2α, 11 days apart, and 500 IU PMSG was adminstrated at the second PGF2α injection intramuscularly. The observed variables included ewes' performance after parturition and post-natal lamb's growth. The obtained data were analyzed by multivarians of analysis (MANOVA) with $\alpha = 0.05$ and continued with Tukey's Test. The result showed that feeding ewes with SI without PMSG stimulation resulted in the highest number of pregnancies, litter size, and lactation compared to other treatments. Feed type and PMSG stimulation factors has no any interaction effect ($p > 0.05$) on birth weight, weaning weight, and milk production. However, birth weight and milk production were affected ($p < 0.05$) by the feed, while weaning weight was affected ($p < 0.05$) by the PMSG stimulation. The fastest lamb growth rate was found in the groups of ewes fed by SI without PMSG stimulation (120 g/head/day). It can be concluded that SI could improve the ewe's reproductive performance and the post-natal growth of Garut lambs. Meanwhile, the PMSG hormone could beneficially with sorghum-indigofera mixed feed.

Keywords: Garut sheep, PMSG, post-natal performance, sorghum-indigofera

Received: May 16, 2024 **Revised:** October 26, 2024 **Accepted:** November 27, 2024

INTRODUCTION

The main challenge in meeting domestic market demand in Indonesia is low sheep production, which always rises over time (Shiddieqy and Priyono, 2022). Besides genetic factors, the environment also dramatically influences sheep productivity. Garut sheep, which is often called Priangan sheep, is reported to have a prolification trait like other sheep worldwide, which is the role of the single gene FecJ (Davis, 2005). However, this genetic potential might only be realized if these animals are properly kept in herds under good farming management. As reported by Khotijah *et al*. (2015), Garut sheep that were reared traditionally had a low average litter size, namely ±1.2 head per ewes. Aside from that, a common issue is the high mortality rate of lambs from birth to weaning. One of the causes could be the traditional maintenance system (Somanjaya *et al*., 2015).

The feed quality is another factor influencing the ewe's reproductive success rate. According to Harlow *et al*. (2022), dietary deficiencies could lead to decreased reproductive performance due to the inhibition of gonadotropin-releasing hormone (GnRH) and luteinizing hormone (LH) secretion. As a result of the inhibition of these two hormones, puberty was delayed, increased anestrus postpartum duration, and the ovulation cycle was obstructed (Jardstedt *et al*., 2020). Calorie restriction, as reported by I'Anson *et al*.

(2000), had been shown to inhibit the release of GnRH, which ultimately reduced LH secretion so that it could reduce the rate of ovulation. Based on this phenomenon, improving feed quality, particularly energy and protein feed sources, is necessary to increase the reproductive success rates of Garut sheep in traditional rearing systems.

Sorghum and indigofera forages respectively represent energy and protein source forages with high palatability. Sorghum and indigofera are tolerant to dry conditions because they require less water for growth than other cereal plants. These two plants could still grow and produce biomass during the dry season and potential to supply energy and protein throughout the year. Sorghum forage contained gross energy, crude protein, and crude fiber by 4100 Kcal/kg, 7.82, and 28.94%, respectively. These nutrient contents were higher than those of elephant grass, which contains 6% crude protein and 34.25% crude fiber, and sugar cane leaves, which contain crude protein and fiber 5.33 and 35.48%, respectively (Purnomohadi, 2006). The protein content of indigofera forage was relatively high, equivalent to alfalfa, which ranged from 28–31%, and minerals, such as Ca, P, Mg, Zn, which were optimal for livestock with a low tannin and high beta-carotene content (Palupi *et al*., 2014). According to Abdullah *et al*. (2012) indigofera could boost milk production and could compensate for a commercial feed of goats.

Improvement of sheep reproductive performance can also be made with hormonal applications. Pregnant mare serum gonadotropin hormone (PMSG) has been widely applied as a superovulation agent in various types of livestock and also known as equine chorionic gonadotropin (eCG), is a glycoprotein hormone produced by pregnant mares between days 40 and 120 of gestation (Thach *et al*., 2022). It has been widely used to improve reproductive performance in various domestic species due to its LH and follicle stimuating hormone (FSH)-like activities (Thompson *et al*., 2023). PMSG is a serum from pregnant mares that double contains FSH and LH. The application of PMSG will strengthen the processes of folliculogenesis and ovulation to trigger superovulation (Andriyanto *et al*., 2015).

There has been no use of PMSG combined with sorghum-indigofera (SI) mixed feed to stimulate and increase ewe reproductive performance and Garut lamb growth before weaning. Combining both factors is expected to increase the capability of prolification of Garut ewes since nutrient intake increases and stimulation of the applied PMSG hormone occurs. By improving the quality of feed for the Garut sheep, the application of the PMSG hormone should be more effective in improving the average number of twins with a low mortality rate. This study result may be a technological reference to accelerate the increase of livestock population, especially Garut Sheep. The study aimed to determine the effect of SI mixed feed and stimulation of the PMSG hormone on ewe's reproductive performance and Garut lambs' post-natal growth until weaning period.

MATERIALS AND METHODS

Ethical Approval

All procedures in this study followed the approved protocol by animal care institutions in Animal Ethics Committee, Faculty of Veterinary Medicine, IPB University, Indonesia, with approval number 011/KEH/SKE/V/2021.

Study Period and Location

This study was conducted from March to November 2021 in the Garut sheep farming community in Majalengka District, West Java, Indonesia, at the coordinates 6°48'50.0"S 108°13'35.8"E; 141 m above sea level (asl).

Experimental Design

Twenty-eight healthy multiparous Garut ewes with the following criteria: 2–3 years old, weighed 30 kg, and not pregnant were included in four treatment groups (2 × 2) laid in a factorial completely randomized design (CRD) with seven ewes in each experimental unit. The first factor was the types of feed consisting of local forage (LF) and SI mixed feed, while the second factor was PMSG hormone stimulations.

Diets, Hormonal Treatment, and Pregnancy Diagnosis

The experimental feed consisted of local forage, including local grass (LF) and SI mixed feed with a composition of 50% sorghum forage silage + 40% indigofera forage hay + 10% rice bran (dry matter). This feed is given for nine month, beginning with the feed adaptation until the weaning period. The LF consists of field grass and several creeping legumes commonly fed by local farmers. Meanwhile, the type of sorghum provided was mutant sweet sorghum variety Samurai 1 strain Zh-30 resulting from gamma ray radiation at a wave of 30 Gy produced by the National Nuclear Energy Agency of Indonesia (BATAN). Before being mixed with other ingredients, this forage was ensiled. Furthermore, as a source of protein, the legume *Indigofera zollingeriana* was dried to produce hay.

Sorghum as whole plant was harvested at a dough stage for 70 days after planting and then gathered every 40 days for four harvests. Meanwhile, indigofera forage was harvested every 40 days after the previous harvest. The same care was given to both plants as it was before the first harvest. Both kinds of feed are offered twice a day, in the morning and the evening, along with unlimited access to drinking water. The LF and SI were served in proportions equivalent to 3% of body weight dry matter per day with an average dry matter intake of 1.30 ± 0.10 and 0.79 ± 0.05 kg/head/day, respectively (Somanjaya *et al*., 2022). A comparison of the nutrient content of the experimental feed is shown in Table 1.

Table 1. Nutrient content of local forage and sorghum-Indigofera mixed feed

Nutrient content	Feed types	
	Local forage	**Sorghum-indigofera mixed feed**
Dry matter (%)	30.88	26.45
Ash (%)	11.89	10.34
Crude protein (%)	12.60	19.82
Ether extract (%)	2.18	1.91
Crude fiber (%)	22.90	30.57
Calcium (%)	0.83	1.48
Phosphorus (%)	0.45	0.56
Total digestible nutrient (%)	51.00	59.35
Gross energy (cal/g)	3396	4423

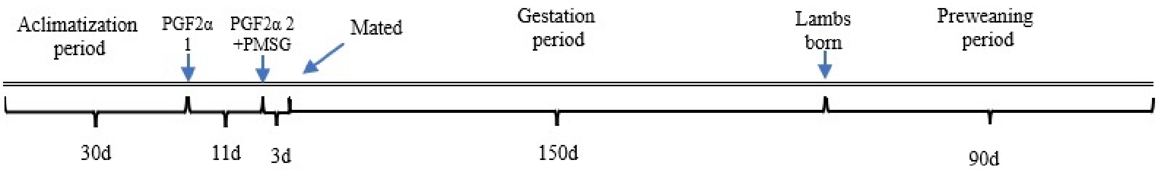

Figure 1. Experimental scheme flow.

Hormone administration was carried out at the end of the feed acclimatization period. Animals were synchronized estrus protocol with PGF2α (Lutalyse®, Zoetis, USA) twice intramuscularly, 11 days apart with a dose of 2.50 mL or the equivalent of 12.5 mg dinoprost tromethamine (Mekuriaw *et al*., 2016). Meanwhile, 500 IU PMSG (Folligon®, Intervet International B.V., Boxmeer, The Netherlands) was administrated using the same method at the second injection of PGF2α (Hussein *et al*., 2021) in half the population of each feed treatment (n = 7). After the ewes exhibit estrus, they were immediately mated with a ram naturally once and given marking. Pregnancy diagnosis was done transrectally on the 30th day after mating using a linear probe ultrasound (SSD500 model 7.5 MHz, ALOKA Co. Ltd., Japan) (Figure 1).

Post-Natal Performance Measurements

Several post-natal performance variables of Garut sheep were observed including the number of parturition ewes, litter size, birth weight, weaning weight, growth rate of lambs, milk production of ewes, and mortality rate of pre-weaned lambs. The number of parturition ewes was determined based on the number of ewes that had previously been certified pregnant based on the findings of ultrasound observations. Following that, observations continued to measure the lambs' litter size and birth weight. Litter size was calculated based on the number of lambs born per ewe that gave birth (Somanjaya *et al.*, 2022), while birth weight was measured by weighing the lamb at the time or a maximum of 24 hours after birth (Málková *et al*., 2021).

When the lambs reach 90 days of age, they are weaned, and weaning weight measurements are made by considering the body weight correction factor at that age. The reason for this is that not all lambs are born at the same time. For the record, when weighed, the age of weaning weight ranges from 90 to 100 days. Determination of weaning weight at 90 days of age is calculated using the following formula:

$$\text{Body weight at 90 days old} = \frac{\textit{Birth weight} + (\textit{Weight when weighed} - \textit{birth weight})}{\textit{Age when weighed}} \times 90$$

The following variable is the growth rate of the lamb, which is observed from birth to weaning by weighing the lamb every week.

Furthermore, milk production measurements were done once a week, from the seventh day after birth until the lambs were weaned. Milk production was measured by the weigh-suckle-weigh method (Mohapatra *et al*., 2020), which starts with separating the lambs from the ewes for 6 hours. Lambs were weighed before and after suckling with a suckling duration of less than 15 minutes. Even though the lambs have ceased nursing, there has been no urinating or excreta. The difference in weight obtained is an estimate of milk production at that time. Milk production is weighed using a digital scale with a sensitivity of 10 g. Daily milk production is estimated by multiplying the six-hour weighing results by four. Meanwhile, one day's production is multiplied by seven to determine weekly milk production. The milk production estimate for one lactation period is obtained by adding the weekly milk production.

The last variable observed in this study is the lamb's mortality rate. Furthermore, the percentage of lamb mortality is calculated by dividing the number of lamb fatalities by the number of lambs born until the age of 90 days in each treatment.

Data Analysis

The effect of the feed type served and the PMSG hormone, as well as their interactions on the post-natal performance of Garut sheep, were analyzed using two-way multivarians of analysis (MANOVA) at a confidence level of 95%. On the other hand, determining the difference in mean values between treatment combinations was tested with Tukey's test. All data were processed with SPSS version 27 (SPSS Inc., Chicago, Illinois, USA) and presented as mean values ± standard error means.

RESULTS AND DISCUSSION

Number of Pregnant, Parturition, and Nursing Ewes

Following confirmation of pregnancy based on ultrasound diagnosis, PMSG-stimulated ewes had lower rates of parturition than those that didn't stimulate the group. Furthermore, after the parturition process, not all ewes were lactated due to pregnancy failure, fetus loss, the death of lambs after birth, and the death of ewes after parturition. Pregnancy failure followed by a low number of lactating ewes occurred most frequently in the LF+PMSG treatment. Only two of the five pregnant ewes reached the lactation stage (Table 2). The low number of nursing ewes in this treatment was caused by the loss of fetuses during pregnancy and the death of ewes after giving birth. According to Ridler *et al*. (2015) about 6.8% of ewes experienced pregnancy failure caused by loss of the fetus after being declared pregnant by trans-abdominal ultrasound examination. The loss of the fetus is closely related to the low body weight of the ewe before

Table 2. Post-natal Indonesian Garut sheep performance after fed sorghum-Indigofera mixed feed and stimulation with pregnant mare serum gonadotropin hormone

Variable	LF		SI		p-value		
	Without PMSG	PMSG	Without PMSG	PMSG	Feed	PMSG	Interaction
Number of ewes (head)	7	7	7	7	-	-	-
Number of pregnant ewes (%)	57.14 (4/7)	71.43 (5/7)	100 (7/7)	42.86 (3/7)	-	-	-
Number of parturitions per pregnant ewes (%)	100 (4/4)	60 (3/5)	100 (7/7)	66.67 (2/3)	-	-	-
Litter size (head)	1.25±0.25[a] (5/4)	1.33±0.33[a] (4/3)	1.43±0.30[a] (10/7)	4.50±1.50[b] (9/2)	0.006	0.008	0.011
Number of lactating per parturition ewes (%)	100 (4/4)	66.67 (2/3)	85.71 (6/7)	100 (2/2)	-	-	-
Birth weight (kg)	3.20±0,40	2.73±0,42	2.64±1,17	1.76±0,53	0.029	0.052	0.544
Weaning weight (kg)	13.02±2.91	12.28±2.12	12.72±3.06	7.59±2.03	0.056	0.028	0.089
Daily milk production (kg/head/day)	0.31±0.02	0.49±0.10	0.61±0.06	0.61±0.15	0.025	0.312	0.295
Number of preweaning lamb's mortality (%)	0	25 (1/4)	30 (3/10)	33 (3/9)	-	-	-

LF = local forage

SI = sorghum-indigofera

PMSG = pregnant mare serum gonadotropin

Mean in the same row with different superscript letters show interaction ($p < 0.05$).

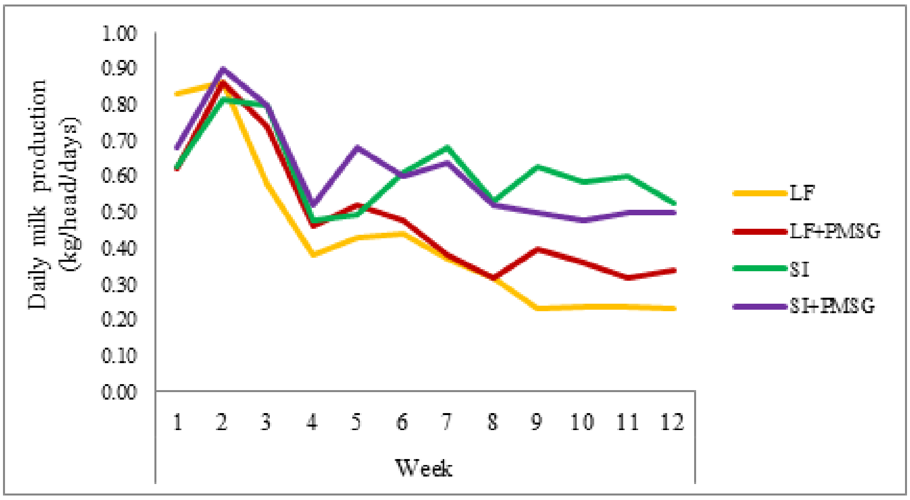

Figure 2. Ewe's milk production pattern during the lactation period (kg). (LF) local forage; (LF+PMSG) local forage + PMSG; (SI) sorghum-indigofera; (SI+PMSG) sorghum-indigofera + PMSG.

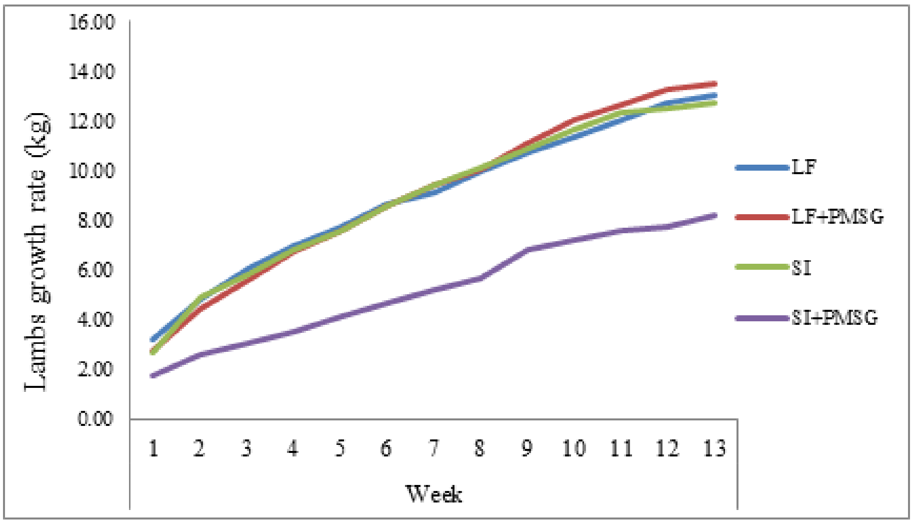

Figure 3. Growth rate of lambs until weaning age.

mating or the low body weight gain of the ewe from the time of mating until the pregnancy period.

In addition, pregnancy failure in this study only occurred in ewes that received PMSG stimulation. This occurrence is thought to be related to the PMSG hormone's lengthy half-life. Pregnancy failure may be related to high concentrations of estrogen in the bloodstream because of PMSG stimulation, which has counteracted properties to progesterone as a hormone that supports the pregnancy process, resulting in pregnancy failure. Khafaji (2018) reported that embryo loss after progestagen-PMSG synchronization occurred due to insufficient progesterone (P4) production to maintain pregnancy.

Birth and Weaning Weight of Lambs and Milk Production of Ewes

The birth weight, weaning weight, and milk production were not influenced ($p > 0.05$) by the interaction between feed type and PMSG hormone stimulation. However, these three variables were influenced by feed type and PMSG as a single factor. Feed type influenced ($p < 0.05$) the birth weight of lambs. The mean birth weight in the LF feed treatment group was higher than in the SI group (2.9 ± 0.46 compared to 2.22 ± 1.01 kg). PMSG administration factors have a greater influence on this variable than weaning weight. The group of lambs whose ewes were stimulated by PMSG had a lower weaning weight ($p < 0.05$) than the lambs whose ewes were not stimulated by PMSG (9.16 ± 3.03 compared to 12.85 ± 2.86

kg). Furthermore, milk production was influenced by the type of feed served ($p < 0.05$) (Figure 2). The average daily milk production in the ewes treated with SI mixed feed was higher than in the LF feed group (0.61 ± 0.15 compared to 0.37 ± 0.12 kg/day) (Table 2).

It was assumed that the greater birth weight of lambs in the LF feed treatment group was because many were single-born. The LF treatment group had seven parturition ewes, with five (71.43%) giving birth to single offspring. In contrast to the conditions in the SI mixed feed treatment group, five ewes (55.56%) delivered single birth, one ewe (11.11%) gave twins delivery, two ewes (22.22%) gave triplets birth, and one ewe (11.11%) gave six twins birth (quintuplets). This condition follows the statement of Dove *et al*. (2018) that the birth weight of lambs is related to the type of birth, the ewe's body condition, and the quantity and quality of feed nutrients intake by the ewes during pregnancy. García-Chávez *et al*. (2020) added that lambs born with the twin birth type had lower ($p < 0.05$) birth weights and weaning weights, but were higher ($p < 0.05$) in total weight of the offspring born and number of mortality compared to the single birth type.

Moreover, Morris *et al*. (2000) reported that environmental factors played a more significant role in lamb birth weight, weaning weight, and survival ability than genetic factors. The results of his study noted that of 55,146 lambs born in three different locations, the post-natal survival rate until weaning was 78.9–80.1%, or the mortality rate was 19.9–21.1%. The number of lamb mortalities in this phase is also linearly influenced by birth weight. The optimum birth weight for good survival for this type of sheep is 4.36–4.77 kg. Meanwhile, the average birth weight and weaning weight of Garut sheep reported by Gunawan and Noor (2006) were 1.73–2.34 kg and 10.30–14.09 kg, respectively. Given the strong correlation between birth weight and weaning weight and heritability values, Garut sheep can be chosen based on these two characteristics.

In the future, the type of feed and PMSG stimulation did not show any interaction ($p > 0.05$) on the daily milk production of the ewe. However, feed factors significantly ($p < 0.05$) influenced milk production. Ewes' average daily milk production in the LF and SI mixed feed treatment groups was 0.37 ± 0.12 and 0.61 ± 0.15 kg/head/day, respectively (Table 2). The findings of this study are consistent with those of Abdullah *et al*. (2012), who found that feeding 40% pure indigofera to Etawah crossbred goats and Saanen goats enhanced daily milk output by 660–762 mL/day. In addition, adding indigofera pure to the ration can reduce feed costs by as much as 15%/l milk for Etawah crossbred goats and 42%/l milk for Saanen goats.

The high content of crude protein and total digestible nutrient (TDN) in the SI mixed feed, as shown in Table 1, could be the cause of the higher daily milk production compared to the group of ewes fed with LF. El-Shinnawy *et al*. (2010) stated that Feeding ewes 100% NRC of TDN and crude protein (CP) led to higher economic efficiency and milk production. The blood delivers feed nutrients as precursors in milk synthesis in udder secretory cells. Protein and TDN in the ratio required by lactating dairy goats are 16 and 60%, respectively. Meanwhile, the low milk production of ewes in the field grass treatment group could be caused by fluctuating nutrient content related to the season. de Moura *et al*. (2021) stated that during the dry season, there is a decrease in the production and nutrient composition of forage, which ultimately has an impact on reducing the production and quality of ewe's milk.

Ewe's milk production for each treatment combination was 25.67 ± 3.96 kg/ewe/lactation (LF); 40.60 ± 11.09 kg/ewe/lactation (LF+PMSG); 51.66 ± 12.97 kg/ewe/lactation (SI); 51.24 ± 17.42 kg/ewe/lactation (SI+PMSG) (Table 2). Feeding ewes with SI may increase nutrient intake since SI has higher protein content, TDN, and Energy than LF as depicted in Table 1. This number is still lower than the results of the study reported by Inounu (2011), in which the milk production of Garut ewes reached 53.4 kg/ewe/lactation. Genetic factors also influence milk production, as proven by the crossing technique between Garut sheep and St. Croix, and M. Carolais can produce milk production of 55.9

and 59.5 kg/ewe/lactation, respectively. This increase in milk production can further increase the survival rate of lambs.

Preweaning Lambs' Mortality

The highest percentage of lamb mortalities occurred in the SI+PMSG treatment (33%) and the lowest in the LF feed treatment without PMSG stimulation (0%) (Table 2). The mortality rate of pre-weaning lambs was higher in the SI+PMSG treatment. This incident is thought to be closely related to the lambs' high litter size and low birth weight. PMSG stimulation in the SI mixed feed treatment resulted in a litter size of 4.5 with an average birth weight of 1.76 kg. As reported in the research of Ratanapob *et al*. (2020), the factors that influence the postnatal mortality rate of lambs are the sex of the lamb, litter size, and birth weight. Andriyanto and Manalu (2012) confirmed this statement that the number of lambs born with more than two lambs has a high mortality rate. In other studies, Andriyanto *et al*. (2015) reported that PMSG stimulation could increase the average number of embryos detected at one month of pregnancy, reaching 2.1. However, this number is followed by a rate of embryo loss or prenatal death of 21.05%. The post-natal mortality rate in livestock groups with low birth weights was higher than in livestock groups with high birth weights, reaching 17%.

Postnatal lamb mortalities occurred more frequently in the twin birth type in the SI treatment group (Table 2). Although the ewe's milk production was higher than the LF treatment group, milk consumption was lower due to the more significant number of lambs born. The average daily milk production of the ewe in the LF control treatment was 310 g/head/day with a litter size of 1.25, so the average milk consumption was ±248 g/head/day, resulting in 0% of the lamb's death. Meanwhile, the average daily milk production of ewes in the SI+PMSG treatment was 610 g/head/day with a litter size of 4.5 litters, so the average milk consumption was ±135 g/head/day and resulted in the number of deaths of pre-weaned offspring as high as 33%. Sorted based on the beginning of embryo formation until the weaning process, the number of lambs produced was closely related to litter size, birth weight, ewe's milk consumption, mortality, and weaning weight of the lamb. Jarmuji (2010) statement supports this condition that an ewe's milk production is related to the amount of milk consumed by her offspring and influences body weight gain, weaning weight, and survival of lambs. The death of pre-weaned lambs might also be related to the amount of colostrum received by the lambs. Swinbourne *et al*. (2022) reported that poor quality colostrum or insufficient consumption could increase the risk of low energy intake and failure of passive immune transfer from the ewe, resulting in lamb death.

Lamb Growth Rate

The growth rate of lambs in the combined SI+PMSG treatment had the lowest value. The growth rate graph in Figure 3 proves that a slower growth rate will follow a low birth weight and end with a low weaning weight. A lamb's growth rate was also related to the type of birth. The type of multiple births with more than two offspring had a risk of slower body growth and higher pre-weaning mortality. The average value of growth rate for pre-weaned Garut lambs obtained by subtracting weaning weight from birth weight and then dividing the length of weaning time was 116.91 g/head/day (LF); 113.69 g/head/day (LF+PMSG); 120 g/head/day (SI); and 69.40 g/head/day (SI+PMSG). Ewes treated with SI mixed feed without PMSG stimulation with a litter size of 1.43 produced the highest lamb growth rate.

Lambs' growth rate was directly correlated with the milk consumtion from their dams. Regardless of high or low milk production, which was influenced by feed factor, it is evident that ewes that gave birth to single lambs or treatment groups that produced small litter size had greater levels of milk consumption and better growth rates. This result differs from that reported by Manalu *et al*. (2000), who found that feed, whether high or low quality, did not significantly affect the growth rate of offspring. However, in the same study, PMSG was found to have a positive impact on the growth rate of lambs by significantly increasing their milk production. It was explained that PMSG administration would increase the number of oocytes, and each ovulation would leave the corpus luteum, which produces the P4 hormone. High P4 secretion in ewes during pregnancy could lead to increased mammary gland development and milk production in the lactation period (Bahari *et al*., 2023).

Other factors influencing lambs' growth rate before weaning were the number of parity ewes and the season. As reported in the study results of García-Chávez *et al*. (2020), in Pelibuey sheep in Brazil, the growth rate of lambs from multiparous ewes was faster than that of primiparous ewes, which resulted in higher weaning weights. The next factor, the best lamb growth rate, occurs in single lambs born from multiparous ewes during the dry season (Hanifah *et al*., 2020).

It should be mentioned that limitations in conducting this research may affect the results obtained, such as the lack of research assistants when measuring the milk production of female sheep. With limited observation time, the data obtained may be less accurate.

CONCLUSION

The number of pregnant to lactating Garut ewes was highest in the group fed with SI mixed feed. Meanwhile, the interaction between the feed type factor and PMSG hormone stimulation was only seen in the litter size variable. It was highest in the combination of SI mixed feed treatment with PMSG stimulation. Furthermore, the milk production of ewes and the birth weight of lambs are more influenced by feed-type factors, while weaning weight is influenced by PMSG stimulation factors.

ACKNOWLEDGEMENTS

We would like to express our thank to The Ministry of Research, Technology and Higher Education of The Republic of Indonesia, for funding this study through the IPB University under the Doctoral Research Grant 2020 (contract number: 1/E1/KP.PTNBH/2020) and BPP-DN 2017 (contract number: 2903/D3/PG/2017).

AUTHORS' CONTRIBUTIONS

RS: Conceptualization, Drafted the Manuscript, and Data Analysis. AMF, SR: Validation and Supervision in Animal Production. LA: Compile and Make Feed Formulations, Writing-Review and Editing. MAS: Review data and provide discussion in the field of animal reproduction. All authors make significant contributions when writing articles and approve the final manuscript.

COMPETING INTERESTS

The authors declare that they have no competing interests.

REFERENCES

Abdullah, L., Apriastuti, D., & Apdini, T. A. P. (2012). Use of Indigofera zollingeriana as a Forage Protein Source in Dairy Goat Rations. *Proceedings of the 1st Asia Dairy Goat Conference, Kuala Lumpur, Malaysia*.

Andriyanto, Amrozi, Rahminiwati, M., Boediono, A., & Manalu, W. (2015). Correlation of stimulated dominant follicle by pregnant mare serum gonadotropin injection with estrous response in Kacang goat. *Indonesian Journal of Veterinary Sciences*, 9(1), 20–23.

Andriyanto, & Manalu, W. (2012). Peningkatan Produktivitas Domba pada Skala Peternakan Rakyat Melalui Pemberian Hormon Pregnant Mare Serum Gonadotrophin. *Jurnal Veteriner*, 13(3), 235–241.

Bahari, B. S., Agoeshermadi, H., Fikri, F., Sardjito, T., Purnomo, A., Chhetri, S., Maslamama, S. T., & Purnama, M. T. E. (2023). Efficacy of intra-vulvo submucosal prostaglandins on estrous cycles in goats. *The Indian Veterinary Journal*, 100(4), 24–27.

Davis, G. H. (2005). Major genes affecting ovulation rate in sheep. *Genetics Selection Evolution*, 37(SUPPL. 1).

de Moura, J. G., da Cunha, M. V., de Souza, E. J. O., Coelho, J. J., dos Santos, M. V. F., Dubeux Júnior, J. C. B., & de Mello, A. C. L. (2021). The vegetal stratum defined the forage bromatology more than the season in seasonal dry tropical forest rangelands. *Agroforestry Systems*, 95(6).

Dove, H., Freer, M., & Foot, J. Z. (2018). The nutrition of grazing ewes during pregnancy and lactation: Relationships between herbage, supplement and milk intakes, and ewe and lamb liveweight and body composition. *Animal Production Science*, 58(7).

El-Shinnawy, M., Ahmed, M., & Sadek, W. (2010). Effect of some feeding schemes on some rumen parametaers, blood profile and productive performance of Rahmani Sheep. *Journal of Animal and Poultry Production*, 1(10), 481–496.

García-Chávez, C. A., Luna-Palomera, C., Macías-Cruz, U., Segura-Correa, J. C., Ojeda-Robertos, N. F., Peralta-Torres, J. A., & Chay-Canúl, A. J. (2020). Lamb growth and ewe productivity in Pelibuey sheep under tropical conditions. *Revista Mexicana De Ciencias Pecuarias*, 11(3), 884–893.

Gunawan, A., & Noor, R. R. R. (2006). Pendugaan Nilai Heritabilitas Bobot Lahir dan Bobot Sapih Domba Garut Tipe Laga. *Media Peternakan*, 29(1), 7–15.

Hanifah, N. F., Ratnani, H., Purnama, M. T. E., Restiadi, T. I., Agustono, B., & Prastiya, R. A. (2020). Effect of Glycerol Concentration in Tris Diluents on Spermatozoa Quality of Sapera Goats Before Freezing. *Jurnal Medik Veteriner*, 3(2), 154–159.

Harlow, K. L., Griesgraber, M. J., Seman, A. D., Shuping, S. L., Sommer, J. R., Griffith, E. H., Hileman, S. M., & Nestor, C. C. (2022). The impact of undernutrition on KNDy (kisspeptin/neurokinin B/dynorphin) neurons in female lambs. *Journal of Neuroendocrinology*, 34(6).

Hussein, E. K., Naoman, U. T., & Al-Ajeli, R. R. (2021). Induction of estrus using human menopausal gonadotrophin in iraqi awassi ewes. *Iraqi Journal of Veterinary Sciences*, 35(3), 529–533.

I’Anson, H., Manning, J. M., Herbosa, C. G., Pelt, J., Friedman, C. R., Wood, R. I., Bucholtz, D. C., & Foster, D. L. (2000). Central inhibition of gonadotropin-releasing hormone secretion in the growth-restricted hypogonadotropic female sheep. *Endocrinology*, 141(2).

Inounu, I. (2011). Pembentukan Domba Komposit Melalui Teknologi Persilangan Dalam Upaya Peningkatan Mutu Genetik Domba Lokal. *Pengembangan Inovasi Pertanian*, 4(3), 218–230.

Jardstedt, M., Nadeau, E., Nielsen, M. O., Nørgaard, P., & Hessle, A. (2020). The effect of feeding roughages of varying digestibility prepartum on energy status and metabolic profiles in beef cows around parturition. *Animals*, 10(3).

Jarmuji. (2010). Produksi Susu Induk Terhadap Pengaruh Pertambahan Bobot Badan, Bobot Sapih Dan Daya Hidup Anak Domba Ekor Tipis Jawa Periode Prasapih. *Jurnal Sain Peternakan*, 5(1), 34–42.

Khafaji, S. (2018). Application of different progesterone protocols on some reproductive hormones during pregnancy in awassi ewes. *Article in Journal of Pharmaceutical Sciences and Research*, 10(6), 1364–1368.

Khotijah, L., Wiryawan, K. G., Agus Setiadi, M., & Astuti, D. A. (2015). Reproductive performance, cholesterol and progesterone status of garut ewes fed ration containing different levels of sun flower oil. *Pakistan Journal of Nutrition*, 14(7), 388–391.

Málková, A., Ptáček, M., Chay-Canul, A., & Stádník, L. (2021). Statistical models for estimating lamb birth weight using body measurements. *Italian Journal of Animal Science*, 20(1).

Manalu, W., Sumaryadi, M. Y., Sudjatmogo, & Satyaningtijas, A. S. (2000). The Effect of Superovulation of Javanese Thin-Tail Ewes Prior to Mating on Lamb Birth Weight and

Preweaning Growth. *Asian-Australasian Journal of Animal Sciences*, 13(3).

Mekuriaw, Z., Assefa, H., Tegegne, A., & Muluneh, D. (2016). Estrus response and fertility of Menz and crossbred ewes to single prostaglandin injection protocol. *Tropical Animal Health and Production*, 48(1), 53–57.

Mohapatra, A., De, K., Prakash, V., Kumar, D., & Naqvi, S. M. K. (2020). Effect of different milking methods on milk yield and growth of lambs. *Indian Journal of Small Ruminants*, 20(1).

Morris, C. A., Hickey, S. M., & Clarke, J. N. (2000). Genetic and environmental factors affecting lamb survival at birth and through to weaning. *New Zealand Journal of Agricultural Research*, 43(4), 515–524.

Palupi, R., Abdullah, L., Astuti, D. A., & Sumiati. (2014). High antioxidant egg production through substitution of soybean meal by Indigofera sp., top leaf meal in laying hen diets. *International Journal of Poultry Science*, 13(4), 198–203.

Purnomohadi, M. (2006). Potensi Penggunaan Beberapa Varietas Sorgum Manis (Sorghum bicolor (L.) Moench) sebagai Tanaman Pakan. *Berkala Penelitian Hayati*, 12(1).

Ratanapob, N., VanLeeuwen, J., McKenna, S., Wichtel, M., Stryhn, H., Rodriguez-Lecompte, J. C., Menzies, P., & Wichtel, J. (2020). Management factors associated with perinatal lamb mortality in Prince Edward Island flocks. *Preventive Veterinary Medicine*, 180.

Ridler, A. L., Vallee, E., Corner, R. A., Kenyon, P. R., & Heuer, C. (2015). Factors associated with fetal losses in ewe lambs on a New Zealand sheep farm. *New Zealand Veterinary Journal*, 63(6), 330–334.

Shiddieqy, M. I., & Priyono. (2022). Sheep Production Management System to Harness Genetic Resources: A case in Bangun Karso Farm, Bogor, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 1020(1).

Somanjaya, R., Fuah, A. M., Rahayu, S., Abdullah, L., & Setiadi, M. A. (2022). Reproductive Performance of Garut Ewes Fed Sorghum-Indigofera after Stimulation with Pregnant Mare Serum Gonadotropin. *Tropical Animal Science Journal*, 45(4), 451–459.

Somanjaya, R., Heriyadi, D., & Iman Hernaman, dan. (2015). Performa Domba Lokal Betina Dewasa pada Berbagai Variasi Lamanya Penggembalaan di Daerah Irigasi Rentang Kabupaten Majalengka. *Jurnal Ilmu Ternak*, 15(1), 41–49.

Swinbourne, A. M., Blagojevic, N., Murdock, N. J., Mills, H. B., Flinn, T., McCarthy, N. L., Kelly, J. M., Kleemann, D. O., & Van Wettere, W. H. E. J. (2022). Validation of hand-held refractometers for assessing Merino ewe colostrum and neonatal lamb serum. *Animal Production Science*, 62(3), 284–294.

Thach, D. T., Cuong, B. K., Van Tong, H., Van Chi, V., Khue, N. K., Hien, N. T. P., Van Hai, N., Combarnous, Y., & Nguyen, T. M. D. (2022). Natural and recombinant equine chorionic gonadotropins past and future in animal reproductive technology. In *Veterinary Integrative Sciences*, 20(3).

Thompson, R. E., Meyers, M. A., Palmer, J., Veeramachaneni, D. N. R., Magee, C., de Mestre, A. M., Antczak, D. F., & Hollinshead, F. K. (2023). Production of Mare Chorionic Girdle Organoids That Secrete Equine Chorionic Gonadotropin. *International Journal of Molecular Sciences*, 24(11).

***