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Innovation and Biotechnology Utilizing Local Microorganisms to Improve the Nutrient Quality of Fermented Cassava Peel Feed

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Abstract:
An alternative feed supply can be achieved by utilizing cassava peel agricultural waste as ruminant feed. Fermentation is a feed processing technique using microorganisms to improve feed quality. This study aimed to determine the effect of using different local microorganisms to improve the nutrient quality of fermented cassava peel waste as livestock feed. The materials of this study used cassava peel, rice bran, rice washing water, effective microorganisms, brown bottles, banana stems, young bamboo, fruit waste, and molasses. The fermentation process used the Solid-State Fermentation (SSF) for 12 days with 4 treatments and 4 replications. P0: control (EM-4); P1: Banana Stem MOL; P2: Young Bamboo MOL; P3: Crystal Guava and Pineapple Waste MOL. The fermented feed was analyzed using proximate analysis in the laboratory. The research design used a Completely Randomized Design (CRD). The research data were tested statistically by ANOVA and continued with Dunnett's further test to determine the significantly different interactions ($P<0.05$) between treatments. The result study was cassava peel fermentation showed the best results in crude protein content in P1 (8.65%) and P3 (8.51%), and ash content in P0 (0.52%), while organic matter, dry matter, and crude fiber showed unsignificant results ($P>0.05$). Local microorganisms from banana stems, bamboo shoots, and fruit waste can be used as a substitute for commercial biostarter EM-4 for fermented feed fermenters). It can be carried out on the application of fermented feed on digestibility and productivity of ruminant livestock.

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INTRODUCTION

Feed is the costliest component that can affect production efficiency. Ruminant feed consists of green fodder, concentrates, vitamins, and minerals as supplementary feed. Green fodder for ruminants accounts for 70% of the total feed intake, with the remainder being concentrates (Saking & Qomariyah, 2017). During the dry season, feed availability declines in both quality and quantity, impacting livestock productivity (Sitindaon, 2013). This problem can worsen due to rising concentrate prices on the market. An alternative to providing feed during the dry season is the production of fermented feed based on agricultural waste.

Utilizing local agricultural waste as a feed source through fermentation is an alternative feed supply. Agricultural waste is rarely utilized and is a byproduct of processing (Musdi et al., 2022). Bondowoso Regency is a center of tape production, using cassava as its main ingredient. Cassava

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consumption in Bondowoso Regency reaches 4 tons, increasing to 6 tons during holidays (Purnamasari et al., 2024).

The cassava tape manufacturing industry produces solid waste in the form of cassava peels, which are still underutilized and have the potential to pollute the environment. Cassava peels account for 16% of the total tuber (Rafif et al., 2024). Cassava peels have relatively low nutritional quality and contain high levels of HCN. The HCN content in cassava peels ranges from 29 to 109 ppm per 100 grams (Devinasari et al., 2022). Fermentation technology can degrade HCN levels and improve the nutritional quality of cassava peels (Hermanto & Fitriana, 2018).

Fermentation is a livestock feed processing technology that can be used to alleviate feed supply constraints. Fermentation occurs due to chemical changes mediated by microorganisms, namely bacteria and fungi, under certain conditions, and can occur under anaerobic or aerobic conditions (Ayesha et al., 2021). The success of the fermentation process depends on pH, the type of microorganism, temperature, fermentation time, and media composition. Local Microorganisms are biostarters that can be used in the fermentation process to create quality feed (Suari et al., 2019).

Local Microorganisms (MOL) are microorganisms often used as bioactivators in the production of organic fertilizers or fermented feed. MOL is a fermented liquid made from various local ingredients. MOL can be made using waste found around us, such as fruits and vegetables, bamboo shoots, and other waste (Swandi et al., 2023). MOL liquid contains macro and micronutrients and contains various types of microbes capable of decomposing organic materials (Swandi et al., 2023). The fermentation process using MOL bioactivators can increase protein content and involves bacteria such as Rhizobium sp., Asospirelum sp., and Bacillus sp. (Ginting & Pase, 2018). MOL from fruit waste is known to increase the crude protein content of Turbinaria Murayama seaweed (Reski et al., 2022). MOL from young bamboo can accelerate the decomposition of organic matter because it contains Lactobacillus, Streptococcus, Azotobacter, and Azospirilium bacteria (Fatoni & Sukarsono, 2016). The use of MOL from banana stems can increase crude protein content and reduce crude fiber content in fermented coffee skins (Karyono & Novita, 2021).

METHOD

The study was conducted from February to March 2025. Fermented feed production was conducted in Poncogati, Curahdami District, Bondowoso Regency. Nutrient content was tested at the Feed Nutrition Laboratory of the Batu City Animal Husbandry Training Center. The equipment used in this study included a fermentation tool, a set of proximate analysis tools (dry matter, crude protein, ash content, crude fiber), and stationery and documentation. The equipment used during the preparation of MOL production was plastic jars, hoses, plastic bottles, plasticine, and tape. The fermentation tools included knives, tarpaulins, and airtight plastic bags. The materials used in this study consisted of 16 kg of cassava peel waste, 5 kg of bran, 1 liter of molasses, 1 liter of EM-4, 1 kg of banana stems, 1 kg of young bamboo, 1 kg of fruit waste, and 3 liters of rice washing water. The MOL production formulation is shown in Table 1. The MOL fermentation process was carried out anaerobically for 14 days (Ole, 2013). The formulation for MOL is based on research by Khasanah et al. (2020).

Table 1. Formulation of local microorganism manufacturing materials

Materials	Treatments			
	P0	P1	P2	P3
Banana stump (kg)	-	1 kg	-	-
Young bamboo leaves (kg)	-	-	1 kg	-
Crystal guava fruit waste 0,5 + pineapple 0,5 (kg)	-	-	-	1 kg
Rice Washing Water (liter)	-	1 liter	1 liter	1 liter
Molasses (ml)	-	100 ml	100 ml	100 ml

This study used different biostarters, namely P0: control (EM-4); P1: Banana Stem MOL; P2: Young Bamboo MOL; P3: Crystal guava and pineapple waste MOL. The fermentation was carried out anaerobically using chopped and sun-dried cassava peels, mixed with different types of MOL for each treatment, for 12 days (Sandi et al., 2023). Fermentation was carried out through a combination and adoption of the formulation of Priono et al. (2022) with modifications using cassava peel waste as the main ingredient. The formulation for fermented feed is shown in Table 2.

Table 2. Fermentation formulation

Treatments	Materials				
	Cassava skin (g)	Molasses (ml)	Rice bran (g)	Water (ml)	Local microorganisms (ml)
P0	1000	50	50	300	60
P1	1000	50	50	300	60
P2	1000	50	50	300	60
P3	1000	50	50	300	60

After 12 days, the nutritional quality of fermented cassava peel was analyzed based on proximate analysis (SNI 01-2891, 1992), namely the levels of Dry Matter (DM), Ash, Crude Fiber (CF), and (AOAC, 2005) for Crude Protein (CP) content. The data analysis results were tested with ANOVA (Analysis of Variance), and if significant differences were found, the Dunnett test was used.

RESULT

Dry Matter (%)

The dry matter content of fermented cassava peel using different Local Microorganisms (MOL) as a substitute for EM-4 is presented in Table 3. The average dry matter values were P0 (94.19%), P1 (91.70%), P2 (91.66%), and P3 (92.14%). Statistical analysis showed that the use of different MOL treatments had no significant effect ($p>0.05$) on dry matter content.

Table 3. Dry Matter Content of Fermented Cassava Peel

Treatments	Dry Matter (%) (Mean ± SD)
P0	94.19 ± 2.64
P1	91.70 ± 2.33
P2	91.66 ± 2.75
P3	92.14 ± 3.75

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Ash Content (%)

The ash content of fermented cassava peel is shown in Table 4. The average values were P0 (0.52%), P1 (0.68%), P2 (0.79%), and P3 (0.84%). Statistical analysis indicated a significant effect of MOL treatments on ash content (p < 0.05), with the highest value observed in P3.

Table 4. Ash Content of Fermented Cassava Peel

Treatments	Ash Content (%) (Mean ± SD)
P0	$0.52^{a} \pm 0.01$
P1	$0.68^{b} \pm 0.10$
P2	$0.79^{bc} \pm 0.05$
P3	$0.84^{c} \pm 0.03$

Note: Different superscripts indicate significant differences (p<0.05).

Organic Materials (%)

The organic matter content of fermented cassava peel is presented in Table 5. The average values were P0 (93.70%), P1 (91.01%), P2 (90.89%), and P3 (91.37%). There was no significant effect (p>0.05) of MOL treatments on organic matter content.

Table 5. Organic Matter Content of Fermented Cassava Peel

Treatments	Organic Matter (%) (Mean ± SD)
P0	93.70 ± 2.64
P1	91.01 ± 2.34
P2	90.89 ± 2.80
P3	91.37 ± 3.70

Crude Protein (%)

The crude protein content of fermented cassava peel is shown in Table 6. The average values were P0 (8.03%), P1 (8.63%), P2 (7.96%), and P3 (8.51%). Statistical analysis showed that treatments P1 and P3 were significantly higher (p<0.05) than P0, while P2 was not significantly different from P0.

Table 6. Crude Protein Content of Fermented Cassava Peel

Treatments	Crude Protein (%) (Mean ± SD)
P0	$8.03^{b} \pm 0.19$
P1	$8.63^{a} \pm 0.27$
P2	$7.96^{b} \pm 0.24$
P3	$8.51^{a} \pm 0.16$

Note: Different superscripts indicate significant differences (p<0.05).

Table 7. Crude Fiber Content of Fermented Cassava Peel

Treatments	Crude Fiber (%) (Mean ± SD)
P0	24.17 ± 3.91
P1	20.13 ± 1.63
P2	23.26 ± 1.22
P3	22.05 ± 0.97

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Crude Fiber (%)

The crude fiber content of fermented cassava peel is presented in Table 7. The average values were P0 (24.17%), P1 (20.13%), P2 (23.26%), and P3 (22.05%). There was no significant effect ($p>0.05$) of MOL treatments on crude fiber content.

DISCUSSION

The findings indicate that substituting EM-4 with various Local Microorganisms (MOL) did not significantly affect dry matter, organic matter, or crude fiber content, but did significantly affect ash and crude protein levels. The non-significant differences in dry matter suggest that microbial fermentation activity across treatments was relatively similar. Dry matter represents the total nutrient content excluding water (Manikari et al., 2020). The decrease in dry matter during fermentation is associated with microbial metabolic activity, particularly the production of lactic acid and water (Hadisutanto et al., 2020). Increased microbial activity can lead to higher H_2O production, thereby reducing dry matter content. Additionally, nutrient degradation during fermentation increases lactic acid and water content (Amaliah et al., 2019). Despite these reductions, all treatments met the minimum dry matter requirement for ruminant feed (≥86%; SNI 3148, 2017), indicating acceptable feed quality.

The organic matter content showed no significant differences among treatments, which is consistent with its relationship to ash content. Organic materials in feed include protein, crude fiber, fat, and nitrogen-free extract, while inorganic components consist of minerals such as calcium, phosphorus, magnesium, potassium, and sodium (Helmiati et al., 2020). Organic matter content is inversely proportional to ash content, as mineral accumulation reduces the proportion of organic components. During fermentation, microorganisms contribute to the breakdown and dissolution of nutrients, influencing organic matter levels (Utama et al., 2020).

In contrast, ash content was significantly affected by MOL treatments, particularly in P3, which showed the highest value. This increase is likely due to the mineral-rich composition of the substrates used in MOL, especially fruit waste. Pineapple and crystal guava contain substantial amounts of minerals, including calcium, phosphorus, potassium, and iron (Datundugon et al., 2020; Chauliyah et al., 2015; Masnita et al., 2020). Ash content reflects the total mineral content of feed ingredients and serves as an indicator of feed quality and processing efficiency (Amelia et al., 2021). The relatively low ash values observed across treatments remain within acceptable limits, as feed ash content should not exceed 12% (Latief et al., 2023).

Crude protein content was significantly higher in treatments P1 and P3 compared to the control. This increase is attributed to the presence of beneficial microorganisms in MOL, particularly from banana stem and fruit waste. Banana stem MOL contains microbes such as Bacillus sp., Aeromonas sp., and Aspergillus niger (Suhastyo, 2011). The presence of Aspergillus niger enhances nitrogen-binding activity and contributes to protein synthesis (Suari et al., 2019). Nitrogen plays a critical role in microbial growth and protein formation, thereby influencing crude protein content. Proteolytic enzymes produced by these microbes convert complex proteins into peptides and amino acids (Suari et al., 2019).

Additionally, MOL derived from fruit waste contains microorganisms such as Pseudomonas sp., Bacillus sp., and Azospirilium sp. (Sari, Surya F.I., 2018). These microbes produce various enzymes, including protease, amylase, and lipase, which enhance nutrient availability and fermentation efficiency (Prihatiningsih et al., 2019). The high sugar content in pineapple and crystal guava supports microbial growth, further optimizing fermentation. Pineapple also contains

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bromelain, a proteolytic enzyme that contributes to protein breakdown (Arti et al., 2019). These mechanisms collectively explain the increased crude protein content, consistent with previous findings that fermentation can increase cassava peel protein from approximately 1% to over 8% (Yana et al., 2020; Ginting & Pase, 2018).

Although crude fiber content decreased in MOL treatments, the differences were not statistically significant. This suggests that all treatments had a comparable effect on fiber degradation. Fermentation improves feed quality by reducing crude fiber through microbial enzymatic activity. MOL contains probiotic microorganisms such as Lactobacillus, Streptococcus, and Bacillus, which produce cellulase enzymes capable of degrading hemicellulose and lignin (Widianingrum et al., 2019). The breakdown of lignocellulosic structures occurs through hydrolysis processes that disrupt lignin and silica bonds in plant cell walls (Karyono et al., 2022).

Furthermore, the dominance of lactic acid bacteria during fermentation contributes to fiber degradation by producing organic acids that lower pH and facilitate structural breakdown (Weinberg et al., 2004). Despite these mechanisms, the absence of significant differences indicates that fiber degradation occurred at a similar rate across treatments. Comparable findings have been reported, with fermented cassava peel exhibiting a crude fiber content of around 21.2% (Nurlaeini et al., 2022). Overall, these findings demonstrate that MOL can effectively substitute EM-4 as a biostarter in cassava peel fermentation. While most nutritional parameters remained stable, specific MOL types, particularly those derived from banana stems and fruit waste, provide added benefits in enhancing crude protein and mineral content without compromising overall feed quality.

CONCLUSION

The study demonstrated that the application of Local Microorganisms (MOL) as a substitute for the commercial biostarter EM-4 did not produce a statistically significant effect on dry matter, organic matter, and crude fiber content of fermented cassava peel (P>0.05). These findings indicate that all treatments yielded outcomes that were relatively comparable for these parameters, suggesting that MOL performs similarly to EM-4 in maintaining the basic nutritional composition of the fermented product. In contrast, a statistically significant effect (P<0.05) was observed in ash content and crude protein levels. Ash content was lowest in the control treatment using EM-4, while treatments utilizing MOL showed higher mineral content. Meanwhile, crude protein content was significantly higher in specific MOL treatments, particularly those derived from banana stems and fruit waste, indicating enhanced protein enrichment during fermentation. These results suggest that MOL derived from natural sources, such as banana stems, bamboo shoots, and fruit waste, can effectively replace commercial EM-4 as a biostarter in cassava peel fermentation, with the added benefit of improving certain nutritional components, particularly crude protein and mineral content.

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CONFLICT OF INTEREST

All authors have seen and approved the manuscript being submitted. We warrant that the article is the authors' original work. We warrant that the article has not received prior publication and is not under consideration for publication elsewhere. On behalf of all co-authors, the corresponding author shall bear full responsibility for the submission.

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