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Chemical Characteristics of Fermented Local Waxy White Corn as an Effort to Improve the Quality of *Bose* Corn

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ABSTRACT

Bose waxy corn is limited in storage and of low quality so that need to e improved. This research aims to test the physical and chemical properties of bose waxy corn products modified with tape yeast and to find the right chemical properties of bose waxy corn products modified with tape yeast and to find the right time and amount of tape yeast to improve the quality of bose corn products. The research was carried out experimentally with 2 factors tested, namely faktor I: tape yeast concentration (R): R1= 0.1%, R2= 0.2%, and R3= 0,3%, faktor 2: Fermentation time (F): F1= 12 H, F2 = 24 H, and F3 = 36 h. The results of the research showed that chemically the best modified bose waxy corn was treated with a tape yeast concentration of 0.1% with a fermentation time 24 h (R1F2). The moisture content of modified bose corn was obtained at 9.75%, the lowest pH was 4,5 and the highest total acid was 0.067% can give corn a whiter color and longer shelf life. The R1F2 treatment also produced the highest protein of 9.07%, soluble protein of 0.26%, amylose content of 5.78% and was not significantly different from R2F2. The ash content was higher in the R2F1 treatment, that is 0.57% and not significantly different from R2F2, namely 0.56%.

1. INTRODUCTION

Local white corn from Timor is one of the staple foods alongside rice for the people of East Nusa Tenggara (NTT). The productivity of local corn, which is 2.08 tons/ha, is lower compared to superior varieties. This is due to the characteristics of local corn and the cultivation system practiced by communities in dry land areas. Despite the low productivity, this type of corn remains a preferred choice to meet household food needs. Local varieties are also more resistant to pest attacks, particularly from *Sitophilus sp*, compared to new superior varieties.

There are three types of local white corn in NTT, particularly on Timor Island, known as white chalk corn, white stone corn, and waxy corn (Menge & Seran, 2017). Waxy corn, or sticky corn (*Zea mays ceratina. L*), is a special type of corn that has potential as a source of food diversification and industrial material due to its sticky and tasty texture. Waxy corn contains 97% to 100% amylopectin (Sahilatua *et al*., 2019). The three types of corn have different physico-chemical properties. White chalk corn has a crumbly texture, white stone corn is hard, and waxy corn is sticky and chewy like glutinous rice when boiled. These differences also lead to varying processing methods. The diversification of local corn as a staple food includes shelled corn "ketemak", "bose" corn, and milled corn. White chalk corn is processed into *katemak* by boiling it directly and mixing it with beans and vegetables. Meanwhile, white stone corn and waxy corn are processed by husking to produce bose corn.

The husking process for bose corn involves pounding it in a wooden mortar with a little water added to facilitate the peeling of the bran and germ. The husked corn is stored for cooking or marketing, with a relatively short shelf life due to increased moisture content during husking, leading to mold growth (*Aspergillus flavus*), which causes the corn to turn dull white and slightly dark with a musty smell. Additionally, pests are found in stored corn. Research by Manueke & Pelealu (2015) found that *Sitophilus oryzae* and *Sitophilus zeamais* infest rice and shelled corn. *Sitophilus zeamais* damages corn in tropical and subtropical areas. *Sitophilus oryzae* is found in hot and humid regions, attacking various cereals, primarily corn. Another fact presented by Nino *et al*. (2021) is that the use of bose corn as a food ingredient for ready-to-eat meals requires a relatively long boiling time of 2 - 3 h, making it less frequently consumed due to the lengthy processing time and substandard health quality of the corn. To shorten the cooking time and improve the quality of bose corn, modifications through physical methods, enzyme addition, and fermentation are performed. Waxy corn starch and modified starch are widely used because of their unique properties (viscosity, heat stability, and pH) after hydration. The texture of modified starch is smoother than the original starch (Richana & Suarni, 2007). Improving the quality of bose corn can be done by modifying the physico-chemical properties of corn starch through fermentation using tape yeast. This microorganism is chosen because it contains a mixed culture and can ferment natural starch, and it is easily available in the market, facilitating its use by corn farmers.

According to Aini *et al*. (2016), tape yeast is a mixed culture of several microorganisms: fungi such as *Amylomyces rouxii*, *Mucor sp*, *Chlamydomucor oryzae*, *Rhizopus sp*, and *Aspergillus oryzae*. These microorganisms produce amylolytic enzymes that hydrolyze starch into dextrin and disaccharides. The yeast group includes *Saccharomyces cerevisiae* and *Candida sp*, which produce zymase to convert some of the simple sugars into alcohol and CO_2. The subsequent fermentation involves bacteria like *Pediococcus* and *Acetobacter* that hydrolyze alcohol into acetic acid, succinic acid, and malic acid, and the conversion of pyruvic acid to lactic acid catalyzed by *Pediococcus pentosaceus*. Research by Rahmawati *et al*. (2013) identified 8 species of fungi, 3 species of yeast, and 5 species of lactic acid bacteria growing sequentially during spontaneous corn slurry fermentation. The four amylolytic fungi species identified were *Penicillium citrinum*, *Aspergillus flavus*, *Aspergillus niger*, and *Acremonium strictum*, with *Candida famata* as the identified yeast species.

Several studies on fermented corn flour modification have been conducted by Aini *et al*. (2016) using tape yeast (from the market), *Lactobacillus bulgaricus*, and *Lactobacillus casei*. The factors tested were fermentation media (water, lactic acid bacteria, *Lactobacillus casei*, and tape yeast) and fermentation time (20, 40, 60, and 80 h). The results showed that the best functional properties (in terms of gelatinization) were achieved with corn flour fermented using *Lactobacillus casei* for 60 h. However, this study did not determine the optimal concentration and fermentation time for tape yeast. Therefore, further research is needed on the fermentation media using tape yeast to benefit bose corn farmers since tape yeast is more readily available in the market compared to other fermentation media. Medho *et al*. (2018) also modified the properties of local white Timor corn through fermentation using *Lactobacillus casei*. The results showed that fermentation for 36 h with a 2% concentration could increase protein content from 8.7% to 10%. Research on bose corn with tape yeast fermentation media has not been conducted, and this study aims to improve the quality of bose corn by modifying its processing method through fermentation using tape yeast. The objective of this research is to examine the chemical properties of fermented bose corn using yeast and determine the appropriate amount and duration of tape yeast fermentation to improve the quality of bose corn.

2. MATERIALS AND METHODS

2.1. Materials and Equipment

The main materials used in the production of fermented bose corn include local Timor dry shelled white waxy corn, tape yeast, and water, along with other materials for analysis. The primary equipment for making bose corn includes a mortar, fermentation containers, scales, and corn drying containers. The main equipment used in the analysis includes Soxhlet flasks, Kjeldahl flasks, drying oven, distillation apparatus, pH meter, desiccator, aluminum crucibles, porcelain crucibles, aluminum foil, trays, filter paper, and glassware.

2.2. Methods

The research was conducted from March to November 2022 and comprised two stages. Stage I involved the production of fermented bose corn with the addition of tape yeast. Stage II involved the characterization of the chemical properties of the modified fermented bose corn.

2.2.1. Experimental Design

The experiment was arranged factorially (3x3) in a randomized block design with three replications. Factor I was the concentration of tape yeast (R): R1= 0.1%, R2= 0.2%, and R3= 0.3% per kg of corn. Factor II was fermentation time (F): F1 = 12 h, F2= 24 h, and F3= 36 h, resulting in 9 treatment combinations. The observed variables included moisture content using the drying method (AOAC, 2007), ash content using the direct ashing method (AOAC, 2007), fat content using the Soxhlet method (AOAC, 2007), total protein content using the micro Kjeldahl method (AOAC, 2007), and starch content using the perchloric acid extraction method (Apriyantono *et al*., 1989). Acidity was measured using a pH meter, and total titratable acidity (TTA) was determined using the acid-base titration principle.

2.2.2. Measurement of starch content:

0.2 g of flour is placed in a centrifuge tube and washed with 80% hot ethanol (v/v), the residue is washed with 52% perchloric acid (v/v), centrifuged (supernatant discarded), filtered, anthrone added, heated (100°C for 12 minutes), cooled, and absorbance measured at 607 nm. Compared with a standard.

2.2.3. Fermented Bose Corn Production

The production of fermented bose corn followed the modified method of Medho *et al*. (2018), with modifications in the fermentation medium using tape yeast. Local Timor dry shelled white waxy corn with a moisture content of approximately 12% was manually husked using a pounding tool. During husking, water was added gradually until the bran peeled off, then cleaned using a winnowing tool to separate the bran and germ. The husked corn was then fermented by soaking it in a tape yeast medium according to the specified tape yeast amount and fermentation duration. The ratio between the material and the fermentation medium was 1:2, and fermentation was carried out for 12, 24, and 36 h. After fermentation, the corn was drained and dried using sunlight (approximately 55°C) for 8 h, ensuring the moisture content was below 12%.

2.2.4. Statistical Analysis

The data were analyzed using the Friedman test (F-test) at a confidence level of 99% (α = 5%). If the treatment effect showed a significant impact on the observed variables, further analysis was conducted using Duncan's Multiple Range Test (DMRT) at a 99% confidence level (α = 5%) to determine significant differences between treatments.

3. RESULTS AND DISCUSSION

3.2. Bose Corn Product

The fermentation of dehulled corn kernels as the initial step in the modification process was carried out to change the characteristics of bose corn, thereby improving its quality both physically, such as in color, and chemically, as well as its shelf life. The differences between fermented and non-fermented bose corn with a storage period of 1.5 months are shown in Figure 1.

Figure 1. Non-fermented and fermented bose corn products with a storage period of 1.5 months

Figure 1 shows that the fermented bose corn product using tape yeast exhibits a bright white color compared to non-fermented bose corn, which appears slightly dull white or even somewhat black after 1.5 months of storage. This change indicates the growth of the fungus *Aspergillus flavus*, which produces *aflatoxin toxins*, and even the presence of black weevils or pests *Sitophilus zeamais* on the corn product, resulting in powdery residue after 2 months of storage. This is due to the habit of farmers to soaking the corn during dehulling with added water but not following up with further handling processes such as washing and drying, resulting in a higher moisture content of 15-16%.

3.3. Moisture Content

Moisture content is the amount of water contained within the corn kernels and is expressed as a percentage of wet weight. Moisture content greatly affects the shelf life of a food product. A food material must have a low moisture content to be stored for a long time. Flour-type food materials must have a moisture content below 10% to be stored for a long time (Aini *et al*., 2016). The average moisture content of fermented bose corn is presented in Table 1.

Table 1. The effect of fermentation time and tape yeast concentration on changes in moisture content of bose corn

Fermentation Time	Tape Yeast Concentration			Average
	R_1	R_2	R_3	
F1	9.55^{c}	10.06 ^{b}	10.09 ^{ab}	9.9 ^{b}
F2	9.75^{bc}	9.84 ^{abc}	9.53 ^{c}	9.71 ^{b}
F3	10.14^{ab}	10.12^{ab}	10.16 ^{a}	10.14 ^{a}
Average	9.81^{a}	10.00^{a}	9.93 ^{a}	(+)
Coefficient of Variation		2.4%		

Notes: Numbers followed by the same letter in the same column and treatment are not significantly different at DMRT 5%. The (+) sign indicates an interaction between the two treatments. F1 = 12 h fermentation; F2 = 24 h fermentation; F3 = 36 h fermentation; R1 = yeast concentration 0.1%; R2 = yeast concentration 0.2%; R3 = yeast concentration 0.3%.

Table 1, based on variance analysis results, shows that fermentation time (F) has a significant effect on the changes in moisture content of modified bose corn, whereas tape yeast concentration (R) does not significantly affect the moisture content changes. However, the interaction (RxF) significantly affects the moisture content changes. The Duncan test at the 5% level shows that the moisture content of modified glutinous bose corn with a fermentation time of 12 h and 24 h differs from the moisture content of modified glutinous bose corn with a fermentation time of 36 h. The lowest moisture content is found at a fermentation time of 12 h, with a moisture content value of 9.55%, which is not significantly different from a fermentation time of 24 h with a value of 9.53%. The moisture content of modified glutinous bose corn increases at a fermentation time of 36 h, with a moisture content value of 10.16%. The moisture content of modified bose corn in all treatments ranges from 9.5% to 10.16%, meeting the quality standard of SNI 01-3727 (1995) for corn flour moisture content, which is set at a maximum of 10% wet weight, and is comparable to the moisture content of hulled corn or bose corn before being floured. The moisture content of modified glutinous bose corn that meets the storage standards for long-term preservation is in the treatment with tape yeast concentration of 0.1% to 0.3% with a fermentation time of 24 h, with the obtained moisture content below 10%. During fermentation, there is an increase in moisture content with the extension of fermentation time. For comparison, Arumsari *et al*. (2022) also showed an increase in moisture content during the fermentation process of fermented soybeans. This increase in moisture content is due to microbial activity breaking down carbohydrates in the substrate. The result of carbohydrate breakdown is simple sugars converted into energy with by-products in the form of metabolites, acids, CO_2, and water. Longer fermentations result in the higher moisture content.

The impact of moisture content on the storage of modified glutinous bose corn in Medho's (2022) study showed that the moisture content of non-fermented bose corn from farmers was 15-16%. This is due to the habit of bose corn farmers soaking the corn during dehulling with added water. Further handling such as washing and drying is not carried out, causing the shelf life of bose corn to be short. The storage of fermented bose corn with tape yeast for 45 days showed a bright white color compared to non-fermented bose corn, which had a dull white or black color, indicating the growth of the fungus *Aspergillus flavus*, which produces *aflatoxin toxins*. The damage to bose corn is more severe in non-fermented products, with the presence of black weevils or pests *Sitophilus zeamais* and powdery residue after 2 months of storage (Medho *et al*., 2022). According to Sunarti *et al*. (2017) in Ali *et al*. (2023), corn kernels to be stored should have a moisture content of 13% to prevent mold growth and reduce corn respiration. This is consistent with Winarno (1997) statement that food products with a moisture content of less than 14% are sufficiently safe to prevent mold development.

3.4. pH and Total Acid of Fermented Bose Corn

pH indicates the degree of acidity in a food product and is related to the taste and shelf life of the product. Total acid is calculated from lactic acid and other organic acids produced during fermentation. Total acid is a parameter for the shelf life of a food product, especially those processed with acid. pH is a crucial indicator in the principles of food preservation because pH is related to the survival of microorganisms. The lower the pH, the more the food can be preserved as spoilage microorganisms cannot survive (Sukainah *et al*., 2017). The average pH and total acid of modified glutinous bose corn produced from the fermentation process are presented in Tables 2 and 3.

Table 2. Effect of fermentation time and tape yeast concentration on pH changes in bose corn

Fermentation Time	Tape Yeast Concentration			Average
	R_1	R_2	R_3	
F1	5.86	5.84	5.29	5.67 [a]
F2	4.57	4.51	4.43	4.50 [c]
F3	4.75	4.89	4.78	4.81 [b]
Average	5.05[a]	5.08 [a]	4.83 [a]	**(-)**
Coefficient of Variation	5.16%			

Notes: Numbers followed by the same letter in the same column and treatment are not significantly different at DMRT 5%. The (+) sign indicates an interaction between the two treatments. F1 = 12 h fermentation; F2 = 24 h fermentation; F3 = 36 h fermentation; R1 = yeast concentration 0.1%; R2 = yeast concentration 0.2%; R3 = yeast concentration 0.3%.

Table 3. Effect of fermentation time and tape yeast concentration on total acid changes in bose corn

Fermentation Time	Tape Yeast Concentration			Average
	R_1	R_2	R_3	
F1	0.05	0.04	0.06	0.05 [b]
F2	0.07	0.07	0.06	0.06 [a]
F3	0.06	0.06	0.06	0.06 [a]
Average	0.06[a]	0.06 [a]	0.06 [a]	
Coefficient of Variation	2.4%			

Notes: Numbers followed by the same letter in the same column and treatment are not significantly different at DMRT 5%. The (+) sign indicates an interaction between the two treatments. F1 = 12 h fermentation; F2 = 24 h fermentation; F3 = 36 h fermentation; R1 = yeast concentration 0.1%; R2 = yeast concentration 0.2%; R3 = yeast concentration 0.3%.

Table 2 shows that pH changes in modified glutinous bose corn are greatly influenced by fermentation time and not by tape yeast concentration, and there is no interaction between the two treatments. The longer the fermentation time, the lower the pH of bose corn. The pH value of non-fermented corn is 6.25, and there is a pH decrease at 12 h of fermentation with a value of 5.67, which continues to drop at 24 h of fermentation with a value of 4.5. However, at 36 h of fermentation, there is an increase in pH with a value of 4.8. This pH decrease occurs due to several microorganisms in the tape yeast sequentially producing amylolytic enzymes that hydrolyze starch into dextrins and disaccharides. Next, the yeast groups *Saccharomyces cerevisiae* and *Candida sp.* produce zymase enzymes to convert some of these simple sugars into alcohol and CO_2. Further fermentation by *Pediococcus* and *Acetobacter* bacteria hydrolyzes alcohol into acetic acid, succinic acid, and malic acid, and the conversion of pyruvic acid into lactic acid is catalyzed by *Pediococcus pentosaceus* bacteria. However, at 36 h of fermentation, the bacteria's ability to degrade the substrate decreases, resulting in lower lactic acid production and a higher pH value. For comparison, Medho *et al.* (2018) conducted fermentation of local white stone corn using the fermentation medium of *Lactobacillus casei*, and found a pH decrease in corn fermented for 24 h with a pH value of 4.83, 36 h with a pH of 4.25, and 48 h with a pH of 4.32.

The pH change also causes the modified glutinous bose corn to appear whiter, as shown in Medho *et al.* (2022), where the higher the yeast amount, the cloudier the fermentation liquid, and the more intense the sour aroma, resulting in a lower pH of the corn. Similarly, the color of bose corn becomes whiter compared to non-fermented bose corn. This occurs because the fermentation process can remove color-forming components (Edam, 2017), resulting in white-colored fermented flour when viewed visually. Iswari *et al*. (2016) in Pasca *et al*. (2021) also stated that the fermentation process produces a higher degree of flour whiteness. The longer the fermentation time, the whiter the flour color due to complex compounds degraded by microorganisms during fermentation, causing pigment components to decompose and dissolve in water. Ntau *et al*. (2017) also found that fermented sweet corn flour has a good brightness value. The function of fermentation in flour production can modify the physicochemical and functional properties of corn flour. This is supported by Sukainah *et al*. (2017) who stated that the desirable properties of modified starch (which are not present in natural starch) include higher brightness (whiter starch), lower retrogradation, lower viscosity, clearer gel formation, softer gel texture, lower tensile strength, easier starch granule breakdown, higher gelatinization time and temperature, and lower time and temperature for starch granule breakdown.

Table 3 also shows that total acid changes are greatly influenced by fermentation time and not by tape yeast concentration. The total acid content of modified glutinous bose corn increases with longer fermentation times. The total acid value without fermentation is 0.045% and increases at fermentation times of 12 h, 24 h, and 36 h with total acid levels of 0.049%, 0.063%, and 0.061% respectively. This total acid content is very low compared to Arief *et al*. (2023) which found a total acid value of corn flour at 0 h of fermentation to be 0.5%, increasing to 3.06% at 72 h of fermentation. This difference is due to the amount of tape yeast used, which is 2% compared to 0.1% - 0.3% in this study. Medho *et al*. (2018) also found higher total acid levels in corn flour, ranging from 0.20 to 0.41%, with the highest total acid value obtained at 36 h of fermentation with a 2% concentration of *Lactobacillus casei* bacteria. The increase in total acid during fermentation occurs due to the growth and activity of microorganisms present in the tape yeast. The higher the total acid produced, the longer the shelf life of modified glutinous bose corn. Therefore, the best fermentation time for glutinous bose corn using tape yeast is 24 h, resulting in low pH and high total acid, which positively affects the long-term shelf life of modified glutinous bose corn.

3.5. Protein and Soluble Protein

Total protein is a measurement of nitrogen (N) content in a sample. Soluble protein consists of oligopeptides or amino acids that are easily absorbed by the digestive system. The total protein content of fermented bose corn ranges from 8.61% to 9.23%, and the soluble protein content ranges from 0.13% to 0.26%. The average values for total protein and soluble protein are presented in Tables 4 and 5.

Analysis of variance showed that yeast concentration (R) and fermentation duration (F) did not significantly affect the total protein content of modified bose corn, but the interaction between yeast concentration and fermentation duration (RxF) significantly affected the total protein content. Figure 4 shows that the highest protein content in modified bose corn was observed with 0.1% yeast concentration and 12 h fermentation (R1F1) at 9.28%, which significantly differed from the treatment with 0.1% yeast concentration and 24 h fermentation (R1F2) and 0.2% yeast concentration and 12 h fermentation (R2F1) with protein levels of 9.07% and 9.03%, respectively. The lowest protein content was observed in R2F2 treatment with a protein content of 8.61%. In comparison, the protein

Table 4. Effect of fermentation time and yeast concentration on protein content of bose corn

Fermentation Time	Tape Yeast Concentration			Average
	R_1	R_2	R_3	
F1	9.28^{a}	9.03^{ab}	8.81^{bc}	9.04^{a}
F2	9.07^{ab}	8.61^{c}	8.94^{abc}	8.87^{a}
F3	8.70^{bc}	8.82^{bc}	8.88^{bc}	8.80^{a}
Average	9.02^{a}	8.82^{a}	8.88^{a}	(+)
Coefficient of Variation		2.75%		

Notes: Numbers followed by the same letter in the same column and treatment are not significantly different at DMRT 5%. The (+) sign indicates an interaction between the two treatments. F1 = 12 h fermentation; F2 = 24 h fermentation; F3 = 36 h fermentation; R1 = yeast concentration 0.1%; R2 = yeast concentration 0.2%; R3 = yeast concentration 0.3%.

Table 5. Effect of fermentation time and yeast concentration on soluble protein content of bose corn

Fermentation Time	Tape Yeast Concentration			Average
	R_1	R_2	R_3	
F1	0.13^{e}	0.17^{cd}	0.19^{bc}	0.18^{b}
F2	0.26^{a}	0.20^{b}	0.19^{bc}	0.22^{a}
F3	0.17^{cd}	0.16^{d}	0.19^{bc}	0.17^{b}
Average	0.18^{b}	0.18^{b}	0.21^{a}	(+)
Coefficient of Variation		7.98%		

Notes: Numbers followed by the same letter in the same column and treatment are not significantly different at DMRT 5%. The (+) sign indicates an interaction between the two treatments. F1 = 12 h fermentation; F2 = 24 h fermentation; F3 = 36 h fermentation; R1 = yeast concentration 0.1%; R2 = yeast concentration 0.2%; R3 = yeast concentration 0.3%.

content in this study was higher than that in the study by Aprilliani *et al*. (2013), which reported protein content in spontaneously fermented corn flour using *Lactobacillus casei* and yeast tape ranging from 7.19% to 8.46%. Aini *et al*. (2016) also reported protein content of 7.6% to 8.5% in local corn fermentation using yeast tape. Medho *et al*. (2018) in their study on local white corn from Timor using *Lactobacillus casei* reported the highest protein content of 8.66% at 36 h fermentation with 2% *L.casei*, which was almost similar to the 8.61% protein content at 24 h fermentation with 0.2% yeast concentration in this study. Akbar & Yunianta (2014) reported protein content in hybrid corn flour affected by Na2S2O5 soaking and yeast tape fermentation ranging from 7.41% to 9.81%, with a decrease in protein content with longer fermentation times. This was attributed to the hydrolysis of proteins into simpler compounds by microorganisms in the yeast tape starter, particularly *Rhizopus sp*., which produces protease. Longer fermentation time results in higher the proteolytic or protease enzyme activity in breaking down protein molecules by hydrolyzing peptide bonds into simpler compounds such as peptones, polypeptides, and amino acids. The breakdown of proteins into simpler compounds allows these compounds to degrade further, both water-soluble and volatile.

Table 5 and variance analysis showed that yeast concentration (R) and fermentation duration (F) and their interaction (RxF) significantly affected soluble protein content. The more yeast and the longer the fermentation time, the higher the soluble protein content. This is because the longer the fermentation process, the more microorganisms in the yeast tape will produce lactic acid. However, if the fermentation process is not stopped, it may affect the taste and aroma of the product.

The highest soluble protein content in modified bose corn was observed with 0.1% yeast concentration and 24 h fermentation (R1F2) at 0.26%, which was not significantly different from 0.3% yeast concentration and 12 h fermentation (R3F1) at 0.24%, but significantly different from 0.2% yeast concentration and 24 h fermentation (R2F2) at 0.196%. The lowest soluble protein content was observed with 0.1% yeast concentration and 12 h fermentation (R1F1) at 0.125%. Higher yeast concentration in bose corn fermentation resulted in higher soluble protein content, and longer fermentation times also increased soluble protein content, but decreased at 36 h fermentation due to increased pH of 4.8 compared to 4.5 at 24 h fermentation. As soluble protein levels are affected by pH changes during fermentation, the interaction of 0.2% yeast concentration with 24 h fermentation is optimal, resulting in a modified bose corn protein content of 8.61% and soluble protein content of 0.196%. Aprilliani *et al*. (2013) reported soluble protein content of 1.63% with 0.1% yeast concentration and 24 h fermentation, which increased to 1.80% at 48 h and 2.02% at 72 h fermentation. Aini *et al*. (2016) also reported soluble protein content of 1.63% to 2.23% in local corn fermentation with yeast tape. Differences in total and soluble protein content in this study could be due to the type or variety of corn and the type and concentration of microorganisms used as fermentation media.

Fermentation of bose corn with yeast tape can increase soluble protein content. This occurs because soluble proteins can be hydrolyzed into amino acids by strong acids or bases. During fermentation, microorganisms in the yeast tape break down carbohydrate energy substrates and produce large amounts of lactic acid. The produced lactic acid lowers the pH of the growth environment, and soluble proteins hydrolyze into amino acids, increasing soluble protein content. Therefore, the treatment of 0.1% yeast concentration with 24 h fermentation (R1F2) is optimal for producing high levels of total and soluble protein.

3.6. Ash Content

Ash content represents the mixture of inorganic or mineral components found in a processed food material. The average ash content of fermented glutinous bose corn is presented in Table 6. Analysis of variance show that tape yeast concentration (R) does not significantly affect the ash content, whereas fermentation time (F) and the interaction (RxF) have a significant effect on the ash content. The ash content of modified glutinous bose corn ranges from 0.35% to 0.57%. The longer the fermentation, the lower the ash content. The highest ash content is observed at 12 h of fermentation (F1) with 0.57%, and the lowest at 36 h (F3) with 0.39%. The interaction between treatments shows the highest ash content at 0.2% tape yeast concentration and 12 h of fermentation (R2F1) with 0.57%, which is not significantly different from R2F2, and the lowest ash content at R1F2, which is significantly different from R2F3 with 0.35%. Thus, the mineral content in samples R2F1 and R2F2 is the highest. These results are in line with SNI 01-3727 (1995) for corn flour, which stipulates a maximum ash content of 1.5% (Aini *et al*., 2016). The decrease in ash content at the end of fermentation is not due to the fermentation process itself but due to the leaching of minerals during soaking. This is reinforced by Aini *et al*. (2010) in Aini *et al*. (2016) that during the fermentation process, some minerals leach into the soaking water. According to Sahlin (1999) in Aprilliani *et al*. (2013), ash content is not affected by fermentation unless salt is added during the process, causing leaching when the liquid part is separated from the fermented food.

Table 6. The effect of fermentation time and tape yeast concentration on the ash content of bose corn

Fermentation Time	Tape Yeast Concentration			Average
	R_1	R_2	R_3	
F1	0.55^{a}	0.57^{a}	0.57^{a}	0.56 ^{a}
F2	0.47^{b}	0.56^{a}	0.44^{bc}	0.49 ^{b}
F3	0.42^{c}	0.35^{d}	0.41^{c}	0.39 ^{c}
Average	0.48^{a}	0.49^{a}	0.47 ^{a}	(+)
Coefficient of Variation		5.24%		

Notes: Numbers followed by the same letter in the same column and treatment are not significantly different at DMRT 5%. The (+) sign indicates an interaction between the two treatments. F1 = 12 h fermentation; F2 = 24 h fermentation; F3 = 36 h fermentation; R1 = yeast concentration 0.1%; R2 = yeast concentration 0.2%; R3 = yeast concentration 0.3%.

Table 7. The effect of fermentation time and tape yeast concentration on the amylose content of bose corn

Fermentation Time	Tape Yeast Concentration			Average
	R_1	R_2	R_3	
F1	6.35^{c}	5.76^{de}	5.76^{a}	5.96 ^{b}
F2	5.78^{de}	5.78^{de}	6.07^{dc}	5.87 ^{b}
F3	5.45^{c}	7.50^{b}	8.13^{a}	7.03 ^{a}
Average	5.96^{e}	6.35^{b}	6.65 ^{a}	(+)
Coefficient of Variation		5.24%		

Notes: Numbers followed by the same letter in the same column and treatment are not significantly different at DMRT 5%. The (+) sign indicates an interaction between the two treatments. F1 = 12 h fermentation; F2 = 24 h fermentation; F3 = 36 h fermentation; R1 = yeast concentration 0.1%; R2 = yeast concentration 0.2%; R3 = yeast concentration 0.3%.

3.7. Amylose Content

Amylose is a linear polymer of α-D-glucose linked by α-(1-4)-D-glucose bonds (Hoseney, 1988 in Aprilliani *et al*., 2013). Amylose primarily influences the texture of the product. In white glutinous corn (sticky corn), amylose content is lower, and 97% to 100% of the starch consists of amylopectin. Amylopectin content affects the texture and taste of glutinous corn. Generally, the higher the amylopectin content, the softer and more tender the texture and taste of the glutinous corn. The average amylose content of fermented bose corn is presented in Table 7.

Table 7 and analysis of variance show that tape yeast concentration (R), fermentation time (F), and the interaction (RxF) have a significant effect on the amylose content. The amylose content of modified glutinous bose corn ranges from 5.45% to 8.13%. As a comparison, the amylose content of white glutinous corn flour ranges from 2.52% to 3.62% (Sahilatua *et al*., 2019). The treatment with 0.3% tape yeast concentration and 36 h of fermentation (R3F3) results in the highest amylose content of 8.13%. The higher the amylose content, the denser the product texture. This is because the higher the amylose content, the lower the water absorption capacity and elasticity, resulting in increased hardness (Aini *et al*., 2016). The more tape yeast used and the longer the fermentation time, the higher the amylose content in the modified glutinous bose corn. This is due to the breakdown of starch into simpler sugars by microbes during fermentation. Enzymes such as pullulanase and glucoamylase, produced by microbes like *Bacillus sp*. (producing pullulanase, EC 3.2.1.41) and *Endomycopsis fibuligera* (producing glucoamylase, EC 3.2.1.3), catalyze the hydrolysis of α-1,4 bonds in starch polysaccharides, amylose, and amylopectin, and the hydrolysis products (dextrins) release free D-glucose. These enzymes also catalyze the hydrolysis of α-1,6 bonds in amylopectin, but at a slower rate, converting amylopectin into amylose, resulting in a decrease in amylopectin content and an increase in amylose content (Akbar & Yunianta, 2014).

Another possible reason is that the number of pullulanase-producing starter microbes differs from that of amylase or glucoamylase-producing microbes, resulting in varying enzyme activities and causing more amylopectin to be broken down into amylose than amylose into simpler sugars, thus increasing the amylose content in the flour. The increase in amylose content is due to the breaking of amylopectin branch chains at α-1,6 bonds, automatically reducing the number of amylopectin branch chains and increasing the number of linear amylose chains as a result of branch chain breaking (Akbar & Yunianta, 2014).

4. CONCLUSION

The quality improvement of glutinous bose corn can be achieved by modifying its physical and chemical properties through fermentation using tape yeast. Chemically, the best-modified glutinous bose corn is obtained with 0.1% tape yeast concentration and 24 h of fermentation (R1F2), resulting in a modified glutinous bose corn moisture content of 9.75%, the lowest pH of 4.5, and the highest total acid of 0.067%, providing a whiter corn color and longer shelf life. The R1F2 treatment also yields the highest protein content of 9.07%, soluble protein of 0.26%, and amylose content of 5.78%, not significantly different from R2F2. However, the highest ash content is observed in the R2F1 treatment with 0.57%, not significantly different from R2F2 with 0.56%.

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