Effect of drying temperatures on physical characteristics of sorghum flour modified with lactic acid

G J Manuhara¹, B S Amanto¹, T A Astuti¹
¹Department of Food Science and Technology, Faculty of Agriculture, Sebelas Maret University, Jl. Ir. Sutami no.36A, Surakarta, Central Java, Indonesia

E-mail: godrasjati@yahoo.com

Abstract. Different drying temperatures produce different starch structure, while the remains of lactic acid in sorghum grain might continue starch modification during drying. The purpose of this study was to determine the effect of drying temperatures (40, 50, 60° C) on physical characteristics of sorghum flour modified with lactic acid. Higher drying temperatures produced sorghum flour, with higher viscosity and swelling power, but lower whiteness and solubility. Modified sorghum flour showed higher value than the unmodified flour at all characteristics. Infrared spectroscopy showed that modification shifted absorption peak from 1,334 cm⁻¹ to 1,373 cm⁻¹, but there was no difference between samples dried at different temperatures.

1. Introduction
Sorghum is the most important cereal in the world after wheat, rice, corn and barley. In fact, sorghum plant is adaptable to dry land, high temperature, and floods as compared to other cereals, and is harvested after 100-110 days cultivated so the production cost is relatively low. Sorghum grains contain 10.4% protein.

Although in certain countries, sorghum grains are utilized for bioethanol and industrial raw materials, processing sorghum grain into an acceptable food is still limited. Moreover, in the developing countries, sorghum grain are only supplied for cattle. The sensory quality of food produced from sorghum is also not good as the product of other types of cereals, causing its application in food production is not attractive. For example, the texture of the bread and biscuits produced from a mixture of wheat flour and sorghum flour tend to be drier, sintered and harder, whereas sorghum flour is known to perform high gelatinization temperature and low water holding capacity [1]. The higher gelatinization temperature, the more cooking time or more energy required.

The modification of starch or flour using acid hydrolysis has been widely applied to cleave the glycosidic bonds of polysaccharides chains, lower gelatinization temperature, reduce cooking time, increase water holding capacity or swelling power [2, 3]. The similar modification using lactic acid produced sorghum flour with higher swelling power, whiteness, protein and sugar content than using acetic acid.

It is important to note that acid was also absorbed into the starch granules during the modification, so it was still possible to continue the hydrolytic activity during the subsequent processing step (drying). Higher drying temperature might affect the reaction kinetic, so physical characteristic of flour sorghum might also be affected. This study aimed to determine the effect of different drying temperatures in the modification process using lactic acid to whiteness, solubility, viscosity, and the swelling power of...
sorghum flour. In addition, the FTIR analysis was also performed to detect any changes in functional groups of the starch structure in the flour as the result of the modification.

2. Materials and Methods

2.1. Materials

Sorghum grains (Numbu variety) were obtained from the Perseroan Terbatas Perkebunan Nusantara (PTPN) XII Surabaya, Indonesia, while the lactic acid p.a was supplied by MERCK.

2.2. Methods

Lactic acid solution 1% was prepared in 600 ml of distilled water. Sorghum grains (200 grams) were soaked in the lactic acid solution, whereas the unmodified sorghum grains were soaked in 600 ml of distilled water. The grains in the lactic acid solution were stirred periodically while heated in a water bath at 45°C for 60 minutes [4]. After being soaked, the grains were dried with cabinet dryer at 40, 50, and 60°C until the equilibrium moisture content was reached finally. The dried grains were then sized reduced by using miller and sieved into 80 mesh size.

Sorghum flour was then analyzed to obtain its moisture content, whiteness, viscosity, swelling power, solubility and infrared spectrum. Factorial randomized design consisting of two factors: the concentration of lactic acid and drying temperature, was used. Each treatment was performed in three repetitions and then analyzed in two repetitions. The data was analyzed by the analysis of variance (ANOVA). Duncans Multiple Range Test (α = 0.05), was then performed after the ANOVA demonstrated any significant effect of the drying treatments.

3. Result and Discussion

| Drying temperature | Moisture (%) | Whiteness (%) | Viscosity (cP) | Swelling power (%) | Solubility (%) |
|--------------------|--------------|---------------|---------------|--------------------|---------------|
| Unmodified flour    |              |               |               |                    |               |
| 40°C               | 10.38 ± 0.21 | 81.10 ± 0.07  | 821 ± 177.9   | 3.14 ± 0.18        | 2.74 ± 0.59   |
| 50°C               | 9.06 ± 0.31  | 80.92 ± 0.59  | 1,424 ± 31.8  | 3.27 ± 0.13        | 2.53 ± 0.67   |
| 60°C               | 8.14 ± 0.32  | 80.74 ± 0.64  | 1,470 ± 95.0  | 3.30 ± 0.19        | 1.92 ± 0.49   |
| Modified flour      |              |               |               |                    |               |
| 40°C               | 9.73 ± 0.28  | 81.25 ± 0.35  | 1,888 ± 232.3 | 3.65 ± 0.06        | 4.45 ± 0.14   |
| 50°C               | 8.66 ± 0.39  | 81.21 ± 0.29  | 2,409 ± 166.5 | 3.80 ± 0.11        | 3.87 ± 0.83   |
| 60°C               | 8.11 ± 0.33  | 81.19 ± 0.19  | 2,721 ± 607.1 | 3.99 ± 0.31        | 2.14 ± 0.45   |

3.1. Moisture content

The moisture content of the modified sorghum flour was significantly lower than the unmodified sorghum flour (table 1). The starch modification by acid probably produce starch granules with the lighter structure that led to the rapid evaporation of water molecules during drying.

As the higher drying temperature, the thermal energy received by materials is also greater, so that water molecules bound with starches is more easily released and evaporated.

The moisture content of modified or unmodified flour ranged between 8.11% - 10.38%. It has already met the Codex Standards which specify the requirements is 15% [5]. Lower moisture content prevent the growth spoilage microorganisms and slow down the rate of degradation reaction associated with water in food stuff so that product shelf life is prolonged. The results demonstrated that there was significant difference (p<0.05) between the modified and unmodified flour. The significant differences were also noted between at different drying temperatures (table 1).
3.2. Whiteness
Modified sorghum flour showed higher whiteness (table 1). The increase in whiteness was possibly, due to the pigment degradation and the inhibition of enzymatic browning reaction in sorghum flour associated with the decrease in pH.

Sorghum grains contain anthocyanin pigments (0-2800 mg/g) and proanthocyanidin (0-68000 mg/g). Both are water-soluble pigment which its degradation rate increased in acidic conditions. Sorghum flour modifications in lactic acid solution lowered the pH, result in the inactivation of phenolase [6]. Phenolase enzyme serves as a catalyst in the enzymatic browning reaction. Thus, the browning reaction in modified sorghum flour was inhibited, and resulted in the whiter flour. Kawali variety sorghum flour contain phenolic compounds to 975.61 mg/100 g dry weight [7], which is contained in the testa, a layer of pigment in sorghum grain.

The lower whiteness due to the longer drying causing discoloration into darker appearance. The decrease in whiteness was also probably caused by the Maillard reaction whereas interaction between reducing sugars with amino acids, peptides or proteins was involved that result in a very dark products called with melanoidin. The rate of the Maillard reaction is tend to greater when the higher drying temperature was employed, so that sorghum flour produced from drying at 60°C performed the lowest whiteness.

The whiteness of sorghum flour ranged from 80.74 to 81.25%, whereas the previous study showed that Numbu variety performed 83.41% whiteness. Based on ANOVA test, there was no significant difference at various drying temperatures (p>0.05), but the significant difference was noted between modified and unmodified flour.

3.3. Viscosity
The viscosity of modified sorghum flour was higher than the unmodified flour (table 1). The viscosity of modified flour was about doubled compared to unmodified flour. Previous study showed that along with the increase in acetic acid (but at a lower concentration range) then the viscosity of cassava starch also increased [8]. The ANOVA test showed significant differences between them (p<0.05). There was no significant difference in viscosity between the flour produced at drying temperature of 50 and 60°C, but there was significant difference between the flour produced at drying temperature of 40°C with 50°C and 60°C (p < 0.05).

The cleavage reaction at α-1,4-glycosidic and α-1,6-D-glycosidic bond increased starch tendency to form gel so that viscosity increased. The hydrolysis using acid produced starches with weaker intermolecular hydrogen bonds so that the starch granules are easier to inflate during heating. Thus, the viscosity increased.

Amylose content in starch may also affect the viscosity. As the higher amylose content, then the viscosity of the starch was also higher. The amylose content of the modified starch was higher than unmodified flour. The results of this research work also demonstrated that at higher drying temperature, the amylose content was also higher (data not shown). Amylose is a fraction starch that role in the formation of gel so the more amylose content in the flour, then the gel was also firmer.

3.4. Swelling power
Swelling power of modified starch flour was higher than unmodified (figure 4.19). This is similar with previous research that found that longer time of hydrolysis result in the increase of swelling power. The hydrolysis by acid weaken the hydrogen bonds that ultimately led to the less dense structure of starch granules. This causes the water molecules is easily to penetrate into the starch granules, so then the starch swell better [9].

Swelling power of modified flour also increased as the increase of drying temperature. The hydrolysis by the remaining acid in the flour allegedly continued during drying, so that at higher drying temperature, hydrolysis reaction rate was also higher. Thus, the structure of the starch granules probably became less dense.
Swelling power of modified sorghum flour is higher than unmodified flour and even sorghum flour produced by previous study. The ANOVA test showed that there was significant difference between the modified sorghum flour and unmodified sorghum flour. The significant difference in swelling power was also noted between the flour produce at drying temperature of 60°C with 40°C and 50°C. But there was no significant difference at (p>0.05) the flour produce at drying temperature of 40°C with 50°C.

3.5. Solubility
The hydrolysis by acid cleave glycosidic bonds in starch to produce simpler compounds include dextrin, maltose and glucose. The increase in solubility is probably due to the formation of reducing sugars which is easily dissolved in water [10, so that sorghum flour modified with lactic acid performed higher solubility than unmodified flour (table 1).

However, the inconsistent results (when the result of starch hydrolysis is considered as the cause of higher solubility), are shown in different drying temperature. The higher drying temperature resulted in a lower solubility. Further observation to the formation complex of lipid-amylose at the higher processing temperature is needed to study this phenomenon.

ANOVA test showed that there was significant difference between the modified sorghum flour with unmodified flour. There was significant difference (p<0.05) between the flour produced at the drying temperature of 40°C with 50°C and 60°C, but there was no significant difference (p>0.05) between the flour produced at the drying temperature of 50°C with 60°C.

3.6. FTIR
The absorption peaks (figure 1) at 1,651 cm⁻¹ were the characteristic of stretching C = O carbonyl vibration, while 2,924 and 3,425 cm⁻¹ were the stretching C – H bond and O-H carboxyl vibration, respectively. Starch modification using lactic acid for hydrolysis cleave the glycosidic bond. Termination of α-1,6 glycosidic bond is supposedly easier than α-1,4 glycosidic bond as these branch bonds construct the amorphous regions which are easily attacked by acid. Thus, the modification reduce the amount of glycosidic bond.

In sorghum flour with drying temperature of 60°C, the absorption peak of glycosidic bonds was shifted from 1,334 cm⁻¹ (unmodified flour) to 1,373 cm⁻¹ (modified flour). Consistent result was shown by modified flour with drying temperature of 40°C, which resulted in the absorption peak associated with glycosidic bond at 1,373 cm⁻¹. The shift of the wave number is also reported in the previous study [11]. The modification by lactic acid reduced the glycosidic bond which the cleavage of glycosidic bond (α-1,6) in amylopectin into short-chain amylose took place during the drying process [12].

4. Conclusion
Higher drying temperature produced sorghum flour with higher viscosity and swelling power, but lower whiteness and solubility. Modified sorghum flour showed higher value than the unmodified flour at all characteristics. Infrared spectroscopy showed that modification shifted absorption peak from 1334 cm⁻¹ to 1373 cm⁻¹, but there was no difference between samples dried at different temperatures.
Figure 1. FTIR spectra of modified sorghum flour dried at 40°C (a), 60°C (b), and unmodified sorghum flour dried at 60°C (c)
References

[1] Munck L 1994 New milling technologies and products: Whole plant utilization by milling and separation of the botanical and chemical components Sorghum and Millets: Chemistry and Technology ed Dendy D A V (St. Paul: American Association Cereal Chemistry)

[2] Pessa E Suortti T Autio K Poutanen K Espoo 1992 Starch/starke 44 64-69

[3] Okunlola A and Akingbala O 2013 Braz. J. Pharm. Sci. 49 699-708

[4] Yauwardana Basito Muhammad D R A 2013 Jurnal Teknosains Pangan 2 1

[5] Codex Standart 1989 Codex Standart for Sorghum Flour

[6] Davidek J Velisek J Pokorny J 1990 Chemical Changes During Food Processing (Amsterdam: Elsevier Science Publishers)

[7] Salimi Y K 2012 The role of sorghum (Sorghum bicolor L) extracts and flour in the inhibition of cancer in vitro and in vivo of mice (Bogor: Institut Pertanian Bogor)

[8] Jyothi A N SasiKiran K Sajeev M S Revamma R Moorthy S N 2005 Starch/Stärke 57 547–555

[9] Leach H W Mc Cowen L D Schoch T J 1959 Cereal Chem. 36 534-544

[10] Subekti D 2008 Design of vertical screw mixer type machine for maltodextrin production by dry hydrolysis method using clorida acid (Bogor: Institut Pertanian Bogor)

[11] Yuanita L 2009 Jurnal Ilmu Dasar 10 49-55

[12] Faridah D N Fardiaz D Andarwulan N Sunarti T C 2010 Jurnal Teknologi dan Industri Pangan 21 135-142