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Research Article
Nutritional Value of Fermented Palm Oil Fronds as a Basis for Complete Feed for Ruminants

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Abstract
Objective: This study aimed to evaluate the nutritional value of a complete feed based on palm oil fronds fermented with microorganisms derived from rumen contents. **Methodology:** This study used a completely randomized design. The five feed treatment groups with 3 replicates were used. One group was complete feed containing 30% field grass+10% fermented palm oil frond+60% concentrate (R1), the other groups were 20% field grass+20% fermented palm oil frond+60% concentrate (R2), 10% field grass+30% fermented palm oil frond+60% concentrate (R3), 0% field grass+40% fermented palm oil frond+60% concentrate (R4) and 20% field grass+20% palm oil frond+60% concentrate (R5). **Results:** The experimental results show that the feed treatments significantly affected the contents of dry matter, organic matter, acid detergent fiber, hemicellulose and the digestibility of the dry matter ($p<0.05$) but had no effect on ash, crude fiber, crude protein, crude fat, neutral detergent fiber, lignin and cellulose ($p>0.05$). The treatments significantly ($p<0.05$) affected feed efficiency but had no effect on the average daily gain or feed consumption ($p>0.05$) in Kacang goats. **Conclusion:** It was concluded that palm oil fronds could be used as forage for Kacang goats.

Key words: Complete feed, nutrient content, palm oil frond

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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 is the most extensive plantation commodity compared with other plantation areas in Indonesia. In 2014, the total area of palm oil plantations in Indonesia was approximately 10,956,231 ha and in the Province of Jambi, it was approximately 688,810 ha[1]. One or two pieces of palm oil fronds are cut during the harvest of fresh fruit bunches to facilitate pollination and the next harvest. Palm oil frond production reaches 40-50 pieces per tree per year and the weight of each piece is 4.5 kg. The production of palm oil fronds is estimated to be approximately 6,400-7,500 pieces $year^{-1}$ ha^{-1} the plantation[2]. Palm oil plantations offer a good opportunity to harness the ligno-cellulosic biomass or byproducts of palm oil plants including the frond. Palm oil fronds are available daily throughout the year when palms are pruned during the harvest of fresh fruit bunches[3].

Palm oil fronds may have potential as feedstuff for ruminants[4]. However, palm oil fronds are limited as feedstuffs due to their high lignin content (30.18%)[5]. Feeding ruminants low-quality feedstuff can result in rumen dysfunction. Several technologies are required to improve feed quality and to optimize the rumen. The advantages of biofermentation for improving the quality of feedstuffs have been known for a long time[6-8]. Additionally, fermented products are good sources of peptides and amino acids[9-11]. Astuti *et al.*[12] reported that the use of local wastes, such as local microorganism sources is beneficial due to lower costs and easier processes.

Complete feed is a feeding strategy in which roughage and concentrates in a specific proportion are mixed and formed into a specific shape. This complete feed has good nutritional value for maintenance and production. Ginting[13] stated that complete feed can be used to improve the quality of wet by products. Therefore, the present study was conducted to evaluate the nutrient value of a complete feed based on palm oil frond fermented by microorganisms derived from rumen contents.

MATERIALS AND METHODS

Fermentation process: The rumen contents were collected from cattle in fields and placed in tubes. Sugar and coconut water were added to the tubes. The tubes were then incubated for 10 days under anaerobic conditions.

The palm oil fronds were chopped into small pieces using a manual chopper and then incubated with the rumen contents for 7 days[8].

Complete feed wafer: Complete feed wafers were composed of palm oil fronds as the forage source and concentrate. The forage and concentrate were formulated to meet the nutritional requirements of Kacang goats. To form complete feed, the concentrate was mixed with palm oil fronds and formed into a cube using hot felt. The complete feed wafers were pressed under hot conditions. Each wafer was $5\times7\times2$ cm. The purpose of the wafer shape was to reduce the dust properties of feed, improve feed palatability, reduce feed waste, reduce the voluminous nature of the feed and facilitate handling during storage and transportation[14]. The complete feed wafers were a light brown due to a non-enzymatic browning reaction-a reaction between organic acids with reducing sugars and amino acids with reducing sugars. The overall complete feed wafer exuded a distinctive aroma of fermentation acids.

Experimental design: The study design was completely randomized with five treatment groups with 3 replicates each. The treatments included the following: R1: 30% field grass+10% fermented palm oil frond+60% concentrate, R2: 20% field grass+20% fermented palm oil frond+60% concentrate, R3: 10% field grass+30% fermented palm oil frond+60% concentrate, R4: 0% field grass+40% fermented palm oil frond+60% concentrate and R5: 20% field grass+20% palm oil frond+60% concentrate. The observed variables included the dry matter, organic matter, crude protein and crude fiber contents of the palm oil fronds. The above nutritional components were analyzed using the AOAC method[15]. Palm oil fronds and concentrate were formed into complete feed wafers, whereas field grass was provided in fresh form. The variables measured were palm oil frond composition and the *in vitro* dry matter digestibility of palm oil fronds. The *in vitro* dry matter digestibility was measured according to the instruction for the Daisy Incubator (ANKOM Technology).

To test performance, Kacang goats aged 9-12 months (body weights ranging from 9.5-24.75 kg) were distributed into five treatment groups with 3 replicates each. They were given the diets. A completely randomized block design was used in this study. All Kacang goats were given a diet at a level of 3% b.wt., on a dry matter basis. The formulation of complete feeds is presented in Table 1.

Statistical analysis: All data were subjected to an analysis of variance[16] and significant differences were further tested by Duncan's multiple range test.

Table 1: Formulation of complete feed (%) based on palm oil fronds

Feeds	R1	R2	R3	R4	R5
Field grass	30	20	10	0	20
Fermented palm oil frond	10	20	30	40	0
Palm oil frond non fermented	0	0	0	0	20
Rice bran	20	20	20	20	20
Cassava flour	10	10	10	10	10
Palm sugar	5	5	5	5	5
Cornstarch	10	10	10	10	10
Flour anchovy head	13	13	13	13	13
Salt	1	1	1	1	1
Mineral	1	1	1	1	1
Total	100	100	100	100	100

Table 2: Average nutrient contents of the complete feed based on palm oil fronds

	Ration treatments					
Variables (%)	R1	R2	R3	R4	R5	SE
Dry matter	66.94^{b}	70.82^{b}	78.32^{a}	83.03^{a}	65.12^{b}	1.28
Organic matter	83.44^{a}	57.13^{c}	62.78^{c}	77.80^{b}	75.32^{b}	1.30
Crude fiber	16.28	18.90	17.80	18.73	14.52	0.91
Nitrogen-free extract	54.70	51.90	54.41	55.36	51.63	1.01
Crude lipid	3.19	3.24	3.13	2.27	3.65	1.53
Ash	16.56	14.76	13.84	13.65	15.10	0.38

R1: 30% field grass+10% fermented palm oil frond+60% concentrate, R2: 20% field grass+20% fermented palm oil frond+60% concentrate, R3: 10% field grass+30% fermented palm oil frond+60% concentrate, R4: 0% field grass+40% fermented palm oil frond+60% concentrate, R5: 20% field grass+20% palm oil frond+60% concentrate. $^{a-c}$Significant differences between the rows ($p<0.05$)

RESULTS AND DISCUSSION

Nutritional contents of complete feeds: The nutrient contents of the complete feeds are presented in Table 2. The experimental results show that the type of complete feed significantly ($p<0.05$) affected the contents of the dry matter and organic matter ($p<0.05$) but had no effect on ash, crude fiber, crude protein, crude fat or nitrogen-free extract ($p>0.05$). The R4 had the highest dry matter content ($p<0.05$), whereas R1 had the lowest. Furthermore, R1 had the highest organic matter and R2 and R3 had a lower organic matter than that of R4 and R5.

The higher dry matter content might be partly caused by the substitution of field grass with palm oil fronds. The highest dry matter content in R4 was caused by the highest fermented palm oil frond content. The lowest dry matter in R1 was partly caused by the higher moisture content in field grass.

When R2 and R5 were compared, it appeared that the fermented palm oil fronds had a lower dry matter content than that of unfermented palm oil fronds. The fermentation process reduced the dry matter content[17]. Fermentation requires O_2 for respiration and produces CO_2 and H_2O.

Table 3: Average of crude fiber fraction and dry matter digestibility of the complete feed based on palm oil fronds

	Ration treatments					
Crude fiber fraction (%)	R1	R2	R3	R4	R5	SE
NDF	41.59	42.14	41.34	40.61	41.23	0.73
ADF	34.33^{ab}	34.55^{ab}	32.61^{b}	39.96^{a}	35.08^{b}	1.20
Cellulose	21.68	21.77	19.82	25.58	21.71	1.63
Hemicellulose	7.47^{a}	7.74^{a}	8.80^{a}	0.65^{b}	6.15^{a}	0.94
Lignin	12.97	12.73	12.77	14.37	11.64	0.93
Dry matter digestibility	67.65^{a}	68.88^{a}	64.03^{a}	66.47^{a}	53.34^{b}	1.93

R1: 30% field grass+10% fermented palm oil frond+60% concentrate, R2: 20% field grass+20% fermented palm oil frond+60% concentrate, R3: 10% field grass+30% fermented palm oil frond+60% concentrate, R4: 0% field grass+40% fermented palm oil frond+60% concentrate, R5: 20% field grass+20% palm oil frond+60% concentrate. $^{a-c}$Significant differences between the rows ($p<0.05$)

Gervais[18] stated that changes in the dry matter content result from the growth of microbes and changes in moisture content. Changes in moisture content occur due to substrate hydrolysis or metabolic water production. Fardiaz[19] stated that during fermentation, the microorganisms use carbohydrates as an energy source to produce H_2O and CO_2 molecules. Most of the H_2O molecules remain in the product, therefore, the moisture content of the product increased.

The data show that unfermented palm oil fronds had a higher organic matter content than that of fermented palm oil fronds (R2 vs R5). It appears that the fermentation process used organic matter, such as carbohydrate and nitrogen, resulting in a lower organic matter content. The data also show that a higher inclusion of fermented palm oil fronds would increase the organic matter content.

The substitution of field grass by palm oil frond did not change the contents of crude fiber, crude protein, ash or crude lipid, indicating that all treatment groups contributed the same amounts of these nutrients.

Crude fiber fractions: The results showed that the rationed treatments significantly affected ADF and hemicellulose ($p<0.05$) but had no effect on NDF, lignin and cellulose ($p>0.05$) (Table 3). The R4 had a significantly lower lignin content ($p<0.05$) than the other treatment groups. The R4 had a lower ADF ($p<0.05$) than that of R3 and R5.

The NDF represents the content of a cell wall comprising lignin, cellulose, hemicellulose and the proteins that bind to the cell wall. It appears that the content of NDF is inversely correlated with the lignin content. A lower lignin content resulted in a higher NDF content. This agrees with the statement of Crampton and Harris[20] that NDF levels decrease due to an increase in lignin and decrease in hemicellulose. Van Soest[21] stated that microbial enzymes can reduce the levels of NDF.

It appears that the ADF content was positively correlated with the cellulose content. Microbes could digest the hemicellulose content of the cell wall components but they could not digest hemicellulose when high levels of lignin were present.

The lower hemicellulose content in R4 indicates that fermentation can decrease the hemicellulose content of the feed. Fermentation produces enzymes to digest the fiber produced by microbes. Astuti *et al.*[8] found 8 isolates of thermophilic, Gram- positive bacteria among microorganisms in the rumen content.

Dry matter digestibility: There was a significant effect ($p<0.01$) on dry matter digestibility. The R5 had the lowest dry matter digestibility. The R1, R2, R3 and R4 contained fermented palm oil fronds as the source of forage, whereas R5 contained unfermented palm oil fronds as forage.

Rahman *et al.*[22] reported that the degradability of palm oil fronds improved when white rot fungi were included. Fermentation improves the nutritional value of feedstuffs, breaking down complex compounds into simpler compounds[23] for easier digestion. Astuti and Yelni[24] reported that fermentation improved the dry matter digestibility of palm oil frond. Maynard and Loosli[25] stated that the digestibility values are not fixed for every meal or every head of cattle but rather are influenced by several of the following factors: Chemical composition, food processing, amount of food given and type of animal. The digested feed is absorbed by livestock and not excreted in the feces. Zain *et al.*[5,26] stated that the addition of some microbes as a probiotics in feed could stimulate the microbes of the rumen and improve the digestibility of feed in ruminant livestock.

The lack of changes in dry matter digestibility in the treatment with a higher substitution of grass with fermented palm oil fronds was contrary to the observation by Imsya *et al.*[27], who found that higher fermented palm oil frond contents resulted in lower dry matter digestibility. This difference may have resulted from differences in inoculum used. Fariani *et al.*[4] reported no change in the dry matter of a complete feed based on fermented palm oil fronds compared with that based on unfermented palm oil fronds.

Performance of Kacang goats: The experimental results show that the treatments significantly affected feed efficiency ($p<0.05$) but had no effect on the average daily gain or feed consumption ($p>0.05$) (Table 4). The DMRT test showed that R2 had a higher feed efficiency than that of R1, R3 and R5 ($p<0.05$). Thus, the best performance occurred when Kacang goats were given the diet comprising 20% field grass+20% fermented palm oil frond+60% concentrate.

Table 4: Average feed consumption, daily gain and feed efficiency of Kacang goats

Treatments	Feed consumption (g head^{-1} day^{-1})	Daily gain (g head^{-1})	Feed efficiency (%)
R1	432.01	42.85	10.05[a]
R2	300.87	53.57	17.79[b]
R3	445.71	28.91	7.04[a]
R4	422.13	50.00	13.45[ab]
R5	535.39	39.10	8.55[a]

R1: 30% field grass+10% fermented palm oil frond+60% concentrate, R2: 20% field grass+20% fermented palm oil frond+60% concentrate, R3: 10% field grass+30% fermented palm oil frond+60% concentrate, R4: 0% field grass+40% fermented palm oil frond+60% concentrate, R5: 20% field grass+20% palm oil frond+60% concentrate. [a-c]Significant differences between the rows ($p<0.05$)

This finding is consistent with the observation by Hamidah *et al.*[28] who reported that feeding palm oil fronds and field grass at a 50:50 ratio to fat-tailed rams was the best diet as indicated by the highest body weight gain. They also reported that providing more than 50% palm oil fronds resulted in lower body weight gain. Ebrahimi *et al.*[29] reported that palm oil fronds could substitute concentrate at a level of 25% without reducing the growth performance of goats. The better feed efficiency of Kacang goats fed the R2 diet may have resulted from enhanced dry matter digestibility.

CONCLUSION

It was concluded that for ruminants palm oil fronds could be used as forage up to 100%, whereas fermented palm oil fronds could substitute field grass.

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