Comparation between maize and sorghum silage quality: A meta-analysis study

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Abstract. Forage maize silage and sorghum silage might be comparable in terms of nutrient content, especially in fermentation quality. Many studies have been conducted on this matter, but no comprehensive analysis exists. Therefore, this study aimed to evaluate the nutrient content of both maize and sorghum silage through a meta-analysis method. A total of 190 articles relevant to the keyword were further selected until 17 scientific articles according to the determined criteria for this study. The articles were entered into the database. Hedges'g effect was used to measure the estimate with a 95% confidence interval (CI) using random-effects models. The results showed that the pH of forage sorghum silage was significantly ($p<0.05$, Estimate = 1.029, 95% CI = 0.404 to 1.653) higher than that of forage maize silage. And then, lactic acid (Estimate = -1.174, 95% CI = -1.797 to -0.551) and ammonia (Estimate = -3.180, 95% CI = -4.885 to -1.484) were significantly ($p<0.05$) lower than maize silage and no effect ($p>0.05$) in ammonia value. Based on this study, sorghum silage potentially a substitute for maize silage.

1 Introduction

Silage is one way of preserving forage with a lower risk of losing feed nutrient value due to unfavourable conditions. Almost all plants can be processed into silage, such as forage maize and sorghum, are currently being developed. Maize (*Zea mays* L.) is an ideal plant for making silage because it contains complete nutrients [1], high water-soluble carbohydrates, low buffering ability [2], and fresh forage production reaches 44.54 tons ha^{-1} [3]. The utilization of maize plants in making silage has been done widely. Previous research [1] found the pH of maize silage to be 3.64 with a nutrient content of 8.70% PK, 39.50% NDF, 23.50% ADF, 5.46% lactic acid, and 1.72% acetic acid. The use of maize forage is considered less economical in Indonesia because it requires more expensive costs for forage production and can only be harvested once in one production cycle. Therefore, alternative forages are needed to replace maize forage.

Sorghum (*Sorghum bicolor* (L.) Moench) is an alternative animal feed being developed as a substitute for maize. The cost of production of sorghum forage is IDR 268 kg^{-1}, which is 50% cheaper than the cost of maize production. Sorghum plants can be harvested 3-4 times in one cycle so that forage production is abundant. According to [4] sorghum forage

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production ranges from 38-45 tons ha^{-1}. The use of sorghum as raw material for silage is now being to be developed. Fermentative quality is one of the parameters that describe the success of the fermentation process.

The inconsistent result from numerous studies have been reported on the fermentative value of maize and sorghum silage. Therefore, scientific synthesis using a meta-analysis approach is needed to get a more comprehensive [5]. This study aims to evaluate the fermentative quality of maize and sorghum forage silage by integrating data from various related studies in a meta-analysis approach.

2 Method

2.1 Procedure

The material used in this research are Microsoft Excel 2019, Microsoft Word 2019, Publish or Perish 8, and OpenMEE. Data collected from various Scopus-indexed journal with several appropriate criteria. Literature searches were conducted on several scientific sources: Google Scholar, Science Direct, Research Gate, and Springer. The keywords used were "maize silage", "sorghum silage", and "comparation maize with sorghum silage", with the criteria that the articles used in the form of experimental research, published from 2008-2022, in English, and contained quantitative data in the form of mean, standard deviation, and a number of samples. A total of 190 potential articles were found, and then selected so that 17 articles were used in database (Table 1).

Table 1. Studies used in database.

Studi	Type of silage	Control silage	Stage		Ensilage
			Maize	Sorghum	
[1]	Sorghum, sorghum+ seed	Maize	*Maturity*	*Maturity*	72
[6]	Sorghum	Maize	*NA*	*NA*	42
[7]	Sorghum	Maize	*Maturity*	*Early bloom*	60
[8]	Sorghum	Maize	*Maturity*	*Early bloom*	15
[9]	Sorghum, sorghum+ xylanase	Maize	*Maturity*	*Bloom*	10
[10]	Sorghum	Maize	*NA*	*NA*	10
[11]	Sorghum	Maize	*Maturity*	*Maturity*	NA
[12]	Sorghum	Maize	*Dough*	*Dough*	NA
[13]	Sorghum	Maize	*Soft dough*	*Soft dough*	40
[14]	Sorghum, sorghum high sugar	Maize	*Milk stage*	*Milk stage*	120
[15]	Sorghum	Maize	*Maturity*	*Maturity*	60
[16]	Sorghum pegah 1, pegah 2, speedfeed 1, speedfeed 2	Maize	*Maturity*	*Soft dough*	136, 60
[17]	Sorghum	Maize	*Milk stage*	*Flowering*	30
[18]	Sorghum	Maize	*Milk stage*	*Soft dough*	30
[19]	Sorghum	Maize	*Milk stage*	*Milk stage*	40
[20]	Sorghum	Maize	*Dough*	*Milk stage*	60
[21]	Sorghum, DK67, Niquel, RBH, RBN	Maize	*Dough*	*Dough*	55

NA : Non Available

2.2 Data Analysis

The database was analysis using OpenMEE to see the effect size and heterogeneity values. The analysis was done with random effect models at a 95% confidence interval. The effect size value used Hedge's g to measure the distance comparison of fermentation quality

compared to maize silage as a control. Data analysis results are presented in tables. Analysis of bias look at the value of Egger's test using the JASP application.

3 Result and Discussion

Descriptive statistical results of sorghum forage silage were higher in pH and acetic acid parameters and lower in lactic acid and ammonia parameters than maize forage silage. The results of descriptive statistics for fermentation quality are presented in Table 2.

Table 2. Descriptive statistic fermentation quality.

Silage	Parameters	N	Mean	SD	Min	Max
Maize	pH	27	3.73	0.21	3.51	4.31
	Lactic acid	25	6.29	2.58	3.00	13.60
	Acetic acid	23	2.06	1.51	0.92	8.50
	Ammonia	18	3.71	2.70	0.53	7.00
Sorghum	pH	27	3.86	0.28	3.47	4.37
	Lactic acid	25	5.63	3.02	2.28	14.50
	Acetic acid	23	2.10	1.58	0.79	7.80
	Ammonia	18	3.33	2.43	0.42	7.52

n: a number of observations, SD: standard deviation, Min: minimum, Max: maximum

The results of the analysis using the random effect model showed that the pH, lactic acid, and ammonia of sorghum forage silage were significantly different ($p<0.01$) from the control group of maize forage silage. However, the results were not significant in the acetic acid. Effect size and heterogeneity values using the meta-analysis are presented in Table 3.

Table 3. Meta-Analysis of fermentation quality

Parameters	N	Effect size			SE	p value	Heterogeneity		Egger's test
		Estimate	LB	UB			I^2	p value	
pH	27	1.029	0.404	1.653	0.319	0.001	79.889	<0.001	0.064
Lactic acid	25	-1.174	-1.797	-0.551	0.318	<0.001	72.837	<0.001	0.728
Acetic acid	23	-0.013	-0.678	0.653	0.340	0.970	74.938	<0.001	0.762
Ammonia	18	-3.180	-4.885	-1.484	0.870	<0.001	91.088	<0.001	0.002

The model is highly significant at $p<0.01$, significant at $p<0.05$, n: a number of observations, SE: *Standard Error,* LB: *Lower Bound*, UB: *Upper Bound*

Meta-analysis showed the results were significant, the pH value of forage sorghum silage was higher with the estimated (estimate=1.029, p=0.001, I^2 =79.889). The heterogeneity test resulted in a value of I^2 >50%, which means that this study used a very diverse study and there was no publication bias as seen from the Egger's test value greater than 0.05. The effect size is positive, indicating that high pH values of forage sorghum silage. The result of pH ranged from 3.47-4.37. This value is still classified as good according to [21], which states that good silage has a pH from 3.2-4.5. The difference in pH because the protein value in sorghum silage is higher than maize, it's causing buffering capacity. High buffering capacity inhibit decrease pH [2]. Silage with high crude protein will produce a high pH. In addition, the difference in pH is related to the content of water-soluble carbohydrates and starch. The water-soluble carbohydrates (WSC) content in forage sorghum is relative low at 6.7% [24] and in maize 10.16%. High WSC content in feed ingredients provides optimal

conditions for lactic acid bacteria to increase carbohydrate fermentation into organic acids [2]. WSC is needed by bacteria in order to reduce pH to 3.5.

The meta-analysis resulted in an estimate value (Estimate = -1.174, $p<0.01$) indicating that sorghum silage contains significant lower lactic acid. This result was shown in the descriptive statistical analysis (Table 3), which was 6.29% vs 5.23%. The increase in lactic acid is in line with the decrease in pH [7]. However, the lactic acid content formed is still within the normal range according to [22] which is 3-18%.

Meta-analysis on ammonia showed an estimate value (-3.180, $p<0.001$), meaning that the experiment group was significantly lower than the control group. Based on Table 3, the ammonia content of sorghum forage silage is 3.33%. According to [15], the ammonia value of sorghum silage is low due to the content of tannin which can protect proteins from microbial degradation. The ammonia content in both types of silage treatment is classified as good because it is in the range of less than 7% total N [15], [22].

4 Conclusions

In summary, forage sorghum silage produces ideal fermentation quality, with lower ammonia, lactic acid, and acetate content compared to maize silage, but higher pH content. The fermentation quality of sorghum forage silage is still in the normal range, so sorghum forage silage can potentially substitute maize forage silage.

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