Natural spontaneous fermentation effects on the properties of sweet potato flour and the resulting wet noodles

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Abstract. Sweet potato flour has several weaknesses that hinder its application in noodle making processes. The aim of this study was to improve sweet potato flour by using starch modification through fermentation and to find a wheat flour substitute when making wet noodles. The fermentation took place spontaneously naturally, and through the addition of Lactobacillus plantarum. The modification consisted of M1 = without modification, native; M2 = 4 days natural fermentation of 0.5 cm thickness sweet potato; M3 = 4 days natural fermentation of 1 cm thickness sweet potato; M4 = 2 days L. plantarum fermentation of 0.5 cm thickness sweet potato; and M5 = 2 days L. plantarum fermentation of 1 cm thickness sweet potato. The concentration of sweet potato flour (K) as wheat flour substitute for the noodle were K1 = 25%, K2 = 50%, and K3 = 75%. The flour of M2 natural spontaneous fermentation had the highest viscosity at 80°C and 26°C. Moreover, the noodle made from M2 flour at all the different concentrations possessed the highest elasticity. In addition, the M2 flour at 50% concentration resulted as the best interaction treatment for producing noodles with acceptable sensory descriptive values.

1. Introduction
Noodles are one of the most common carbohydrate-based food products in Indonesia and throughout Asia. The rapidly increasing consumption of noodles raises concerns since most noodles are made from wheat flour [1] which is an imported commodity for countries in the tropics and subtropics that rarely produce wheat. There has been growing interest in exploring the prospect of supplementing wheat flour with flour from relatively cheap and easy-to-produce root tubers, such as cassava, sweet potato, and potato, which are more common in topic and subtropic regions [2], [3].

Sweet potatoes have the distinction of being abundant, rich in nutrients (vitamins, minerals, dietary fiber, phenolic acids, anthocyanins, and balanced amino acid composition) [4], [5], low on the glycemic index, and gluten-free. Sweet potato starch and flour are being explored for their use in baked goods, snacks, confectionaries, noodles, beverages, staple food products, and also in non-consumables such as food wrappers, cosmetics, bioethanol, adhesives, insulating component, paper, and textiles [6], [7].
Despite the large range of potential usages for sweet potatoes, the application and development of sweet potato starch stands insubstantial due to some its shortcoming properties. Ding et al., [8] had found that wheat starch is highly compatible with sweet potato starch. However, native or natural sweet potato starch and flour have some weaknesses, such as being insoluble in water, resulting unstable, opaque, and quite hard paste, it also takes a long time to cook, has an inconsistent viscosity and gelling ability, and has a low stability [9]. Different treatments have been used to improve sweet potato properties. Biological, chemical, and physical starch modification has been used to improve its characteristics [10]–[13].

Fermentation as one of the oldest and most economical processing methods has increasingly been used to modifying starches. It is been reported that fermentation improves nutritional, physicochemical, and engineering properties of rice, waxy rice, corn starches, and flour [14]–[16]. Liao and Wu [17] found that fermenting sweet potato starch using Lactobacillus plantarum significantly improved the starch and the resulting noodles. After researching sweet potato starch, they concluded that spontaneous fermentation is a potential process for reforming starches. In this study, sweet potato modification was carried out by natural spontaneous fermentation and through the addition of Lactobacillus plantarum, with the aim of obtaining improved flour properties, which in turn resulted in high-quality, wet noodles.

2. Materials and method
2.1. Materials
The Lactobacillus plantarum was obtained from Food Analysis Laboratorium, Institut Pertanian Bogor (IPB), Indonesia. Pale cream-colored sweet potato tubers and commercial wheat flour (Cakra Kembar, Indonesia) were purchased from a retail market in Banda Aceh, Indonesia.

2.2. Preparation of the lactobacillus plantarum
One loop of pure Lactobacillus plantarum culture from De Man, Rogosa, Sharpe (MRS) agar was transferred into a 10 mL Broth (MRSB) medium and cultured in an incubator at 37°C for 24 hours. Then, the cultured solution was shaken for 24 hours at 37°C, and centrifuged at 3,000 rpm for 15 minutes to obtain the precipitated L. plantarum cells.

2.3. Preparation of unfermented and fermented sweet potato flour
In order to prepare the native, unmodified, unfermented flour, the sweet potato tubers were peeled, cleansed with tap water, cut to a thickness of 0.5 cm and 1 cm, dried under the sun, ground, and passed through an 80-mesh sieve. The preparation for modified, fermented sweet potato flour was carried out using natural spontaneous fermentation, and fermentation using Lactobacillus plantarum. The 0.5 cm and 1 cm thickness sweet potato tubers were soaked in tap water at ratio of 1 L water per kg of sweet potato and fermented in a container covered with a filter cloth. Fermentation was carried out for 4 days for the spontaneous fermentation and 2 days for the L. plantarum fermentation. The L. plantarum cells were used at 0.3% of the sweet potato weight. After fermentation, the fermented sweet potatoes were washed, drained, dried under the sun, milled, and sieved through an 80 mesh.

2.4. Preparation of noodle
To produce the noodles, sweet potato flour at concentrations of 25%, 50%, and 75% is mixed with wheat flour to produce 100% flour, then blended with 2% table salt and 20% water and formed a dough. The dough is stirred for 20 minutes, rolled, left to rest for 15 minutes, and then formed into a 2 mm thick sheet. The sheet is cut to produce noodles which are then boiled for 2 minutes and cooled with water.

2.5. Analysis of sweet potato flour
The sweet potato flour samples were determined for starch granule images, moisture content, swelling power, water solubility index, and viscosity. The sweet potato granule images were observed at 200-400 magnification under a light microscope equipped with a micrometer lens. The moisture content was analyzed by drying the flour to a constant weight in an oven at 105°C.
The swelling power (SP) and water solubility index (WSI) were determined using a method described by Li and Yeh [18] with some modification. Briefly, 0.14 g ($W_0$) sweet potato flour was weighed into a centrifuge tube and 14 mL water was added, then heated at 60°C and 90°C for 30 min with frequent shaking. Afterwards, the mixture was cooled in an ice water bath and centrifuged at 3,000 g for 30 min. The supernatant was transferred to an aluminum pan and dried to a constant weight ($W_1$) at 105°C. The remaining sediment in the centrifuge tube was also weighed ($W_s$). The WSI and SP of the sweet potato flour were calculated using equations 1 and 2.

$$WSI = \frac{W_s}{W_0} \times 100\%$$  \hspace{1cm} (1)

$$SP = \frac{W_s}{W_0 \times (1 - WSI)}$$ \hspace{1cm} (2)

The viscosity was analyzed using a viscometer (Brookfield Engineering Laboratories Inc., USA) by method of [10] with modification. Viscosity of 5% (mixed 5 g flour in 100 ml distilled water) flour paste was measured after heating the solution to 80°C. The flour paste was subsequently cooled rapidly in cold water to a temperature of 26°C (ambient temperature), then the viscosity was determined again.

2.6. Analysis of sweet potato noodle
The noodles were analyzed for water absorption, cooking loss, elasticity, and descriptive sensory test. Water absorption and cooking loss were determined using a method by Kang et al. [19] with adjustments. The analysis began with boiling 5 g of noodles in 150 mL water for 3 min, cooling for 1 min, and removing the excess water. The cooking loss was determined by drying at the noodles at 105°C, then cooling and weighing them. The results were calculated using a formula described by Kang et al., [19].

The elasticity was analyzed using Darmawan et al., [20] method of taking a boiled noodle strand and mounting it on the sample holder equipped with a ruler. One end of the noodle was pulled until the noodle broke. The number on the ruler where the noodles broke was recorded as the elasticity value.

The sensory quality of the noodles was evaluated using Qualitative Descriptive Analysis (QDA) method by 30 semi-trained panelists, who had previous experience in sensory evaluation. The panelists evaluated the products based on the sour aroma, stickiness, elasticity, and sour taste of the wet noodles. A 5-point scale was used for evaluation (1 representing very sour, very sticky, or very inelastic and 5 representing not sour at all, not sticky at all, or very elastic) with a high sensory point/value indicating favorable traits. Unsalted crackers and still water were provided to refresh the palate.

2.7. Statistical analysis
Experimental data were expressed as mean and analyzed through analysis of variants ANOVA followed by Least Significant Differences test at P<0.05 using SAS (SAS 9.3, SAS Institute Inc., Cary, NC, USA).

3. Results and discussion
3.1. Effects of fermentation on the properties of sweet potato flour
Figure 1 shows that the shape of native and fermented sweet potato starch granules varied with primarily round, oval, round polygonal, or irregular polygonal shapes. The findings were in accord with those described by Cui and Zhu [11], Liao and Wu [17], Li and Yeh [18]. Some starch granules from modified, fermented sweet potato were slightly bigger in size than native starch granules.

Native starch granules exhibited smooth surfaces (Fig. 1a) which were also reported by Cui and Zhu [11], Liao and Wu [17]. On the contrary, the surface of fermented sweet potato starch granules showed morphological change, becoming uneven as indicated by the darker shades (Figure 1b-1e). Liao and Wu [17] found similar results and indicated that the change was due to corrosion and revealed that the starch granules surface was already uneven, degraded, and showed cracks on the third day fermentation using L. plantarum. Alvarado et al., [22] exhibited that the morphological changes were due to endocorrosion and exocorrosion during fermentation. The granule surface was degraded through
corrosion, resulting in damage on the starch granule surface. Fermentation induced starch degradation started from relatively rich amylose areas in the amorphous regions of the starch granules. The degradation converted amylose to soluble molecules which came out of the granules.

![Figure 1.](image)

**Figure 1.** Light microscope images of (a). M1 (native, without modification/fermentation), (b). M2 (4 days natural fermentation 0.5 cm sliced sweet potato), (c). M3 (4 days natural fermentation 1 cm sliced sweet potato), (d). M4 (2 days _L plantarum_ fermentation 0.5 cm sliced sweet potato), and (e). M5 (2 days _L plantarum_ fermentation 1 cm sliced sweet potato).

The data on the properties of the sweet potato flour are presented in Table 1. The native, unmodified and modified, fermented sweet potato flour showed no significant difference (P>0.05) in moisture content and swelling power at 60°C. Additionally, there was no significant difference in the water solubility index at 60°C, although water solubility index at 90°C showed significant variations (P<0.05). The flour moisture content was 4.82–5.62% with an average of 5.26%, in the range found by Cui and Zhu [23].

![Table 1](image)

**Table 1.** Properties of sweet potato flour.

| Modification/  | Moisture content (%) | Water solubility index (%) | Swelling power (g/g) | Viscosity (cP) |
|----------------|----------------------|---------------------------|----------------------|---------------|
| Fermentation   | 60°C | 90°C | 60°C | 90°C | 80°C | 26°C |
| M1             | 5.62 | 0.29 | 0.41 | 5.53 | 8.18 | 264.65 | 369.9 |
| M2             | 4.82 | 0.19 | 0.22 | 3.87 | 11.26 | 1088.9 | 2561.5 |
| M3             | 5.34 | 0.30 | 0.17 | 6.69 | 10.64 | 259.35 | 613.10 |
| M4             | 5.40 | 0.15 | 0.19 | 6.39 | 11.06 | 462.25 | 285.15 |
| M5             | 5.13 | 0.25 | 0.23 | 4.80 | 9.32 | 282.45 | 499.90 |

Values in the same column with different letters differ significantly (P < 0.05).

Water solubility index at 60°C and 90°C of sweet potato flour was at an average of 0.24%, which was much lower compare to those reported by Liao and Whu [17]. The fermentation caused significant differences (P<0.05) in the water solubility index at 90°C. Water solubility index at 90°C of native flour (M1) was the highest (P<0.05) compared to those of fermented flour (M2–M5). Swelling power increased steadily with the increase in temperature. It was averagely 5.46 g/g at 60°C, and was 10.09 g/g at 90°C which were much higher than those of around 2 g/g found by Liao and Whu [17]. There was a higher swelling power in the fermented flours (M2–M5) than the native one (M1), presumably caused by the increase in the amounts of short amylopectin chains resulting from fermentation [24].
Viscosity at 80°C was on average 455.52 cP, the highest viscosity was of M2 with a value of 1008.9 cP followed by M4 with a value of 462.25 cP. The M2 treatment (4 days natural fermentation of 0.5 cm thickness sliced sweet potato) also resulted in the highest viscosity at 26°C. Using _L. plantarum_ for fermentation of sweet potato, Liao and Whu [17] also reported that final viscosity increased after the first day of fermentation and decreased after the third day. Cold viscosity (26°C) is a parameter used to observe gel behavior of modified yellow sweet potato starch under cold conditions (26°C). The modification process of starch is anticipated to create starch with a higher cold viscosity. The higher the cold viscosity, the higher the starch's ability to progress [18]. It was noteworthy that the fermentation improved the viscosity of the starch after 4 days natural more than 2 days fermentation with _L. plantarum_. These findings are in accord with Liao and Whu [17] report, that 1-day fermentation using _L. plantarum_ resulted in better sweet potato flour and noodle properties than 2 or 3 days of _L. plantarum_ fermentation.

3.2. Effects of fermentation on the properties of sweet potato noodles

Noodles properties, among others, can be described through the cooking properties of cooking loss, noodle water absorption, and elasticity. The modification of sweet potato flour through fermentation had no significant effect (P>0.05) on the cooking loss of the wet noodles. The cooking loss were 3–11.74% with an average of 6.48% which is in line with that found by Kang et al., Yadav et al. [19,25].

The water absorption of sweet potato flour noodles were 154.88–209.66% with an average of 201.04% which was higher than that reported by Yadav et al. [25] who used a blend of refined wheat flour and 25% native sweet potato flour which resulted in noodle water absorption of 189%. Fermentation caused the water absorption to decrease (P<0.05) from 201% in native, non-fermented flour (M1) noodles to about 170–180% in all the fermented flour (M2–M5) noodles (Figure 2) resulting in better fermented noodle texture than M1. The noodles’ water absorption may affect the noodles eating quality. Hard and coarsely textured noodles result from insufficient water absorption, but on the contrary, excess water absorption can cause overly soft and sticky noodles [26].

![Figure 2. The water absorption of sweet potato flour noodles of different fermentation/modification process.](image-url)
A report by Liao and Whu [17] showed that the hardness, extension, and broken rate of fermented sweet potato starch noodles were better than the native ones, which implied that fermentation improved the quality of the sweet potato starch noodles.

The elasticity or the extension of sweet potato flour noodles were determined by measuring the extent of noodle break when pulled. The elasticity of the wet noodles were 0.5–2.25 cm with an average of 1.28 cm. The noodles were affected (P<0.05) by interaction treatments of fermentation and the concentration of sweet potato flour (Figure 3). The noodle elasticity was low in native, non-fermented wet noodles, increased with fermentation, and were maximum in wet noodles fermented naturally for 4 days. Wheat flour substitution with more than 50% of fermented sweet potato flours caused the elasticity to decrease except for the M2 and M4. Wheat flour contains gluten, while sweet potato contains a small amount of non-gluten protein. Reports by Yadav et al., [19], Cho and Hwang [27] showed that lower gluten content could lower the viscoelasticity of dough and may deteriorate the textural properties of non-wheat noodles.

![Graph showing the elasticity of sweet potato flour noodles of different fermentation and various sweet potato flour concentrations](image)

**Figure 3.** The elasticity of sweet potato flour noodles of different fermentation / modification processes and various sweet potato flour concentrations

The sensory profile of the sweet potato wet noodles is shown in Figure 4–7. A sensory value of 1 represented a very sour, very sticky, or very stiff sensation, while a value of 5 represented not sour at all, not sticky at all, or very elastic sensations. A high sensory value indicated favorable traits. In general, fermentation of sweet potato flour improved the stickiness and elasticity of the noodles, but it also caused slightly sour aroma. The sensory value of sour aroma, stickiness, elasticity, and sour taste of wet noodles from modified fermented sweet potato flour were mostly between 2–3 with an average value of around 3, which was denoted acceptable. The native unfermented noodles mostly resulted in better sour aroma value (value of 4) and sour taste value (value of 3) than the fermented ones. However, the sensory values of stickiness and elasticity of the native, unfermented noodles were low, as the noodles were sticky and inelastic. The 4 days natural spontaneous fermentation (M2) generally improved all the noodles sensory quality attributed analyzed.
Figure 4. The sensory profile of sweet potato flour noodles. Wet noodles sensory qualitative descriptive of sour aroma.

Figure 5. The sensory profile of sweet potato flour noodles. Wet noodles sensory qualitative descriptive of stickiness.
4. Conclusion
Fermentation altered the morphological surface of the fermented sweet potato flour’s starch granules. Compared to the native, non-fermented/unmodified sweet potato flour, the fermented (naturally/spontaneously or with *Lactobacillus plantarum*) sweet potato flour had a higher viscosity.
The fermentation improved quality of sweet potato flour noodles in term of their water absorption, elasticity, and sensory properties. Noodles made of sweet potato flour from M2 (4 days naturally spontaneous fermentation of 0.5 cm thickness sweet potato) at concentration of 25, 50, and 75% possessed high elasticity. In addition, noodles of the M2 flour at 50% concentration had the highest and acceptable sensory descriptive values.

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