International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2015): 78.96 | Impact Factor (2015): 6.391

Characteristics of Spontaneously Fermented Corn

Andi Sukainah[1], Eva Johannes[2], R. P. Putra[1]

[1]Faculty of Engineering, Universitas Negeri Makassar, Makassar, South Sulawesi, Indonesia
[2]Faculty of Mathematics and Science, Hasanuddin University, Makassar, South Sulawesi, Indonesia
evajohannes[at]ymail.com, andisukainah[at]yahoo.com

Abstract: ***This study was aimed to examine the effect of fermentation on nutritional content, thermal properties, and pasting characteristic of corn powder. The corn powder variants used in this study was the Bisi-2 variant obtained from Jeneponto regency, South Sulawesi province, whereas the Pop variant were obtained from supermarket. The procedures consisted of three steps. The first step was corn polishing in which the corn seeds that had been cleaned from dirts and flawed seeds were immersed for one hour, and then were polished using polisher machine of PPK N 70 type. The polished corns were then cleaned from corns peel and ready to be processed to the next step. The second step was the corn flour preparation and: the polished corns were immersed for 12 hours followed by milling (disc mill type 9FZ-33), drying, and meshing (mesh 60). The third step was corn fermentation: the corn flours were mixed with water (2:1), fermented for 2 days, dried, milled (disc mill type 9FZ-23), and meshed (60 mesh). Study results indicated that fermentation reduced the carbohydrate, amylose, and starch content of corn flour while increased the protein and water content. Fermentation reduced the enthalpy value, making the starch structure less harder, and thus, reduced the crystalline characteristic of the two corn variants studied presumably by bacterial activities during fermentation which break the starch carbon bonds into smaller bonds. Fermentation could reduce the peak viscosity, breakdown value, final viscosity, and trough viscosity value of the flour.***

Keywords: Flour, Corn, Fermentation

1. Introduction

Corn is a source of carbohydrate and cultivated in almost all areas in Indonesia. Central Bureau of Statistics stated that local corn production in 2009 reached 17.1 million tons. The export potential can be up to 1.1 million tons of the national corn needs (16.3 million tons) [1] The corn production in 2014 is estimated to be 32 to 34 million tons or will be increased by about 80 percents from 2008 production. When this production volume is reached, the export potential in 2014 can reach 50 percents of national corn needs (16.3 million tons).

The nutritional content of the corn, however, is of low quality. The quality of content is due to the low essential amino acid content such as lysine and tryptophan. Lysine content is only 0.28% and tryptophan 0.06% of the total seed protein. This value is less than a half of the recommended value by Food and Agricultural Organization (FAO) [1]. The utilization level of the corn in society is still low due to the relatively more challenging processing compared to other carbohydrate sources such as rice and tubers. The hard corn seeds and its larger size need longer processing time compared to other cereals. Therefore, an intermediate product of the corn is needed, the corn flour.

The corn flour is more acceptable among people because it is more flexible to be used as an alternative to wheat flour or rice flour. The storage of corn flour is also easier than corn seeds. However, the corn flour has very different physical characteristics compared to other flours. Thus its use is still limited in certain products. Therefore, attempts to improve the physical characteristic of the corn flour are needed. One of them is fermentation.

Corn fermentation had been studied by [2] and suggested that corn flour fermentation increased the protein and amino acid content, particularly lysine, which has been considered as a limiting factor for maize flour. Also, [3] found that corn fermentation can reduce the total amino acid of the corn, that the corn flour quality improved. Fermentation process increased the globulin and albumin content of the corn flour [4]. Therefore, fermentation treatment can be expected to improve the physical characteristic of the corn that it can be utilized in more products and can be used as a comparable alternative to other flours.

2. Method

2.1. Materials

Materials used in this study were hybrid corns of Bisi 2 variant obtained from Jeneponto regency and Pop variant purchased from a Makassar supermarket. Substances to support the analysis included distilled water, HCl, petroleum benzene, anhydrous glucose, H_2SO_4 pa, NaOH pa, K_2SO_4, ethanol 95%, carbon, filter paper, Whatman filter paper, water, and aquadest.

2.2. Equipment

Equipments used in this study were dessicator, blender, test tube, tube rack, centrifuge, vortex, hot plate, beaker glass, measuring flask, oven, porcelain disk, clamp, analytical weight, measuring glass, volumetric pipette, thermometer, spectrophotometer UV mini 1240 “Shimadzu”, Thermolyne furnace, pH meter, water bath, reverse cooler, Erlenmeyer, Kjeldahl flask, soxhlet, burette, disc mill type 9FZ-23 machine, corn polishing machine of PPK N 70 type, Rapid Visco Analyzer (RVA) (Newport Scientific, Warriewood, NSW, Australia) and Differential Scanning Calorimeter (DSC) (DSC 1, Mettler Toledo, Schwerzenbach, Switzerland).

2.3. Procedures

2.3.1. Corn Polishing

Corn polishing involved the following steps: (1) Corn seeds were cleaned from dirt and flawed seeds. After that, the corn seeds were immersed for one hour, (2) The corn seeds were polished using polisher machine of PPK N 70 type, (3) The polished corns were then cleaned from the peel and ready for the processing.

2.3.2. Corn Flour Preparation

Corn seed selection. The selected corn seeds were the intact, mold-free, and clean seeds, b) Corn polishing by removing the peel and seed, c) Immersion for 12 hours, d) Milling (disc mill type 9FZ-23), e) Drying, and f) Meshing (mesh 60).

2.3.3. Corn Flour Fermentation

a) Mixing the corn flour with water (1:1) to produce dough; b) Fermentation for two days; c) Drying, d) Milling (disc mill type 9FZ-23); and e) Meshing (60 mesh)

3. Result and Discussion

3.1. Corn flour

Color representation test using Adobe Photoshop CS2 indicated the color difference between the fermented and non-fermented flours as shown in Table 1.

Table 1: Color Representation of the Flours

Variables	R	G	B	L	a	b
Bisi-2 flour	212	209	202	84	1	4
Fermented Bisi-2 flour	202	201	197	81	0	2
Pop flour	194	193	169	78	-3	13
Fermented Pop flour	174	179	156	72	-4	11

Note: R: Red, G: Green, B: Blue, L: Lightness, a+: red-ness, and b+: yellowness.

The color of the fermented corn flour looks whiter than corn flour without fermentation. The color is due to the activity of microorganisms in the fermentation process that utilizes the reducing sugar available on corn flour to inhibit the reaction of non-enzyme browning when the flour is dried. Also, some of the microorganisms involved, especially heterofermentative lactic acid bacteria, produce alcohol sugars that contribute brightness to the fermented starch.

3.2. Nutritional Content

Analysis of nutritional content for Bisi-2 and Pop corns indicated that there was a decrease in carbohydrate, starch, ash, and amylose content for fermented corn flour. While the protein and water content was increasing.

3.3. Carbohydrate

Analysis of carbohydrate content, as shown in Figure 1, indicated that there was a decrease in carbohydrate content from the non-fermented to fermented corn flour by about 2% in the two studied corn variants. Analysis of variance indicated that fermentation had a significant influence on carbohydrate content. The interaction between maize varieties and fermentation did not show a significant effect on the carbohydrates content of starchy.

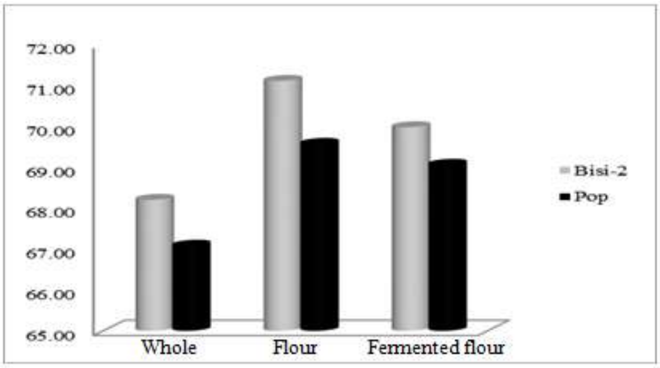

Figure 1: Carbohydrate content

Carbohydrate content of corn starch decreased after the fermentation process, in both types of corn used. Decreased carbohydrate levels after fermentation were positively correlated with decreased starch size (Figure 2) and amylose levels (Figure 3) after fermentation. Starch is the main constituent of corn starch carbohydrate.

The decrease in carbohydrate content of the flour after fermentation was due to starch subjecting to fermentation process will have a degradation into glucose that its glucose content increased and starch content decreased. The sugar will be used by microorganisms as a source of energy in fermentation.

Besides starch, carbohydrates in corn starch also contain non-starch polysaccharides (cellulose, hemicellulose, and pectin) on the cell walls of corn kernels. Several studies have reported that some indigenous microorganisms involved during the spontaneous fermentation process of starch can cause changes in the structure of non starch carbohydrate in corn because they are capable of producing cellulase enzymes. Cellulase enzyme is an enzyme that can break down cellulose into a simpler form.

3.4. Starch and amylose content

Analysis results of starch and amylose content of fermented and non-fermented corn flours were shown in Figure 2 and 3, respectively.

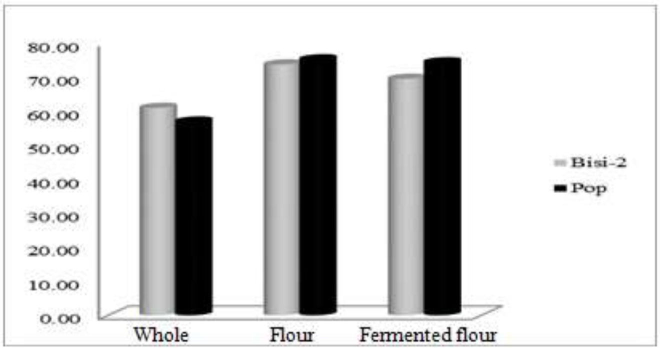

Figure 2: Starch content

Figure 2 indicates that there was a decrease in starch content by 6% from non-fermented to fermented Bisi-2 flour and by 2% from non-fermented to fermented Pop flour. Analysis of variance indicated that corn variant and fermentation had a significant influence on starch content, and interaction of these two variables indicated to influence on starch content. Figure 3 indicates that there was a decrease in amylose content by 13% from non-fermented to fermented Bisi-2 flour and 12% from non-fermented to fermented Pop corn flour.

During the fermentation process, corn starch decreases. Similar results have also been reported by [5] during the fermentation process, the cassava starch decreases. Decreased starch content occurs due to the destruction of starch by microorganisms during the fermentation process. The highest decrease of starch content occurred in the type of Bisi-2 corn. The starch content is positively correlated with the amylose content contained in each cornstarch (Figure 3). The level of amylose in these two types of maize is different, the amylose content of pop corn is higher than that of BISI-2 corn, before and after the fermentation process. Amylose content is the main ingredient of starch besides amylopectin. Therefore, a decrease in amylose levels during fermentation causes a reduction in starch content in corn starch

Changes in starch content in both types of corn starch produced before and after fermentation will affect the physicochemical characteristics of each starch. The starch that has high amylose content will have enough gel properties, while starch has a lower amylose content. Amylose content influences swelling power, water-binding capacity of starch molecules, hydrogen bonds, and degree of crystallization of starch granules [6].

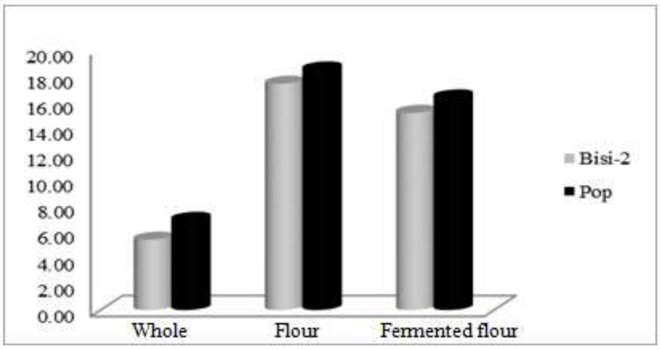

Figure 3: Amylose content

Analysis of variance on amylose content indicated that corn variant and fermentation had a significant influence on amylose content. However, the interaction between corn variant and fermentation indicated no significant influence on amylose content. Starch and amylose content decrease after fermentation process was due to the starch degradation during the fermentation. Analysis of starch and amylose was necessary for this study because starch has a close relationship to the gelatinization process of corn flour.

Amylose content in corn flour, both corn flour Bisi-2 and pop corn starch decreased after the fermentation process. During the spontaneous fermentation process, some indigenous microbes (molds, yeasts, and bacteria) are involved in the fermentation process. Kapang is one type of microorganism that is capable of producing enzyme α-amylase. This enzyme serves to break the bonds of amylose into a simpler form (desktrin), so it can be more easily utilized as a source of carbon by microorganisms during growth.

Decreased amylose content during the fermentation process is also caused by the activity of indigenous lactic acid bacteria. Lactic acid bacteria is a bacterium capable of producing lactic acid as the main product of metabolism. The production of lactic acid by lactic acid bacteria causes the decrease of the pH value to become smaller (acid). Increasingly acidic pH values can disrupt the bonding of amylose and amylopectin structures. Lactic acid causes the binding of amylose and amylopectin bonding structures to a compound with shorter bonding structures.

3.5. Protein content

Analysis of protein content, as shown in Figure 4, indicated that there was a relatively high increase in protein content of Bisi-2 variant (20.5%) from the non-fermented to fermented flour. Whereas, for the Pop variant there was a relatively small increase (0.01%) in protein content after fermentation.

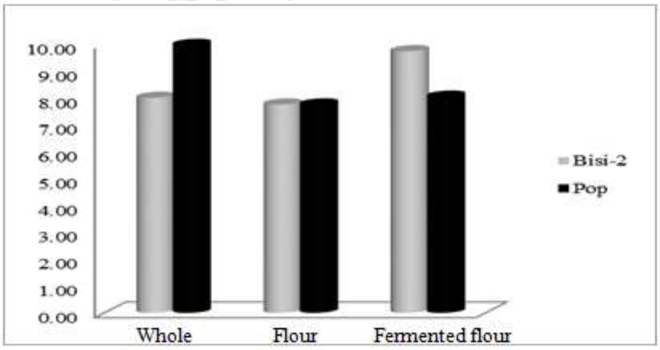

Figure 4: Protein Content

Analysis of variance for protein indicated that corn variant and fermentation, including the interaction between them, indicated a significant influence on protein content. The increase in protein level of fermented corn flour was due to the protein enrichment contributed by the microbial cell as a result of microbial growth that produced a single-cell protein or cell biomass that contains about 40-65% protein. Also, [2] suggested that fermentation increased the protein level and improved the solubility and palatability of the protein.

The content of protein flour corn Bisi-2 after fermentation increased. However, this increase does not occur in Pop corn flour after fermentation. This difference is due to differences in the type of indigenous microorganisms in Corn Bisi-2 and Pop maize.

During the growth process, indigenous microorganisms can synthesize proteins from available sources of nutrients. The synthesis of proteins by indigenous microbes is indicated to cause an increase in protein in corn starch. However, the increase in the protein content of fermented corn flour depends on the type of microorganisms involved in the fermentation process.

3.6. Water content

Figure 5 shows that the moisture content of Bisi-2 corn is higher than that of pop corn, in the form of grain or the kind of flour.
The water content in Bisi-2 corn flour has decreased after the fermentation process, while the content of pop corn flour has increased after the fermentation process. The moisture content of the fermented corn flour depends on the natural component of corn starch, especially on starch and amylose. The starch content (Figure 2) and the amylose content (Figure 3) of Bisi-2 cornstarch decreased significantly compared to the pop corn starch. The reduction of starch content and amylose content of fermented corn flour indicated that during the fermentation process, starch content and amylose content of corn, utilized by microorganism as an energy source during the fermentation process.

The significant decrease of starch content and amylose content in the Bisi-2 fermented corn flour showed that this type of corn flour component was more easily used by microorganisms than Pop fermented corn flour. The process by the microorganisms will change the complex compound into a simple compound, which in reaction to this change also causes many bonds of chemically bonded water released. So during drying, the amount of water released more in the Bisi-2 corn flour than the pop corn starch [7].

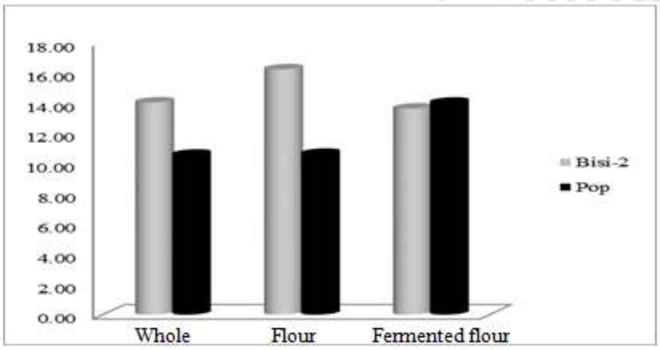

Figure 5: Water Content

Also, suggested that fermentation treatment on starch will produce products such as ethanol that reduce the moisture content of flour.

3.7. Ash content

Ash content of the corn, as shown in Figure 6, indicated a significant decrease in ash content from seeds to flour, although the ash content decrease from non-fermented to fermented flour was not equal to that from seeds to flour (33% for Bisi-2 and 42% for Pop).

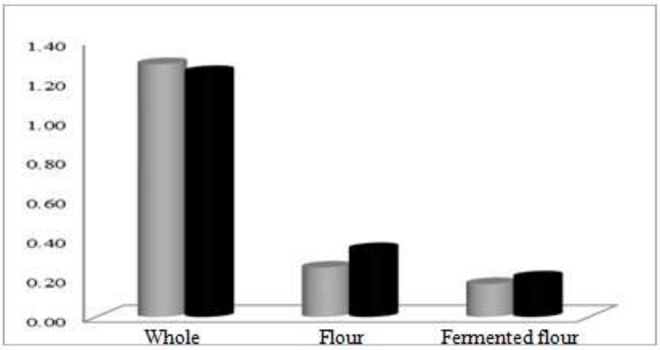

Figure 6: Ash content

Analysis of variance indicated that corn variant, fermentation, and interaction between these two variables had a significant influence on flour ash content. The assessment of total ash content can be used for various purposes, for example, to determine the bads and goods of a process, to know the used material, and as a determinant of the nutritional value of a food material. Analysis of ash content indicated that all treatment types resulted in ash level below the Indonesian National Standard. Therefore, the processing of non-fermented and fermented corn flour had a positive value due to decreased ash content.

The content of corn ash which has been processed in fermentation is lower when compared with corn flour without fermentation, on Bisi-2 corn flour and Pop corn flour. The decrease in ash content after fermentation is due to the growth of the microorganisms involved during the fermentation process. The microbial growth process requires a source of carbon and nitrogen and some mineral components. In addition to being a source of nutrients for microbes, some mineral components also become cofactors to activate the necessary metabolic enzymes in the process of removing complex components into simpler forms.

3.8. Thermal characteristic

Table 2: Thermal characteristics of Bisi-2 and Pop corn flour

Sample	Onset (^oC)	Peak (^oC)	Endset (^oC)	Enthalpy
Bisi-2	67.49	72.61	77.61	8.5
Bisi-2 flour	67.7	72.6	78.03	8.15
Pop	61.59	71.16	85.03	9.71
Pop flour	67.02	72.93	78.84	3.86

Table 1. Indicates that for the bisi-2 variant, flour fermentation had no significant effect on initial and peak temperature of gelatinization but significantly affected the late temperature of gelatinization. The result indicated that

fermented corn flour had resistance similar to that of non-fermented flour at initial temperature to peak temperature of gelatinization, and resistance to heat was higher for fermented flour at the end of gelatinization process.

In contrast, for the Pop variant, fermentation treatment could increase the corn flour resistance against initial temperature until peak temperature of gelatinization, although the resistance against hot would decrease at the end of gelatinization process.

Enthalpy observation indicated that fermentation decreased enthalpy value in significant number for Pop variant while for Bisi-2 variant the decrease was very small. Enthalpy (ΔH) is the energy needed to release amylose double-helix bond and the energy required to break the crystalline bond suggested that enthalpy degree is related to crystals load in starch (either at double-helix structure or single-helix). Whereas endothermic temperature relates to crystal characteristic, temperature stability, and resistance of the starch to gelatinization temperature [8]

Therefore, fermentation causes the starch structure less hard, thus capable of disturbing the crystal properties of the two corn variants studied, which was presumably caused by bacterial activities during fermentation that breaks the carbon bonds of the starch into smaller bonds. Therefore, the starch of the fermented flour will be easier gelatinized during heating. Because of the starch breakdown, its size became smaller, which in turn reduced the transition temperature [9]

3.9. Pasting characteristic

Table 3: Pasting characteristic of corn flour

Sample	Bisi-2	Ferm. Bisi-2	Pop	Ferm. Pop
Peak	4372.33	2771.66	2470.66	2143.56
Through	2095.3	2260.3	1904.3	1762.6
Break-down	2278.3	511.3	566.6	381.3
Final Visc.	3887.3	3236.3	3362.6	2701
Set-back	1791.6	975.6	1458.6	937.6
Peak time	5.35	5.34	5.26	5.27
Pasting temp.	73.63	77.23	79.13	75.42
Initial	25.33	30.33	33.67	22.67

3.10. Peak Viscosity

Peak viscosity is a condition in which the flour granules subject to maximum expansion. Fermentation treatment in this study reduced the peak viscosity of the flour, either that of Bisi-2 or Pop variant. The reduction of peak viscosity was because during fermentation the starch carbon chains were broken by bacteria, resulting in shorter chains that favor water absorption. The higher water absorption during fermentation caused the starch granule wall ruptured, resulting in higher porosity when the flour dry. Therefore, water absorption of flour is faster than non-fermented flour. It means that the temperature to achieve perfect gelatinization on the fermented flour is lower than that of nonfermented flour.

Suggested that peak viscosity is related to starch thickness, so that the lower the peak viscosity of starch the lower its thickness, causing faster gelatinization. Also, [9] suggested that decreased peak viscosity of starch is due by the breaking off parts of the starch structure, causing its structure weak to have gelatinization easily [10].

3.11. Through viscosity and breakdown

Through viscosity and breakdown are the two interrelated parameters because the value of breakdown is the difference between peak viscosity and through viscosity.

Study results indicated that fermentation treatment increased the through viscosity value and decreased breakdown value for Bisi-2 corn. Whereas for the Pop corn variant, there was a decline in through viscosity and breakdown due to fermentation. The result suggested that fermentation led to more stable starch granule structures against concoction, that the viscosity is not easy to drop during concoction and other mechanic treatments.

The formation of stable starch granules after fermentation probably resulted from the bond formation between starch and protein produced from microorganism metabolism during the fermentation process. The formation was corroborated by the increased protein content of the fermented flour.[11].

This is by [12] who suggest that the through viscosity value indicates the starch resistance during the cooling process and breakdown value explains the ease of starch to break after subjecting to expansion. Also, [13] suggested that starch with low breakdown value indicates that the starch structure will easily produce a stable paste.

3.12.Final viscosity and setback

Final viscosity is a parameter related to the tendency of starch to have retrogradation in cold viscosity process. [13] suggested that the setback value is related to the ability of a starch paste to form a gel or toward retrogradation.

Study results indicated that fermentation decreased the final viscosity and through viscosity values, either in basic-2 or Pop variants. Therefore, the fermented corn flour had granules that were not easily reunified after gelatinization. The form of fermented corn flour was because starch had been saturated in binding with other starch.

4. Conclusion

Fermentation reduces the enthalpy value, thus results in a less hard starch structure that will reduce the crystal characteristic of corn flour and presumably caused by bacterial activities during fermentation which breaks the carbon bonds of the starch into smaller bonds. Fermentation reduces the peak viscosity value, breakdown value, final viscosity value, and through viscosity value of corn flour.

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