Research Article

Enhancing Corn Silage Quality with Soft Cassava and Pineapple Peel Additives

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Abstract | Lampung Province has a large agro-industrial center and generates substantial waste, particularly pineapple peel waste and soft cassava. To improve the corn silage quality, additive such as soft cassava and pineapple waste which have a higher water-soluble carbohydrate. This research aimed to determine the corn silage quality using soft cassava and pineapple waste as additive. This research used Complete Random Design with 3 treatments and 4 replications. The treatments: T1: corn silage using 5% pineapple peel waste+ 2% soft cassava; T2: corn silage using 5% pineapple peel waste+ 3% soft cassava; and T3: corn silage using 5% pineapple peel waste+ 4% soft cassava. The result shown using 5% pineapple peel waste+ 4% soft cassava significantly ($P<0.05$) affect color , pH, extract ether, crude fiber, ash, crude protein, and non-nitrogen extract, but did not have a significantly affect on aroma and texture. The additive combination of 4% soft cassava and 5% pineapple peel waste optimized fermentation quality through improved acidification and reduced crude fiber, while acknowledging the accompanying reduction in crude protein.

Keywords | Agro-industrial by product, Additive, Chemical composition, Corn silage, Pineapple peel waste, Soft cassava

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INTRODUCTION

The use of corn as animal feed represents a breakthrough in efforts to develop corn as potential feed source. This is based on the fact that corn is a forage that is easily cultivated in tropical regions and boasts relatively high productivity (Central Statistical Agency, 2023) which shows that corn production in Lampung Province reached 3.2 million tons. However, the majority of the total corn production in Lampung Province is still used as a feed crop, primarily for the production of corn kernels for poultry feed. The utilization of corn among livestock farmer as forage is still limited, although corn have the potential to be developed into a source of forage. The utilization of corn as green fodder presents several challenges, including its high crude fiber.

The crude fiber of corn is relatively high, so efforts are needed to reduce this composition. One method of feed processing is the production of corn silage through fermentation. The fermentation process is carried out anaerobically in a silo with a higher moisture (60-70%) and in an acidic environment (Wang *et al.*, 2024). Silage production is one way to optimize feed potential and preserve feed, especially during the dry season when forage is scarce. During the fermentation process, physical, chemical, and biological decomposition occurs. Physical changes occur with the breakdown of the corn wall structure, softening it due to the breakdown of complex plant tissue bonds. Chemically, changes in the stalk nutrient components occur, and biologically, lactic acid bacteria play a role during the ensiling process. During this process, complex structures are transformed into simpler ones, and the resulting silage achieves optimal digestibility (Jiao *et al.*, 2021). This silage-making process is further optimized by the addition of additives with water-soluble carbohydrate (WSC) properties to accelerate ensiling. A good WSC source contains readily fermentable carbohydrates that can be rapidly utilized by lactic acid bacteria to support effective acid production and pH reduction during ensiling process (Zhou *et al.*, 2019).

Lampung Province, as an agro-industrial center, has a superior production of pineapples amounting to 859 thousand tons and cassava reaching 5.9 million tons (Ministry of Agriculture, 2023). In their processing, these two products produce waste in the form of pineapple peel waste and soft cassava that has undergone water reduction through pressing. These two products are waste products that are produced in large quantities with an estimated production of pineapple peel waste reaching 15% and approximately 105 thousand tons (Saraswaty *et al.*, 2016) and tapioca processing waste reaching 22% approximately 1.30 million tons (Jerry *et al.*, 2023). Research by Hartinger *et al.* (2024) indicates that pollard, molasses, rice bran, and cassava flour are energy sources that can be used as additives in corn silage production. Another potential additive is soft cassava, due to its soluble carbohydrate. Soft cassava contains 40.8-46.5% starch, making it easily digested by lactic acid bacteria and accelerating the silage process. In addition to soft cassava, pineapple peel waste contains 8.8% reducing sugars and 9% total sugars (Hemalatha and Anbuselvi, 2013). Hossain *et al.* (2015) explain that pineapple peel waste also has potential as an additive, with a nutrient content of 8.2% reducing sugars, 8.8% non-reducing sugars, and 9.75% total sugars. Although soft cassava and pineapple peel waste have been individually explored as silage additives in various forage materials, studies evaluating their combined use in corn silage remain limited. Soft cassava provides fermentable carbohydrates, while pineapple peel waste supplies soluble sugars and proteolytic enzymes that may modify fermentation patterns. However, the potential synergistic effects of combining these two agro-industrial by-products on the chemical composition and fermentation quality of corn silage have not been sufficiently investigated.

MATERIALS AND METHODS

Material

This research was conducted over a two-month period at the Animal Nutrition and Feed Technology Laboratory, Faculty of Agriculture, University of Lampung. Samples of 65-day-old corn were obtained from local corn farmers in Central Lampung. Pineapple peel waste (produced by PT. Great Giant Pineapple, Center Lampung Regency) and soft cassava (produced by PT. Umas Jaya Agrotama, Center Lampung Regency) were obtained from suppliers in East Lampung Regency. This research used laboratory-scale plastic bucket silos were used. Anaerobic conditions were achieved through manual compaction and airtight sealing.

Method

This study used a completely randomized design (CRD) with three treatments, each with four replications. A total of 12 experimental silos were used. The treatments were as follows:

- T1: corn + 2% soft cassava + 5% pineapple peel waste
- T2: corn + 3% soft cassava + 5% pineapple peel waste
- T3: corn + 4% soft cassava + 5% pineapple peel waste

Research procedure

The corn was cut into 3-5 cm pieces using a chopper. Before weighing, the corn was proximate analyses especially moisture to know moisture requires. The fresh corn forage contained approximately 79,51% moisture, while the dry matter content reached approximately 95%. However, all corn materials originated from the same fresh forage and were wilted overnight before chopping and additive application. Next, 10 kg of corn were weighed and additives were added according to the treatment. All ingredients were then homogenized and stored under anaerobic conditions for 21 days. Silage storage was carried out at room temperature in the same storage area, without light exposure. Anaerobic conditions were consistently ensured across all replications by applying the same manual compaction procedure to expel air, followed by airtight sealing of each silo. Prior to treatment, the research materials were proximate analyze, as listed in Table 1. After 21 days, organoleptic testing was conducted, including color, aroma, and texture tests using a scoring method. The scores given by panelists ranged from 1 to 5.0, as listed in the questionnaire in Table 2. Furthermore, testing was carried out by 25 panelists who had a fairly good sensitivity to silage quality. In addition, pH testing was also carried out using a pH meter, as well as moisture, ash, crude fiber, crude protein, and extract ether testing using the AOAC Method (2005).

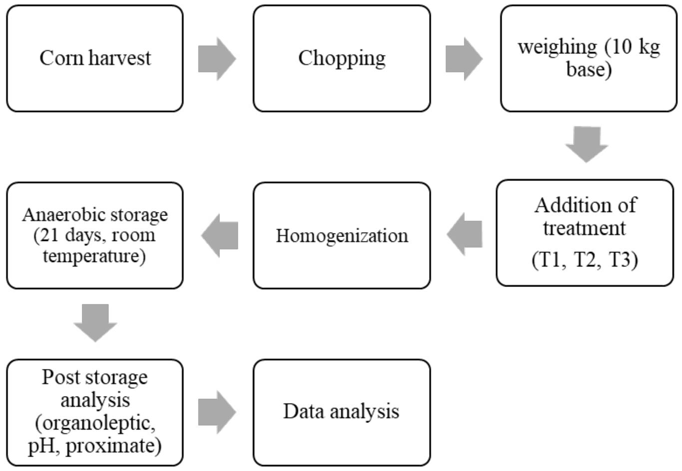

Figure 1: Research procedure.

Table 1: Nutrient composition of research material (% dry matter basis).

Material	Nutrient composition (%)				
	Ash	Crude Protein	Extract ether	Crude fiber	Non-nitrogen extract
Corn	8.69	11.92	10.64	30.03	38.72
Soft cassava	2.94	2.57	9.17	12.26	73.06
Pineapple peel waste	4.36	8.61	1.49	13.65	71.89

Table 2: Organoleptic test.

Assessment criteria	characteristic	Score
Color	1. Yellowish green	4-5
	2. Brownish green	3-4
	3. Brownish	2-3
	4. Blackish brown	1-2
Texture	1. Clumpy crumbs	4-5
	2. Non-clumpy crumbs	3-4
	3. No crumbs, slightly clumpy	2-3
	4. No crumbs, clumpy	1-2
Aroma	1. Sweet fragrance	4-5
	2. A bit sour	3-4
	3. Sour	2-3
	4. Rotten	1-2

Observed variables

The variables observed in this study were physical quality of corn silage (color, texture, and aroma), pH, and chemical composition (ash, crude fiber, crude protein, extract ether, and non-nitrogen extract).

Data analysis

The data obtained were analyzed statistically using analysis of variance with the help of SPSS 25. Duncan's Multiple Range Test was selected to detect differences among treatments with relatively higher sensitivity, which is suitable for exploratory nutritional studies with a limited number of treatments. (Dakhlan and Fathul, 2021).

RESULTS AND DISCUSSION

Effect treatment on physical quality and pH

Based on the analysis of variance (Table 3), the results showed that the addition of 4% soft cassava and 5% pineapple peel waste significantly affect ($p<0.05$) on color and pH, but did not have a significant effect on aroma and texture of corn silage. This condition is suspected because the aroma and texture of the resulting silage are relatively similar to the final result of the silage making process. During the silage process, temperature changes occur, thus changing the texture of the corn from hard to soft (Muck *et al*., 2020). This is associated with crude fiber in this treatment. Table 4 showed crude fiber decrease during ensiling and it affected on lower texture of silage. The aroma in this research reported did not have a significant and it indicated same condition during ensiling make a bit sour condition. The color of corn silage significantly affected ($P<0.05$) because in addition, the heat generated can also change the color of the stalk from green to slightly yellowish. The existence of relatively similar changes during this silage is thought to provide similar assessment results by the panelists (Tahuk *et al*., 2020; Sukri *et al*., 2023).

Table 3: Physical quality and pH.

Parameter	T1	T2	T3	P-value	SEM
Color	3.95^{a}	3.77^{ab}	3.65^{b}	0.044	0.118
Aroma	3.87	3.74	3.65	0.169	0.077
Texture	3.80	3.74	3.65	0.222	0.508
pH	4.13^{a}	4.06^{b}	3.99b	0.000	0.035

Table 4: Chemical composition of corn silage by DM.

Parameter	T1	T2	T3	P-value	SEM
Ash	9.08^{a}	8.77^{ab}	7.88^{b}	0.040	0.407
Extract ether	9.46^{a}	7.51^{ab}	5.68^{b}	0.007	0.887
Crude fibre	34.01^{a}	27.94^{ab}	27.15^{b}	0.017	2.059
Crude protein	9.54^{a}	8.67^{ab}	8.32^{b}	0.044	0.416
Non nitrogen extract	37.91^{b}	47.12^{a}	50.97^{a}	0.001	2.162

T1: corn + 2% soft cassava + 5% pineapple peel waste; T2: corn + 3% soft cassava + 5% pineapple peel waste; T3: corn + 4% soft cassava + 5% pineapple peel waste.

The pH analysis showed a highly significant effect ($P<0.01$). treatment T1 resulted in a higher pH compared with T2 and T3. This condition indicating that the treatment has affected on decreasing corn silage pH during ensiling and indicated as good silage with acid condition (Table 3). This is related to contribution of WSC of soft cassava and pineapple peel waste to optimizing fermented during ensiling and affected on produce higher lactic acid bacteria and preserving silage quality (ChengLi *et al*., 2012; Saricicek *et al*., 2016).

Effect treatment on chemical composition

The analysis variance showed ash composition have a significant effect (P<0.05). This condition indicated that soft cassava and pineapple peel waste didn't improve ash of corn silage, but has tendency reduce ash during ensiling. It allegedly because organic matter increasing and mineral composition decreased. During ensiling, mineral did not degradation by microbial and did not affect with ash (Kung *et al*., 2018; Freitas *et al*., 2023)

The analysis of variance also showed a significant effect on the extract ether of corn silage (P<0.05) and showing the lowest value in treatment T3. This difference in extract ether is thought to be due to fat degradation by lactic acid bacteria due to microbial activity during fermentation. Furthermore, Fat components are susceptible to oxidation and hydrolysis during the fermentation process. Liu et al. (2025) reported that during the corn silage making process, the fat component is easily oxidized during ensiling. The increase in oxidation is also supported by the pH level of the silage. This low pH value is thought to accelerate the oxidation process during ensiling (Bernardes *et al*., 2019). According to Kung *et al*. (2018), it was also reported that the composition of fatty acids in corn silage decreased due to low pH. Additionally, a reduction in crude fat levels may occur due to acidic conditions causing changes in lipid structure and decreased lipid stability during ensiling.

The analysis of variance demonstrated a significant effect of the treatments on the crude fibre of corn silage (P<0.05). Treatment T1 has a higher crude fibre compare to T3 has decrease during ensiling. This response is likely related to the treatment on increasing fibre fraction especially cell walls. This condition supported by soft cassava and pineapple peel waste to fermentative activity and it indirectly with bromelain enzyme present in pineapple peel waste, particularly bromelain. Hasiib *et al*. (2024) reported that pineapple peel waste contains bromelain, which plays a role in facilitating the breakdown of plant cell wall components. Adrizal *et al*. (2017) similarly noted that bromelain contributes to the degradation of the crude fibre fraction. On the other wise, pH condition related with crude fibre during ensiling. Treatment T3 showed the lowest pH and this it associated with crude fibre. Furthermore, soft cassava also functions as an important WSC source, as it is readily utilized by lactic acid bacteria for lactic acid production (Muck et al., 2020). The rapid accumulation of lactic acid leads to a faster decline in silage pH, which subsequently suppresses the growth of microorganisms responsible for fibre and protein degradation (Vijayalakshmi et al., 2020). The lactic acid bacteria also produce the enzymes cellulose and hemicellulose, which will cause depolymerization of structural fibers, thereby reducing crude fiber (Addah *et al*., 2016; Heuzé *et al*., 2025)

Different results were seen in the observation of crude protein. The analysis variance showed using soft cassava and pineapple peel waste significant affected on crude protein (P<0.05), but the result decrease of crude protein on T2 and T3. This difference is thought to be due to the low protein in the materials used. The results of proximate analysis showed that the corn used had a crude protein of 9.64% (as fed). The low protein content is also attribute to be due to the presence of the enzyme bromelain in pineapple peel waste. Hasiib *et al*. (2024) reported that bromelain is a group of proteolytic enzymes capable of degrading feed protein. During the ensiling process, protein degradation by bromelain is suspected (Nogoy *et al*., 2023). As a proteolytic enzyme, this enzyme breaks down protein into non-protein nitrogen (NPN) compounds, which will reduce the crude protein value. Furthermore, the additives used, whether pineapple peel waste or cassava waste, tend to have low protein. In this study, cassava waste had a crude protein of 2.94%, while pineapple peel waste had a crude protein of 8.61%. The ash in this study also showed no significant difference. This can be attributed to the fact that ash only represents the total mineral and is relatively stable during the ensiling process.

Non-nitrogen extract increased significantly (P= 0.001) in T2 and T3, accompanied by a reduction in crude fibre content. This indicates a shift from structural carbohydrates toward more readily fermentable carbohydrate fractions. The inclusion of soft cassava, which is rich in starch, and pineapple peel waste, a source of soluble sugars, likely contributed to this increase. From a practical nutritional perspective, higher NEE suggests improved energy availability and potential enhancement of rumen fermentation efficiency (Xie *et al*., 2025).

CONCLUSIONS

Based on the research that has been carried out, it can be concluded that using soft cassava and pineapple peel waste as additive with 5% pineapple peel waste+ 4% soft cassava significantly affect (P<0.05) on color, pH, extract ether, crude fiber, crude protein, ash, and non-nitrogen extract, but did not significantly effect on aroma and texture. The additive combination of 4% soft cassava and 5% pineapple peel waste optimized fermentation quality through improved acidification and reduced crude fiber, while acknowledging the accompanying reduction in crude protein. Practical recommendations and suggestions for future research, including animal feeding trials to evaluate the effects of these chemical changes on digestibility and performance.

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NOVELTY STATEMENT

The use of agro-industrial by product, especially soft cassava dan pineapple waste on corn silage has not been widely studied; therefore, this research aims to provide an understanding of the extent of their benefits and impact.

AUTHORS CONTRIBUTION

All authors contributed equally to this work.

Generative AI and AI-assisted technology statement

The authors confirm that generative AI was not used to produce the scientific content, data analysis, or conclusions of this manuscript. AI tools were used only for language editing and clarity. The authors fully take responsibility for the work's integrity and originality

Conflict of interest

The authors have declared no conflict of interest.

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