PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
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OPEN ACCESS Pakistan Journal of Nutrition

ISSN 1680-5194
DOI: 10.3923/pjn.2017.612.617

Research Article

Effects of Using Different Levels of Oil Palm Fronds (FOPFS) Fermented with *Phanerochaete chrysosporium* plus Minerals (P, S and Mg) Instead of Napier Grass on Nutrient Consumption and the Growth Performance of Goats

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Abstract

Objective: The objective of this study was to evaluate the effect of substituting Napier Grass (NG) with Fermented Oil Palm Fronds (FOPFs) plus minerals (P, S and Mg) on consumption and growth performance of goats. **Materials and Methods:** This study was carried out using a randomized block design with 5 treatments and 3 replications. The treatments for this study were: A = 40% NG+0% FOPFs+60% concentrate, B = 20% NG+20% FOPFs+60% concentrate, C = 0% NG+40% FOPFs+60% concentrate, D = 20% NG+20% FOPFs+60% concentrate plus P, S and Mg and E = 0% NG+40% FOPFs+60% concentrate plus P, S and Mg. The data were analysed using a one-way analysis of variance (ANOVA) and Duncan's Multiple Range Test (DMRT) was used to test the differences between treatments. The observed parameters were feed consumption and growth performance of goats. **Results:** The results of the study show that substituting NG with FOPFs (100%) plus minerals (P, S and Mg) in goat rations (treatment E) showed the highest nutrient consumption and average daily weight gain and the lowest feed conversion. **Conclusion:** It is concluded that FOPFs can be used as an alternative to NG in goat rations.

Key words: Fermented oil palm frond, Napier grass, performance, goat rations, nutrient consumption

Received: April 11, 2017 Accepted: June 19, 2017 Published: July 15, 2017

Citation: Dewi Febrina, Novirman Jamarun, Mardiati Zain and Khasrad, 2017. Effects of using different levels of oil palm fronds (FOPFS) fermented with *Phanerochaete chrysosporium* plus minerals (P, S and Mg) instead of Napier grass on nutrient consumption and the growth performance of goats. Pak. J. Nutr., 16: 612-617.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Palm oil plantations in Indonesia in 2015 covered 11,300,370 ha, with the largest area in the province Riau (7,333,610 ha)[1]. Oil Palm Fronds (OPFs) are a by-product of oil palm plantations. Febrina[2] reported that the nutritional content of oil palm fronds were as follows: Dry matter, 46.02%; organic matter, 94.50%; crude protein, 2.67%; crude fibre, 50.00%; NDF, 81.91%; ADF, 70.00%; hemicellulose, 11.91%; and cellulose, 39.63%. The utilization of oil palm fronds as feed is limited because of the high content of lignin (30.18%)[3].

Biological treatment using microorganisms can reduce the lignin content of feed substrates. *Phanerochaete chrysosporium* (*P. chrysosporium*) is a white rot basidiomycete that is capable of completely degrading all major components of plant cell walls, including cellulose, hemicellulose and lignin[4] via the activity of ligninolytic enzymes[5]. Calcium and manganese are minerals that are required for the activity of fungal ligninolytic enzymes[6]. The growth of fungus can be improved by adding Ca[7] and Mn[8] to the medium. The addition of Ca and Mn to support the growth of *P. chrysosporium* has been shown to give positive results, as reported by Suparjo[9] in cocoa pod husks and by Febrina[2] in OPFs.

Napier grass has a high productivity[10] and most popular in Kenya[11]. Febrina[2] reported the nutritional contents of Napier Grass (NG) are as follows: Dry matter, 20.52%; crude protein, 13.45%; ADF, 39.67%; NDF, 69.15% and lignin, 6.24%.

The utilization of by-products of oil palm plantations as feed has been reported by multiple researchers. Rations based on by-products of oil palm plantations can improve the growth performance of cattle[12] and Fermented Oil Palm Fronds (FOPFs) treated with *P. chrysosporium* can be used as a substitute for NG at levels up to 40% in ruminant rations[13]. The Ca, P, Mg and S contents of OPFs are 0.530, 0.109, 0.180 and 0.096 mg kg^{-1} DM, respectively[14] and the content of the crude protein is low at 2.67%[2], which leads to low consumption rates and nutrient digestibility. Dahlan[15] stated that the supplementation of Ca, P and S was necessary to balance the nutritional content of OPFs; deficiencies of these minerals in the diet causes the disruption of livestock growth[16]. The purpose of this study was to evaluate the effect of substituting NG with FOPFs plus minerals P, S and Mg on feed consumption and growth performance of goats.

MATERIALS AND METHODS

This study used fifteen 1 year old goats with initial body weights ranging from 11.03-13.92 kg. Goats were placed in individual cages supplied with feed and water. The study was conducted over three periods, namely, the adaptation, introduction and collection periods. The adaptation period lasted for 15 days and aimed to allow the goats to adjust to the experimental environment. The introductory period lasted for 15 days and aimed to eliminate the influence of the previous rations fed to the animals. The collection period lasted for 7 days, for faeces collection and 28 days to observe feed consumption and weight gain. Rations consisted of NG, rice bran, tofu and FOPFs.

Protein contents of rations ranged from 12.04-12.64% and TDN contents from 64.58-66.76%. Feeding was performed twice a day, at 08.00 and 17.00[17]. Feed was provided according NRC recommendations[18], which is 4% of body weight based on dry matter content. Drinking water was provided as ad libitum. The ratio of concentrates to forage was 60:40[19].

Oil palm frond fermentation: The substrate used in this research was OPFs that had been cut and dried and then finely milled. Ca was provided as $CaCl_2$ and Mn was provided as $MnSO_4.H_2O$. *Phanerochaete chrysosporium* was maintained on Potato Dextrose Agar (PDA) slants at 4°C and then transferred to PDA plates at 37°C for 6 days and subsequently grown on rice bran. The fermentation process was initiated by adding water to the OPF so that the water level reached 70% and then, Ca and Mn were added. Fermentation lasted for 10 days according to the procedure described by Febrina *et al.*[20] and then, the resulting product was dried and P, S and Mg were added according to the specific treatment. The sources of P, S and Mg were Na_2HPO_4, Na_2SO_4 and MgO, respectively.

Experimental design and statistical analysis: This study used a randomized block design with 5 treatments and 3 replications. Duncan's multiple range test was used to determine significant difference between treatments.

The treatments for this study were given below:

A = 40% NG+0% FOPFs+60% concentrate
B = 20% NG+20% FOPFs+60% concentrate
C = 0% NG+40% FOPFs+60% concentrate
D = 20% NG+20% FOPFs+60% concentrate plus P, S and Mg
E = 0% NG+40% FOPFs+60% concentrate plus P, S and Mg

RESULTS AND DISCUSSION

Table 1 shows the effects of the substitution of NG with FOPFs on nutrient consumption for each treatment.

Feed consumption was lowest in treatment A, which was significantly ($p<0.05$) lower than that of treatments D and E, but the consumption of treatment D was not significantly different from treatment E. Feed consumption was lower in treatment A due to the high water (79.48%) and crude fibre (32%) contents, which limited the ability of goats to consume the ration. Goats that consume rations with a high water content, such as Napier Grass, become satiated faster, so goats reduce their consumption of this feed. Similar results were reported by Jarmuji *et al.*[21] for Setaria grass, which also has a high water content. A high crude fibre content of a ration will also reduce the consumption and digestibility of nutrients[22]

According to Febrina[2], the processing of OPFs through biological delignification using *P. chrysosporium* with the addition of 2,000 ppm Ca and 150 ppm Mn causes the lignin content to decrease by 25.77% (from 30.18-22.4%). The addition of FOPFs to the rations showed a positive response, with increases in palatability and feed intake. This was seen in treatments B, C, D and E, which resulted in higher feed intake compared to that of treatment A. Palatability is an important factor that can increase feed intake[23]. Lignin can also limit the digestibility of forage and an increase in lignin degradation will improve feed digestibility and intake[22]. The administration of FOPFs that have been mixed with other concentrates, such as rice bran and tofu, such that goats cannot choose their preferred feed items, results in the goats consuming feed in larger quantities.

Supplementation of minerals (P, S and Mg) in the rations (treatments D and E) had a positive effect on increasing the consumption of nutrients compared to the effects of treatments A, B and C. This indicates that the rations that include by-products of oil palm plantations are deficient in minerals and that mineral supplementation is necessary for microbial growth and supporting the metabolic processes in the rumen. Soetan *et al.*[24] reported that the availability of minerals can affect the rate of metabolism; a high rate of metabolism will increase energy requirements to support metabolic activity such that cattle consume feed in larger quantities[25]. Livestock that consume agricultural by-products are subject to mineral deficiencies, therefore, the addition of minerals to their diets is needed to support the growth of rumen microbes and to improve digestibility[26] and livestock production[27].

Sulfur plays a role in the synthesis of sulfur-containing amino acids and some vitamins, therefore, the metabolic process of rumen microbes should be optimized to increase the consumption and digestibility of nutrients. The supplementation of sulfur in the diet increases feed intake[28], as well as digestibility, nitrogen and sulfur utilization and microbial protein bio-synthesis[29]. Sulfur is needed by livestock, but if given in excessive amounts, it has negative effects on the performance and health of livestock[30]. Supplementation of minerals in goat rations increases the intake and digestibility of dry matter[24].

Phosphorus is required to digest cell walls and higher quantities of phosphorous are required to degrade cellulose that are needed to degrade hemicellulose and amylose[31]. Nurhaita *et al.*[32] reported that the supplementation of S and P and cassava leaves to ammoniated palm leaves in sheep rations improved the digestibility of dry matter and ADF.

Table 2 shows that the effects of the substitution of Napier grass with FOPFs on the performance of goats.

Table 1: Effects of the substitution of Napier grass with FOPFs on nutrient consumption for each treatment

	Treatments				
Consumption	A	B	C	D	E
Dry matter (g day^{-1})	336.58±16.3^{c}	398.41±128.4^{bc}	451.11±38.8^{bc}	521.84±63.8^{ab}	613.10±115^{a}
BW (%)	2.87^{c}	3.28^{bc}	3.78^{b}	3.84^{b}	4.810^{a}
Organic matter (g day^{-1})	294.91±14.3^{c}	357.47±115.2^{bc}	417.26±35.9^{bc}	468.22±57.3^{ab}	567.09±106.4^{a}
Crude protein (g day^{-1})	42.55±2.0^{c}	48.21±15.5^{bc}	54.31±4.6^{bc}	63.14±7.7^{ab}	73.82±13.8^{a}
TDN (g day^{-1})	217.36±10.5^{c}	260.80±80.0^{bc}	301.16±25.9^{bc}	341.60±41.8^{ab}	409.31±76.8^{a}
Crude fibre (g day^{-1})	91.55±4.4^{c}	114.54±36.9^{bc}	135.20±11.6^{b}	150.03±18.3^{ab}	183.75±34.4^{a}
NDF (g day^{-1})	170.98±8.2^{c}	223.07±71.9^{bc}	281.40±24.2^{b}	292.18±35.7^{b}	382.45±71.7^{a}
ADF (g day^{-1})	110.80±5.3^{c}	149.12±48.0^{bc}	188.56±16.2^{b}	195.32±23.9^{b}	256.28±48.1^{a}
Hemicellulose (g day^{-1})	91.45±4.4^{c}	103.39±33.3^{bc}	113.32±9.7^{bc}	135.42±16.5^{ab}	154.01±28.9^{a}
Cellulose (g day^{-1})	75.90±3.6^{c}	98.90±31.8^{bc}	123.92±10.6^{b}	129.55±15.8^{b}	168.42±31.6^{a}
Ether extract (g day^{-1})	17.17±0.8^{b}	17.93±5.7^{ab}	15.93±1.3^{b}	23.48±2.8^{a}	21.64±4.0^{ab}

Means in the same row with different letters (a, b and c) are significantly different ($p<0.05$), A = 40% Napier Grass (NG)+0% Fermented Oil Palm Fronds (FOPFs)+60% concentrate, B = 20% NG+20% FOPFs+60% concentrate, C: 0% NG+40% FOPFs+60% concentrate, D: 20% NG+20% FOPFs+60% concentrate plus P, S and Mg, E: 0% NG+40% FOPFs+60% concentrate plus P, S and Mg

Table 2: Effects of the substitution of napier grass with FOPFs in rations on the performance of goats

	Treatments				
Parameters	A	B	C	D	E
Average daily gain (g head^{-1} day^{-1})	31.56±5.73^{d}	43.80±2.83^{cd}	55.04±6.40^{bc}	68.48±18.11^{ab}	79.78±6.75^{a}
Feed conversion	10.83±1.59^{a}	9.16±3.20^{ab}	8.21±0.26^{ab}	8.04±2.72^{ab}	7.66±1.05^{b}
Feed efficiency	9.36±1.3	12.02±4.79	12.18±0.40	13.28±3.77	13.23±1.94

Means in the same row with different letters (a and b) are significantly different ($p<0.05$), A: 40% Napier Grass (NG)+0% Fermented Oil Palm Fronds (FOPFs)+60% concentrate, B: 20% NG+20% FOPFs+60% concentrate, C: 0% NG+40% FOPFs+60% concentrate, D: 20% NG+20% FOPFs+60% concentrate plus P, S and Mg, E: 0% NG+40% FOPFs+60% concentrate plus P, S and Mg

The FOPF supplementation in rations (treatments B, C, D and E) increased Average Daily Gain (ADG) compared with ADG in goats without FOPF supplementation (treatment A). This indicates that the nutritional value of a by-product of oil palm plantations can be improved via feed processing technology and that administration of this by-product to livestock can result in better performance. Sheep that consume OPF silage show better performance than those that consume Nipah frond silage[33] and FOPFs used in a complete ration can also improve the growth performance of goats[34].

Supplementation of P, S and Mg with FOPFs (treatments D and E) significantly improved the ADG of the animals ($p<0.05$) compared to the effects of treatment B, but the effect of treatment B was not significantly different ($p>0.05$) from that of treatment C. ADG was highest in treatment E (79.78 g head^{-1} day^{-1}), but this was not significantly different ($p>0.05$) because the ADG was associated with treatment D. These results indicate that the supplementation of P, S and Mg in a ration containing FOPFs can support microbial growth, increase feed consumption and efficiency and weight gain in livestock. According to the findings of Suttle[35], a mineral deficiency can reduce feed consumption and efficiency, body weight gains and fertility in livestock, mineral supplements are needed to improve the use of nutrients and the productivity of goats[24-26].

Sulfur supplementation in rations (D and E treatments) resulted in higher ADG compared with the effects of rations with no sulfur supplementation (treatments A, B and C). This indicates that S is indispensable for the growth of rumen microbes and the fermentation process that yields products such as Volatile Fatty Acids (VFAs). Propionic acid is one of the VFAs product and is the main precursor of body fat, therefore, it can be used as an indicator of ADG.

The combination of organic micronutrients can improve the digestibility of rations and enhance the growth and activity of microbes[36]. Richer[37], Summer[38] and Zain *et al.*[39] reported that sulfur supplementation in rations can increase the body weight gain of livestock. Mineral supplementation with Ca and P significantly ($p<0.05$) increased body weight gains compared with weight gains in goats without mineral supplementation[24]. The Mg supplementation in the rations (treatments D and E) resulted in an increase in ADG. This indicates that Mg is needed for metabolism and other functions. Ramirez *et al.*[40] reported that an increase in the dietary Mg level in rations increases ADGs and feed efficiency in Holstein steers.

Feed conversion is related to consumption and body weight gain. A lower feed conversion indicates better feed. The lowest feed conversion was 7.66, which occurred in treatment E and this was significantly lower ($p<0.05$) than the conversion associated with treatment A but was not significantly different ($p>0.05$) from the feed conversion in treatments B, C and D. The lower feed conversion in treatment E was due to the high consumption of nutrients, which increases the digestibility of the feed, resulting in the highest body weight gains. Feed conversion in this study ranged from 7.66-10.83 and similar results were reported by Martawidjaja *et al.*[41], who showed feed conversion values ranging from 7.35-9.31 in Kacang goats. Sheep who got a complete feed based on fermented cocoa pods showed conversion values ranging from 7.5-7.7[42].

Ration efficiency is the ratio between the amount of the ration that is consumed and the ADG. Feed efficiency was highest in treatment E, i.e., 13.23. This is due to the fact that feed intake and ADG were the highest in treatment E, resulting in the best feed efficiency in this treatment group. In ruminants, feed efficiency is influenced by feed quality, the nutritional content of rations, body weight and the digestibility of the ration[42,43].

CONCLUSION

Use of 0% NG, 40% FOPFs and 60% concentrate plus P, S and Mg in goat ration can improve the consumption of nutrients, average daily weight gains and a lower feed conversion. FOPFs can be used as an alternative feed source to NG in goat rations.

SIGNIFICANCE STATEMENTS

This study evaluates the effects of substituting of FOPFs plus minerals (P, S and Mg) on nutrient consumption and growth performance of goats. The results show that P, S and Mg supplementation can be beneficial for ruminants that consume forage-based waste from oil palm plantations such as FOPFs. This study will help the researchers to uncover the critical function of P, S and Mg supplementation in the metabolic processes by rumen microbes that result in the utilization of nutrients in FOPFs. This is a process that few researchers have explored previously. Thus, this study may lead to a new theory regarding the optimal combinations of minerals (P, S and Mg) in the metabolic processes of rumen microbes and their effects on nutrient consumption and growth performance of goats.

ACKNOWLEDGMENTS

This study was partially supported by the DP2M Directorate General of Higher Education, Republic of Indonesia and was part of the Ph.D. dissertation of Dewi Febrina in Animal Nutrition, Faculty of Animal Science, Andalas University. The authors are very grateful to the Directorate General of the Department of Higher Education, National Education of the Republic of Indonesia, which funded this experiment through the "Hibah Pasca" grant program in 2015. Contract no: 030/SP2H/PL/Ditlitabmas/II/2005.

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