Effects of Various Moringa Leaf Preparations in Complete Rations Based on Fermented Lemongrass Waste on Nutrient Composition

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Abstract. This study aimed to evaluate the effects of Moringa (Moringa oleifera) leaf supplementation using different preparation methods on the dry matter (DM), organic matter (OM), and crude protein (CP) content of complete rations formulated with fermented lemongrass (Cymbopogon nardus) waste. The lemongrass waste was fermented to enhance its nutritional value, while Moringa leaves—renowned for their high antioxidant and protein content—were incorporated in various forms to assess their impact on overall feed quality. A Completely Randomized Design (CRD) was employed, comprising four treatments: T0 (control, no Moringa supplementation), T1 (supplementation with dried Moringa leaves), T2 (Moringa leaf extract), and T3 (Moringa leaf extract concentrated using a rotary evaporator). The results demonstrated that Moringa supplementation significantly affected ($P < 0.01$) all evaluated parameters. Dry matter content notably decreased in treatments utilizing Moringa in liquid form, particularly in T2 and T3. Conversely, organic matter and crude protein content increased markedly with the application of Moringa leaf extract. Among all treatments, T2 (Moringa leaf extract) yielded the most favorable results, with the highest crude protein content (15.02%) and organic matter content (90.97%), despite a lower dry matter content (47.24%). These findings suggest that Moringa leaf extract can improve the nutritional quality of rations based on fermented lemongrass waste, especially in terms of crude protein and organic matter content. However, attention should be paid to the resulting moisture level.

1 Introduction

Livestock products, particularly meat and milk, are nutritious food sources that play a strategic role in supporting national food security. The availability of quality, economical, and sustainable feed throughout the year is essential to ensure optimal livestock productivity. Unfortunately, reliance on natural pasture as the main source of forage is increasingly

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threatened by land conversion and seasonal changes, especially during the dry season, leading to unstable and often insufficient supply for ruminants.

Therefore, exploring alternative forages that are sustainable and rich in nutrients is highly important. In Solok City, West Sumatra, citronella (Cymbopogon nardus) is extensively cultivated, covering an area of approximately 36.93 hectares with a total production of around 59.10 tons [1]. From each ton of raw material, only about ±8 kg of essential oil is obtained, while the rest becomes solid and liquid waste. The solid waste of citronella distillation still holds nutritional potential, including protein (7.0%), crude fiber (25.73%), metabolizable energy (3,353 kcal/kg), and essential minerals [2] [3], making it a candidate as a fiber and energy source in ruminant feed formulation. Research by Astuti et al (2024) showed that the use of up to 40% The solid waste of citronella distillation in complete feed (50% concentrate: 50% forage) did not reduce the digestibility of dry matter, organic matter, or crude protein [4].

However, the high moisture content makes solid waste of citronella distillation highly perishable and prone to mold, requiring processing through fermentation. The use of bioactivators derived from cattle rumen contents has been shown to improve the shelf life and nutritional quality of the solid waste of citronella distillation significantly [5].

In addition, to maintain nutritional stability and livestock health, antioxidant supplementation in feed is highly needed [6] [7]. One of the potential natural antioxidant sources is Moringa oleifera leaves, which are rich in protein (≈27–30%) and bioactive compounds such as flavonoids and high antioxidants [8] [5]. Its nutrient content includes crude protein (26.43%), crude fat (2.23%), crude fiber (23.57%), ash (6.77%), and nitrogen-free extract (52.25%). According to Soetanto (2011) [9], feeding fresh Moringa leaves at 0.5–1.5 kg/head/day can increase goat growth up to 87 g/head/day and milk production by 0.5 liters/head/day.

Moringa leaves contain phenolic compounds that can counteract free radicals. Fresh Moringa leaves contain about 3.4% phenols, while extracted Moringa leaves contain about 1.6%. Moringa leaves are rich in antioxidants and several bioactive flavonoid compounds [10]. Kasolo et al. (2010) reported that Moringa leaves contain phytochemicals that act as antioxidants such as tannins, steroids and triterpenoids, alkaloids, saponins, anthraquinones, and flavonoids [11]. Antioxidants play an important role in protecting the body from the effects of free radicals, which can cause various diseases. Free radicals are naturally produced in the body as a byproduct of metabolism.

This study aims to evaluate the effect of Moringa leaf supplementation in three different forms on the dry matter, organic matter, and crude protein content of fermented LPSW-based complete feed. This study hypothesizes that Moringa leaf supplementation in various forms significantly affects the dry matter, organic matter, and crude protein content of the complete feed based on fermented citronella waste.

2 Materials and Method

This study utilized fermented citronella waste as the main feed ingredient, combined with rice bran, palm kernel meal, tofu pulp, premix/minerals, and salt. Additionally, Moringa (Moringa oleifera) leaf antioxidants in various forms were supplemented into the ration. The equipment used in feed preparation included a chopper machine, drums, buckets, digital scales, hanging scales, spraying tools, gloves, masks, dippers, sacks, ropes, shovels, brooms, and tarpaulins. Laboratory analysis was conducted using various instruments such as 25 mL beakers, 30 mL porcelain crucibles, Büchner funnels (4.5 cm diameter), desiccators, muffle furnaces, hot plates, crucible tongs, analytical balances, hekter seeds, and Erlenmeyer flasks. Proximate analysis was carried out using standard equipment including a moisture analyzer, Kjeldahl apparatus, Soxhlet extractor, muffle furnace, and drying oven.

The experimental method used a Completely Randomized Design (CRD) consisting of four treatments with four replications. The supplementation dose of Moringa leaf used was 0.2% of the total dry matter of the ration. The treatments applied were as follows:

P0 = Complete ration without Moringa leaf supplementation (control)
P1 = Complete ration supplemented with dried Moringa leaf
P2 = Complete ration supplemented with Moringa leaf extract
P3 = Complete ration supplemented with rotary evaporated Moringa leaf extract

Table 1. Complete ration formulation.

Feed Ingredients	Amount %
Fermented Lemongrass Waste	50
Tofu Dregs	24
Rice Bran	6.5
Palm Kernel Meal	17.5
Minerals/Premix	1
Salt	1
Total	100

Note: Results of trial and error calculations

2.1 Preparation of rumen-based bioactivator

1. Rumen contents were collected from a slaughterhouse in Solok City, Indonesia.
2. The rumen contents were mixed with chopped oil palm fronds and leaves, molasses, and soybean soaking water (from tofu production). The ingredients were combined in a jar at a ratio of 1:1:8 (rumen contents: molasses: soybean soaking water), as described by [12].

2.2 Fermentation of citronella waste

Citronella waste was chopped using a copper machine and then mixed evenly with a 10% solution of rumen-based bioactivator based on the dry matter of the feed ingredients. The mixture was compacted and incubated anaerobically for 21 days to allow proper fermentation.

2.3 Preparation of complete feed

1. Ingredients: tofu dregs, rice bran, palm kernel meal, premix or minerals, salt, and fermented citronella waste.
2. All ingredients were mixed thoroughly, starting with those in smaller quantities.
3. Once uniformly mixed, fermented citronella waste was added and thoroughly blended again to ensure a homogeneous complete ration.

2.4 Preparation of moringa leaf extract

Fresh Moringa (*Moringa oleifera*) leaves were collected from local households, then dried in the shade or in an oven at 40–50°C. The dried leaves were ground into powder and macerated using ethanol at a ratio of 1:10 (w/v). The mixture was soaked for 24 hours with occasional stirring, kept away from direct sunlight to preserve antioxidant compounds. The mixture was then filtered to separate the residue from the filtrate.

2.5 Concentration of extract

The filtrate was concentrated using a rotary evaporator at 40–50°C and 40 mmHg pressure until a thick extract was obtained.

2.6 Measured parameters

The parameters measured included Dry Matter (DM), Crude Protein (CP), using proximate analysis based on the Weende method.

2.7 Data analysis

The data obtained from the laboratory analysis (Faculty of Animal Science, Andalas University, Padang) were statistically analyzed using a Completely Randomized Design (CRD). Significant differences among treatments were further tested using Duncan's New Multiple Range Test (DNMRT),

3 Results and Discussion

3.1 Dry matter content of the ration

The average dry matter (DM) content of the complete rations formulated using fermented citronella waste supplemented with Moringa (Moringa oleifera) leaves is presented in Table 2.

Table 2. Average dry matter content of complete rations based on fermented citronella waste supplemented with moringa leaves.

Treatments	Dry matter	Organic matter	Crude Protein
P0	$92{,}94^{a}$	$90{,}21^{b}$	$10{,}18^{c}$
P1	$92{,}49^{a}$	$89{,}50^{c}$	$12{,}37^{b}$
P2	$47{,}24^{c}$	$90{,}98^{a}$	$15{,}02^{a}$
P3	$50{,}22^{b}$	$91{,}16^{a}$	$12{,}00^{b}$
SE	0,39	0,14	0,17

Note: Different superscripts in the same column indicate a highly significant difference (P<0.01).
P0 = Complete ration without moringa leaf supplementation, P1 = Complete ration supplemented with dried moringa leaves, P2 = Complete ration supplemented with moringa leaf extract, P3 = Complete ration supplemented with rotary moringa leaf extract.

The results of the analysis of variance showed that the treatment of moringa leaf supplementation in the complete ration with different presentations in the complete ration based on fermented lemongrass waste showed a highly significant effect (P<0.01) on drymatter content. The dry matter (DM) content of a ration is a crucial parameter in evaluating feed quality, as it directly affects storage stability, feed intake efficiency, and nutrient availability for livestock. The results of this study showed that the treatment without Moringa leaf supplementation (P0) had the highest DM content (92.94%), followed by the treatment with dried Moringa leaves (P1) at 92.49%. These two treatments did not show statistically significant differences (P>0.05), indicating that supplementation with dried Moringa leaves did not significantly affect the moisture content of the ration.

The consistent dry matter content observed in treatments P0 and P1 may be attributed to the physical characteristics of the ration components, which were not subjected to additional moisture. Dried Moringa leaves, used as a supplement in P1, have low moisture content due to the intensive drying process, thus contributing minimal additional moisture to the ration. This finding is in line with [13], who stated that drying is effective in removing water from Moringa leaves, rendering them physically and chemically stable.

In contrast, the treatments involving liquid Moringa leaf extract supplementation (P2 and P3) showed a highly significant reduction in dry matter content (P<0.01), with values of 47.24% and 50.22%, respectively. This decrease reflects the high water content in the Moringa extracts, which is attributable to the use of aquadest as the solvent in the extraction of bioactive compounds. Although a rotary evaporator was employed in P3 to reduce the water content, it was insufficient to restore the DM level to that observed in P0 and P1.

Gupta et al. (2018) support these findings by reporting that herbal extracts obtained using water-based solvents tend to retain high moisture content [14]. Moreover, evaporation methods such as rotary evaporation may not completely remove water unless followed by further drying techniques such as freeze-drying or spray-drying. Therefore, despite the beneficial bioactive compounds (e.g., flavonoids and phenolics) contained in Moringa extract, its liquid form presents challenges in feed formulation aimed at maintaining high dry matter content.

The results of the Duncan's Multiple Range Test (DMRT) further reinforce this analysis. P0 and P1 belonged to the same statistical group, showing that dry-form supplementation does not compromise ration stability. In contrast, P2 and P3 differed significantly from P0 and P1, indicating that the physical form and moisture content of supplementary ingredients strongly influence the total dry matter content of the ration. McDonald et al. (2010) emphasized that the dry matter content of feed is determined by both the raw material composition and processing method, which directly impact feed quality and shelf life [15].

Moreover, the decrease in dry matter content observed in P2 and P3 may not only affect physical stability and storage but also reduce nutrient density. Rations with higher moisture content tend to have lower nutrient concentration per unit weight, potentially diminishing feed intake efficiency by livestock. This is a critical consideration in the formulation of ruminant feed, particularly in complete feed systems, where the balance between moisture content and nutrient composition is vital.

These findings are consistent with the results reported by Astuti et al. (2023), who found that rations based on fermented citronella waste had dry matter contents ranging from 45.22% to 48.88%, similar to those observed in P2 and P3 [5]. Thus, the combination of high- moisture feed ingredients (fermented waste) and liquid-form supplements (Moringa extract) exacerbates the reduction in dry matter content.

Overall, the findings of this study highlight that the physical form and processing techniques of supplemental ingredients (Moringa leaves) play a crucial role in determining the final quality of the ration, particularly in terms of dry matter content. Supplementation in dry form is recommended to maintain feed stability, especially in formulations based on high-moisture waste materials. The use of liquid extracts should be accompanied by further drying processes to enhance the efficiency and stability of the final product.

3.2 Organic matter content of complete rations based on fermented citronella waste supplemented with moringa leaves

The organic matter content was ranked from highest to lowest as follows: P3 > P2 > P0 > P1. Analysis of variance (ANOVA) revealed a highly significant effect ($P < 0.01$) of Moringa supplementation in different forms on the organic matter content of the ration. This indicates that the supplementation form plays a crucial role in influencing nutrient composition, particularly through the concentration and availability of bioactive compounds.

The significantly higher organic matter content in treatments P2 and P3 is likely due to the use of Moringa extracts, which are richer in bioactive substances compared to the dried leaf form. As reported by Moyo et al. [8], Moringa leaf extracts contain higher concentrations of polyphenols, flavonoids, and saponins due to the efficient separation of active components during extraction. These compounds improve ruminal microbial activity and organic matter degradation, thereby enhancing feed quality.

Further statistical analysis using Duncan's Multiple Range Test (DMRT) showed that P3 differed significantly from P0 ($P < 0.05$), while P1 was not significantly different from P2. This suggests that rotary evaporated and freeze-dried Moringa extracts are more effective at improving organic matter content due to higher bioavailability of functional metabolites. Dried Moringa leaves (P1), in contrast, retain higher crude fiber content and tend to hold bioactive compounds in bound forms, limiting their accessibility to rumen microbes. This structural limitation may result in reduced digestibility of organic matter. The findings are consistent with Moyo et al. [8], who found that the drying process preserves more indigestible fiber, which could hinder the release and absorption of polyphenols and flavonoids.

Overall, the form in which Moringa is supplemented plays a decisive role in enhancing the nutritional value of complete rations. The rotary evaporated and freeze-dried extracts proved to be more efficient due to their concentrated bioactive content and enhanced digestibility properties.

3.3 Crude protein content of complete rations based on fermented lemongrass waste supplemented with moringa leaves

The average crude protein (CP) content of the complete rations based on fermented lemongrass waste supplemented with Moringa leaves in different treatments, in descending order, was P2, P1, P3, and P0. The analysis of variance revealed that supplementing the rations with Moringa leaves in different forms resulted in a highly significant difference ($P< 0.01$) in the crude protein content. This finding indicates that both the presence and the processing method of Moringa leaves substantially influence the protein content and its bioavailability in the rations.

The elevated CP content in P2 is attributed to the high protein concentration in Moringa leaf extract. Oduro et al. (2008) [13] noted that drying Moringa leaves into a powder form enhances shelf life but may result in a slight reduction in protein content due to oxidation and nutrient degradation caused by excessive heat exposure during the drying process.

Interestingly, although rotary evaporated extract (P3) was expected to have high protein content, it yielded a slightly lower value (12.00%) than P1. This reduction may be due to potential protein loss or structural changes during the rotary evaporation process, which involves exposure to elevated temperatures. This is supported by Gupta et al. (2018), who explained that heat-based extraction techniques may cause protein degradation and reduce the bioavailability of nutrients in plant-based extracts [14].

The results of the DNMRT post hoc test indicated that treatment P2 was significantly different from P0, whereas treatments P1 and P3 were not significantly different from each other. This suggests that the form and method of Moringa supplementation critically influence the CP content. P2, which utilized fresh extract, likely retained a higher protein concentration and better bioavailability. This finding emphasized that the extraction process can reduce antinutritional factors such as tannins and phytates that interfere with protein absorption, thus enhancing protein utilization in ruminant diets.

4 Conclusion

Based on the results of the study, it can be concluded that the complete rations formulated from fermented lemongrass waste supplemented with Moringa leaves in different forms had a highly significant effect ($P<0.01$) on dry matter, organic matter, and crude protein content.

The best treatment was observed in P2 (Moringa leaf extract), which showed the highest crude protein content with an average value of 15.02%.

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