Effect of the Ratio Between Corn Forage and Pineapple Peel Waste on Ph, Lactic Acid, Ammonia, and Organic Matter Changes in Silage

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ABSTRACT

This study aims to evaluate the effects of different ratios of corn stover and pineapple peel waste on pH, lactic acid content, ammonia concentration, and changes in organic matter (OM) of silage as indicators of fermentation quality. The research was conducted using a Completely Randomized Design (CRD) with four treatments: P1 (90% corn stover + 10% pineapple peel), P2 (80% + 20%), P3 (70% + 30%), and P4 (60% + 40%), each with five replications. The ensiling process lasted for 22 days under anaerobic conditions with the addition of 4% molasses. The results showed that variations in ingredient composition did not have a significant effect on pH, lactic acid content, or OM changes, but they had a significant effect on ammonia levels. The pH values ranged from 3.69 to 4.06, indicating stable fermentation. Lactic acid concentrations ranged from 1.30% to 1.46%, which is within the acceptable range for good-quality silage. Ammonia levels decreased as the proportion of pineapple peel increased, with the best results observed in P3 and P4, indicating lower protein degradation during fermentation. Changes in OM were relatively small across all treatments, reflecting consistent nutrient conservation efficiency. Overall, the combination of corn stover and pineapple peel waste was able to produce silage with good fermentation quality, with P3 and P4 providing the most optimal performance in reducing ammonia formation and maintaining organic matter integrity.

Keywords: Corn Stover Silage, Pineapple Peel Waste, Fermentation quality, Ammonia Concentration, Organic Matter Change

INTRODUCTION

Improving the quality and quantity of feed is a key strategy for increasing the productivity of ruminant livestock. Feed plays an essential role in supporting the life functions of livestock. Therefore, innovation is needed in utilizing local resources, particularly through the use of agricultural waste as a high nutritional value feed ingredient. One commonly applied fermentation technology in feed processing is silage production (Chrysostomus et al., 2020). Silage is a feed preservation technique used to maintain and improve feed quality through anaerobic fermentation.

The principle of silage production is the fermentation of forage by bacteria that predominantly produce lactic acid. Fermentation is carried out by homofermentative lactic acid bacteria as the environment transitions from aerobic to anaerobic conditions, resulting in lactic acid as the primary end product. The lactic acid produced through this process acts as a preservative, effectively inhibiting the growth of spoilage microorganisms. Nutritionally, the feed provided must meet the the standard requirements of livestock. Since it is closely related to intake and digestibility, the levels of dry matter and organic matter need to be carefully considered. A higher percentage of dry matter digestibility in feed ingredients indicates better nutritional quality (Sondakh et al., 2018).

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Agricultural waste, such as corn stover, contains high levels of fibre and carbohydrates and is easily accessible, making it one of the commonly used ingredients for silage production. However, corn stover is less optimal when used as a single ingredient due to its low crude protein content. Pineapple peel, which contains bromelain and vitamins, shows potential as an economical and high-quality alternative feed source. However, pineapple peel alone is insufficient to meet the nutritional requirements of ruminants. Therefore, additional protein-rich green feed derived from agricultural waste is required.

This study aims to examine how silage formulations based on corn stover and pineapple peel waste affect pH, lactic acid concentration, ammonia levels, and changes in the organic matter of the silage. These issues indicate the necessity of conducting this research.

MATERIALS AND METHODS

Tools and Materials

Several tools and ingredients as material used in this study included 90-day-old corn stover, chopped pineapple peel waste cut into 1–2 cm pieces, molasses, distilled water, 10-liter plastic jars, 40×60 cm plastic bags, an 8×6 m tarpaulin, a vacuum sealer, a machete, clamp pliers, a scale, a pH meter, beaker glasses, titration equipment, drop pipettes, Conway dishes, Erlenmeyer flasks, an electric oven, a muffle furnace, aluminum dishes, porcelain crucibles, and a desiccator.

Research Place

The research was conducted at the Ruminant Animal Nutrition and Animal Feed Chemistry Laboratory, Faculty of Animal Husbandry, Padjadjaran University, from October to November 2025.

Silage Production

The ensiling procedure for corn stover and pineapple peel waste was carried out as follows: The pineapple peel waste was first chopped and wilted for 24 hours. Corn stover was then wilted for 2 hours. After wilting, the corn stover and chopped pineapple peel waste were mixed according to the treatment. Molasses diluted with water at a 1:1 ratio was added at 4% of the total material weight for each treatment. All ingredients were then thoroughly mixed. The mixed corn stover and pineapple peel waste were placed into plastic bags and vacuum-sealed. The sealed bags were then put into plastic containers, secured with adhesive tape, and fermented at room temperature for 22 days. After fermentation, the silage was removed and spread out. Samples of the silage were collected for the measurement of pH, lactic acid, ammonia content, and changes in organic matter.

Variables Observed

pH Silage

The pH measurement was conducted to determine the acidity level of the silage as an indicator of successful fermentation. The samples that had completed the ensiling process were measured using a pH meter calibrated with pH 4 and pH 7 buffer solutions. This method allows for an accurate assessment of acidity under actual fermentation conditions, serving as an indicator of lactic acid fermentation dominance and silage stability.

Lactid Acid

Lactic acid was measured using the method described by Cappuccino and Natalie (1991). The principle of lactic acid determination is based on calculating the volume of NaOH used during titration, with the assumption that 1 ml of NaOH corresponds to 9.008 g of lactic acid. The silage was mixed thoroughly, and a 10 g sample was placed into an Erlenmeyer flask, followed by the addition of 10 ml of distilled water. The sample was heated on a hot plate until the CO_2 was completely released. After cooling, five drops of phenolphthalein indicator were added to the solution. The sample was then titrated with 0.1 N NaOH until a light pink colour appeared.

Ammonia (NH_3)

Ammonia produced from papaya-stem silage was measured using the Conway microdiffusion method (General Laboratory Procedures, 1966). Before use, the rim of the Conway dish was coated with petroleum jelly. A 1 ml aliquot of the supernatant obtained from the fermentation process after 4 hours of incubation was placed on one side of the Conway dish groove, while 1 ml of saturated Na_2CO_3 solution was placed on the opposite side. The supernatant and the Na_2CO_3 solution must not be mixed at this stage. A small amount (1 ml) of boric acid solution with mixed indicators of bromocresol was placed in the central well of the dish. The Conway dish was then tightly sealed to ensure it was airtight. After sealing, the dish was gently shaken to allow the supernatant and Na_2CO_3 to mix thoroughly, and then left at room temperature for 24 hours. After this period, the boric acid indicator solution was titrated with 0.005 N H_2SO_4 until it turned reddish in colour.

Organic Mattes Changes

Changes in Organic Matter (OM) are widely used in silage research as an indicator of nutrient conservation efficiency, since organic matter represents the primary component utilised by microorganisms during fermentation. Losses in OM may result from initial respiration, microbial activity, or the disappearance of soluble solids throughout the fermentation process (Wróbel et al., 2023).

The OM value is determined through ash analysis, in which the sample is combusted at 550°C until a constant weight is achieved. Organic matter is then calculated as 100% minus the ash content. Changes in OM are measured by comparing the initial OM content before fermentation with the final OM content after fermentation, following formulas commonly used in studies on mixed-forage silage (Mudhita et al., 2024).

Data Analysis and Method

This research employed an experimental method using a Completely Randomised Design (CRD) with four treatments, each replicated five times. The treatments were as follows:

P1: 90% corn stover + 10% pineapple peel waste

P2: 80% corn stover + 20% pineapple peel waste

P3: 70% corn stover + 30% pineapple peel waste

P4: 60% corn stover + 40% pineapple peel waste

The observational data were analysed using Analysis of Variance (ANOVA). If the results showed a significant difference among treatments ($P < 0.05$), a post hoc test was conducted using Duncan's Multiple Range Test at a 5% significance level to determine differences between treatments.

RESULT AND DISCUSSION

Table I Effect of the Balance of Corn Stover and Pineapple Waste on pH, Lactic Acid, Ammonia and Changes in BO

Parameter	Treatment			
	P1	P2	P3	P4
pH	4,06 ± 0,06	4,01 ± 0,06	3,96 ± 0,02	3,69 ± 0,03
Lactic Acid	1,43 ± 0,21	1,46 ± 0,11	1,35 ± 0,14	1,3 ± 0,07
Ammonia	3,6 ± 0,22	3,21 ± 0,31	2,65 ± 0,27	2,66 ± 0,43

Organic Matter Change	0,3 ± 0,75	-0,22 ± 0,69	0,15 ± 0,71	0,04 ± 1,08

Data are presented as mean ± SD. All parameters showed no significant differences among treatments based on ANOVA ($p > 0.05$); therefore, superscript letters are not included. Note: P1 = 90% Corn stover + 10% pineapple peel waste; P2 = 80% Corn stover + 20% pineapple peel waste; P3 = 70% Corn stover + 30% pineapple peel waste; P4 = 60% Corn stover + 40% pineapple peel waste.

pH

The analysis of variance showed that the ratio of corn stover to pineapple peel waste had no significant effect on silage pH. The statistical analysis produced a p-value of 0.068, which is above $\alpha = 0.05$, indicating that the differences in pH among treatments were not statistically significant. The four treatments (P1–P4) showed pH values ranging from 3.69 to 4.06, with an average of 3.93 ± 0.02. This range meets the criteria for good-quality silage and aligns with Hanifah et al. (2023), who reported that the optimal pH range for silage is approximately 3.2–4.2 and that lower pH values are linked to lactic acid bacteria activity, better silage quality, suppression of spoilage microorganisms, and less nutrient loss during storage.

The highest pH value was observed in P1 (4.06), followed by P2 (4.01), P3 (3.96), and P4 (3.69), the latter showing the highest acidity. Descriptively, a decreasing pH trend from P1 to P4 is evident, although the maximum difference is only around 0.37 pH units, which is relatively small in biological and technological terms. This suggests that the acid–base components in the silage matrix possess adequate buffering capacity, preventing substantial pH shifts despite the different treatment proportions. According to David et al. (2021), pH reduction occurs due to the increased population of microorganisms, especially lactic acid bacteria, which accelerate the ensiling process and consequently lower silage pH. A lower resulting pH indicates a more effective and stable ensiling and preservation process.

The low pH values observed across treatments indicate that the fermentation process proceeded optimally, as lactic acid bacteria fermented soluble carbohydrates (derived from both corn stover and the simple sugars in pineapple peel) into organic acids that lowered the pH and inhibited spoilage microbes. Therefore, the combination of corn stover and pineapple peel waste has the potential to produce silage that is safe, stable, and has good storage durability for use as ruminant feed.

Lactid Acid

The analysis of variance showed that the ratio of corn stover to pineapple peel waste did not significantly affect lactic acid content ($p = 0.278 > 0.05$), with an average value of 1.39 ± 0.06. These indicate that varying the proportion of pineapple peel waste did not lead to significant differences in lactic acid concentration.

According to Ranjhan (1980), high-quality silage typically contains 1.5–2.5% lactic acid. In this study, the lactic acid levels in P1 and P2 were slightly higher (approximately 1.4%) than those in P3 and P4 (approximately 1.3%). Although these values are marginally below the upper threshold reported by Ranjhan, all treatments remained within the 1–2% range, which is classified as an indicator of proper silage fermentation. This level of lactic acid is sufficient to lower the pH to an acidic range and inhibit the growth of spoilage microorganisms. Farihah (2005) emphasizes that higher lactic acid levels are associated with improved silage quality, as increased lactic acid helps maintain a low pH, thereby enhancing silage stability and shelf life of the silage.

The addition of pineapple peel waste provides a readily fermentable carbohydrate source (simple sugars), which act as substrates for lactic acid bacteria. However, the relatively uniform anaerobic conditions and comparable fermentation capacity across treatments likely resulted in stable lactic acid production. Pineapple peel also contains organic acids that help suppress the growth of aerobic bacteria. As stated by Jones et al. (2004), fermentation is a biologically mediated process in which lactic acid bacteria convert simple sugars into organic acids, predominantly lactic acid.

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Ammonia

The analysis of variance indicated that the ratio of corn stover to pineapple peel waste had a significant effect on silage ammonia content ($p = 0.001 < 0.05$), with values ranging from 2.65% to 3.60% (3.03 ± 0.09). These ammonia levels remain within the threshold of high-quality silage, in accordance with Kurnani (1995), who states that high-quality silage contains less than 11% ammonia of total nitrogen. Additionally, the results showed a clear decreasing trend in ammonia levels from P1 to P3 and P4, indicating that the inclusion of pineapple peel waste at appropriate proportions effectively reduced ammonia formation, which is associated with protein degradation during the fermentation process.

Ammonia levels in P1 and P2 remained relatively higher compared to those in P3 and P4, which contained higher proportions of pineapple peel waste. At these higher proportions, pineapple peel appeared to better support the optimal growth of lactic acid bacteria, leading to a more rapid pH decline. The resulting acidic environment effectively inhibited the activity of proteolytic microorganisms responsible for ammonia formation. This observation aligns with Telleng (2017), who reported that a lower pH suppresses the growth of undesirable Clostridia bacteria that degrade protein.

The addition of pineapple peel waste was therefore effective in reducing protein degradation in corn-stover silage, with P3 and P4 producing the best results. The lower ammonia levels observed in P3 and P4 indicate a more efficient fermentation process, better preservation of feed protein, and higher nutritional value of the silage for ruminant livestock. These findings are in line with Woolford (1984), who identified ammonia as an indicator of silage spoilage because it reflects protein breakdown and can increase silage pH.

Organic Matter Change

The results of the analysis of variance for the effect of corn stover–pineapple peel silage ratios showed relatively small variations in organic matter (OM) change, ranging from –0.22% to 0.30%, with an average change of 0.07 ± 0.19%. Statistical analysis indicated that the treatments had no significant effect on OM change ($p = 0.790 > 0.05$). This suggests that the addition of pineapple peel waste at different levels did not produce significant differences in the OM content of the silage. This condition may be attributed to the natural sugars in pineapple peel, which serve as an energy source for lactic acid bacteria, being insufficient to maximize the fermentation process. This is supported by Khan et al. (2014), who stated that sugar content is a crucial factor for the development of lactic acid–producing bacteria during fermentation.

The greatest OM loss occurred in P2 (–0.22%), while the smallest occurred in P4 (0.04%). The OM loss in P2 may be associated with a portion of soluble carbohydrates being utilized as fermentation substrates by lactic acid bacteria. Conversely, P4 exhibited the smallest OM change, which practically indicates almost no difference between pre- and post-ensiling conditions. This suggests that at the highest pineapple peel proportion (P4), the integrity of organic matter was best preserved.

Organic matter is determined by the difference between dry matter content and ash content. The ash content in silage reflects its mineral composition. A higher ash content indicates lower OM levels, whereas lower ash content corresponds to higher OM levels. Utomo (2015) states that OM content is influenced by several factors, including the rate of fermentation, wherein lactic acid bacteria work optimally when acidic conditions are rapidly established.

CONCLUSIONS

This study evaluated the effect of different ratios of corn stover and pineapple peel waste on silage quality, including parameters such as pH, lactic acid content, ammonia concentration, and changes in organic matter. The results showed that the variation in ratios did not significantly affect pH, lactic acid content, or changes in organic matter, but had a significant effect on ammonia levels. Increasing the proportion of pineapple peel reduced ammonia concentration and improved the fermentation process. Overall, the addition of pineapple peel waste proved effective in reducing protein degradation and preserving nutrients during fermentation, particularly in certain treatments, thereby producing high-quality silage suitable for ruminant feed.

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