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Improvement of Nutritional Quality and In-Vitro Digestibility of Sugarcane Tops (Saccharum officinarum) as Feed through Lime Solution Treatment

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Abstract— *This study aimed to evaluate the effect of treating sugarcane tops (Saccharum officinarum) with calcium hydroxide ($Ca(OH)_2$) solution on their nutritional quality and in-vitro digestibility. The research was conducted using an experimental method with a Completely Randomized Design (CRD), consisting of four treatments: P0 (untreated/control), P1 (4% lime solution treatment), P2 (5% lime solution treatment), and P3 (6% lime solution treatment). The observed parameters included dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), nitrogen-free extract (NFE), neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose, as well as in-vitro dry matter digestibility (IVDMD) and in-vitro organic matter digestibility (IVOMD). The results indicated that the lime solution treatment had a highly significant effect ($P<0.01$) on all observed parameters. The treatment effectively reduced the structural fiber fractions (CF, NDF, ADF, and cellulose) while increasing the NFE content and the digestibility values of dry matter and organic matter. The improvement in digestibility is attributed to the loosening and partial cleavage of lignin bonds with the structural carbohydrate components of the cell wall due to the alkalization process. Based on the balance between improved nutritional composition and enhanced digestibility, the application of a 5% lime solution for a 48-hour treatment period was identified as the optimal level for enhancing the quality of sugarcane tops as a feedstuff for ruminants.*

Keywords— *Sugarcane tops, lime solution, chemical treatment, feed quality, in-vitro digestibility.*

I. Introduction

Sugarcane (*Saccharum officinarum*) is a major plantation commodity extensively cultivated in Indonesia. The total sugarcane plantation area in Indonesia has reached 409.70 hectares (Central Bureau of Statistics, 2019). During harvest, in addition to the sugarcane stalks produced for sugar production, waste in the form of sugarcane tops is obtained, with a production yield of approximately 16.05 tons per hectare (Akhadiarto, 2008). Sugarcane tops are the remaining portions of the plant after stalk harvesting, consisting of the upper stalks and leaves.

Sugarcane tops have the potential to be utilized as feed for ruminants; however, their nutritional quality is relatively low. The reported nutrient content of sugarcane tops includes 39.9% dry matter (DM), 74.0% organic matter (OM), 4.76% crude protein (CP), 42.30% crude fiber (CF), and 2.90% ether extract (EE) (Lamid et al., 2012). Furthermore, sugarcane tops contain 45.06% nitrogen-free extract (NFE) and 10.21% ash (Musofie, 1984), as well as high fiber fractions consisting of 77.1% neutral detergent fiber (NDF), 48.9% acid detergent fiber (ADF), 28.2% hemicellulose (Kuswandi, 2007), 32.0% cellulose (Susanti et al., 2020), and approximately 14% lignin (Ensminger et al., 1990). The high content of structural fiber and lignin results in low digestibility of sugarcane tops, thereby limiting their utilization as livestock feed.

Efforts to improve the quality of sugarcane tops as a feedstuff can be achieved through chemical treatments, one of which involves the alkalization process using lime solution. Alkalization with lime solution is known to loosen and degrade portions of the lignocellulosic bonds, particularly the bonds between lignin, cellulose, and hemicellulose, making the fiber fractions more accessible for digestion by rumen microbes (Iswanto et al., 2019; Amin et al., 2014). Lime is selected as an alkaline agent because it is relatively inexpensive, readily available, and safer to use compared to other strong alkaline agents.

The treatment of sugarcane tops with the addition of lime solution is expected to enhance their nutritional quality, as indicated by changes in the content of dry matter, organic matter, crude fiber, NFE, NDF, ADF, and cellulose, as well as improvements in *in-vitro* dry matter and organic matter digestibility.

II. Materials and Methods

Materials

The materials used in this study were sugarcane tops (Saccharum officinarum) in as-fed form and lime solution ($Ca(OH)_2$). The equipment utilized included digital scales, a chopper, sprayer bottles, and polybags. Additionally, a set of laboratory apparatus for feed chemical analysis and equipment for measuring in-vitro feed digestibility were employed.

Methods

This study followed an experimental method using a Completely Randomized Design (CRD). The treatments consisted of four levels:
P0: Sugarcane tops without treatment (control)

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P1: Sugarcane tops treated with 4% lime solution (w/w of sample weight)
P2: Sugarcane tops treated with 5% lime solution (w/w of sample weight)
P3: Sugarcane tops treated with 6% lime solution (w/w of sample weight)

The treatment process began by chopping the sugarcane tops to a size of approximately 1 cm. Each experimental unit utilized 500 g of sugarcane tops. $Ca(OH)_2$ was weighed according to the treatment levels and then dissolved in water at a ratio of 1:10 (w/w). The lime solution was transferred into sprayer bottles and applied evenly over the entire surface of the weighed sugarcane tops.

The treated sugarcane tops were then placed into polybags, tied tightly to prevent air entry, and stored at room temperature for 48 hours. After the treatment period, the sugarcane tops were removed from the polybags and spread out to reduce any remaining lime solution. Subsequently, samples were randomly collected for chemical composition analysis and in-vitro dry matter and organic matter digestibility testing.

Research Variables

The variables observed in this study included the content of dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), nitrogen-free extract (NFE), neutral detergent fiber (NDF), acid detergent fiber (ADF), and cellulose. Additionally, in-vitro dry matter digestibility (IVDMD) and in-vitro organic matter digestibility (IVOMD) were measured.

The analysis of DM, OM, CF, and NFE content was conducted according to the AOAC (1980) methods. The measurement of fiber fractions, including NDF, ADF, and cellulose, followed the Van Soest (1970) method. Meanwhile, in-vitro dry matter and organic matter digestibility were measured using the Tilley and Terry (1963) method.

Data Analysis

The data obtained were analyzed using Analysis of Variance (ANOVA) in accordance with the experimental design. If the results indicated significant effects among treatments, the analysis was followed by the Least Significant Difference (LSD) test to determine the differences between treatments.

III. Results and Discussion

The results of the study regarding the quality of sugarcane tops treated with lime solution are presented in Table 1.

TABLE 1. Nutritional Quality of Sugarcane Tops under Lime Solution Treatment

Variable	P0	P1	P2	P3
BK (%)	88,79	88,60	88,56	88,40
BO (%)	86,10^{a}	90,71^{b}	94,71^{c}	98,97^{d}
PK (%)	4,47^{a}	5,94^{b}	7,04^{c}	7,21^{c}
SK (%)	39,19^{d}	35,88^{c}	33,82^{b}	30,29^{a}
BETN (%)	47,69^{a}	49,95^{b}	51,31^{c}	53,41^{d}

Note: Means in the same row with different superscripts (a–d) differ significantly (P<0.01).

Based on the research results presented in Table 1, the treatment of sugarcane tops with the addition of lime solution had a highly significant effect (P<0.01) on nutritional quality. The dry matter (DM) content exhibited a declining trend as the concentration of the lime solution increased. This reduction in DM is likely associated with the increased moisture content resulting from the addition of the lime solution during the treatment process.

The treatment also had a highly significant effect (P<0.01) on the organic matter (OM) content of the sugarcane tops. The OM content increased alongside the rising concentration of the lime solution. This increase is suggested to occur due to the relative decrease in the ash fraction compared to organic matter, as well as structural changes in the cell walls that cause the organic fraction to become more dominant within the dry matter.

Crude protein (CP) content significantly increased (P<0.01) following the lime solution treatment. This increase in CP is relative, potentially caused by the reduction in fiber fractions and the subsequent concentration of other nutrients within the dry matter, rather than the addition of nitrogen from the lime solution itself. The measurement of crude fiber (CF) showed a highly significant decrease (P<0.01) due to the treatment. This decline in CF content indicates that the alkalization process with lime solution is effective in reducing the structural fiber fractions of sugarcane tops. According to Saha (2003), alkaline treatment with lime solution is capable of cleaving portions of the bonds between lignin, cellulose, and hemicellulose, as well as disrupting lignin–silica bonds, thereby creating a more accessible cell wall structure. The loosening and degradation of these lignin bonds allow the fiber fractions to be more easily degraded, which is reflected in the decreased crude fiber content of the sugarcane tops.

The nitrogen-free extract (NFE) content experienced a highly significant increase (P<0.01) as the lime solution concentration increased. The rise in NFE indicates an increase in the non-structural carbohydrate fraction, which is potentially more fermentable by rumen microorganisms; thus, it is expected to enhance the energy value of sugarcane tops as a ruminant feedstuff. The contents of nitrogen-free extract (NFE), neutral detergent fiber (NDF), acid detergent fiber (ADF), and cellulose in this study were all highly significantly affected (P<0.01) by the treatment of sugarcane tops with various concentrations of lime solution.

TABLE 2. Fiber Fractions and In-Vitro Digestibility of Sugarcane Tops under Lime Solution Treatment

Variable	P0	P1	P2	P3
NDF (%)	70,37^{d}	63,03^{c}	53,75^{b}	50,21^{a}
ADF (%)	59,29^{c}	53,38^{b}	43,98^{a}	46,17^{a}
Selulosa (%)	50,63^{d}	44,91^{c}	40,21^{b}	37,92^{a}

Note: *Means in the same row with different superscripts (a–d) indicate highly significant differences (P<0.01).*

The NDF content of sugarcane tops significantly decreased (P<0.01) as the concentration of the lime solution applied during the treatment process increased. The lowest NDF reduction was observed in the P3 treatment, indicating that the alkalization process was able to disrupt the plant cell wall structure and reduce the structural fiber fraction. According to Pina et al. (2009), the incubation process with alkaline agents

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induces structural changes in the cell wall carbohydrates, making the fiber fractions more susceptible to degradation by rumen microorganisms.

The ADF content also exhibited a highly significant decrease ($P<0.01$) due to the treatment. The decline in ADF is suggested to be related to the loosening and partial cleavage of lignin–cellulose bonds during the alkalization process. Maharani et al. (2015) stated that alkaline treatments at specific concentrations can enhance reaction temperatures and accelerate the degradation of lignocellulosic bonds, thereby reducing crude fiber and ADF fractions.

The cellulose content of sugarcane tops showed highly significant differences ($P<0.01$) among treatments, with a downward trend as the lime solution concentration increased. This decrease in cellulose content is presumably caused by the enhanced release of cell wall components during the treatment period. According to Ni'mah et al. (2014), the release of cell wall constituents increases with prolonged contact between the material and heat or alkaline solutions, resulting in a more accessible and degradable cellulose structure.

The reduction in NDF, ADF, and cellulose fractions in this study demonstrates that the lime solution treatment is effective in lowering the structural fiber components of sugarcane tops, which subsequently has the potential to enhance digestibility and nutrient utilization by ruminants.

TABLE 3. In-Vitro Dry Matter and Organic Matter Digestibility of Sugarcane Tops under Lime Solution Treatment

Variable	P0	P1	P2	P3
KcBK (%)	55,98[a]	56,86[a]	61,84[b]	64,96[b]
KcBO (%)	30,66[a]	36,27[b]	41,25[c]	44,36[d]

Note: *Means in the same row with different superscripts (a–d) indicate highly significant differences ($P<0.01$).*

The results demonstrated that the treatment of sugarcane tops with the addition of lime solution had a highly significant effect ($P<0.01$) on both *in-vitro* dry matter digestibility (IVDMD) and *in-vitro* organic matter digestibility (IVOMD). Both IVDMD and IVOMD values increased alongside the rising concentration of the lime solution utilized during the treatment process.

The improvement in dry matter digestibility of sugarcane tops was clearly observed in the P2 and P3 treatments, which exhibited higher IVDMD values compared to the control and P1 treatments. Although the highest IVDMD value was numerically obtained in the P3 treatment, the P2 treatment already showed a significant increase in digestibility, thus being considered biologically effective in enhancing the digestibility of sugarcane tops.

Organic matter digestibility (IVOMD) also experienced a highly significant increase ($P<0.01$) with the increasing concentration of lime solution. This enhancement in IVOMD is closely related to the reduction of structural fiber fractions (NDF, ADF, and cellulose) due to the alkalization process, which rendered the organic matter fractions more accessible for digestion by rumen microorganisms.

The positive impact of the treatment process on the increase of dry matter and organic matter digestibility is suggested to be caused by the loosening and partial cleavage of lignin bonds with the structural carbohydrate components in the cell walls of sugarcane tops. According to Setyono et al. (2009), treatment with the addition of lime solution is capable of increasing feed digestibility and suppressing fungal growth in feed materials. With the improved digestibility values, the treated sugarcane tops possess better potential for utilization as ruminant feed.

IV. Conclusion and Recommendations

Conclusion

The treatment of sugarcane tops using lime solution is proven to enhance the nutritional quality and digestibility of sugarcane tops as a ruminant feedstuff. The alkalization process with the addition of lime solution had a highly significant effect on reducing structural fiber fractions and increasing the nitrogen-free extract (NFE) content, as well as improving *in-vitro* dry matter and organic matter digestibility. Based on the research results, the application of a 5% lime solution demonstrated the most optimal results in enhancing the quality of sugarcane tops, considering the balance between improved nutritional composition and increased digestibility. Therefore, this concentration is considered effective and efficient for implementation as a feed treatment method.

Recommendations

To improve the quality of sugarcane tops as a ruminant feedstuff, it is recommended to process the material through a 48-hour treatment using a 5% lime solution (w/w). Further research is suggested to evaluate intake response, palatability, and ruminant performance to support the field application of these findings.

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Badat Muwakhid, Umi Kalsum, and Djoko Subagyo, "Improvement of Nutritional Quality and In-Vitro Digestibility of Sugarcane Tops (Saccharum officinarum) as Feed through Lime Solution Treatment," *International Research Journal of Advanced Engineering and Science*, Volume 11, Issue 1, pp. 98-101, 2026.

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Badat Muwakhid, Umi Kalsum, and Djoko Subagyo, "Improvement of Nutritional Quality and In-Vitro Digestibility of Sugarcane Tops (Saccharum officinarum) as Feed through Lime Solution Treatment," *International Research Journal of Advanced Engineering and Science*, Volume 11, Issue 1, pp. 98-101, 2026.