



# Effects of Corn Bran on the Nutritional Quality of Pineapple Peel Silage

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## ABSTRACT

Combining pineapple peel waste with a specific level of corn bran produces high-quality silage that meets the nutritional needs of ruminants. The present study aimed to evaluate the effectiveness of incorporating corn bran in improving the physical properties and nutritional quality of pineapple peel silage for ruminant feeding in tropical regions. The silage treatment was conducted using a completely randomized design with four treatment groups and five replications. The experimental diets consisted of four levels of pineapple peel and corn bran, including 100% of pineapple peel with no bran (P0), 95% of pineapple peel with 5% of bran (P1), 90% of pineapple peel with 10% of bran (P2), and 85% of pineapple peel with 15% of bran (P3). Each treatment group received 5% of molasses as an additive. Silage quality was analyzed using near-infrared spectroscopy. To evaluate rumen fermentation and digestibility, the *in vitro* Conway method was utilized, employing rumen fluid obtained from fistulated Holstein-Friesian bulls. Pineapple peel silage containing different corn starches exhibited a higher pH than the control group. Group P3 significantly produced higher crude protein (CP) and nitrogen-free extract (NFE) levels than the other treatment groups. Increasing the amount of corn bran in group P3 increased ammonia (NH<sub>3</sub>) production by 11.15 mM and total volatile fatty acids (VFA) by 134.20 mM compared to the control group. Group P3 exhibited the highest digestibility coefficients, with dry matter and organic matter values reaching 82.77% and 82.46%, respectively. The feed mixture comprising 85% pineapple peel and 15% corn bran is recommended for ruminants in tropical regions due to its superior overall nutritional quality. This feed mixture elevated CP, NFE, NH<sub>3</sub> production, total VFA, dry matter, and organic matter.

**Keywords:** Corn bran, Digestibility, Rumen, Tropical region

## INTRODUCTION

Providing ruminant feed, particularly in tropical countries, commonly encounters different complex issues such as scarcity and poor nutritional quality. Natural grass is commonly used on grazing land to lower production costs, offering an economical and efficient energy source (Dillon et al., 2005; Gyamfi et al., 2025). During the rainy season, grass is abundant; however, in the dry season, its availability declines because forage land, which provides fiber, is often converted into agricultural land (Teferedegne, 2000; Herrmann et al., 2020; Woldemariam, 2021). Consequently, implementing a forage development strategy is essential, as ruminant diets depend on natural grasses (Alemayehu et al., 2017; Billen et al., 2018). Since pasture grass often fails to meet nutritional standards, farmers regularly supplement it with different concentrates, resulting in higher feed costs and reduced efficiency (Al-Jassim et al., 1997). This condition persistently results in financial losses in the livestock industry. Consequently, it is important to investigate innovative feed sources derived from alternative agricultural waste materials, including pineapple peel waste. Pineapple plants are widely available in Indonesia, producing significant quantities of peel waste.

Pineapple peel waste exhibited a favorable nutritional profile, characterized particularly by its high glucose content. Pineapple waste yields approximately 34 g/L of glucose, 12 g/L of fructose, and 10 g/L of sucrose (Ferone et al., 2019). According to Sukruansuwan and Naphathorn (2018), pineapple peel waste specifically contains 22.9% cellulose, 13.9% hemicellulose, and 5.1% lignin. To preserve the nutritional quality of pineapple peel waste as animal feed, it should be processed into silage with corn bran and molasses. Silage is a preservation method based on fermentation that decreases pH and generates a distinctive odor (Kung et al., 2013; Bai et al., 2023). The success of the fermentation process within the silo is highly reliant on anaerobic conditions, the availability of water-soluble carbohydrates (WSC), and an optimal dry matter content to facilitate the proliferation of lactic acid bacteria (LAB) and capable of decreasing pH (Weinberg and Muck, 1996; Xu et al., 2022). Corn bran and molasses serve as non-structural carbohydrate sources that provide high energy levels for LAB metabolism (Ferraretto et al., 2013). Non-structural carbohydrates, such as the starch found in



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plant cells, are abundant in corn bran, whereas molasses typically contains 50% sucrose (Nikodinovic et al., 2013). Rumen microbes favor these carbohydrates for their rapid effects on rumen pH (Russell and Wilson, 1996; Shi et al., 2025). Rumen digestibility is measured by the adequacy of dry matter (DM), organic matter (OM), and fermentation value. Ultimately, a well-balanced nutritional profile in silage ensures proper levels of DM and OM, improving feed digestibility and boosting overall rumen function. Higher rumen digestibility coefficients suggest that the feed is readily fermentable, enabling optimal metabolite utilization to support animal growth and production. The present study aimed to thoroughly assess the physical characteristics, nutritional profile, fiber fractions, rumen fermentation parameters, and *in vitro* digestibility of pineapple peel waste silage supplemented with corn bran for ruminant feed.

## MATERIALS AND METHODS

### Ethical approval

This experiment adhered to research ethics guidelines for livestock, in accordance with the Animal Science and Health regulations outlined in Government Law No. 41/2014 of the Republic of Indonesia.

### Silage preparation and treatments

The silage production process began with the physical processing of pineapple peel waste. The peels were diced into 3-5 cm segments and allowed to wilt for 18 hours to reduce their moisture content. The silage ingredients were then prepared using a completely randomized design comprising four treatments and five replications. The treatment groups consisted of 100% of pineapple peel with no bran (P0), 95% of pineapple peel with 5% of corn bran (P1), 90% of pineapple peel with 10% of corn bran (P2), and 85% of pineapple peel with 15% of corn bran (P3), with all treatments supplemented with 5% of molasses. Once the ingredients were thoroughly combined, they were transferred to a 10-liter silo, compacted, and sealed securely to preserve the anaerobic environment. The mixture was subsequently fermented for 21 days. After fermentation, the silo was opened, and the silage was assessed for color, texture, odor, and mold (Ali et al., 2023). Subsequent analyses were performed to quantify crude protein (%), crude fiber (%), ether extract (%), and nitrogen-free extract (NFE %) using near-infrared spectroscopy (NIRS; Despal et al., 2020). The content of neutral detergent fiber (NDF), acid detergent fiber (ADF), lignocellulose, cellulose, and hemicellulose was evaluated using fiber fractionation methodology (Vansoest, 1963). Additionally, OM, DM, dry matter digestibility (DMD), organic matter digestibility (OMD), ammonia (NH<sub>3</sub>) production, and total volatile fatty acids (VFA) were measured through *in vitro* analysis (Tilley and Terry, 1963).

### Physical quality of silage

A panel of 50 untrained assessors evaluated the physical quality of the silage, considering texture, color, odor, and mold presence. The assessment followed the scoring system and indicators adapted from Marselinus et al. (2019), in which odor was categorized from foul (1.0-1.9) to slightly sour (4.0-4.9), and mold growth was rated from extensive (1.0-1.9) to none (4.0-4.9). Color quality ranged from black (1.0-1.9) to the ideal golden yellow (4.0-4.9), while texture was assessed from very coarse (1.0-1.9) to soft and easily separable (4.0-4.9). Additionally, silage quality was determined by pH values classified as excellent (3.2-4.2), good (4.2-4.5), or poor (> 4.5).

### Chemical composition and fiber fraction measurement

The NIRS analysis employed a Buchi NIRFlex N500, Butchi Company (Switzerland), equipped with dense cells. Spectral data were collected from dry samples that had been ground and placed in a Petri dish, which was then placed in a Petri dish holder. The samples were irradiated with near-infrared radiation in the wavelength range of 4,000 to 10,000 cm. The irradiation process was repeated three times to generate three spectra for each sample. These chemical structures served as indicators of quality parameters, including protein, fiber, carbohydrates, fat, DM, and moisture content, as well as NDF, ADF, hemicellulose, and lignin (Vansoest, 1963; Despal et al., 2020).

### Fermentation rumen characteristic

Ammonia production and total VFA were measured *in vitro* using the method developed by Tilley and Terry (1963). Rumen fermentation and digestibility were assessed using a two-stage *in vitro* technique with rumen fluid obtained from fistulated Frisian Holstein bulls aged 2-3 years and averaging 320 ± 60.08 kg, a reliable source maintained at the Dairy Animal Nutrition Laboratory, Bogor Agricultural University, Indonesia. Fermentability analysis was performed in 100 mL fermentation tubes. A 0.5 g sample was combined in each tube with 40 mL of preheated McDougall's buffer from Sigma Aldrich Limited Company (Scotland) and 10 mL of rumen fluid. The contents of rumen liquid were aerated with CO<sub>2</sub> gas for 30 seconds to establish anaerobic conditions, then sealed with a ventilated rubber stopper and incubated in a

shaking water bath at 39°C for four hours. After fermentation, the tubes were centrifuged at 3500 g for 15 minutes, and the supernatant was collected for analysis of NH<sub>3</sub> and total VFA. The NH<sub>3</sub> levels were measured using the Conway method (Department of Dairy Science, 1966), while total VFA was determined by steam distillation. The digestibility analysis comprised two stages. The initial stage followed the fermentation process, which lasted for 48 hours. After 48 hours, the tubes were centrifuged once more at 3500 g for 15 minutes, and the resultant pellet was collected. This residue was subsequently combined with 40 mL of HCl-pepsin solution and incubated aerobically in a water bath maintained at 39°C for an additional 48 hours.

#### ***In vitro* nutrient digestibility**

After 48 hours of enzymatic processing, the residue was filtered, dried, and weighed to determine the DM residue. The OM content of the residue was determined by incineration in a muffle furnace at 600°C for 6 hours. The DM and OM digestibility coefficients were calculated using the following formulas (Tilley and Terry, 1963).

$$\text{DMD} = \frac{(\text{sample weight} \times \text{DM}) - (\text{residue weight} \times \text{DM} - \text{blank weight} \times \text{DM})}{(\text{Sample weight} \times \text{DM})} \times 100\% \quad (\text{Formula 1})$$

$$\text{OMD} = \frac{(\text{sample weight} \times \text{OM}) - (\text{residue weight} \times \text{OM} - \text{blank weight} \times \text{OM})}{(\text{Sample weight} \times \text{OM})} \times 100\% \quad (\text{Formula 2})$$

#### **Statistical analysis**

Data were analyzed with one-way ANOVA in SPSS version 20.0 (IBM Corp., USA). When significant differences among treatments were observed, Duncan's multiple-range test was used for mean separation. The threshold for statistical significance was  $p < 0.05$ , and all results were expressed as mean  $\pm$  standard deviation (SD).

## **RESULTS AND DISCUSSION**

#### **Physical quality of silage**

The physical properties of pineapple peel silage supplemented with different levels of corn bran are presented in Table 1. The silage condition was classified as good. Including up to 15% corn bran did not significantly change the silage's color ( $p > 0.05$ ). The silage retained its characteristic color, ranging from brownish-yellow to golden-yellow, with average color scores of 3.77 to 4.00, primarily brownish-yellow. This color alteration from the original golden-yellow to brownish-yellow was probably due to the addition of diverse carbohydrate sources and the 21-day fermentation process. Similarly, Anas et al. (2024) reported that corn straw silage mixed with different legumes resulted in brown and yellowish-brown colors. Furthermore, color alterations were influenced by temperature during the ensiling process (Sukri et al., 2023). The initial phase of ensiling involved aerobic respiration, which persisted until the plant sugars and remaining oxygen supply were depleted. During the initial phase of the silage process, sugars were metabolized into CO<sub>2</sub> and water, generating heat and increasing the temperature (Martens et al., 2024). Sio et al. (2022) reported that the color of rice straw silage remained yellowish-green after adding molasses and cattle rumen fluid, similar to the result.

Regarding odor, the treatment groups significantly affected silage odor, with Group P3 recording the highest score (3.68;  $p < 0.05$ ). Odor scores ranged from 3.60 to 3.78, indicating noticeable differences due to added ingredients, such as corn bran. The sour odor observed in this study was due to fermentation, in which active anaerobic bacteria converted sugars into organic acids. Lactic acid bacteria inoculants could alter the odor by changing microbial communities of the alfalfa silage (Zhang et al. 2021). Similarly, the texture of the pineapple peel silage was significantly affected by the inclusion of different carbohydrate sources ( $p < 0.05$ ). The texture scores ranged from 3.64 to 3.89, indicating a soft, cohesive consistency that was hard to separate, reflecting superior silage quality. Group P2 demonstrated the highest texture value, probably due to the high moisture and carbohydrate content naturally present in pineapple peel waste.

Finally, the treatment groups significantly affected silage pH, with average values ranging from 2.77 to 2.91 ( $p < 0.05$ ). This pH result reflected the positive impacts of carbohydrate-based ingredients on the fermentation process, as the easily soluble carbohydrates in pineapple peels served as an excellent substrate for lactic acid bacteria. The silage achieved an optimal pH level, presumably attributable to a 21-day fermentation period that facilitated bacterial proliferation. A higher concentration of lactic acid produced during fermentation effectively lowers the pH, thereby inhibiting the proliferation of spoilage bacteria and extending the shelf life of the feed (Yu et al., 2023). In the present study, the observed pH level was lower than the range of 3.77-4.04 reported by Ramirez et al. (2020) for sunflower silage with different additives. Furthermore, the pH levels observed in the current study were lower than those reported by Ferreira et al. (2022) for mixed Tanzanian grass and babassu fruit by-product silage used as feed for dairy cattle, which ranged from 5.08 to 5.26.

### Chemical composition of silage

The chemical composition of pineapple peel silage supplemented with corn bran is presented in Table 2. Incorporating corn bran at concentrations up to 15% did not significantly affect the DM content of the pineapple peel silage, with no substantial increase observed at the 5%, 10%, or 15% levels ( $p > 0.05$ ). Any minor fluctuations in DM content were primarily driven by respiration prior to the establishment of anaerobic conditions. The inclusion of corn bran significantly increased the crude protein content relative to the control group ( $p < 0.05$ ). Group P0 exhibited the lowest crude protein content (6.84%), attributable to the absence of corn bran, which likely reduced microbial activity and, consequently, microbial protein synthesis. Conversely, an increase in the bacterial population enhanced the contribution of bacterial amino acids to the total protein content. Notably, the crude protein values observed in the present study exceed those reported by Kizilşimşek et al. (2020), who found average values ranging from 6.16% to 7.48% in corn silage intercropped with legumes. The ether extract content of the silage was affected by the treatments, with the highest value recorded in Group P1 at 3.97% and the lowest in Group P0 at 3.43% ( $p < 0.05$ ). The crude fiber content was significantly affected by the addition of corn bran. Group P0 exhibited the highest crude fiber level at 23.71%, whereas Group P3 recorded the lowest crude fiber level at 10.53%. The increased levels of crude fiber in Group P0 were due to restricted energy availability, which limited microbial activity required for fiber decomposition (Li et al., 2026). Finally, the addition of corn bran significantly increased NFE levels in the P3 group compared to the other treatments ( $p < 0.05$ ). The highest NFE level was observed in Group P3 at 74.02%, while the lowest NFE level was observed in Group P0 at 53.86%. The NFE levels observed in the present study were higher than the 40.34% to 45.04% reported by Sriagtula et al. (2026), who used sorghum silage with indigofera and molasses.

**Table 1.** Physical value of pineapple peel waste silage by the addition of different levels of corn starch

Parameter	Treatment	Mean $\pm$ S.D
Color	P0	3.92 $\pm$ 0.29
	P1	3.96 $\pm$ 0.08
	P2	3.99 $\pm$ 0.13
	P3	3.72 $\pm$ 0.18
Odor	P0	3.64 $\pm$ 0.13 <sup>a</sup>
	P1	3.77 $\pm$ 0.06 <sup>b</sup>
	P2	3.65 $\pm$ 0.06 <sup>a</sup>
	P3	3.68 $\pm$ 0.08 <sup>ab</sup>
Texture	P0	3.73 $\pm$ 0.08 <sup>b</sup>
	P1	3.77 $\pm$ 0.10 <sup>b</sup>
	P2	3.89 $\pm$ 0.09 <sup>c</sup>
	P3	3.65 $\pm$ 0.06 <sup>a</sup>
Mold	P0	4.41 $\pm$ 0.05 <sup>c</sup>
	P1	4.32 $\pm$ 0.05 <sup>b</sup>
	P2	4.28 $\pm$ 0.03 <sup>ab</sup>
	P3	4.26 $\pm$ 0.05 <sup>a</sup>
pH	P0	2.76 $\pm$ 0.03 <sup>a</sup>
	P1	2.84 $\pm$ 0.02 <sup>b</sup>
	P2	2.90 $\pm$ 0.02 <sup>c</sup>
	P3	2.86 $\pm$ 0.07 <sup>bc</sup>

P0: 100% pineapple peel; P1: 95 % pineapple peel + 5 % corn bran; P2: 90% pineapple peel + 10% corn bran; P3: 85 % pineapple peel + 15 % corn bran; <sup>abcd</sup> Different superscript letters in the same column indicate significant differences ( $p < 0.05$ ); S.D: Standard deviation

**Table 2.** Chemical value of pineapple peel waste silage by the addition of corn starch

Parameter (% DM)	Treatment	Mean $\pm$ S.D
Dry Matter	P0	88.15 $\pm$ 0.62
	P1	88.10 $\pm$ 0.51
	P2	88.54 $\pm$ 0.50
	P3	88.15 $\pm$ 0.55
Ash	P0	12.17 $\pm$ 0.93 <sup>c</sup>
	P1	8.25 $\pm$ 1.27 <sup>b</sup>
	P2	6.72 $\pm$ 0.88 <sup>b</sup>
	P3	3.93 $\pm$ 1.45 <sup>a</sup>
Crude Protein	P0	6.84 $\pm$ 0.80 <sup>a</sup>
	P1	8.72 $\pm$ 0.99 <sup>b</sup>
	P2	8.47 $\pm$ 0.78 <sup>b</sup>
	P3	8.04 $\pm$ 0.96 <sup>b</sup>
Eter Extract	P0	3.43 $\pm$ 0.53 <sup>a</sup>
	P1	3.97 $\pm$ 0.35 <sup>b</sup>
	P2	3.95 $\pm$ 0.22 <sup>b</sup>
	P3	3.49 $\pm$ 0.20 <sup>ab</sup>
Crude Fiber	P0	23.71 $\pm$ 1.36 <sup>d</sup>
	P1	17.50 $\pm$ 3.17 <sup>c</sup>
	P2	14.00 $\pm$ 1.14 <sup>b</sup>
	P3	10.53 $\pm$ 2.46 <sup>a</sup>
NFE	P0	53.86 $\pm$ 0.97 <sup>a</sup>
	P1	61.55 $\pm$ 3.09 <sup>b</sup>
	P2	66.85 $\pm$ 0.97 <sup>c</sup>
	P3	74.02 $\pm$ 3.84 <sup>d</sup>

P0: 100% pineapple peel; P1: 95 % pineapple peel + 5 % corn bran; P2: 90% pineapple peel + 10% corn bran; P3: 85 % pineapple peel + 15 % corn bran; <sup>abcd</sup> Different superscript letters in the same column indicate significant differences ( $p < 0.05$ ); NFE: Nitrogen free extract

### Fiber fraction of silage

Table 3 presents the fiber fractions of pineapple peel waste silage supplemented with corn bran. The analysis of these fiber components was conducted to evaluate the nutritional impact of different levels of corn bran inclusion on silage quality. Corn bran supplementation significantly reduced the fiber content of the silage ( $p < 0.05$ ). Specifically, NDF decreased from 54.14% in Group P0 to 30.87% in Group P3 ( $P < 0.05$ ). Similarly, the ADF content was highest in

P0 (29.48%) and lowest in P3 (16.68%). The decrease in these NDF and ADF fractions, which consist of lignin, cellulose, and hemicellulose, was accelerated by the addition of corn bran. Higher levels of corn bran supplementation enhanced microbial activity during ensiling, facilitating the degradation of these structural components. Consequently, the silage was more easily digestible, leading to higher digestibility coefficients. Furthermore, the treatments significantly affected the hemicellulose and cellulose contents ( $p < 0.05$ ). The highest hemicellulose value was observed in Group P0 at 24.66%, whereas the lowest value (14.19%) was observed in Group P3. Similarly, the control group had the highest cellulose content at 24.16%, while Group P3 had the lowest cellulose content at 12.76%.

The NDF values observed in the present study (30.87%-54.14%) were similar to those reported by [Kaplan and Akcura \(2021\)](#) for mixed bean and corn silage, which ranged from 39.36% to 51.20%. Furthermore, the lignin content in the present study was lower than the 13.76%-14.91% noted by [Tekin and Kara \(2020\)](#) in tomato herb silage supplemented with molasses and barley.

**Table 3.** Fiber fraction of pineapple peel waste silage with added levels of corn starch

Parameter (% DM)	Treatment	Mean $\pm$ S.D
NDF	P0	54.14 $\pm$ 2.55 <sup>c</sup>
	P1	42.05 $\pm$ 1.31 <sup>b</sup>
	P2	41.38 $\pm$ 5.25 <sup>b</sup>
	P3	30.87 $\pm$ 6.15 <sup>a</sup>
ADF	P0	29.48 $\pm$ 2.02 <sup>c</sup>
	P1	21.97 $\pm$ 1.37 <sup>b</sup>
	P2	20.81 $\pm$ 2.35 <sup>b</sup>
	P3	16.68 $\pm$ 1.34 <sup>a</sup>
Hemisululosa	P0	24.66 $\pm$ 2.80 <sup>b</sup>
	P1	20.08 $\pm$ 2.17 <sup>b</sup>
	P2	20.57 $\pm$ 3.64 <sup>b</sup>
	P3	14.19 $\pm$ 4.83 <sup>a</sup>
Lignin (ADL)	P0	3.87 $\pm$ 1.57 <sup>b</sup>
	P1	4.41 $\pm$ 1.06 <sup>b</sup>
	P2	4.35 $\pm$ 0.95 <sup>b</sup>
	P3	1.96 $\pm$ 0.03 <sup>a</sup>
Selulosa	P0	24.16 $\pm$ 1.27 <sup>b</sup>
	P1	17.57 $\pm$ 0.33 <sup>b</sup>
	P2	15.48 $\pm$ 1.88 <sup>b</sup>
	P3	12.76 $\pm$ 1.29 <sup>a</sup>

P0: 100% pineapple peel; P1: 95 % pineapple peel + 5 % corn bran; P2: 90% pineapple peel + 10% corn bran; P3: 85 % pineapple peel + 15 % corn bran; <sup>abcd</sup> Different superscript letters in the same column indicate significant differences ( $P < 0.05$ ). S.D: Standard deviation; NDF: Neutral detergent fiber; ADF: Acid detergent fiber

**Table 4.** Rumen fermentability and *in vitro* digestibility of pineapple peel waste silage

Parameters	Treatment	Mean $\pm$ S.D
NH <sub>3</sub> Production (mM)	P0	7.67 $\pm$ 1.00 <sup>a</sup>
	P1	10.91 $\pm$ 1.29 <sup>b</sup>
	P2	10.86 $\pm$ 1.77 <sup>b</sup>
	P3	11.15 $\pm$ 1.09 <sup>b</sup>
VFA Total (mM)	P0	79.62 $\pm$ 9.67 <sup>a</sup>
	P1	105.32 $\pm$ 17.24 <sup>b</sup>
	P2	132.94 $\pm$ 21.47 <sup>c</sup>
	P3	134.20 $\pm$ 9.13 <sup>c</sup>
DMD (%)	P0	71.09 $\pm$ 1.23 <sup>a</sup>
	P1	72.69 $\pm$ 1.73 <sup>a</sup>
	P2	80.66 $\pm$ 2.72 <sup>b</sup>
	P3	82.77 $\pm$ 1.58 <sup>b</sup>
OMD (%)	P0	70.35 $\pm$ 1.20 <sup>a</sup>
	P1	71.72 $\pm$ 1.71 <sup>a</sup>
	P2	80.15 $\pm$ 2.91 <sup>b</sup>
	P3	82.46 $\pm$ 1.58 <sup>b</sup>
Rumen pH	P0	6.92 $\pm$ 0.01 <sup>b</sup>
	P1	6.88 $\pm$ 0.01 <sup>c</sup>
	P2	6.83 $\pm$ 0.02 <sup>a</sup>
	P3	6.82 $\pm$ 0.01 <sup>a</sup>

P0: 100% pineapple peel; P1: 95 % pineapple peel + 5 % corn bran; P2: 90% pineapple peel + 10% corn bran; P3: 85 % pineapple peel + 15 % corn bran; <sup>abcd</sup> Different superscript letters in the same column indicate significant differences ( $P < 0.05$ ); DMD: Dry matter digestibility; OMD: Organic matter digestibility; S.D: Standard deviation; NH<sub>3</sub>: Ammonia; VFA: Volatile fatty acids

### Rumen fermentation and *in vitro* digestibility of silage

The rumen fermentation characteristics and *in vitro* digestibility of pineapple peel silage supplemented with corn bran are presented in Table 4. The treatments significantly increased NH<sub>3</sub> and total VFA production in pineapple peel silage ( $p < 0.05$ ). The highest concentrations were observed in Group P3, with values of 11.15 mM for NH<sub>3</sub> and 134.20 mM for total VFA. Conversely, the lowest NH<sub>3</sub> and total VFA production were observed in the control group at 7.67 mM and 79.62 mM, respectively. The increased NH<sub>3</sub> production observed in the supplemented groups was attributed to the protein content in the corn bran concentrate, which was rapidly degraded by rumen microorganisms into ammonia. The NH<sub>3</sub> concentrations observed in the current study were higher than those reported by [Htet et al. \(2021\)](#) for corn straw silage with soybean bran (8.00-10.60 mM), but lower than the 10.50-12.88 mM reported by [Tresia et al. \(2024\)](#) in corn

straw silage. Similarly, adding 15% of corn bran increased total VFA production by supplying easily fermentable carbohydrates that rumen microbes efficiently converted into end products such as lactic, acetic, and propionic acids. However, the total VFA concentrations in the current study remained lower than those reported by Kielb et al. (2021), who observed values ranging from 190.8 mM to 361.0 mM in sorghum, corn, and grass silages.

Furthermore, corn bran supplementation significantly influenced the DMD and OMD of the silage ( $p < 0.05$ ). The highest DMD was observed in Group P3 at 82.77%, while the lowest value was recorded in the control group at 71.09%. A similar trend was observed for OMD, which peaked at 82.46% in Group P3 and was lowest in Group P0 at 70.35%. This superior digestibility observed in the 15% corn bran P3 group was predominantly attributed to its reduced crude fiber content. Elevated fiber levels led to thicker cell walls, which hindered microbial penetration and, consequently, decreased digestibility. Increased corn bran levels enhanced LAB growth and increased acid production. Conversely, the lower OMD in Group P0 was due to the absence of corn bran, which limited degradation during fermentation. Since OM is a major component of DM, its digestibility values indicated a strong correlation. Notably, the DMD values observed in the present study were higher than the 58.26%-66.14% range reported by Gul (2023) for Caramba silage supplemented with wheat bran and molasses.

## CONCLUSION

The silage composed of 85% pineapple peel and 15% corn bran yielded the most favorable overall outcomes. This specific ratio successfully maintained the physical quality of the silage while improving its chemical profile by increasing crude protein and NFE content and reducing crude fiber. Furthermore, 85% of pineapple peel and 15% of corn bran effectively reduced the structural fiber fractions, including NDF, ADF, ADL, hemicellulose, and cellulose. As a result of the substantial reduction in structural fibers, this optimized silage formulation was anticipated to enhance rumen fermentation and increase *in vitro* digestibility. Finally, further studies involving *in vivo* feeding trials on ruminants are recommended to comprehensively assess the palatability, feed intake, and actual growth performance of this formulated pineapple peel silage

## DECLARATIONS

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### Authors' contributions

Triani Adelina conducted the literature review, experimental investigations, and exploratory examinations and drafted the manuscript. Anwar Efendi Harahap supervised all experimental steps and the preparation of the manuscript and verified the results. Jepri Juliantoni, Arsyadi Ali, and Sigit Sepriadi supervised all experimental procedures and the development of the manuscript. All authors have reviewed and approved the final edition of the manuscript.

### Availability of data and materials

The datasets generated and/or analyzed during this research are available upon reasonable request from the corresponding author.

### Competing interests

The authors have not declared any conflict of interest.

### Ethical considerations

The authors affirm that the manuscript is original, has not been published elsewhere, and that the most recent version has been verified prior to publication. Additionally, the authors declare that no AI tools were utilized in the preparation and composition of this article.

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