Additive Nutrition in the Feeding of Pote Goat Madura Maintained the Fertility Post-Infected of Foot and Mouth Disease

Suherni Susilowati[1], Mirni Lamid[2], Imam Mustofa[1]*, Zulfi Nur Amrina Rosyada[2], Ali Agus[3], Chandra Brahmantya[4], Adeyinka Oye Akintunde[5], Herry Agoes Hermadi[1], Aswin Rafif Khairullah[6], Mutasem Abuzahra[7], Riza Zainuddin Ahmad[6], Siti Rani Ayuti[8]

[1]Division of Veterinary Reproduction, Faculty of Veterinary Medicine, Universitas Airlangga, Surabaya 60115, East Java, Indonesia, [2]Division of Animal Husbandry, Faculty of Veterinary Medicine, Universitas Airlangga, Surabaya 60115, East Java, Indonesia, [3]Faculty of Animal Husbandry, Universitas Gadjah Mada, Bulaksumur, Depok, Sleman, Daerah Istimewa Yogyakarta 55281, Indonesia, [4]Veterinarian in Galis Animal Health Center, Bangkalan Livestock Service, Bangkalan, Indonesia, [5]Department of Agriculture and Industrial Technology, Babcock University, Ilishan-Remo, Ogun State, Nigeria, [6]Research Center for Veterinary Science, National Research and Innovation Agency (BRIN), Bogor 16911, West Java, Indonesia, [7]Doctoral Program of Veterinary Science, Faculty of Veterinary Medicine, Universitas Airlangga, Surabaya 60115, East Java, Indonesia, [8]Faculty of Veterinary Medicine, Universitas Syiah Kuala, Kota Banda Aceh 23111, Aceh, Indonesia.

*Corresponding author: imam.mustofa@fkh.unair.ac.id

Abstract

Mineral and nutritive supplements improve animal reproductive performance, especially after Foot and Mouth Disease (FMD) infecteds, to establish sustainable food security solutions. This study aimed to investigate the effects of mineral addition, particularly through premix and concentrate booster supplementation, on the body weight gain and reproductive performance of Pote goats in Madura post-infected of foot and mouth disease (FMD). Thirty-six non-pregnant Pote goats that cured from foot and mouth lesion based on veterinarian examination, were divided into three groups and fed differently for 45 days. Group T0 received standard feed comprising 3-4 kg of forage and 300 g of concentrate with a crude protein content of 16–17%, along with ad libitum water. Groups T1 and T2 received standard feed supplemented with 15g/head/day of premix booster and immune booster, respectively. Results showed no significant increase in body weight with supplementation. However, higher blood urea nitrogen and albumin levels were observed in both T1 and T2-supplemented groups. The estrus rate was higher in goats given mineral supplements than with standard feed alone. Although the onset and duration of estrus did not differ significantly, ultrasound scans showed follicular development before estrus synchronization, indicating restoration of the estrus cycle. Overall, mineral addition in feeding post-FMD infected in Pote goats appears to enhance reproductive performance and overall health.

Keywords: concentrate, estrus, food security, minerals, progesterone

Received: November 17, 2024 **Revised:** January 1, 2025 **Accepted:** February 3, 2025

INTRODUCTION

The Pote goat is an unclumped indigenous Indonesian goat native to Bangkalan, Madura. Genetic selection may be utilized to acquire Pote goat varieties as germplasms in order to increase genetic diversity (Imaniah *et al.*, 2023). The Pote goat, residing in Bangkalan, East Java, is categorized as either a small or large variety of indigenous Indonesian goats according to the shoulder height and body weight of mature female goats, respectively. As age progressed, body weight and size increased. The dominant qualitative characteristics of the subject are its white body color, convex facial profile, drooping and widened ears that are relatively short in size, straight right and left horns, rewound fur, absence of papillae, and jug-shaped udder (Rohman *et al.*, 2023[a]).

In the lowland region of Madura Island, the Pote goat population is characterized by the following proportions: 34.83% males and 65.17%

females. The male-to-female ratio among adults is 1:12.20. Annually, the percentage of goat offspring who died was 8.08% (males 2.31%, females 5.77%). Among goats of varying ages, a mortality rate of 9.34% was recorded (males 2.77% and females 6.57%). As the age of the doe increases, the average litter size rises from 1.76±0.54 to 1.98±0.47 head per birth. The birth categories comprised the following: triplet births (10.39%), quadruplet births (1.43%), twin births (73.48%), and single births (14.70%) (Rohman *et al*., 2023[b]).

Two genotype types (AG and GG) and two alleles (A and G) were present. AG and GG had respective genotype frequencies of 0.40 and 0.60. A and G, respectively, have frequencies of 0.40 and 0.80. Litter size was significantly associated with the a.2912 A>G mutation. An inverse correlation has been observed between litter size traits and GDF9 gene diversity in Pote goats. The litter size of Pote goats is correlated with polymorphisms in the GDF9 gene, which may serve as genetic markers for the selection of this trait (Imaniah *et al*., 2023).

Foot and mouth disease (FMD) continues to be a significant animal health concern in the majority of Southeast Asia (SEA), where it is endemic. Madura Island was afflicted with FMD between 1906 and 1913 (Blacksell *et al*., 2019). In Indonesia, hundreds of thousands of livestock have been re-infected with foot and mouth disease following a 32-year FMD-free streak that began in 1990. FMD is an extremely transmissible animal disease that impacts various species with cloven hoofs, including cattle, buffaloes, sheep, goats, piglets, deer, camels, and elephants (Majid *et al*., 2023; Septiyani *et al*., 2023). As of November 18, 2022, FMD remains prevalent in 146 regencies/cities across 17 provinces, affecting 578,060 heads of infected cows, 508,494 heads of recovered cows, 13,177 heads of conditionally cut cows, 10,269 heads of deceased cows, and 5,847,113 heads of vaccinated cows (Sutawi *et al*., 2023).

FMD virus infection in goats is characterized by lesions of the soles and buccal mucosa. Vesicles and bullae develop swiftly on the snout, nostrils, lips, and tongue within the oral cavity. As a consequence, a decrease in appetite ensued, which in turn led to a reduction in dietary consumption (Grubman and Baxt, 2004). Carbohydrate, lipid, protein, mineral, and vitamin deficiency is deleterious to the physiological well-being and reproductive capabilities of animals (Asín *et al*., 2021). Nevertheless, there is a lack of research examining the impact of a combination of macro and micro minerals on the reproductive performance of Pote goats following an infected of FMD. Consequently, the objective of this research endeavor was to ascertain the impact of supplementing concentrate and mineral feed on the reproductive performance of female Pote goats subsequent to infection with FMD.

MATERIALS AND METHODS

Ethical Approval

The authors adhere that procedures imposed on the animals were carried out by the Universitas Airlangga Research Ethical Clearance Commission with certificate number: 1250/HRECC.FODM/XI/2023.

Study Period and Location

This research was carried out from October 23, 2022 to January 30, 2023 in Pote goat Farming in Patengteng Village, Modung District, Bangkalan Regency, Madura Island, Indonesia, which is located at 7°43'53"S and 111°27'54"E (Figure 1).

Experimental Animals and Feeding

This study included 36 healthy and non-pregnant Pote goats that cured from foot and mouth lesion based on veterinarian examination. Pote goat individuals aged 1–2 years, weighing 30–35 kg, with more than one parity. Standard feed consists of 3–4 kg forage and 300 g concentrate (containing 16–17% crude protein, crude fat of 7%, calcium content of 0.8–1.3%, phosphorus content of 0.4–0.8%, and total digestible nutrients (TDN) of 69%), and drinking water was always available. The Pote goats were divided randomly into three groups. In the T0 group, the Pote goat was fed with standard feeding. In the T1 group, Pote goat fed with standard feeding added premix booster (mineral composition shown in Table 1) 15 g/head/day. In the T2 group, the Pote goat was fed with standard feeding plus concentrate booster (nutrient composition shown in Table 2) 15 g/head/day. The feeding treatment was conducted for 45 days.

The Pote goat was weighed before treatment and 45 days after treatment with hanging spring scales, with a scale of 0–100 kg (Nops, China). On the 21st day, the ovaries were scanned using a Full Digital Ultrasonic Diagnostic Instrument (Xuzhou Kaixin Electronic Instrument Co., Ltd., Jiangsu, China). Furthermore, the blood samples were collected to measure progesterone levels before estrus synchronization.

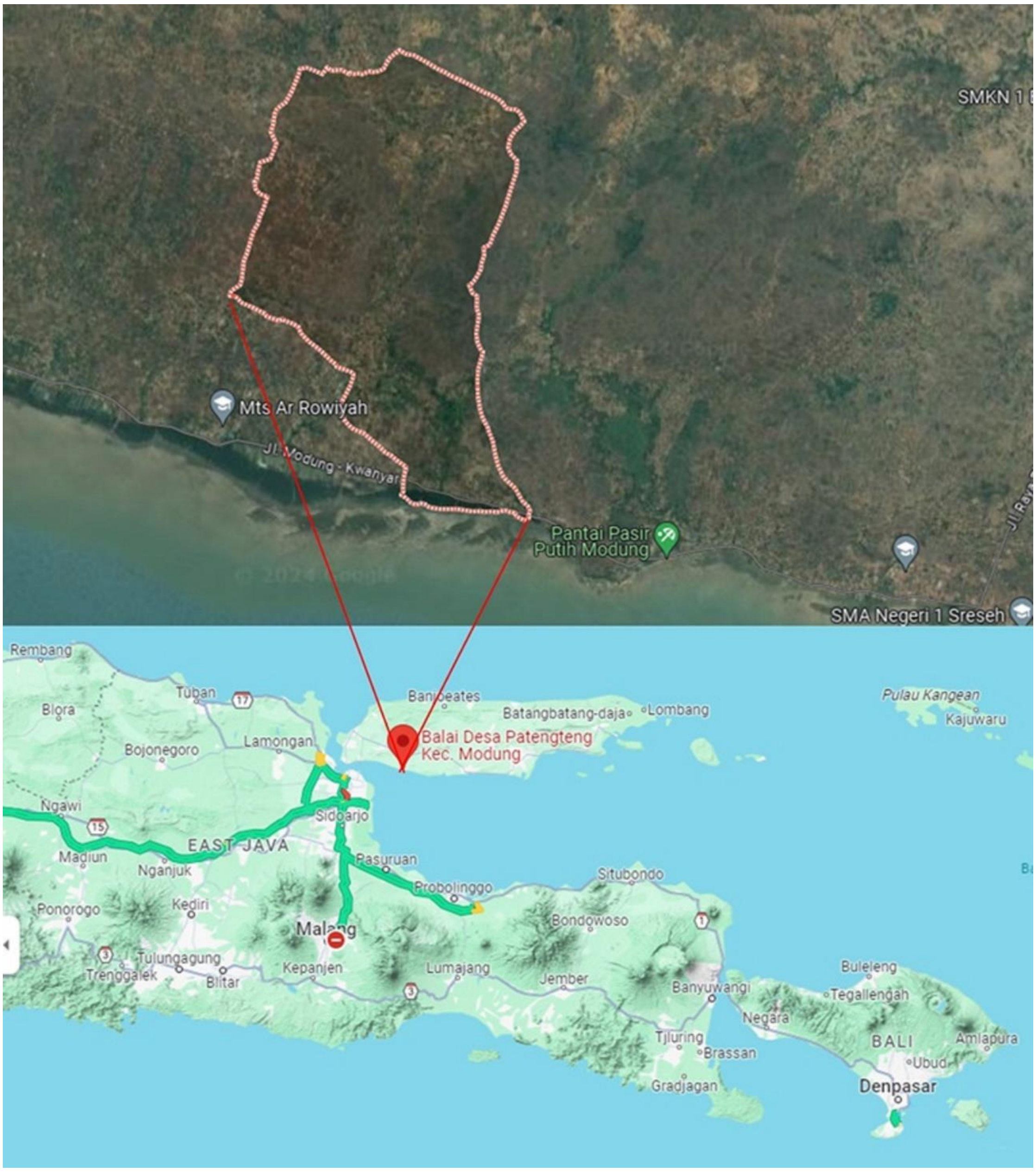

Figure 1. Site of study: Patengteng Village, Modung District, Bangkalan Regency, Madura Island, Indonesia (Source: Google Maps).

Estrus Synchronization

Estrus synchronization was conducted with 200 µg Prostaglandin (PG) F2α (Sigma-Aldrich) intramuscularly. Signs of estrus were assessed to determine the onset and duration of estrus. At estrus, the ovarian profile of the does was scanned using ultrasound, and blood samples were collected for estrogen level measurement.

Progesterone and estrogen levels were measured using an enzyme-linked immunosorbent assay according to the protocol on the Progesterone Competitive ELISA Kit Catalog Number EIAP4C21 and EIAP4C21X10 (ELISA, Thermo Fisher Scientific).

Estrus examination was carried out at 04.00 AM, 10.00 AM, 04.00 PM, 10.00 PM. Estrus was characterized by tail up, reddish vaginal mucous membrane, a lot of cervical mucus (Triagil *et al*., 2020). The estrus behavior that has been recorded were mounting each other, standing to be mounted, tail wagging, bleating, and sniffing. The clinical signs of estrus are reddening of vulva, swollen vulva and discharge from vulva (Salleh *et al*., 2021). Estrus events with typical signs such as swollen, reddish and slimy vulva, excessive urination and restlessness (Aftabuddin *et al*., 2022; Bahari *et al*., 2023). The end of estrus was marked by calmness again, relaxed tail, non-swollen vulva, and non-red vaginal mucosa. The onset of estrus is calculated from the time of treatment until the appearance of one of the signs of heat, while the duration of estrus is calculated from the time the sign of heat appears until the female goat is calm again and the tail is relaxed, followed by an examination of the vulva to see if it is not swollen and the vaginal mucosa is not reddish.

Data Analysis

The data were analyzed using a one-way ANOVA followed by Tukey's Honest Significant Difference test at a 95% confidence level (SPSS Version 23, IBM, New York, United States).

RESULTS AND DISCUSSION

Body Weight

The effect of mineral premix booster and concentrate booster addition on body weight and size was shown in Table 3. Mineral premix booster (T1) and concentrate booster (T2) supplementation had no significant increase ($p > 0.05$) in body weight in each group before and after 45 days of treatment or between the treatment groups (Table 3).

FMD causes painful lesions in the mouth and on the feet, make it difficult to eat and drink, leading to reduced feed intake. FMD virus infection in cows is characterized by lesions of the soles and buccal mucosa. Vesicles and bullae develop swiftly on the snout, nostrils, lips, and tongue within the oral cavity. As a consequence, a decrease in appetite ensued, which in turn led to a reduction in dietary consumption (Underwood *et al*., 2015). However, in this study, the goats were declared cured of FMD with a lesions in the mouth and hooves had healed.

Nutrition as a dietetic feed is a special formula that contains complete, balanced, and high-density macro, micro, and additive nutrients or nutrients to enhance immune function and help accelerate the process of healing and recovery of sick livestock. Most Pote goats originate from community farms, where goat reproduction tends to lack minerals, resulting in low animal reproductive performance (Rohman *et al*., 2023[b]). Minerals, both macro and trace, play an important role in regulating livestock reproduction and production. The presence of mineral deficiencies in feed can cause reproductive disorders in animals. Micronutrients, especially mineral elements, are necessary for proper metabolic systems and physiological functions in livestock. Minerals are widely known for their regulatory functions in growth, production, and reproduction (Nasreldin *et al*., 2023). Mineral supplementation can also increase the percentage of pregnancy rate in animals that experience repeated mating (Van Emon *et al*., 2020). The use of mixed minerals in livestock feed has also been shown to help in increasing growth, feed efficiency, milk production, reproductive performance, and immunity, minimizing the incidence of certain metabolic diseases, and reducing birth intervals (Khalil *et al*., 2019; Van Emon *et al*., 2020).

This study found that variations in feeding treatments over a 45-day period did not result in significant differences in the body weight of female Pote goats either within groups or between the periods before and after the treatment (Table 3). Conversely, protein, feed energy, and supplementary feeds such as mineral premixes generally impact feed efficiency and the average daily increase in body weight (Wang *et al*., 2020). Mineral premixes have been shown to improve the rumen microbial environment, nutrient digestibility, productivity, and the development of enzymatic systems, thereby influencing average daily feed intake (Sahoo *et al*., 2017). Moreover, mineral premixes also play a role in metabolism, production, and biological processes (Byrne and Murphy, 2022; Spears *et al*., 2022). Studies on buffalo calves (Hassan *et al*., 2016) and camels (Alhidary *et al*., 2016) have demonstrated that supplementation with mineral premixes containing zinc, copper, manganese, and selenium can enhance daily weight gain and growth rates (Spears *et al*., 2022; Willmore *et al*., 2021). Additionally, trace elements such as Zn, Se, Cu, iodine (I), and Mn directly influence ruminant productivity and also indirectly affect it through thyroid hormone activity and the regulation of enzymatic, metabolic, and productive functions (Byrne and Murphy, 2022).

Table 1. Composition of premix booster

Minerals content	Amount
Copper (Cu)	20 mg
Zink (Zn)	95 mg
Sulphur (S)	3.5 g
Phosphor (P)	85 g
Selenium (Se)	10 mg
Calcium (Ca)	250 g
Potassium (K)	12 g
Magnesium (Mg)	30 g
Sodium (Na)	18 g
Iron (Fe)	55 gr
Manganese (Mn)	27 mg
Cobalt (Co)	15 mg
Iodine (I)	1.2 mg

Source: Laboratory analysis of animal feed, Animal Husbandry Division, Gadjah Mada University, Yogyakarta (2022).

Table 2. Composition of concentrate booster

Nutrient content	Percentage (%)
Dry material	61.94
Ash	10.80
Crude protein	18.03
Crude fat	3.37
Crude fiber	20.92

Source: Laboratory analysis of animal feed, Animal Husbandry Division, Gadjah Mada University, Yogyakarta (2022).

Table 3. Body weight (kg) of Pote goat before and after feeding treatment for 45 days

Group	Before treatment	45 day of treatment
T0	25.93 ± 3.42	28.66 ± 3.84
T1	22.42 ± 2.87	23.90 ± 1.54
T2	24.48 ± 4.94	24.17 ± 4.49

Note: No significant differences were observed ($p > 0.05$). T0: Pote goats are given standard feed (forage and concentrate), T1: Pote goats are given standard feed and premix, T2: standard feed and immune booster.

Table 4. Blood urea nitrogen (BUN), total protein (TP), and albumin (Alb) levels of Pote goat after feeding treatment for 45 days

Group	BUN (mg/dL)	TP (g/dL)	Alb (g/dL)
T0	11.24 ± 2.71[a]	6.46 ± 1.10	3.39 ± 0.62[a]
T1	16.31 ± 2.05[b]	7.87 ± 0.89	3.54 ± 0.40[a]
T2	15.77 ± 2.89[b]	7.68 ± 1.24	5.99 ± 1.39[b]

Note: Different superscripts indicate significant differences ($p < 0.05$). T0: Pote goats are given standard feed (forage and concentrate), T1: Pote goats are given standard feed and premix, T2: standard feed and immune booster.

Table 5. Estrus rate, the onset of estrus, and duration of estrus of Pote goat after estrus synchronization

Group	Estrus rate (%)	Onset of estrus (hours)	Duration of estrus (hours)
T0	75% (9/12)	48.44 ± 0.88	12.22 ± 0.67
T1	100% (12/12)	35.78 ± 1.56	12.67 ± 2.00
T2	100% (12/12)	46.83 ± 1.47	12.33 ± 0.82

Note: T0: Pote goats are given standard feed (forage and concentrate), T1: Pote goats are given standard feed and premix, T2: standard feed and immune booster.

Table 6. Ultrasonograph of Pote goat's ovarian before estrus synchronization (pre-tx) and at estrus

Group	Parameters	Pre tx			Estrus		
		Sof	Dom	CL	Sof	FdG	CL
T0	Rate	66.67% (8/12)	58.33% (7/12)	33.33% (4/12)	-	33.33% (4/12)	-
	Average	1.50 ± 0.76	1.43 ± 0.53	1.50 ± 0.71	-	1.00 ± 0.00	-
T1	Rate	100% (12/12)	66.67% (9/12)	100% (12/12)	-	100% (12/12)	-
	Average	3.25 ± 0.87	1.00 ± 0.00	1.00 ± 0.00	-	1.00 ± 0.00	-
T2	Rate	50% (6/12)	-	25% (3/12)	-	100% (12/12)	-
	Average	4.50 ± 1.64	-	3.00 ± 0.00	-	1.00 ± 0.00	-

Note: T0: Pote goats were given standard feed (forage and concentrate), T1: Pote goats were given standard feed (forage and concentrate), and premix, T2: standard feed + concentrate + immune booster. Sof: subordinate follicle; Dom: dominant follicle; FdG: follicle de Graaf, CL: corpus luteum.

Table 7. Serum progesterone levels before estrus synchronization (pre-tx) and estrogen levels at estrus of Pote goat

Group	Progesteron pre tx (ng/mL)		Estrogen Estrus (ng/mL)	
	Range	Average	Range	Average
T0	33.98 – 51.06	38.95 ± 7.38	42.88 – 70.52	57.10 ± 9.58
T1	39.84 – 72.49	53.52 ± 12.44	52.21 – 71.03	62.06 ± 7.11
T2	35.72 – 56.71	47.40 ± 8.22	42.64 – 76.65	56.53 ± 12.59

Note: T0: Pote goats are given standard feed (forage and concentrate), T1: Pote goats are given standard feed (forage and concentrate) and premix, T2: standard feed + concentrate + immune booster.

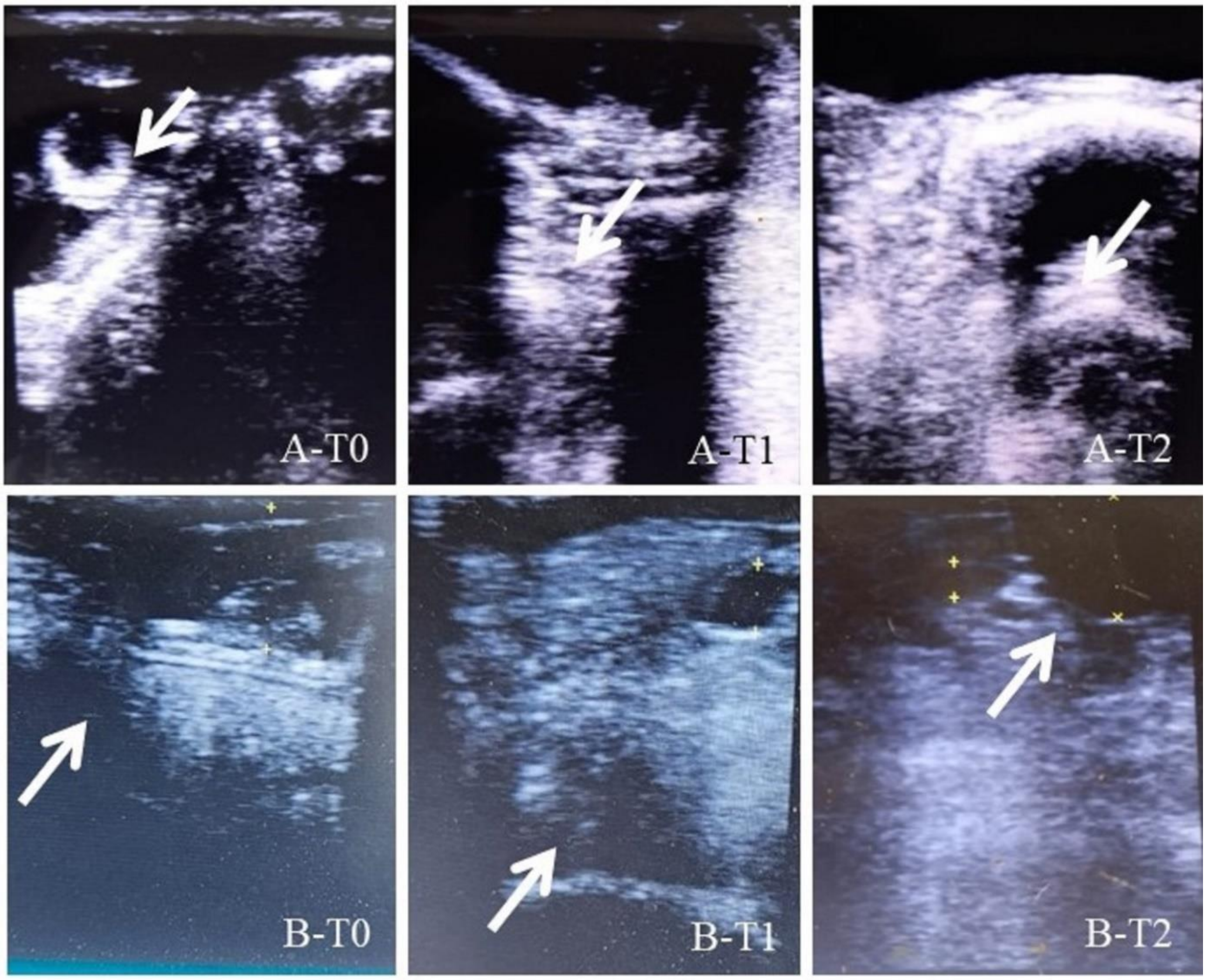

Figure 2. Ultrasonographic features of the ovaries in Pote goats. (A) before estrus synchronized (arrow: corpus luteum), (B) at estrus (arrow: developing follicle). (T0) Pote goats were given standard feed (forage and concentrate), (T1) Pote goats were given standard feed (forage and concentrate) and premix, (T2) standard feed immune booster.

Interestingly, this study found no significant body weight gain in female Pote goats treated with mineral premixes and immune boosters. Similar observations were reported by Pal *et al*. (2010) and Mandal *et al*. (2007), where supplementation with organic sources of Cu and Zn did not result in differences in final body weight, average daily gain, and feed efficiency. Additionally, Engle and Spears (2001) reported that dietary supplements, which accumulate Cu in the liver at concentrations slightly above normal levels of about 15 mg/kg DM, even lower than the Cu used in this study, have been associated with poor animal performance, including reduced feed intake and daily weight gain. In line with the findings of Prieto *et al*. (2000) and Chobtang *et al*. (2009), who found no significant effect of different levels of protein in the diet on the feed intake, body weight, and growth performance of Thai indigenous male goats, Spanish, and Boer-Spanish crossbred kids. Additionally, it's important to note that while increasing mineral intake, balance with vitamins and other essential elements is crucial for optimal animal health and performance.

According to López-Alonso (2012) and Härter *et al*. (2015), a goat may ingest adequate minerals but fail to absorb them due to nutritional deficiencies. Simply increasing the mineral content will not necessarily address the deficiency. Some minerals rely on specific vitamins for proper absorption. For instance, calcium and selenium absorption require vitamins D and E, respectively. In cases where goats exhibit symptoms of selenium deficiency, supplementing with vitamin E alone may not suffice. Therefore, goats lacking vitamins A, D, E, and K may require additional supplementation along with fats to aid in their absorption.

Mineral deficiencies are not solely caused by inadequate mineral intake. Selenium, for example, depends on vitamin E, which in turn relies on fats for absorption. Similarly, supplementation of solar or synthetic vitamin D is necessary for calcium absorption, which also requires fats. Additionally, as reported by Kawamoto *et al*. (2020), fat sources often contain high levels of phosphorus. An imbalance in the calcium-to-phosphorus ratio can result in urinary tract stones in male goats. Therefore, if fats are added to their feed, the ratio should be adjusted to restore balance. Merely increasing mineral intake may not suffice because multiple trace minerals and vitamins may be involved in a single physiological function. Consequently, low feed efficiency, which is positively correlated with average daily weight gain, may cause female Pote goats to gain relatively little body weight.

Blood Urea Nitrogen, Total Protein, and Albumen

Pote goats that were fed standard feed and premix (T1) and that were given standard feed and immune-booster (T2) resulted in higher ($p < 0.05$) blood urea nitrogen than goats fed standard feed. There was no significant difference ($p > 0.05$) in the total protein levels among the treatment groups. Albumen levels of Pote goats fed standard feed and immune-booster (T2) were higher ($p < 0.05$) than those of the other groups. In regard to the result of blood urea nitrogen (BUN), total protein (TP), and albumin (Alb) levels of Pote goat after feeding treatment for 45 days was shown in Table 4.

Female Pote goats receiving standard feed and concentrate booster supplementation exhibited significantly higher levels of blood urea nitrogen (BUN) and albumin compared to the other groups ($p < 0.05$) (Table 4). However, the total protein (TP) levels among the treatment groups were similar.

Normal BUN levels in goats range from 12 to 28 mg/dL (Kalio, 2014). The BUN levels in this study fell within the typical reference range for urea concentrations. Additionally, there is evidence of a direct correlation between blood or plasma urea-nitrogen levels and dietary crude protein intake in ruminants (Paengkoum *et al*., 2021).

The concentration of urea in the serum is influenced by various interconnected factors, including the intake and degradability of dietary protein in the rumen, the composition of dietary amino acids, the ratio of protein intake to requirement, liver and kidney function, muscle tissue breakdown, and the amount of dietary carbohydrates and intake of effective rumen degradable protein (Baset *et al*., 2010). In line with Hussein (2014), an incremental increase in total protein and albumin concentrations was observed as protein levels rose in response to the addition of immune enhancers.

Plasma protein content is frequently used in ruminant nutrition evaluation. Total protein levels in each experimental group generally fall within the expected range of 6–8 g/dL, as reported by Levitt and Levitt (2016). Increased protein intake is associated with elevated blood albumin levels, as demonstrated by Afroz *et al*. (2020) and Lohakare *et al*. (2006). The availability of protein is reflected in total protein and albumin concentrations within the body; in the absence of proteins, these substances accumulate.

Estrus Synchronization

Ultrasonography of Pote goat ovaries showed corpus luteum form before injection of PGF2α, and development of follicle at estrus (Figure 2). The estrus rate of Pote goat in T1 and T2 was higher than the T0 group. However, the onset and duration of estrus were not significantly different ($p > 0.05$) among groups (Table 5).

Descriptively, the ultrasonograph of Pote goat does ovaries before estrus synchronization or pre-transplantation (pre-tx) showed developing follicles, dominant follicles, and corpus luteum. However, at the estrus there only developing follicles were found, without dominant follicles, and corpus luteum in all of the groups (Table 6). Serum progesterone levels were detected before estrus synchronization and estrogen levels were measured at estrus of all Pote goats (Table 7).

To synchronize estrus with PGF2α, the presence of the corpus luteum is crucial. Before PGF2α injection in this study, ultrasound confirmed the presence of the corpus luteum along with other ovarian structures. The corpus luteum plays a key role in producing the progesterone hormone through a specific synthesis mechanism (Przygrodzka *et al*., 2021). Progesterone biosynthesis involves two enzymatic steps: the conversion of cholesterol to pregnenolone by P450 side chain cleavage (P450scc) in the mitochondria's inner membrane, and the conversion of pregnenolone to progesterone by 3β-hydroxysteroid dehydrogenase (3β-HSD) in the smooth endoplasmic reticulum (SER). Studies have shown that during luteinization of granulosa and theca cells, there are significant changes in the organization and quantity of both mitochondria and SER, leading to increased cellular progesterone synthesis (Bassi *et al*., 2021; Hu *et al*., 2010).

In goats, the corpus luteum was confirmed before PGF2α injection in this study by progesterone levels ranging from 38.95 to 53.52 ng/mL among the groups. During the luteal phase (presence of the corpus luteum), serum estrogen levels in goats increased, ranging from 56.53 to 62.06 ng/mL. PGF2α is injected intramuscularly and circulates in the bloodstream to reach the ovaries, where it regresses the corpus luteum through a counter-current mechanism (Monaco and Davis, 2023).

The estrus rate of does feed with premix booster or concentrate booster was higher than that of does feed standard feed (forage and local concentrate). Premix mineral booster supplementation improved the nutrition, health, and reproduction of female Pote goats in this feeding study. Elevated blood progesterone levels indicate corpus luteum activity, suggesting that premix mineral booster supplementation may enhance ovarian activity and facilitate conception (Meza-Herrera *et al*., 2013). Luteal cells produce progesterone by modulating superoxide dismutase activity with Cu and Zn (Sales *et al*., 2011). Zinc is essential in sexual development and rearrangement of progesterone-producing ovarian follicles (Chen *et al*., 2023). Zinc also impacts estrus, pregnancy, and lactation, especially in female estrus (Garner *et al*., 2021). According to Yatoo *et al*. (2018), Fe, Zn, Mn, and progesterone in heifers are positively correlated. However, macronutrients Ca, P, and Mg, when isolated, do not typically impact animals' reproductive status directly, although disruptions in the Ca-P-Mg homeostasis may have consequences for reproduction (Amin *et al*., 2016; Ullah *et al*., 2010). Other studies have shown that mineral supplements improve ruminant nutrition and reproduction. Niaz *et al*. (2017) reported that administering 100 g of concentrate and 0.5 g of an area-specific mineral combination to Ganjam goats raised blood mineral levels and improved reproductive function.

In this study, the onset and duration of estrus were not significantly influenced by nutrition. The quality of the feed was one of the factors affecting the weight gain of female Pote goats. Body weight is a determinant of the success of estrus synchronization and livestock pregnancy. Animals with body weights exceeding the ideal weight may experience reproductive disorders and metabolic diseases. Conversely, animals with body weights below the ideal range may experience adverse effects on their reproductive system (Azis *et al*., 2023; Nourin *et al*., 2024). Therefore, increased feed intake and daily weight gain could improve the overall nutritional status, potentially creating a more favorable environment for follicular and oocyte development (Łakoma *et al*., 2023). Additionally, higher ovulation rates were observed with higher body weight and body condition score levels, consistent with previous reports. Body weight, body condition score, and feed consumption levels typically influence ovulation rates (Dunnz and Moss, 1992).

Moreover, mineral premix supplementation resulted in a modest increase in the number and size of dominant ovarian follicles, although not statistically significant. However, it did not significantly impact reproductive performance parameters such as days until first estrus, estrogen, and progesterone levels. The findings suggest that mineral premix or concentrate booster supplementation contributes to maintaining the estrous cycle in goats, although not significantly, which aligns with previous studies (Kleemann and Walker, 2005; Marai *et al*., 2007). An association was observed between increased ovulation and higher body weight and condition score levels, consistent with previous findings (Dunn and Moss, 1992). Dunn and Moss (1992) have shown that body weight, body condition score, and feed consumption levels typically affect follicle development and ovulation rates. Thus, supplementation with mineral premix and immune boosters led to higher blood urea nitrogen and albumin levels. Ultrasonography confirmed corpus luteum formation before estrus synchronization, with enhanced estrus rates in the supplemented groups. Progesterone and estrogen levels confirmed ovarian activity during estrus. However, no significant difference in body weight gain was observed, potentially due to complex interactions between mineral supplementation, feed quality, and metabolic factors. Nevertheless, supplementation positively impacted reproductive parameters, suggesting its potential for improving Pote goat reproductive performance post-FMD. Further research is needed to validate these findings across diverse animal species and environments.

CONCLUSION

This study investigated the impact of mineral and feed supplementation on the reproductive performance of female Pote goats post-FMD infection. While supplementation didn't significantly increase body weight, it positively affected reproductive parameters like estrus rates and ovarian activity. Supplemented groups showed improved metabolic health markers. Despite the lack of significant weight gain, the study underscores the potential of supplementation in enhancing goat reproductive performance (follicle development and estrus rate) after FMD. Further research is needed to validate these findings across different animal species and environments, aiding in improved reproductive and health management strategies.

ACKNOWLEDGEMENTS

Authors would like to thanks to the Universitas Airlangga for supporting facilities during this study (Contract number: 1286/UN 3.1.6/PT/2023).

AUTHORS' CONTRIBUTIONS

IM, SS: designed, conceptualized, supervised, analyzed data and wrote the manuscript. ML, ZNAR, AA, CB, AOA, HAH, ARK, MA, RZA, SRA: performed the experiment, analyzed data and wrote the manuscript. All authors have read and approve the final manuscript.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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