Swelling power and solubility of modified breadfruit flour using *Lactobacillus plantarum*

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Abstract. Breadfruit has the high nutritional and carbohydrate content which is comparable with wheat, so it is potential to be processed as the breadfruit flour. However, some studies showed the breadfruit flour has low swelling power (SP) and water solubility (WS) compared to wheat. Hence, the flour required modification. The main purpose of this research was to increase the value of SP and WS on breadfruit flour through a fermentation process. Sterile breadfruit flour (50 g) was suspended using sterile distilled water in a 250 ml glass beaker to obtain the flour concentration of 25%, 30%, 35%, 40% and 45% (g/ml). A certain concentration of *L. plantarum* was added (5, 7.5, 10, and 12.5%, ml/ml) then incubated at 30°C for 24, 48, 72, 96 and 120 h. The obtained solid cake was washed before being dried. The effect of cultural concentration on swelling power (SP) and water solubility (WS) is presented in Figure 1. The optimum fermentation condition was achieved by a 35% concentration of breadfruit flour which fermented with 10% *L. plantarum* for 24 h fermentation. At this condition, all parameter showed an increase of carbohydrate, protein, SP and WS into 84.761, 3.776, 8.870% and 0.136%, respectively.

1. Introduction

The change of lifestyles makes people more preferably eat bread for their breakfast and it also happens in Indonesia. Indonesia had to import wheat as much as 5,692,630 MT [1] in the first half in 2016 to keep these needs. On the other hand, Indonesia has natural resources of agricultural products that are carbohydrate-rich content such as breadfruit (*Artocarpus altilis*), yams, taro, and so on. Breadfruit has a similar proximate content with wheat flour. According to Ajani et al. [2] wheat flour contains 97.57% carbohydrate, 0.42% fat, 1.08% protein, 0.93% ash, 0.08425% fiber and 12.755% water; while breadfruit flour has 96.91% carbohydrate, 0.595% fat, 1.345% protein, 1.045% ash, 1.26% fiber and 9.065% water. Although the proximate contents are similar, the breadfruit flour still as a less desirable characteristic such as low SP and low solubility [3]. SP of breadfruit flour is 4.84-6.32 and WS 0.0801 – 0.1129% [4]. To have comparable properties with the wheat, the breadfruit should be modified to improve its functional properties.

According to Balagopan et al., [5], SP increase in volume and weight, which is the starch in the air. Swelling strength improves quality. The strength of the swelling provides a soft texture on food products [6]. Flour that has high WS will make the flour is easier to be digested by the body [7]. Retnowati et al. [8] reported that SP is a parameter of acceptability of starch as food because it can affect the texture. Flour with high SP values can be applied to the manufacture of products such as...
noodles, vermicelli, and analog rice. High WS and viscosity flour absorbed water and formed a gel easily. Hence, it can be used as a gelling agent or thickening agent.

One method of flour modification is fermentation which is relatively efficient and low energy requirement but extend shelf life [9]. Research on fermented breadfruit is rarely found; Appiah et al. [10] reported that natural fermentation of breadfruit increases a concentration of protein and fat. Natural fermentation improved SP of breadfruit flour although insignificant, from 7.02 to 8.72 [10].

*L. plantarum* which found in a natural fermentation process converts the sugar into the organic acid and lowering the pH. According to Putri et al. [11], modification of cassava starch assisted by ultraviolet light as well as fermentation of lactic acid bacteria such as *L. plantarum* and *L. amylophilus* result in changing of physical properties such as SP and solubility. In this study, the highest SP was found in non-fermented starch, 22.28 g/g, while the highest water solubility (WS) was in fermented starch with *L. amylophilus* at 13.95 g/100g. The starch content of cassava was 6.61 ml/g. However, fermentation using *L. amylophilus* and *L. plantarum* increased the starch to 8.54 ml/g and 10.6 to 11.25 ml/g, respectively. Gunawan [12] reported that modification of cassava flour fermented with *Lactobacillus plantarum* had the highest protein content (8.58%) compared to that of *Saccharomyces cerevisiae* (2.29%) or *Rhizopus oryzae* (4.72%).

The purpose of this research is to study the effect of concentration of microorganisms, fermentation time, and concentration of flour on functional properties and proximate of breadfruit flour.

2. Material and Method
Breadfruit flour was prepared by peeled the skin of fresh breadfruit, washed with water to remove the dirt and sliced to shrink in size. After dried under the sun, breadfruit was milled and sieved to obtain the flour of 80 meshes and ready to be used. Bacterial cultures *L. plantarum* 3074 was bought from the Food and Nutrition Research Center Gajah Mada University. *L. plantarum* was cultivated in MRS broth according to Anggraini et al. [13] and incubated at 37°C for 24 h. Breadfruit flour fermentation was fermented following the method developed by Putri et al. [11]. Sterile breadfruit flour (50 g) was suspended using sterile distilled water in a 250 ml glass beaker to the concentration of 25%, 30%, 35%, 40% and 45% (w/v). The suspension was inoculated with *L. plantarum* (5, 7.5, 10 and 12.5%, v/v). The glass beaker was then covered with aluminum foil and incubated at 30°C for 24, 48, 72, 96 and 120 hours. Fermented breadfruit flour is then washed three times with sterile distilled water before being dried in an oven. The breadfruit flour was subjected to analysis of the water content [14], the ash content [14], protein [14], fat [14], carbohydrates [14], SP [14] and WS [15].

3. Result And Discussion
3.1. Effect of Number Culture Bacteria
The experimental results on the effect of the amount of bacterial culture of the SP and WS modified breadfruit flour can be seen in Figure 1. Figure 1 shows that the SP and WS in modified breadfruit flour increased as the number of bacteria culture was added. The SP increased because the number of bacteria that produced extracellular amylase enzyme that broke down or degraded polymer of breadfruit flour into simpler compounds was higher. This extracellular amylase enzyme broke the starch polymer bonds into shorter oligosaccharides or simple sugar molecules. The degradation process caused the granular become porous after drying and subsequently increased the ability to absorb the water. This absorption led the starch granules to swell and expand so that the SP went up [16].
The WS increased because bacteria produce pectinolytic and cellulolytic enzymes that could destroy the cell walls of breadfruit [17]. Tian et al. [18] stated that the smaller the granule size, the higher the starch solubility. However, this increase was not significant could be due to formation of amylose-like fragments caused by enzymatic hydrolysis of amylopectin in the amorphous region of granule. Thus, the fragments could realign and form new hydrogen bonds resulting in greater internal granule stability [19]. This result was consistent with studies conducted by Surojanametakul et al. [20] in the modification of rice with fermentation process using *L. plantarum* which resulted in increasing SP value from 7.6 to 8.9 and WS value from 0.094% to 0.126%.

### 3.2. Effect of Fermentation Time

The experiment result of the effect of fermentation time against SP and WS in modified breadfruit flour can be seen in Figure 2.

![Figure 1. Effect of The Amount of Bacterial Culture of The Swelling power (SP) And Water solubility (WS) Modified Breadfruit Flour](image1.png)

**Figure 1.** Effect of The Amount of Bacterial Culture of The Swelling power (SP) And Water solubility (WS) Modified Breadfruit Flour

Figure 2 shows that the SP and WS of modified breadfruit flour were optimum after 24 fermentation period, and tended to decrease afterward. The SP increased in fermentation for 24 hours because the bacteria were in the exponential phase where the maximum speed of microbial growth resulted in a high number of bacteria. This was consistent with studies conducted by Zareian et al. [21] who found the exponential phase of *L. plantarum* was 24-36 hours. A higher number of bacteria
produced more enzyme, hence digested more flour. Swelling power is strongly influenced by the presence of amylose groups as one of the components of the starch composition and the development of starch granules caused by the substitution of acetyl groups in starch which can weaken the hydrogen bond. The longer the fermentation process leads to reduce amylose, resulting in a decrease of amylose which leads to increase in swelling power [22].

The WS increased in fermentation for 24 h because of the flour degradation by bacteria into simple sugar. Therefore, it was easier to interact with the water due to granule flour bond water and release amylose into the dispersing medium [23].

Swelling power and water solubility decreased along with increasing fermentation time caused by lack of nutrients. The bacteria then enter the stationary phase. Hence, the bacteria activity to break down the starch of breadfruit reduced.

3.3. The Effect of Flour Concentration

The experiment result of the effect of flour concentration against swelling power (SP) and water solubility (WS) in modified breadfruit flour can be seen in Figure 3.

![Figure 3](image.png)

**Figure 3.** Effect of Flour Concentration Against Swelling power (SP) and Water solubility (WS) In Modified Breadfruit Flour

Figure 3 shows that the SP increased as the rising value of the concentration of flour; however, it declined in the flour concentration of 40% and 45%. Values of SP increased at variable concentrations flour 25%, 30%, and 35% due to the higher concentration of flour provided the more amylose number; therefore, the ability to absorb water was higher. Water was absorbed in each granule cause SP value increased because the granules continued to swell and throng around [24]. Values of the WS did not increase significantly because Lii et al. [25] stated that high amylose content is making the properties of flour granules become more rigid and not broken easily, so the value of SP declined on the flour concentration of 40% and 50%.

3.4. Proximate Analysis and Functional Properties of Modified Breadfruit Flour

From this research, it was found that the composition of modified breadfruit flour that gave the best result of SP and WS was 35% concentration of breadfruit flour using 10% L. Plantarum and fermented for 24 h. Therefore, this composition was analyzed on its proximate. The experiment result of proximate analysis and functional properties of the best-modified breadfruit flour could be seen in Table 1.
Table 1. Proximate Analysis and Functional Properties of 100 Grams the Best Modified Breadfruit Flour

| Proximate Analysis          | Native  | Best Modified | Wheat Flour |
|-----------------------------|---------|---------------|-------------|
| Carbohydrate                | 83.430  | 84.761        | 97.570      |
| Protein                     | 2.697   | 3.776         | 1.080       |
| Water                       | 12.272  | 10.136        | 12.755      |
| Ash                         | 0.632   | 0.471         | 0.930       |
| Fat                         | 0.969   | 0.858         | 0.420       |
| Swelling power (SP)(g/g)    | 5.970   | 8.870         | 9.350       |
| Water solubility (WS) (%)   | 0.100   | 0.036         | 1.350       |

The addition of *L. plantarum* bacteria in fermentation could increase the protein and carbohydrate content in modified breadfruit flour. Carbohydrate content increased by 1.595% while protein content 39.95%. The increases in protein content were due to the activity of *L. plantarum* during fermentation which produced the proteinase enzyme as well as peptidoglycan-degrading enzymes. Cell wall was composed of components glycoprotein and lipoprotein [26]. *L. plantarum* was a microorganism that acted as Single Cell Protein (SCP), so it can increase the protein content in the food during fermentation.

The decrease of ash content was caused by the activity of lactic acid bacteria that produced phytase enzymes that hydrolyzed the phytase compounds to protect minerals. Phytase enzymes supported the release of mineral ions. Therefore, the WS increased. This result was supported by Lopez et al. [27] and Panda et al. [28], in which phytic acid (InsP6 - myoinositol hexaphosphat) protected several mineral components. Hence, its availability became limited by lactic acid bacteria fermentation would degrade phytic acid and increase the bioavailability of food.

Syahputra et al. [29] reported that during fermentation, the fat of the material would be hydrolyzed into a simpler substance by lactic acid bacteria for energy sources during fermentation. Taufik [30] reported that the fat content would decrease with fermentation due to the decreasing activity of bacterial fatty acid synthesis along with the decreasing of the bacterial population. Appiah et al. [7] and Gunawan [12] reported that modification would increase the swelling power (SP) and fermentation with *L. plantarum* would increase the protein. Compared with the wheat flour, the modified breadfruit flour with the best formula had comparable proximate contents, the number of SP and WS. Therefore, the breadfruit flour has a potency to be used as a substitute for the wheat flour.

4. Conclusions

The swelling power (SP) increased along with the number of bacteria, extended fermentation time, and flour concentration. Bacteria produced extracellular amylase enzyme that broke down polysaccharides into simpler compounds. Higher concentration of flour provided more amylopectin, hence led ability to absorb more water. However, the solubility did not increase significantly because of the fat degradation. The fat would also be absorbed by the surface of the granules to form a layer that inhibited the water binding by flour granules.

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