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Research Article
Nutritional Value of a Banana Stem (*Musa paradisiaca* Val) of Anaerobic Fermentation Product Supplemented With Nitrogen, Sulphur and Phosphorus Sources

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Abstract
Background and Objective: The banana plant (*Musa paradisiaca* Val) is a popular type of fruit crop that is widely spread throughout the tropics, including Indonesia. In addition to producing fresh and processed fruit, the banana plant has the potential to be used as feed for animals such as sheep. This study aimed to determine the nutritional value of a banana stem of anaerobic fermentation product supplemented with nitrogen (N), sulphur (S) and phosphorus (P). **Methodology:** Research was carried out using the experimental method and a completely randomized design. Different levels of N, S and P used were as follows: NSP-A (2.00% N+0.20% S+0.20% P), NSP-B (2.00% N+0.30% S+0.20% P), NSP-C (2.00% N+0.40% S+0.20% P), NSP-D (3.00% N+0.20% S+0.25% P), NSP-E (3.00% N+0.30% S+0.25% P) and NSP-F (3.00% N+0.40% S+0.25% P). Each treatment was repeated four times. The data obtained were processed using statistical analysis of variance tests followed by Duncan's multiple range tests. **Results:** Supplementation with a combination of N, S and P had no significant effect ($p>0.05$) on water content, dry matter, organic matter, crude fat, crude fiber or material extract without nitrogen and ash: However, there was a significant difference ($p<0.05$) in crude protein content. **Conclusion:** Supplementation with a combination of 3.00% N+0.40% S+0.25% P produced the highest protein content (8.98%).

Key words: Banana stem, aerobic fermentation, nitrogen, phosphorus

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The banana plant (*Musa paradisiaca* Val) is a popular type of fruit crop that is widely spread throughout the tropics, including Indonesia. In addition to producing fresh and processed fruit, the banana plant has the potential to be used as feed for animals. Parts of the banana plant, such as the leaves, young plant, rejected fruit and stems, can be used as fodder for ruminants, particularly cattle, sheep, goats and buffalo. Byproducts of the banana plant, such as leaves, tillers and stems, can produce 11.20 t ha^{-1} [1] of dry matter. In Indonesia, there are 74,751 million ha of land for banana plantations, with a production capacity reaching 2,192,060 t/year[2]. The production capacity of some banana-producing countries in the world, such as India and the Philippines, have reached 3.65 and 4.60 million t, respectively, while the world banana production has reached 65.90 million t[3].

The nutrient content of banana stems varies, as dry matter content ranges from 3.60-9.80%, crude protein ranges from 2.40-8.30%, crude fat ranges from 3.20-8.10%, extract material without nitrogen range from 31.60-53.00%, ash ranges from 18.4-24.70%, crude fiber ranges from 13.40-31.70%, neutral detergent fiber ranges from 40.50-64.10%, acid detergent fiber ranges from 35.60-45.50%, cellulose ranges from 19.70-35.20%, hemicellulose ranges from 4.90-18.70% and lignin ranges from 1.3-9.20%[3]. One type of banana plant grown by the community includes Ambon green bananas, these banana plant stems contain 12.99% dry matter, 4.07% crude protein, 3.80% crude lipid, 36.33% crude fiber, 47.21% material extract without nitrogen and 8.59% ash[4].

Based on the content of contained nutrients in banana trees, parts of this plant can be used as animal feed, especially for ruminants. However, the use of banana stem as feed for ruminants has not been optimized due to constraints, such as the perishability of high water content, the tannins in the banana stem compounds that may affect consumption and the binding protein that could reduce the quality and efficiency of feed. Banana stem tannin content, based on to the results of chemical analysis, vary depending on the type of banana plants and can reach 4.96 mg mL^{-1} of water fraction[3].

Based on the large biomass potential of the banana plant, efforts should be made to optimize its utilization despite limitations. Anaerobic fermentation technology can be used to prevent the decay process as well as reduce tannin compounds. The addition of chemical compounds as a source of nitrogen, sulphur and phosphorus can increase the utility of the food substances. The addition of several chemical compounds can also enhance the nutritional content of the stems, particularly crude protein that is naturally present in very small quantities. This study aimed to determine the nutritional value of a banana stem of anaerobic fermentation product supplemented with nitrogen (N), sulphur (S) and phosphorus (P).

MATERIALS AND METHODS

Research materials: The research materials consisted of stems of banana plants obtained from Pasirlaja, Cijeruk, Pamulihan, Sumedang. Molasses and nitrogen sources (urea) were obtained from KSU Tandangsari, Tanjungsari, Sumedang, while sources of sulphur (Na_2SO_4) and phosphorus (KH_2PO_4) were obtained from PT BRATACO in Kelenteng street, Bandung.

The main tool used in this study was a silo made of a plastic drum with a capacity of 60 L, which was used to examine the content of nutrients contained in the banana stem of the anaerobic fermentation products. Additional tools needed include a forage chopper, scales and a measuring volume.

Research methods: The study was conducted using experimental methods with a completely randomized design. The treatments being tested included anaerobic fermentation of banana stem with combined supplementation sources of nitrogen (2 and 3%), sulphur (0.20, 0.30 and 0.40%) and phosphorus (0.20 and 0.25%), as follows: NSP-A (2.00% N+0.20% S+0.20% P), NSP-B (2.00% N+0.30% S+0.20% P), NSP-C (2.00% N+0.40% S+0.20% P), NSP-D (3.00% N+0.20% S+0.25% P), NSP-E (3.00% N+0.30% S+0.25% P) and NSP-F (3.00% N+0.40% S+0.25% P). Each treatment was repeated four times. Parameters were measured to determine the response from the treatment being tested, including water content, dry matter, organic matter, crude protein, fat, crude fiber, material extract without nitrogen and ash[5]. The obtained data were analyzed using one-way analysis of variance followed by Duncan's multiple range tests[6,7]. Differences of $p<0.05$ were considered statistically significant.

The process of anaerobic fermentation of the banana stem supplemented with combinations of nitrogen, sulphur and phosphorus were conducted in five stages as follows: (1) Chopped banana stems (2-5 cm) weighing as much as 60 kg were appropriated with silo capacity and used for anaerobic fermentation, (2) Weight molasses weighing as much as 5% of the weight of a banana stem was fermented, a source of nitrogen (urea), sulphur (Na_2SO_4) and phosphorus (KH_2PO_4) were added and stirred evenly, (3) Banana stems were flushed with a mixture of molasses, a source of nitrogen and phosphorus and stirred until smooth, (4) At each stage of the fermented material revenues, the mixture was poured gradually into a silo in the form of plastic barrel (capacity of 60 kg) to eliminate air as much as possible and (5) After a silo was filled with fermented feed material, it was closed and stored for 21 days.

RESULTS AND DISCUSSION

The water content of the fermented product of the banana stems was relatively high, at approximately 90.30-90.87%. According to Wina[3] the water content of banana stems in fresh conditions range from 75.70-82.50%. Dhalika *et al*.[4], showed that part of the banana stem has a very broad variety of food composition, such that water content is very high, especially on the banana stem that ranged from 87.01-94.11%. The high water content in the product of anaerobic fermentation banana stems did not cause changes to the content of other nutrients, since these nutrients were stable under the acidic conditions produced by the anaerobic fermentation process.

According to McIlroy *et al*.[8], incomplete emphasis on the process of anaerobic fermentation (*ensilase*) can cause excessive respiration and overheating, which results in a loss of dry matter, conversely, excessive emphasis on the feed material with a high water content can cause reduced heating, thus resulting in bad odors from the fermented products. Furthermore, to create fermented (*ensilase*) products, preservatives are needed under conditions with high water content to serve as a fermentation accelerator.

Supplementation with a combination of nitrogen, sulphur and posphorus did not effect the dry matter or products of the anaerobic fermentation of the organic banana stems, as dry matter and organic matter ranged from 9.13-9.75% and 84.42-85.70%, respectively. According to Wina[3] the dry matter content of fresh banana stems range from 3.60-9.80%. The banana stem was a feed material with high water content (Table 1). The dry matter and organic matter did not differ significantly among treatments, such that the process of anaerobic fermentation did not change the content of dry or organic matter.

According to Widyastuti[9] certain factors must be considered in the process of anaerobic fermentation. As in the production of silage and producing acid, there are less nutrients loss because lactic acid bacteria are needed to ensure the success of anaerobic fermentation, naturally, lactic acid bacteria is found in forage crops.

Supplementation with a combination of nitrogen, sulphur and posphorus significantly ($p<0.05$) increased the crude protein content of fermentated products in anaerobic fermentation. Crude protein content ranged from 6.29-8.98% and the crude protein content of fresh banana stems ranged from 2.40-8.30%[3]. Crude protein content of banana stems of two types of plants, green and white bananas are 4.07 and 5.33%, respectively[4]. Between 3-4% increase (Table 1) was observed in the crude protein content of the banana stems due to the addition of a nitrogen source in the form of urea or $CO(NH_2)_2$. Urea is a nitrogen compound, not a protein, which can be classified as an additive to increase the protein content of feed materials. According to McDonald *et al*.[10], the addition of urea may increase the nitrogenous components of silage, such as crude protein, pure protein, free amino acids and ammonia. The addition of urea not only produced a dual effect on the formation of the pure protein but also occurred during microbial protein synthesis. The results of a study conducted by Lessard *et al*.[11] and cited by McDonald *et al*.[10] showed that the addition of urea increased some types of amino acids, such as alanine, aspartic acid, glutamic acid, isoleucine, lysine, threonine and valine. According to NRC[12] the addition of urea as a nitrogen source is utilized by microbes in the synthesis of proteins. According to Yunus *et al*.[13], combined supplementation of 5 and 0.60% urea molasses improves the nutritional quality and fermented of grass harvested at a young age and increase the nitrogen content in silage.

The addition of nitrogen and sulphur tended to increase the crude protein content indicated in the treatments NSP-A,

Table 1: Nutrient content of the fermentation product made from anaerobic banana stems

	Treatments					
Nutrients (%)	NSP-A	NSP-B	NSP-C	NSP-D	NSP-E	NSP-F
Water	90.87^a	90.30^a	90.79^a	90.31^a	90.55^a	90.33^a
Dry matter	9.13^a	9.75^a	9.18^a	9.68^a	9.44^a	9.66^a
Organic matter	84.42^a	85.62^a	84.76^a	85.70^a	84.91^a	85.57^a
Crude protein	6.29^a	6.49^a	6.47^a	8.57^b	8.37^b	8.98^b
Rough fat	1.21^a	1.20^a	1.20^a	1.14^a	1.07^a	1.32^a
Crude fiber	23.39^a	23.18^a	22.67^a	22.88^a	22.56^a	23.36^a
Extracted materials without nitrogen	53.48^a	54.71^a	54.39^a	53.09^a	52.90^a	52.75^a
Ash	15.37^a	14.38^a	15.26^a	14.29^a	15.08^a	14.42^a

Values are means and different superscripts in the same row are significantly different ($p<0.05$)

NSP-B and NSP-C compared to the treatments NSP-D, NSP-E and NSP-F (Table 1). In addition, posphorus supplementation also increased crude protein content, especially in the supplementation source of lower nitrogen and sulphur, while the supplementation sources of higher nitrogen and sulphur inconsistently increased the crude protein content.

Molasses, available as a carbohydrate compound, can be used as a source of carbon frame for the formation of adenosine triphosphate, which is an important energy source needed for enzymatic reactions, such as the formation of glycogen from glucose and acts as an energy source in microbial protein synthesis, phosphorus ions were one of its constituent elements. In addition, phosphorus formed phosphoprotein, an acid compound that was bound in the form of phosphate ester on radical residues of amino acid serine or threonine of constituent simple protein. Thus, greater phosphorus supplementation can increase the protein content of fermented products. Supplemental nitrogen, sulphur and phosphorus aimed to supply the nutrients in the formation of microbial protein. According to Kung[14] to stimulate good fermentation, various additives must be added to improve the nutrients that might be lost during the process of anaerobic fermentation (*ensilage*).

Sulphur is an important element that affects fermentation and is required as a precursor for the synthesis of essential amino acids such as methionine and cysteine. According to Dervish and Sukara[15], sulphur sources that can be used in the synthesis of amino acids and proteins include inorganic sulphur, such as magnesium sulphate or disodium sulphate. Underwood and Suttle[16] reported that sulphur is only important for plants and microbes because only plants and microbes are able to synthesize amino acids and proteins containing sulphur from inorganic sulphur that can be degraded. According to Erwanto[17] methionine is a component of a compound called metionine formyl transfer RNA that is required at the initial phase of protein synthesis in the microbial cell. Thus, microbial protein synthesis occurs more frequently such that microbial population increases, leading to higher nitrogen requirements, inorganic nitrogen added can be converted into a microbial body protein.

Supplementation with a combination of nitrogen, sulphur and posphorus had no significant effect on the content of crude lipid, crude fiber, extract material without nitrogen and ash of fermented products of banana stems. Substances of fermented food products did not indicate variation compared to the banana stems under fresh conditions. According to Wina[3] and Dhalika *et al.*[4], banana stems under fresh conditions include 3.3-8.1% crude fat, 13.40-31.70% crude fiber, 31.60-53.00% extract materials without nitrogen and 18.40-24.00% ash.

The crude fat, crude fiber, material extract without nitrogen and ash of the fermented products with supplementation of nitrogen, sulphur and phosphorus did not change the product, suggesting that the nutritional content of the food was in a stable condition because the acid situation of almost all bacteria that could affect the food substances did not develop. According to McIlroy *et al.*[8] and McDonald *et al.*[10], acidity can prevent unexpected fermentation, for example, in butyric acid fermentation, butyric acid-forming bacteria will stop the growth at a pH of about 4.2 and butyric acid content that was inside anaerobic fermentation products (*ensilase*) must not exceed 0.10%. According to Widyastuti[9] fermentation can produce lactic acid as the main product because the lactic acid will act as a preservative in the feed material. McIlroy *et al.*[8], reported that the lactic acid content in aerobic fermentation products, such as silage, ranged from 1.55-2.5%. Under this condition, the stability of the nutrients was achieved in the fermented feed material.

CONCLUSIONS

Supplementation with a combination of nitrogen, sulphur and posphorus did not affect water content, dry matter, organic matter, crude fat, crude fiber, material extract without nitrogen or ash, however, it did increase the crude protein content of the fermented product. Supplementation with a combination of 3.00% nitrogen+0.40% sulphur+0.25% phosphorus produced the highest protein content, which was 8.98%, with an increase in crude protein content that reached at 4.91% compared to the fresh conditions.

SIGNIFICANCE STATEMENT

This study discovered the possible synergistic effect of supplementation with a combination of nitrogen, sulphur and phosphorus on anaerobic fermentation in banana stems that can be beneficial to increase protein content. This study will help researchers to find the appropriate combinations for optimal products. Thus, a new theory on these combinations and possibly other combinations, may be explored further.

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