Nutritional Content and Fermentation Profile of Whole-Plant Corn Silage Cultivated in Rice Fields during the Dry Season from Various Varieties and Additives

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Abstract. This study aims to determine the nutritional content and fermentation profile of whole-plant corn (WPC) silage cultivated in rice fields during the dry season from various varieties with additives. This study consisted of 2 treatments, namely V1: Lamuru corn variety and V2: Pioneer P32 corn variety, and 3 groups, namely K0: control, K1: additive rice bran, and K2: additive molasses. The results showed that corn varieties did not significantly affect DM, OM, CP, EE, NFE, Ash, NDF, and ATL. However, hemicellulose levels of V1 were higher, and the CF, ADF, Cellulose, and lignin levels of V1 were lower. Adding additives did not affect DM, CP, CF, NFE, ADF, NDF, cellulose, lignin, and ATL content. Adding rice bran significantly decreased the OM but increased the EE, Ash, and hemicellulose content. Adding molasses significantly decreased the OM content but increased the Ash content. Corn plant varieties did not affect pH, lactic acid, VFA, and ammonia, but the soluble sugar content in V1 was significantly higher. Adding rice bran increased pH and ammonia but did not affect lactic acid, soluble sugars, and VFA. Adding molasses decreased the pH and increased ammonia content but did not affect the lactic acid, soluble sugar, and VFA. Based on the research results, it can be concluded that WPC silage cultivated in rice fields during the dry season on the Lamuru variety has better nutritional content but the fermentation profile is the same as Pioneer P32. The addition of additives reduced some of the nutritional content, and fermentation profile of WPC silage.

Keywords: The nutritional content of silages, Fermentation parameters of silages, corn silage varieties, silage additives, rice land in dry season.

1   Introduction

Previous research indicates that cultivating corn in rice fields during the dry season can yield biomass ranging from 7.74 to 16.25 tons per hectare of dry matter, with a crude

protein content between 8.39% and 10.22% [unpublish]. Ensilage is a method used to preserve the nutritional value of corn biomass, involving the controlled fermentation of plants, greens, or agricultural waste with a moisture content of 50% or more [1], [2]. Corn silage is commonly used in dairy farms worldwide and beef cattle fattening in Europe and North America [3], corn has the highest biomass production and energy content compared to other crops, good nutritional content, and digestibility, and its varieties are diverse so that they can be selected according to each environmental condition, more suitable for use as silage because it has the appropriate dry matter content, sufficient sugar content, and low buffer capacity [2], [4].

Several factors influence the quality of corn silage, including corn variety [5], chopping length [6], [7], [8], the density of silage material [9], [10], [11], [12], and the use of additives [2], [13], [14], [15], [16], [17], [18]. While some studies have found that corn varieties do not significantly impact the silage's nutritional content or fermentation profile (4), others have observed effects on crude protein content and other nutritional components such as Nitrogen-free extract (NFE), Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), cellulose, hemicellulose, lignin, ash, and Total Digestible Nutrients (TDN) [19], [20], [21].

The impact of additives on silage quality remains inconsistent. For example, research by [22] has shown that additives containing bacteria such as Lactobacillus acidophilus, Streptococcus cremoris, Lactobacillus plantarum, and Streptococcus diacetylactis can increase dry matter loss during fermentation. However, other studies suggest that lactic acid bacteria do not significantly affect silage quality [14]. The addition of 10% molasses to dry matter has been found to improve the percentage of dry matter, crude protein, and organic matter, while reducing pH, ash percentage, NDF, and ADF [23]. Conversely, the inclusion of rice bran can decrease dry matter, organic matter, and crude protein percentages, although rice bran can enhance the digestibility of dry matter and NDF in silage [24].

Additives in ensilage serve various purposes, including acting as fermentation stimulants, inhibitors of aerobic damage, nutrient enhancers, and absorbers of excess water [2], [16], [18]. Common fermentation stimulants include easily fermentable carbohydrates like molasses, sucrose, glucose, orange pulp, pineapple pulp, and beet pulp, as well as enzymes such as cellulase, hemicellulase, and amylase. Stimulant bacteria, such as Lactic Acid Bacteria (LAB), and water-absorbing materials like grains, straw, and polysaccharides are also used [18].

This study aims to evaluate the effects of different corn plant varieties and additives on the nutritional content, fiber composition, and fermentation profile of whole-plant corn (WPC) silage. It is hypothesized that variations in corn plant varieties and the addition of specific additives will impact the nutritional quality and fermentation characteristics of silage produced in rice fields during the dry season. The findings are expected to enhance energy efficiency, reduce costs, and optimize the time required for silage production.

2   Materials and Methods

2.1   Research materials

Silage was made using whole corn plants cultivated in post-rice harvest rice fields. Corn cultivation was carried out in Sidenreng Rappang Regency, South Sulawesi Province, Indonesia. Corn plants were harvested at the 1/2 milking phase marked by the milk line in the middle of the seeds. Corn plants were harvested at a distance of 20 cm from the base of the plant and then chopped in 3-5 cm lengths using a chopper machine. The chopped corn plants were added with additives according to the treatment.

2.2   Research materials

This study used a factorial design consisting of 2 treatments, namely P1: Lamuru corn variety and P2: Pioneer P32 corn variety, and 3 groups, namely: K0: Control (without additive), K1: 10% DM rice bran additive, and K2: 10% DM molasses additive.

Each treatment was repeated 5 times so that the experiment totaled 30 units. As many as 1 kg of chopped corn plants were added with 25 gr of additives (10% DM) and then stirred until smooth. The mixture of corn plants and additives was put into a silo bag, then compacted and tightly closed until it was airtight. The corn silage was opened on the 35th day and observations were made on the nutrient content and fermentation profile.

2.3   Research materials

The parameters observed were the nutritional content of whole-plant corn (WPC) silages including dry matter, organic matter, crude protein, crude fat, crude fiber, NFE, and ash content, fiber content including ADF, NDF, cellulose, hemicellulose, lignin, and ATL, and silage fermentation profile including pH, lactic acid, total VFA, and ammonia (N-NH3) and water-soluble sugar content. The nutritional content of corn silage was checked using Proximate analysis referring to [25] and fiber content was checked using Van Soest analysis referring to [26]. The fermentation profile of silage was checked referring to [27], weighing a 35 g sample, the sample was put into 70 ml of distilled water and then macerated at 40 C for 24 hours. The extract was filtered through two layers of cheesecloth and filter paper. The filtrate was used to determine pH, Ammonia Nitrogen (AN), Lactic Acid (LA), Volatile Fatty Acids (VFA), and dissolved sugar. Silage pH was measured using a glass electrode pH meter. Ammonia Nitrogen (NH4) content was determined using the phenol-hypochlorite colorimetric procedure referring to the method developed by Broderick and Kang [28]. Lactic Acid content was determined using the Josefa method [29]. VFA content was determined using the distillation method referred to [28]. Soluble sugar content was determined using the Luff-Schoorl method, referring to [30].

2.4   Research materials

Data on the effect of the combination treatment of corn varieties and the addition of additives and data on the impact of additives were analyzed using analysis of variance (ANOVA) using SPSS 23 from IBM(R) referring to the Completely Randomized Design (CRD). Treatments that showed significant differences were further tested using the Duncan test at the 5% level. Data on the effect of corn plant varieties were analyzed using the T-test using SPSS 23 from IBM(R).

3   Result and Discussion

3.1   Nutritional Content of Corn Silage

The nutritional content of corn silages cultivated in rice fields during the dry season for the Lamuru and Pioneer P32 varieties with the addition of rice bran and molasses additives is shown in Table 1. Proximate analysis revealed that the combination of corn plant variety treatment and adding additives significantly affected ($P<0.05$) dry matter, organic matter, crude protein, crude fat, crude fiber, and ash content of corn plant silage. However, it did not significantly affect the NFE content ($P>0.05$).

Table 1. Nutritional Content (% DM) of Corn Silage in Lamuru and Pioneer P32 Varieties with Rice Bran and Molasses Additives.

Nutritional content (%)	Lamuru			Pioneer P32			Average additives			Average varieties	
	Control	Rice brand	Molasses	Control	Rice brand	Molasses	Control	Rice brand	Molasses	Lamuru	Pioneer P32
DM	46.78[b]	40.09[a]	37.29[a]	40.01[a]	40.81[a]	51.50[b]	43.4	40.45	44.40	41.39	44.11
OM	96.06[b]	95.74[ab]	95.51[ab]	96.03[b]	95.62[ab]	95.28[a]	96.04[b]	95.68[a]	95.40[a]	95.77	95.64
CP	10.77[ab]	11.68[b]	9.45[a]	9.72[a]	10.09[ab]	9.75[a]	10.25	10.88	9.60	10.63	9.86
EE	1.70[a]	3.07[b]	2.37[ab]	2.41[ab]	2.97[b]	2.79[b]	2.05[a]	3.02[b]	2.58[ab]	2.38	2.72
CF	28.22[b]	25.76[a]	27.80[b]	28.84[b]	29.44[b]	28.57[b]	28.53	27.6	28.19	27.26[a]	28.95[b]
NFE	55.37	55.24	55.89	55.05	53.11	54.18	55.21	54.18	55.03	55.50	54.11
Ash	3.94[a]	4.26[ab]	4.49[ab]	3.97[a]	4.38[ab]	4.72[b]	3.96[a]	4.32[b]	4.60[b]	4.23	4.36

Note: DM: dry matter, OM: organic matter, CP: crude protein, EE: extract ether, CF: crude fiber, and NFE: nitrogen-free extract
[ab] different superscripts on the same row indicate significant differences ($P<0.05$)

The treatment's effect on dry matter and crude fiber content did not follow a clear pattern. Specifically, adding additives reduced the dry matter content in the Lamuru variety, while it had the opposite effect in the Pioneer P32 variety. Additives generally decreased the organic matter content in both varieties. Rice bran addition tended to increase crude protein content in both varieties. In contrast, molasses tended to decrease protein content in the Lamuru variety but did not affect the Pioneer P32 variety. Additives generally increased crude fat content in the silages of both corn varieties. Rice bran addition decreased crude fiber content in the Lamuru variety silage but tended to increase it in the Pioneer P32 variety silage. Molasses, on the other hand, did not affect crude fiber content in either variety. Additionally, additives led to an increase in ash content in the corn silage of both varieties.

Statistical analysis revealed that adding rice bran and molasses did not significantly affect (P>0.05) the dry matter, crude protein, crude fiber, or NFE content compared to the control. However, these additives significantly reduced corn silage's organic matter content (P<0.05). The addition of rice bran significantly increased (P<0.05) the crude fat content, whereas molasses did not have a significant effect (P>0.05) on oil fat content. Both rice bran and molasses additives significantly increased (P<0.05) the ash content of corn silage.

In terms of corn varieties, there were no significant differences (P>0.05) in the content of dry matter, organic matter, crude protein, crude fat, NFE, or ash between the two varieties. However, the crude fiber content of the Lamuru variety was significantly lower (P<0.05) than that of the Pioneer P32 variety.

3.2   Fiber Content of Corn Plant Silage

The fiber content of corn silage cultivated in rice fields during the dry season for the Lamuru and Pioneer P32 varieties with various additives is presented in Table 2. Van Soest Analysis Corn silage of Lamuru and Pioneer P32 varieties with rice bran and molasses additives had various effects (Table 2). The combination of corn variety treatment and the addition of additives had a significant (P<0.05) on the ADF, cellulose, hemicellulose, and lignin content but had no significant effect (P>0.05) on the NDF and Acid Detergent Lignin (ATL) content. The addition of rice bran tended to decrease the ADF content of corn silage in both varieties. While adding molasses increased the ADF of silage in the Lamuru variety, the opposite was true for the Pioneer P32 variety. The addition of rice bran and molasses additives tended to decrease the silage content in both corn varieties. The addition of rice bran tended to increase the hemicellulose content of silage in both corn varieties. Still, the addition of molasses tended to decrease the hemicellulose content of silage in both corn varieties. Adding molasses significantly increased the lignin content of Lamuru corn silage, but not significantly in Pioneer P32 corn silage.

Table 2. Fiber Content (% DM) of Corn Silage from Different Varieties with Rice Bran and Molasses Additives.

Fiber content (% of DM)	Lamuru			Pioneer P32			Average additives			Average varieties	
	Control	Rice brand	Molasses	Control	Rice brand	Molasses	Control	Rice brand	Molasses	Lamuru	Pioneer P32
ADF	34.45[ab]	33.45[a]	35.26[abc]	39.52[d]	37.71[bcd]	38.04[cd]	36.98	35.58	36.65	34.39[a]	38.42[b]
NDF	64.69	64.96	62.97	66.71	66.39	64.81	65.7	65.67	63.89	64.21	65.97
Cellulose	29.10[ab]	27.91[a]	28.81[ab]	32.84[c]	30.95[abc]	31.27[bc]	30.97	29.43	30.04	28.60[a]	31.69[b]
Hemicellulose	30.24[bc]	31.51[c]	27.71[ab]	27.19[ab]	28.68[abc]	26.78[a]	28.71[ab]	30.09[b]	27.24[a]	29.82[b]	27.55[a]
Lignin	4.70[a]	5.02[a]	5.98[b]	6.28[b]	6.32[b]	6.37[b]	5.49	5.67	6.18	5.23[a]	6.32[b]
ATL	0.65	0.52	0.47	0.4	0.44	0.39	0.53	0.48	0.43	0.55	0.41

Note: ADF: acid detergent fiber, NDF: neutral detergent fiber, and ATL: acid detergent lignin,
[abcd] different superscripts on the same row indicate significant differences (P<0.05)

Statistical analysis of the effect of additives on fiber content in corn silage cultivated in rice fields during the dry season revealed a significant effect (P<0.05) on hemicellulose

content but no significant effects on ADF, NDF, cellulose, lignin, or ATL content. The hemicellulose content did not differ significantly between the treatments compared to the control.

When analyzing the effect of corn varieties on fiber content, significant differences ($P<0.05$) were observed in ADF, cellulose, hemicellulose, and lignin content but no significant differences ($P>0.05$) in NDF and ATL content. Lamuru corn silage had significantly lower ($P<0.05$) ADF, cellulose, and lignin content compared to Pioneer P32, while the hemicellulose content was significantly higher ($P<0.05$) in Lamuru silage compared to Pioneer P32.

3.3   Characteristics of Corn Silage Fermentation

The characteristics of fermentation for corn silage, cultivated in rice fields during the dry season, for the Lamuru and Pioneer P32 varieties with the addition of various additives are detailed in Table 3. The combination of corn varieties and additives had a significant effect ($P<0.05$) on the pH and VFA (volatile fatty acids) content of corn silage but did not significantly affect ($P>0.05$) the content of lactic acid, dissolved sugar, or ammonia. The effect of rice bran and molasses additives on pH varied between the corn varieties. Adding rice bran did not affect the pH of the Lamuru corn silage but significantly increased ($P<0.05$) the pH of the Pioneer P32 silage. In contrast, molasses addition did not significantly ($P>0.05$) the pH of Lamuru silage but significantly decreased ($P<0.05$) the pH of Pioneer P32 silage. Rice bran had no significant effect ($P>0.05$) on the VFA content in either corn variety. In contrast, molasses significantly increased ($P<0.05$) VFA content in the Pioneer P32 silage but had no significant effect ($P>0.05$) on the VFA content in the Lamuru silage.

Tabel 3. Fermentation Profile of Corn Silage for Different Varieties with Rice Bran and Molasses Additives

Fermentation	Lamuru			Pioneer P32			Average additives			Average varieties	
	Control	Rice brand	Molasses	Control	Rice brand	Molasses	Control	Rice brand	Molasses	Lamuru	Pioneer P32
	4.76c	4.70c	5.06c	3.82b	5.78d	3.22a	4.29a	5.24b	4.14a	4.84	4.27
Lactic Acid (%)	0.64	0.67	0.53	0.49	0.56	0.53	0.57	0.61	0.53	0.61	0.53
Soluble Sugar (%)	8.35	8.11	8.22	7.88	7.63	7.99	8.11	7.87	8.1	8.23b	7.83a
VFA (mM)	22.08ab	23.83b	21.23ab	20.35a	21.68ab	23.40b	21.21	22.76	22.32	22.38	21.81
Ammonia (mM)	2.66	3.6	3.53	2.95	3.78	3.21	2.81a	3.69b	3.37ab	3.26	3.31

Note: DM: dry matter, OM: organic matter, CP: crude protein, EE: extract ether, CF: crude fiber, and NFE: nitrogen-free extract
different superscripts on the same row indicate significant differences ($P<0.05$)

Statistical analysis showed that rice bran and molasses additives significantly affected ($P<0.05$) the pH and ammonia content of corn silage but had no significant effect ($P>0.05$) on lactic acid, VFA, or soluble sugar content. Rice bran significantly increased ($P<0.05$) the pH and ammonia content of corn silage, whereas molasses did not significantly affect ($P>0.05$) pH or ammonia content. Differences between corn varieties re-

vealed that Lamuru corn silage had a significantly higher (P<0.05) soluble sugar content than Pioneer P32 silage. However, there were no significant differences (P>0.05) in pH, lactic acid, VFA, or ammonia content between the corn varieties.

The effects of adding rice bran in this study align with findings from other research, which reported an increase in crude protein and fat content but a decrease in organic matter, ADF (acid detergent fiber), NDF (neutral detergent fiber), and lignin in corn silage. Conversely, adding molasses in this study did not match previous findings that indicated increased protein and organic matter but decreased ADF and NDF content. This study's results regarding the impact of rice bran on silage pH are consistent with prior research, which also noted an increase in pH with rice bran addition, though it reported decreased ammonia and VFA content. Additionally, the observed effect of molasses on reducing silage pH is in agreement with previous studies, which found that molasses addition typically lowers silage pH. The addition of lactic acid bacteria (LAB) has been reported to decrease silage pH but does not significantly affect dry matter, crude protein, NDF, or ADF content.

The effect of corn varieties on silage nutritional content in this study is consistent with findings from previous research [31] regarding dry matter, crude protein, and ADF content. However, there are discrepancies in the hemicellulose content between these studies. Other research has indicated that corn plants' nutritional content as silage material varies across different varieties in terms of dry matter, crude protein, NFE, ash, ADF, NDF, cellulose, hemicellulose, and lignin content [21].

Compared to Pioneer P32 corn silage, Lamuru corn silage demonstrates superior content in crude protein, crude fiber, ADF, hemicellulose, and lignin. Crude fiber is crucial for ruminant livestock as it is linked to rumination activity, saliva flow, and maintaining rumen pH [26], [32]. However, high crude fiber and low crude protein levels can indicate lower nutritional value (33). The crude fat content in both corn varieties is adequate, ranging from 2-3%, which is appropriate for ruminant feed. Crude fat should be between 2-3% and not exceed 5%, as higher levels can reduce feed palatability and digestibility and affect bacteria that degrade structural carbohydrates [1], [33]. Overall, both corn varieties provide sufficient crude protein, aligning with the 8-14.4% crude protein requirement for fattening cattle with an initial weight of 700 lbs [34].

This study's findings suggest that adding rice bran and molasses to corn silage does not substantially alter the silage's nutritional or profile fermentation. Most of the nutritional content parameters and fermentation profiles of corn silage without additives in this study were within the range according to the standard [35]. This is also supported by the results of the study [36] where the addition of molasses did not affect the nutritional content, nutrient loss, and fermentation stability of corn silage, and [24] where the addition of 10% rice bran had no significant effect on total nutrient loss and in vitro digestibility of dry matter of pearl millet silage. This observation implies that the benefits of these additives may not justify their cost, especially considering the additional expenses associated with their purchase and incorporation into the silage. The minor effects observed in organic matter, crude fat, ash, and hemicellulose content may not be significant enough to warrant their use in all circumstances. Therefore, farmers

might benefit from evaluating the cost-effectiveness of these additives relative to their specific silage management goals and operational constraints.

On the other hand, the impact of corn variety on fiber fractions highlights the importance of selecting appropriate corn varieties for silage production. The variation in fiber content among different varieties can influence the overall silage's quality, particularly in terms of its digestibility and nutritional value for ruminants. This finding underscores the need for targeted variety selection based on desired silage characteristics. Future research could explore how different varieties interact with various additives and environmental conditions to optimize silage quality and improve feed efficiency for livestock.

Additives in silage function as fermentation inhibitors, fermentation stimulants, nutrient sources, absorbing excess water [2] [16] [18]. However, according to [2] corn plants as silage materials have a suitable dry matter content of less than 50%, contain sufficient dissolved sugar, and have low buffer capacity. In making silage, even without the addition of additives, the fermentation process continues which is produced by the activity of epiphytic microorganisms [37]. The use of additives in corn plant silage has varying effects. The addition of protease enzymes does not affect the dry matter content, crude protein, and pH but increases the content of lactic acid and acetic acid [38]. The addition of phosphate buffer combined with protease did not significantly affect the dry matter and crude protein content of corn silage on the 45th day of ensilage harvested at high water content, but in silage with lower water content the effect was inconsistent [39]. The addition of phosphate buffer combined with protease to corn silage on the 45th day did not significantly affect the pH and acetic acid content but tended to increase the lactic acid content [39]. The addition of organic acids to corn silage significantly reduced the number of yeast and Muld fungi cells and decreased the pH, but increased the dry matter, crude protein, lactic acid, and acetic acid content [39]. The addition of various acids and bacterial inoculum did not significantly affect the dry matter, crude protein, ADF and NDF content, and dry matter digestibility, but increased the pH, lactic acid, and acetic acid content [40]. The conclusion of various studies shows that microbial inoculation can lower pH in temperate and tropical grass silage as well as in alfalfa and other legumes, but not in corn, sorghum, and sugarcane [16]. According to [16] the use of chemical additives provides more consistent results than inoculum additives. However, chemical additives require higher initial costs than using inoculum, thus hampering their adoption. Therefore [16] suggest finding new compounds or new mixtures of existing compounds to reduce production costs while maintaining good antifungal properties.

4   Conclusion

This study concludes that adding rice bran and molasses to corn silage cultivated in rice fields during the dry season does not significantly affect most essential nutrients or fermentation profiles. However, corn varieties do influence most fiber fractions. Despite this, corn varieties do not affect the fermentation profile of silage under the studied cultivation conditions.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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