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(Research Article)

Dry matter loss, nitrogen fixation, and carbohydrate content of urea cooking products with banana corm flour as a slow-release urea supplement

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Abstract

This study evaluates dry matter loss, nitrogen fixation, and carbohydrate content of urea cooking products with banana corm flour as a slow-release urea supplement. This product results from cooking banana corm flour using a conventional cooking system and a stove. The treatments were: no urea (P0), 2% (P2), 4% (P4), and 6% (P6) urea levels. The study was designed in a completely randomized design with 4 treatments and 4 replications. The data were analyzed using analysis of variance (ANOVA) and continued with Duncan's multiple range test. The results showed that the treatment of urea level ($P<0.01$) significantly affected dry matter loss, nitrogen fixation, and carbohydrate content. It was concluded that the use of urea at the level of 6% in cooking with banana corm flour produced a cooking product with superior characteristics for fermentation in the rumen which was able to reduce dry matter loss, and increase nitrogen.

Keywords: Dry matter loss; Nitrogen fixation; Carbohydrate content; Urea; Banana corm flour; Slow-release urea product

1. Introduction

Increasing the availability of protein and nitrogen in ruminant feed is one of the important focuses in the field of animal husbandry. In the tropics, nitrogen (N) deficiency in crops can occur during the dry season [1]. Supplying additional crude protein to supplement low-quality forages can improve livestock performance in these areas. In addition, the use of urea as a non-protein nitrogen source is often practiced, but the main drawback of urea is its high decomposition speed in the rumen, which can cause toxicity [2]. Slow microbial growth and degradation processes in the rumen can rapidly increase ammonia, resulting in a loss of nitrogen necessary for microbial growth and protein production [3]. One of the challenges in high-producing ruminants is to harmonize energy and nitrogen (N) availability in the rumen in a way that microbes can capture the value of both feed components [4]. The use of slow-release urea (SRU) is expected to address this issue through the gradual release of nitrogen [5]. According to Goulart et al. [6], SRU products can effectively improve the utilization of nitrogen degradation by rumen microorganisms enhance the ability of rumen microbes to synthesize protein, and can be used as a better NPN feed.

SRU products make an important contribution to the improvement of ruminant feed quality and offer a practical solution for safer and more effective urea use. The positive impact of slow-release NPN outweighs potential changes in microbial protein synthesis and nutrient digestion [7]. The efficient use of urea as an N source depends on the fermentability of carbohydrates by rumen microbes for microbial protein synthesis. Efforts have therefore long been made to develop forms of urea that degrade more slowly in the rumen, with the hope of increasing the incorporation of ammonia into the microbial population and reducing the excretion of urea in the urine.

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Banana corm is the original stem of the banana plant that grows underground and is sometimes called a tuber or rhizome [8]. Banana corm is usually left in the field after the banana fruit is harvested and is classified as waste, with a potential production of about 40% [9]. Banana corm contains the following nutrients, dry matter 91.56%; CP 1.72%; CF 7.98%; EE 1.15%; Carbohydrate 88.16% [10]. The use of banana corm flour as an energy source combined with urea and cooked or heated together is thought to produce a product with a slow release of ammonia and improve the synchronization of the two ingredients. Through the cooking process, gelatinization of banana corm flour occurs and slows the degradation of carbohydrates while increasing the efficiency of urea utilization.

According to Soeharsono [11], through the gelatinization process, the entry of water molecules into the starch granules will be accompanied by the entry of soluble protein molecules into the gel structure, so that the protein molecules are trapped in the starch granules. It was hypothesized in this study that the use of urea levels in cooking with banana corm flour would result in a product that is efficient and effective in its nutritional content. Based on this, this study aimed to evaluate the product of urea cooking with banana corm flour in terms of dry matter loss, nitrogen fixation, and carbohydrate content. This study is the first study to use local feed banana corm flour as a source of easily fermentable carbohydrates combined with urea to obtain a slow-release urea product, previously the authors [12] tested the use of gewang (*Corypha utan* Lamk.) stem contents flour as a source of easily fermentable energy combined with urea to obtain a slow-release urea product and the results were quite significant for the growth of Balinese cattle.

2. Materials and Methods

Fresh banana corm was obtained from local farmers in the area around Kupang City, East Nusa Tenggara province, Indonesia. The banana corm was taken from the kepok banana species (*Musa paradisiaca*). The banana corm was chopped into thin slices and then ground with 50 and 100 mesh sieves to obtain banana corm flour with a small particle size [13].

The slow-release urea product is the result of cooking banana corm flour as a carbohydrate source with urea at different levels. The cooking was done naturally using a stove heater. The level of urea in this experiment was determined as 0%, 2%, 4%, and 6% of the total dry matter of banana corm flour. The cooking time was 60 minutes [14]. The treatments applied were:

- P0: Cooking banana corm flour without mixing with urea (0%)
- P1: Banana corm flour with 2% urea
- P2: Banana corm flour with 4% urea
- P3: Banana corm flour with 6% urea

The procedure for implementing the treatments is as follows:

- Banana corm flour (hereinafter referred to as carbohydrate source) was analyzed for dry matter content and weighed as much as 300 grams using an electronic scale type ABJ 220-4.
- The urea level was determined based on the dry matter content of the carbohydrate source. Urea was weighed using a KERN brand digital balance, 220 g capacity; e = 1 mg; min..: 10 mg; d: 0.1 mg.
- Water content was determined to be 60% of the sample amount of the urea and carbohydrate source mixture.
- The specified amount of urea is mixed with water in a stirrer container and then stirred using a Stuart brand stirrer machine, SB 162.
- The carbohydrate source was then mixed with the urea solution into a dough.
- The mixture was then put in a container (Bell brand HDPE plastic) and placed in a cooking container. Water was brought to a boil before cooking began.
- The dough in HDPE plastic is placed in the cooking container when the water has boiled, and cooking begins.
- After reaching the specified time (60 minutes), the samples were removed and cooled in water for 10 minutes.
- The samples were then dried in the sun until the texture was dry.
- The cooking product samples were then ground in preparation for further analysis.

2.1. Measured variables

2.1.1. Dry matter loss of cooked product

Dry matter loss was obtained by calculating the difference between the dry matter of the mixture before cooking and the dry matter of the cooked product.

with the formula:

$$\text{Dry matter loss (\%)} = \frac{A - B}{A} \text{x } 100\%$$

Where:
A = Dry matter of material before cooking (g)
B = Dry matter of cooking product (g)

2.1.2. Nitrogen (N) Fixation of Cooking Products.

Nitrogen fixation was obtained by analyzing the nitrogen content of the cooking product using the Kjeldahl method according to AOAC [15].

2.1.3. Carbohydrate Content (Starch, Amylose, Amylopectin).

Starch, amylose, and amylopectin were analyzed using AOAC (15) procedures.

2.1.4. NDF, ADF, and Cellulose content.

Analysis of NDF, ADF, and cellulose content using the analysis conducted by Van Soest et al. (16).

2.2. Statistical Analysis

Measurement data were tabulated according to the analysis of variance in a completely randomized design (CRD) and if there was an effect of treatment on the parameters, it was followed by Duncan's multiple range test to test for differences between treatments [17].

3. Results and Discussion

3.1. Dry Matter Loss and Nitrogen Fixation

The average dry matter loss due to cooking treatment and urea level in the combined urea-corm flour product produced is shown in Table 1.

Table 1 Average Dry Matter Loss and Nitrogen Fixation in Urea-Cooking Products with Banana Corm Flour (%)

No.	Nutrien	Treatments				SE	P-value
		P0	P2	P4	P6		
1.	Dry Matter	33.356 ± 0.899^{c}	32.802 ± 0.416^{c}	31.010 ± 0.150^{b}	29.842 ± 0.945^{a}	0.810	0.01
2.	Nitrogen	54.518 ± 0.266^{a}	64.355 ± 1.157^{b}	73.136 ± 0.331^{c}	79.500 ± 0.652^{d}	5.428	0.01

The results showed that the increasing level of urea in cooking with banana corm flour decreased the dry matter loss of cooking products. The results of the analysis of variance showed that the treatment had a very significant effect (P<0.01) on the dry matter loss of the cooking product. Heating is an important step in preparing starch-based products, as it will affect product quality due to gelatinization and starch degradation [18]. The results showed that the increasing level of urea in cooking with banana corm flour decreased the dry matter loss of cooking products when starch molecules are heated in excessive water, the semi-crystalline structure will be broken and water molecules will be bound by hydrogen bonds with the hydroxyl groups of the amylose and amylopectin molecules [19]. When the urea level is increased from 0% to 6%, there is an increase in more efficient crude fiber decomposition, which can help reduce dry matter losses. This happens because the ammonia produced from urea works to soften and break down the fiber components, so more of it remains in a usable form after cooking. Levels of urea up to 6% can still inhibit the rate of dry matter loss from getting smaller at a cooking time of 1 hour. In this study, urea levels of 4% (P4) and 6% (P6) were significantly lower in dry matter loss than the use of 2% urea (P2) and no urea (P0).

The results showed that increasing the level of urea in cooking with banana corm flour resulted in increased fixation nitrogen in the cooking product. The fixation nitrogen (N) due to 1-hour cooking of the mixture of urea with banana corm flour was significantly affected (P<0.01) by the level of urea used. The higher the level of urea, the higher the product N fixation. According to Bartley and Deyoe [20], such as the process of urea extraction with starch where urea in the form of a crystalline structure turns into non-crystalline and is found in gelatinized starch. Increased levels of urea in products cooked with banana corm flour can improve nitrogen fixation through various chemical reactions involving urea decomposition and interactions with organic components. This product has great potential to be used as an efficient nitrogen supplement for ruminants. The use of urea at 6% level (P6) showed the highest nitrogen fixation. This is beneficial as the release of energy and carbon skeletons from starch will coincide with urea hydrolysis and the synchronization of the release rates of the two products will result in optimal ammonia utilization.

3.2. Starch, Amylose, and Amylopectin Content

The average carbohydrate content (starch, amylose, and amylopectin) of urea-cooked banana corm starch products is listed in Table 2.

Table 2 Average Content of Starch, Amylose, and Amylopectin of Urea-Cooking Product-Banana Corm Starch according to Urea Level Treatment

Nutrien (%)	Treatments				SE	P-value
	P0	P2	P4	P6		
Starch	48.950±0.109^{a}	47.580±0.075^{b}	47.350±0.145^{c}	46.390±0.128^{d}	0.528	0.01
Amylose	12.045±0.031^{a}	14.775±0.021^{b}	15.250±0.044^{c}	15.320±0.044^{d}	0.777	0.01
Amylopectin	36.905±0.141^{a}	32.805±0.065^{b}	32.100±0.113^{c}	31.070±0.091^{d}	1.279	0.01
NDF	77.999±0.120^{a}	74.440±0.184^{b}	73.169±0.309^{c}	72.118±0.815^{d}	1.272	0.01
ADF	25.611±0.523^{a}	24.393±0.351^{b}	23.854±0.061^{c}	23.614±0.108^{c}	0.445	0.01
Selulosa	16.442±0.274^{a}	15.626±0.257^{b}	15.272±0.315^{b}	15.256±0.078^{b}	0.278	0.01
amilosa: amilopektin	0.33	0.45	0.48	0.49		

Notes: Different superscripts in each treatment of each parameter indicate significant differences (P<0.05) after testing with Duncan's test.

The data in Table 2 shows that as the urea level in urea-banana corm flour cooking increases, the cooking product has a decreased starch and amylopectin content, while the amylose content has increased. The decrease in starch and amylopectin content in urea-cooked products with banana corm flour as the urea level increases from 0 to 6 percent may be due to several chemical and physical processes that affect the starch structure during cooking. Overall, the decrease in starch and amylopectin content as urea content increases from 0% to 6% can be explained by chemical degradation reactions, increased solubility, and changes in starch structure due to urea interaction, especially under heating conditions. Urea is a nitrogenous compound that can affect starch structure. At elevated levels, urea may act as an agent that breaks down the molecular structure of starch, especially when used under heating (cooking) conditions. At high levels of urea, the heating process can trigger a chemical degradation reaction of starch, causing the starch molecules to break down into smaller molecules. This degradation process results in a decrease in the total starch content and its amylopectin component.

Urea, especially at high concentrations, can alter the three-dimensional structure of starch. This can lead to denaturation or breakage of the hydrogen bonds that maintain the stability of the starch structure, eventually leading to a decrease in the starch content in its intact form. Urea can also break down the branches of amylopectin into simpler parts. When amylopectin is broken down, the overall amylopectin content in banana corm flour can decrease, as this branched structure is more susceptible to breakage compared to amylose. In some cases, urea can increase the solubility or water solubility of starch. While this helps in accelerating the gelatinization process, it can also lead to the loss of some of the soluble starch during cooking or further processing.

Increasing the urea level from 0 to 6% in cooking with banana corm flour caused the amylose content of the product to increase. This occurs because urea tends to break down the more branched amylopectin, while the more stable amylose remains intact. This process causes a change in the ratio between amylopectin and amylose, where the amylose content becomes dominant in the final product. The starch in banana corm flour has semi-crystalline properties, where amylose and amylopectin contribute to the crystalline and amorphous structures, respectively. Urea can affect the crystalline phase in starch [21] especially the part rich in amylopectin. With increasing urea, these crystalline phases can be degraded, resulting in more amylose remaining in a more stable amorphous structure. This also explains why the final product shows an increase in amylose content. The results of Gamarano et al. [22] showed that if the urea content in the plasticizer system is higher, the amount of crystalline phase in the thermoplastic starch obtained will be smaller. The study confirmed the effectiveness of urea as a starch plasticizer.

The data in Table 2 also shows that the amylose to amylopectin ratio of the cooking product increases with increasing urea levels. This is probably because large amounts of urea can break the branch bonds in the amylopectin structure so that more amylopectin molecules are degraded or hydrolyzed. This leads to a decrease in amylopectin concentration in the final product. In addition, amylose, which tends to be more structurally stable, is not affected by urea addition and heating treatment as much as amylopectin. As amylopectin is reduced, the amylose content relatively increases, although the absolute amount may remain constant.

The decrease in NDF and ADF content in the product of urea cooking with banana corm flour was significantly influenced by the level of urea (0%, 2%, 4%, 6%). This is due to the decomposition of cellulose and hemicellulose components by ammonia formed from urea. The higher the urea concentration, the greater the decomposition effect, leading to an overall decrease in crude fiber content. Urea, when hydrolyzed in water, will form alkaline ammonia. This ammonia can help soften the structure of plant cell walls, especially the fibers found in banana corm flour. This causes the lignin-cellulose bonds that usually make the fiber indigestible to break down more easily. As the urea level increased (from 0% to 6%), this breakdown process became more effective, leading to a decrease in NDF and ADF content.

NDF measures crude fiber components such as hemicellulose, cellulose, and lignin, while ADF only measures cellulose and lignin. With urea treatment, some of the more soluble hemicellulose is also broken down and separated from the cell wall structure, which contributes to the decrease in NDF. ADF also decreases as cellulose is broken down by ammonia and slowly decreases cell wall stiffness. With the addition of higher concentrations of urea, the effect of softening and decomposing fibers becomes more intensive, so that the crude fiber content (NDF and ADF) in the final product decreases. At the 0% level, there is no urea effect, so NDF and ADF tend to be higher, but with the addition of 2%, 4%, and 6% urea, the degradation effect on fiber is more significant. In this study, the cellulose content of the urea-cooked banana corm flour product was significantly lower than the product cooked without urea (P0). However, the 2%, 4%, and 6% urea levels did not differ in their effect on the cellulose content of the cooking product.

4. Conclusion

The use of urea at a level of 6% in cooking with banana corm flour produced a product that has superior characteristics in rumen fermentation, which can reduce dry matter loss, increase nitrogen fixation, and reduce starch, amylopectin, NDF, ADF, and cellulose content and increase amylose content in the cooked product.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no competing interests.

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