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Effects of palm oil and palm oil zinc soap supplementation on feed intake, feed digestibility, and performance in lamb

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Abstract. This research aims to evaluate the effects of palm oil supplementation (PO) and palm oil zinc soap (POZS) supplementation on feed intake, feed digestibility, and performance of Indonesian local lambs. Fifteen male lambs with an initial body weight of 16.97 ± 1.99 kg in randomized block design were analyzed in three treatments. The diets included: basal diet (60:40 concentrate to forage) with no added supplement as control (CON), basal diet plus PO, and basal diet plus POZS. Rumen partial protected fats used in this research are POZS (75:25 zinc soap to palm oil). The treatment was analyzed for 70 days with two weeks of adaptation period. The data were analyzed statistically with analysis of variance using Minitab 16 after passing the assumption test. Tukey test is used (Honestly Significant Difference = HSD) for a significant difference. The data that did not pass the assumption test was processed using the Friedman nonparametric method. The results showed that the dry matter intake in both forage and concentrate were decreased in POZS even though the digestibility of feed and blood glucose levels were not affected by treatments. Daily weights gain significantly decreased compared to control, i.e. 93.25 g/day (CON) vs 78.43 g/day (PO) and 58.09 g/day (POZS) with low feed efficiency.

1. Introduction

Each breed of lambs in Indonesia has different energy needs for growth, but has the same basic necessities of life. Indonesian local lambs need energy in the form of Energy requirement for growth of 2.75 TDN [1]. Maintenance energy costs represent 60-80% of all energy consumed in ruminant production systems [2]. Oil supplementation will produce energy twice as high as other nutrients when metabolized in the body [3]. Apart from being high in energy, oil has antimicrobial properties [4]. This can cause disturbances in the metabolic processes of the rumen, including low feed digestibility, decreased number of rumen microbes and production of VFA (volatile fatty acids). Su *et al.* [5] stated that 4% flaxseed oil supplementation increased daily mean weight gain and feed conversion in lambs, but did not affect the rumen fermentation of the animal. Bhatt et al. [6] stated that 7.5% coconut oil supplementation reduced concentrate consumption but affected higher feed conversion in the 5% coconut oil treatment.

Oil protection is used to reduce the negative effects of oil supplementation.This is evidenced by Behan *et al.* [7] by using calcium soap, of which it does not interfere with the digestibility of nutrients and rumen fermentation of lamb. Research by Bhatt *et al.* [8] previously also found that supplementation of 4% calcium soap in rice bran oil increased feed energy consumption, but without protection resulted in reduced concentrate consumption, weight gain, and feed conversion.

Oil palm is one of Indonesia's mainstay commodities. The use of palm oil as a supplement is considered because of its availability in large quantities in the market, making it easy to obtain at a lower price than other vegetable oils. This can be seen from the production data of Crude Palm Oil

(CPO) in Indonesia which reached 42.9 million tons with the ability to export CPO and its derivative products reaching 27.89 million tons in 2018 [9]. World commodity price data also show that palm oil is cheaper in metric tons (mt) at US$574 /mt compared to peanut oil at US$ 1,584 /mt, coconut oil at US$830 /mt, and soybean oil at US$684 /mt [10].

The feed fat in the rumen will undergo lipolysisby microbes, and then the unsaturated fatty acids will be hydrogenated to become saturated fatty acids. Bio hydrogenation is a process of bacterial defense from bacteriostatic effects against unsaturated fatty acids. It is thought that the toxicity occurs through metabolic effects, as stated by Maia *et al*. [11], which can inhibit microbial growth.The use of vegetable oil needs to be protected in order to avoid bio hydrogenation and does not change the fermentation of rumen bacteria as evidenced in the research results of Suharti *et al*. [12] using canola oil calcium soap and flaxseed oil. Behan *et al*. [7] stated that the provision of rumen protected fat (RPF) will protect the fat from microbial fermentation and bio hydrogenation and will not dissolve in rumen potential of hydrogen (pH). One form of RPF is to convert oil into soap for ruminant feed supplementation.

Zinc (Zn) plays a role in biological processes, which includes enzyme activity, cell membrane stability, gene expression, and cell signaling ([13],[14]). Zinc is required for the structural and functional integrity of more than 2000 transcription factors and 300 enzymes. It can be said that almost all metabolic pathways in some ways depend on at least one protein requiring Zn [15]. Zn supplementation is necessary, because Zn levels in feed in Indonesia are generally very low [16]. Soap making with Zn mineral is still rarely done. Researchers are interested in researching the provision of energy-dense supplements enriched by minerals that play an important role in biological processes, i.e. palm oil Zn soap, which will be applied to lambs.

2. Methodology

2.1. Locations, Animals, and Cages

The research was conducted in a digestive cage, Faculty of Animal and Agricultural Sciences, Diponegoro University, Semarang, Central Java, Indonesia. Fifteen lambs with an average initial body weight of 16.97 ± 1.99 kg are kept in individual bamboo cages measuring 1.2 m^2 each with a slatted floor 0.5 m above the ground equipped with eating and drinking facilities.Lambs were given research feed for 70 days including 7 days for digestibility test. The time for adaptation to the environment and feed was performed two weeks before the study. The animals were washed, shaved, dewormed and given vitamins before the start of the trials.

2.2. Research Design and Treatment

The experiment was carried out using a randomized block design (RBD) and animals were randomly allocated to three treatments consisting of five animals in each treatment. Random selection of animals was performed using random numbers. The oil used is commercial palm oil. Preparation of palm oil zinc soap was carried out according to Cabatit [17]. Palm oil is measured by the number of soaping, then soap is made based on the soaping rate, KOH is added proportionally to the number of soaping of each oil. The material used for protection is the $ZnCl_2$mineral. Zn mineral is added based on the stoichiometric calculation of the reaction according to Widiyanto *et al*. [18], so that the addition of $ZnCl_2$ is the same as the KOH needed to soak palm oil. The three ration treatments in this study were: CON = basal diet without additional supplementation as a control; PO = basal diet plus 5% palm oil; and POZS = basal diet plus Zn partial protection oil palm soap. The partial protection in question is added 5% oil consisting of 3.75% protection oil and 1.25% unprotected oil.The composition of the ration ingredients is presented in Table 1, while the nutritional value of the feed ingredients and supplements used in this study are presented in Table 2. The forage given is sweet grass (*Hierochloe odorata*). The ratio of forage to concentrate is 60:40. Water is available ad-libitum. The feed intake of each animal was recorded every day based on the amount of feed given and leftovers.

Table 1. Composition of treatment rations

Feed Ingredients and Supplements	Composition of Feed Treatment		
	CON	PO	POZS
Sweetgrass (g)	1000	1000	1000
Rice bran (%)	22.67	22.67	22.67
Coffee skin (%)	15.97	15.97	15.97
Coconut Cake (%)	13.82	13.82	13.82
Palm oil cake (%)	13.56	13.56	13.56
Onggok (%)	12.37	12.37	12.37
Corn (%)	7.84	7.84	7.84
Soybean meal (%)	7.73	7.73	7.73
Molasses (%)	3.30	3.30	3.30
Mineral (%)	1.37	1.37	1.37
Urea (%)	0.69	0.69	0.69
Salt (%)	0.69	0.69	0.69
Palm Oil (%)	-	5	1.25
Palm oil zinc soap (%)	-	-	3.75

CON = diet without suplement; PO = diet with palm oil 5%; POZS = diet with protectedpalm oil 3.75% +1.25% palm oil

Table 2. Nutrient content of sweet grass, concentrates, palm oil, and Zn palm oil soap.

Nutrient	Sweetgrass[1]	Concentrate [1]	Palm oil[2]	Palm oil zinc soap[1]
Moisture (%)	74.21	9.56	0.06	64.3
Ash (%)	13.37	13.03	<0.02	19.50
Crude protein (%)	10.96	18.04	<0.04	0.49
Crude fat (%)	1.39	5.70	100	24.36
Crude fiber (%)	32.01	18.07	<0.02	4.20
Calcium (%)	0.34	1.08	0.18	0.02
Phosphor (%)	0.44	0.57	0.001	0.04
Gross Energy (Kkal/kg)	3958.00	4241.57	9000.00	14726.25
TDN [3] (%)	60.86	72.17	149.66	89.91
ADF (%)	45.20	30.75	-	0.02
aNDF (%)	-	49.02	-	-
NDF (%)	72.82	-	-	0.09

[1]Average test results of the Feed Quality and Certification Testing Agency, Bekasi, 2019-2020.
[2]Test results of PT Saraswanti Indo Genetech, Bogor, 2019.
[3]The calculation results

2.3. Feeding

Feeding was done twice a day, in the morning at 05.00 and in the afternoon at 14.00. 200 grams of concentrate were given first, followed by oil supplements and finally 500 grams of sweet grass each time.Drinking water was given ad libitum. The feed and the leftover feed were sampled every week to measure the dry matter intake (DMI). DMI consumption for feed is calculated by the formula = (amount of feed intake x DMI feed) - (amount of leftover feed x DMI leftover feed).

2.4. Feed Digestibility

Feed digestibility was measured by the total collection method. Feces collection was carried out for 7 days by placing the lambs in the metabolic pen. Feces collection was carried out every day and sprayed with 3% H_2SO_4 every 4 hours. The feces that were collected every day were weighed and then taken as much as 10% as a sample, then dried in the sun to dry, and stored in the freezer for analysis purposes analysis of concentrate, forage, and feces samples on levels of DMI, ash, crude fat, crude protein, crude fiber were carried out according to the method of Association of Official Analytical Chemists Official (AOAC) [19]. TDN value is calculated according to the National Standardization

Agency of Indonesia (BSN) [20]. Energy digestibility calculation was carried out according to McDonald et al. [21].

$$digestibility\ \% = \frac{nutrition\ consumed - nutrition\ excreted\ in\ feses}{Nutrition\ consumed}\ x\ 100\%$$

2.5. Average Daily Gain (ADG)

Each animal's body weight was recorded on the first day of the experiment. Weighing is done every morning before being fed. Weight recording was carried out every two weeks for 70 days of the trial period to determine changes in body weight. Animal productivity was identified by measuring ADG according to Williamson and Payne [22].

$$\text{ADG (g/day)} = \frac{\text{Final BW (g)} - \text{Initial BW (g)}}{\text{observation time (day)}}$$

2.6. Blood Zn and Blood Glucose

Blood samples were taken from each lamb to be analyzed for metabolites and minerals in the blood. Five milliliters of blood were drawn from the jugular vein with a 5 ml syringe. The blood drawn is put into a tube (without EDTA, ethylene diamine tetraacetic acid). The blood is allowed to stand for 30-60 minutes until the serum was formed and then taken to the Health Laboratory and Medical Device Testing Laboratory of the Central Java Provincial Health Office for glucose analysis. The method used to measure glucose is Glucose OXIDASE-PAP (GOD-PAP). The remaining blood serum samples were stored in the freezer for analysis of Zn mineral at the Laboratory of Nutrition and Feed Science, Faculty of Animal Husbandry and Agriculture, Diponegoro University, using Atomic Absorption Spectroscopy (AAS).

3. Results and discussion

3.1. Feed Intake and Digestibility

Consumption of forage DMI, digestible DMI, DMI digestibility, and Total Digestible Nutrients (TDN) were not affected ($p > 0.05$) by treatments. The treatments only affected the consumption of concentrate DMI and total DMI ($p < 0.05$), as shown in Table 3.

Table 3. Effect of palm oil zinc soap supplementation on feed intake and digestibility in lambs.

Parameter	Treatments			p-Value
	CON[3]	PO[4]	POZS[5]	
DMI of forage (g/day) [1]	183.40±25,62	140.08±44.23	146.50±41.62	0.288
DMI of concentrate (g/day) [2]	362.23[a]	335.21[b]	316.00[b]	0.022
DMI of total (g/day) [2]	551.69[a]	520.83[b]	456.30[b]	0.045
DM digested (g/day) [1]	334.44±17.44	308.49±59.40	281.24±54.18	0.369
Digestibility of DM (%)[1]	61.39±4.54	65.69±4.18	59.53±4.74	0.245
TDN total (%)[1]	55.79±3.73	60.53±4.53	54.99±3.29	0.197

[1]The results analysis of variance Minitab 16 used average; [2] The results Friedman nonparametric method used median; [3] CON: basal diet without supplementation; [4] PO: basal diet + palm oil; [5] POZS: basal diet + (75:25 palm oil zinc soap to palm oil); a,b,c means heaving different superscript in each row or significantly different (p-Value <0.05)

The consumption of forage DMI, total DMI consumption, digestible DMI, DMI digestibility, and total TDN were not significantly different between the CON, PO, and POZS treatments, but the consumption of DMI concentrate ($P < 0.05$) showed decreased results in PO and POZS compared to CON (Table 3). The results of this study differ from those of Bhatt et al. [8] who used 4% calcium soap for rice bran oil for lambs, which resulted in a higher DMI consumption than control.However, the results of this study were in line with Fiorentini et al. [23] who found that palm oil supplementation had lower DMI consumption and digestibility than protected and control fats. The decrease in DMI consumption in the palm oil supplementation treatment (PO) and palm oil Zn soap (POZS) was caused by the energy density of the supplemented oil. It is known that livestock consume feed based on their energy requirements.High energy feed will reduce the level of dry matter consumption.

3.2. Blood Zn and Blood Glucose Level

Blood Zn was influenced by treatments (p <0.05), giving partially protected palm oil resulted in blood Zn levels higher than control, but blood glucose levels were not affected by treatments (Table 4).

Table 4. Effect of palm oil zinc soap supplementation on blood Zn and blood glucose level in lambs.

Parameter	Treatment			p-Value
	CON[1]	PO[2]	POZS[3]	
Blood Zn (ppm) [4]	2.80^{b}	1.55^{b}	4.57^{a}	0.022
Blood glucose (mg/dl) [4]	63.9	49.60	63.30	0.247

[1] CON: basal diet without supplementation; [2] PO: basal diet + palm oil; [3] POZS: basal diet + (75:25 palm oil zinc soap to palm oil); [4] The results Friedman nonparametric method used median; a,b means heaving different superscript in each row or significantly different (p-Value <0.05)

The blood Zn level was higher in POZS compared to CON and PO, which is consistent with the study of Page et al. [24] and Farghaly et al. [25] that Zn supplementation both in the forms of inorganic Zn and organic Zn resulted in higher blood levels of Zn than controls. This is because Zn is an essential micro-mineral that is easily absorbed in the intestine. Some researchers stated that organic Zn in the form of bind to protein (Zn-proteinate) and fatty acids (Zn-acetate) is more easily absorbed in the intestine (Muktiani [26]).

Supplementation of rice bran oil calcium soap (Bhatt et al. [8]), grape seed oil (Sharifi et al. [27]), Zn-Met (Jafarpour et al. [28], coconut oil of 25, 50, and 75 g/kg (Bhatt et al. [29]), and 0.02 and 0.04% of oregano essential oil (Gumus et al. [30]) in lambs yielded the same blood glucose levels for all treatments according to the results of this study.Glucose is the result of carbohydrate metabolism in the body, especially the result of changes in propionic acid in the liver. Propionate, apart from being produced from carbohydrate digestion, is also produced from glycerol as a result of lipolysis in the rumen. Furthermore, the body regulates blood glucose levels through the homeostasis system.

3.3. Average Daily Weight Gain, Feed Conversion Ratio, and Feed Efficiency

Initial body weight (BW), final body weight, feed conversion ratio (FCR), and feed efficiency were not affected by treatments, but the average daily body weight gain (ADG) was different between treatments (p <0.05) as shown in Table 5.

Table 5. Effect of palm oil zinc soap supplementation on average daily weight gain, feed conversion ratio in lambs.

Parameter	Treatment			p-Value
	CON[1]	PO[2]	POZS[3]	
Initial BW (kg)[4]	15.57±1.87	18.11±1.43	17.23±2.04	0.150
Final BW (kg)[4]	20.22±1.37	22.01±1.70	19.63±2.71	0.198
ADG (g/hari)[4]	93.25±17.40^{a}	78.43±13.00^{ab}	58.09±17.84^{b}	0.025
Feed Conversion Ratio (F:G)(FCR; gDM/g)[4]	6.05±1.37	6.18±1.72	8.51±2.09	0.149
Feed efficiency(G:F) (%)[4]	17.17±3.66	17.36±5.33	12.42±3.35	0.170

[1] CON: basal diet without supplementation; [2] PO: basal diet + palm oil; [3] POZS: basal diet + (3.75% : 1.25% palm oil zinc soap to palm oil); [4]The results analysis of variance Minitab 16 used average.; superscript "a, b" mean heaving different in each row or significantly different (p-Value <0.05).

The results of this study showed that the final body weight, feed conversion ratio, and feed efficiency were not different, while the ADG was lower in the POZS treatment (Table 5). This is different from the research of Bhatt et al. [8, 31, 32, 33] using vegetable oil calcium soap on lambs before and after weaning resulted in improved ADG, feed conversion ratio, and feed efficiency compared to vegetable oils without protection and control. Otherstudies which used palm oil calcium

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soap in lactating ewes (Gomez-Cortes et al. [34]), lemuru oil fatty acid soap in lambs (Setyaningrum et al. [35]), and 3% calcium salt (Abdelrahman [36]) resulted in the same ADG performance compared to control including final weight and feed efficiency which were not significantly different. Supplementation of various vegetable oils as has been done by Ferreira et al. [37], Sharifi et al. [27], and Gumus et al. [30] resulted in the performance of rams, Akkaramah lambs, and Boluchi lambs that were not significantly different including in final BW, ADG, feed conversion ratio, and feed efficiency. The effects of oil supplementation and protected oil appear to be inconsistent. This is supported by the results of research by Fiorentini et al. [23] which found that oil supplementation had the effect of reducing daily body weight gain followed by a decrease in feed efficiency. The same result was also conveyed by Vazquez et al. [38] using fish oil which found as much as 3.3% negatively impacted the performance of lambs, but increased the long chain fatty acid content of the meat compared to palm oil.

The use of Zn-protected oil supplement in this study was thought to have contributed to a decrease in consumption and daily body weight gain in the studies lambs. Although Zn has a broad function in livestock metabolism, the excess of Zn minerals results in the inhibition of the absorption of other essential minerals, especially Ca, Mg, P. The deficiency of these three minerals is very detrimental to the synthesis process in livestock, so that their productivity decreases.

4. Conclusions

Supplementation of palm oil and palm oil Zn soap resulted in lower dry matter intake consumption and daily body weight gain, although feed conversion and feed efficiency did not differ. It is necessary to study the levels of Zn in feed, rumen fluid, and its metabolic effects in the body to answer the negative effects of palm oil Zn soap supplementation.

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