The Chemical and Physico-Chemical Properties
of Sorghum Starch and Flour

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ABSTRACT

The chemical and physico-chemical properties of starch and flour from sorghum (KU 439 and KU 804) were determined and then these properties were compared with those of starch and wheat flour for alternative replacement. Protein content in sorghum flour from cultivar KU 439 (439F) and KU 804 (804F) were 6.28 and 9.47% respectively, which were lower than those of hard (HWF) and soft wheat flour (SWF) (14.89 and 11.24% respectively). So the starch or flour from sorghum can be used to replace wheat in gluten-free products. Amylose content of sorghum starch (439S and 804S) and wheat starches (HWS and SWS) were 27.18, 25.35, 28.06 and 23.45% respectively. Swelling power (SP) of sorghum and wheat starch were increasing with temperatures. At temperature above 75°C, the SP of sorghum starch became higher than that of wheat starch. Having compared the pasting properties of starch, it was found that the pasting temperature of HWS was higher than that of 804S, 439S and SWS ($p < 0.05$). On the other hand, peak viscosity and breakdown of sorghum of the 439S and 804S were higher than those of wheat starch; while the final viscosity and setback of 439S and 804S were lower. Furthermore, the pasting properties of flour had shown that peak viscosity, final viscosity and setback of 439F and 804F were higher than HWF and SWF; while breakdown value of 439F, 804F and SWF were lower than HWF ($p < 0.05$).

Key words: sorghum, wheat, starch, flour

INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench] is ranked in the fifth place among cereal crops grown worldwide (Taylor *et al.*, 2006). Sorghum, a drought-resistant and easily grown crop is an important exported cereal of Thailand. Though the utilization of sorghum in food products is not popular; it is used mostly as feed. Sorghum is one of the important food cereals providing energy, protein, vitamins and powerful antioxidants. The main constituents of sorghum that affect to quality

of food are starch and protein (Taylor *et al.*, 2006). Starch is a dominant component that plays a crucial role in the food products and it is often used as thickener and gelling agent. In addition, cereal protein is also a crucial component as structure builder in food. The major protein of sorghum grain is kafirin, which is found encapsulated in protein bodies. Normal sorghum protein bodies are presumably made rigid by the disulfide-linked polymeric nature of the gamma- and beta-prolamin protein found at the body periphery. In order to use kafirin in food processing, protein bodies

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(kafirin) must be disrupted or modified the protein structure itself. The protein body structure can be disrupted by using shear forces or high pressure-high temperature (extrusion processing), which caused the improvement of kafirin utilization as functional component in baked product (Hamaker and Bugusu, 2003). Therefore, it is likely that sorghum flour can be used to replace or substitute wheat flour in a variety of products. Due to its lack of gluten, sorghum can be used in gluten-free diets for people with celiac disease, who are intolerant of wheat (Taylor *et al.,* 2006). The objective of this research was to study on the chemical and physico-chemical properties of sorghum starch and flour and compare with those of wheat starch and flour. The finding from these studies will lead to the improvement of the sorghum flour quality for using in food product varieties.

MATERIALS AND METHOD

Material

Sorghum (*Setaria itica* (L) P.Beauv) grains from KU 439 and KU 804 cultivars were harvested from National Corn and Sorghum Research Center, Kasetsart University, Thailand. These grains were used for starch and flour extraction. The commercial wheat flours (soft wheat and hard wheat) were obtained from Pacific Flourmill Co., Ltd. and used for starch extraction.

Flour preparation and starch extraction

Sorghum flour was prepared from decorticated sorghum grains by wet milling method. For starch preparation, sorghum grains were steeped in a mixture solution of sodium bisulfite (0.25%, w/w) and lactic acid (0.5% w/w) at 52°C for 48 h and the ratio of grains to solution was 2 to 1. Sorghum starch was extracted by wet milling followed the method of Wang *et al.* (2000). Wheat starch was extracted from wheat flour by using the AACC (2000) method. Sorghum starch

and flour yields was based on 100 g (db) of sorghum grain and was calculated as the ratio of total weight (db) of starch or flour recovered to total weight (db) of whole sorghum grain.

Chemical composition

Moisture, ash, fiber, lipid and protein contents of starch and flour were determined according to AOAC (2000). Amylose content was estimated by using the Amylose-Amylopectin Assay Kit (Megazyme,Ireland). All measurements were carried out in triplicate.

Swelling power and solubility

Swelling power and solubility were investigated at 55, 65, 75, 85, and 95°C according to Li and Yeh (2001).

Pasting properties of starch and flour

Pasting properties of starch and flour in sorghum and wheat were measured by a Rapid Visco Analyser (RVA-4), using the RVA General Pasting Method (Newport Scientific, 1998). Approximately 25±0.1 ml distilled water was transferred into a canister and then add 3.0 g sample (corrected to compensate for 14% moisture basis). The sample was heated to 50°C and stirred for 10 s for thorough dispersion. The time-temperature profile was: held for 1 min at 50°C, then heated to 95°C in 7.3 min, held at 95°C for 5 min, cooled to 50°C in 7.7 min and finally held at 50°C for 4 min. Pasting temperature (P_{temp}), time to reach PV (P_{time}), peak viscosity (PV), hot paste viscosity (HPV), cold paste viscosity (CPV), breakdown (BD) or (PV-HPV) and set back (SB) or (CPV-HPV) were directly obtained and calculated from the pasting curve, using Thermocline for Window version 1.1 software for the Rapid Visco Analyser (Newport Scientific Pty. Ltd.)

Statistical analysis

Data was analyzed using ANOVA

procedures of the SPSS version 12.0. Means were compared at the 0.1% and 5% significance level using Duncan's multiple range test (DMRT).

RESULT AND DISCUSSION

Yields of sorghum starch and flour

Sorghum flour was prepared from decorticated sorghum grains by wet milling method. The yield values were 16.75 and 18.28% for 439F (KU 439 flour) and 804F (KU 804 flour) respectively. The percent yield of flour were rather low due to the loss during decorticate process. However, when sorghum starch were extracted from steeped sorghum grains, their yield values were 27.55 and 30.72% for 439S (KU 439 starch) and 804S (KU 804 starch) respectively.

Chemical compositions

The chemical compositions of starch and flour from sorghum and wheat are shown in Table 1 and 2. Among the minor constituents, the protein and lipid contents could be responsible for starch properties (Roach and Hoseney, 1995; Wang and Seib, 1996). Moreover, the protein content of starches indicated the purity of starches, which should be lower than 0.6% for pure starch (Tester

et al. 2004). The protein contents of starches were lower than 0.6% (Table 1). Therefore, it could be assumed that the extraction method used for starch preparation was suitable. On the other hand, the protein contents were different only among flours (Table 2). They were appeared in orders: HWF (14.89%) > SWF (11.24%) > 804F (9.47%) > 439F (6.28%) ($p < 0.001$). The protein content of flour was an important component, affecting flour properties and creating structure in food (Ragaee and Abdel-Aal, 2006). Another crucial component was lipid in starch and flour. The lipid contents of 439S and 804S were not significantly different from HWS and SWS ($p \geq 0.001$). However, the lipid contents of 439F and 804F were significantly lower than those of HWF and SWF ($p < 0.001$). The role of starch lipid, particulary lipid that was complexed with amylose, could affect the swelling and pasting properties of starch and flour (Goering *et al.* 1975).

The amylose contents of 439S, 804S, HWS and SWS were 27.18, 25.35, 28.06 and 23.45% respectively (Table 1). The amylose content could play a major role to swelling, pasting properties (Tester and Morrison, 1990 a,b) and gel firmness of starch (Lindqvist, 1979).

Table 1 Chemical compositions of sorghum and wheat starches (%dry basis).

Sample	Moisture	Protein	Lipid	Ash	Fibre	Amylose
439S	10.13±0.16[b]	0.31±0.00[b]	0.05±0.02[a]	0.04±0.00[b]	0.14±0.03[a]	27.18±9.98[a]
804S	10.85±0.14[a]	0.26±0.08[b]	0.08±0.01[a]	0.06±0.01[b]	0.12±0.01[a]	25.35±6.26[b]
HWS	10.03±0.03[b]	0.39±0.08[b]	0.10±0.03[a]	0.23±0.02[a]	0.24±0.02[a]	28.06±4.52[a]
SWS	10.11±0.05[b]	0.56±0.00[a]	0.18±0.11[a]	0.22±0.02[a]	0.23±0.01[a]	23.45±2.27[c]

Means in column followed by different superscript are significantly different ($p < 0.001$).

Table 2 Chemical compositions of sorghum and wheat flours (%dry basis).

Sample	Moisture	Protein	Lipid	Ash	Fibre
439F	9.51±0.06[b]	6.28±0.42[d]	0.15±0.03[c]	0.14±0.02[d]	0.28±0.02[a]
804F	8.32±0.11[c]	9.47±0.14[c]	0.32±0.04[b]	0.39±0.04[c]	0.33±0.01[a]
HWF	10.09±0.31[a]	14.89±0.18[a]	0.67±0.06[a]	0.52±0.01[a]	0.36±0.01[a]
SWF	9.53±0.10[b]	11.24±0.06[b]	0.70±0.05[a]	0.44±0.01[b]	0.23±0.02[a]

Means in column followed by different superscript are significantly different ($p < 0.001$).

Swelling power and solubility

      Swelling power (SP) of starch and flour reflects the ability of starch interacting with water molecules (Tester and Morrison, 1990a). Figure 1 A and C show that the SP increased with increasing temperatures. When the temperature above 75°C, the swelling powers of 439S and 804S were higher than those of HWS and SWS (Figure 1 A). When compare between starch and flour, the results show that the SP of starch was higher than that of flour. It could be due to the effect of protein and lipid, which could inhibit the swelling of starch granules (Wang and Seib, 1996). Figure 1 C shows that the SP of each flour was slightly different and it might be the effect of protein and lipid content in each flour. Starch solubility is an indicator of the degree

of molecule in starch granules dispersion after cooking (Bello *et al.,* 1995). The solubility of starch and flour has illustrated similar trend, increasing with increasing temperature (Figure 1 B and D). The solubility could imply to the amount of amylose leaching out from starch granules when swelling; therefore the higher the solubility the higher of the amylose leaching (Srichuwong *et al*. 2005). However, the solubility of flour was still high even its SP was low (Figure 1 C and D). It might due to the soluble protein in flour.

Pasting properties

      Pasting properties of starch are the phenomena involving granular swelling, exudation of molecular components from the granule and
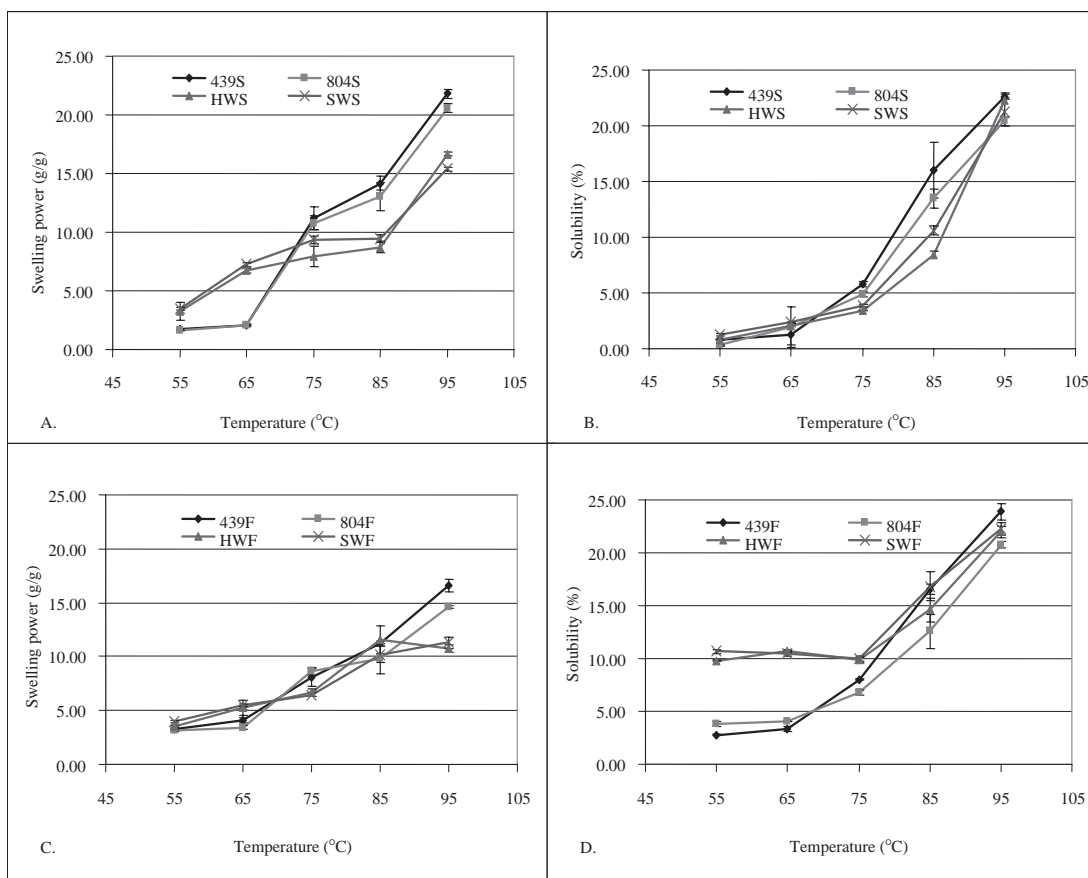

Figure 1 Swelling power of sorghum and wheat starch (A), and flour (C) and solubility of sorghum and wheat starch (B), and flour (D).

eventually, total disruption of granules (Atwell *et al.,* 1988). From Figure 2 A and B, it showed the pasting profiles of starch and flour from both wheat and sorghum and each section of profiles had shown the characteristics of starch responding to temperature changes. When compared among starches, the peak time of HWS (10.80 min) was the longest and followed by that of SWS (10.43 min)> 804S (7.55min)> 439S (7.27 min). It indicated that HWS required the longer time prior to gelatinize. For peak viscosity, it is shown that 439S (340.21 RVU) had the highest peak viscosity, and then followed by 804S (280.44 RVU), HWS (269 RVU), SWS (267 RVU), respectively. Peak viscosity (PV) is related to the degree of swelling of granule during heating and the starch with higher swelling capacity causes the higher PV (Ragaee and Abdel-Aal, 2006). It is therefore implied that 439S had the highest degree of swelling, which also was in an agreement with the SP results (Figure 1 A). Breakdown is also correlated with the stability of starch granule under a high shear condition (Ragaee, and Abdel-Aal, 2006). It is shown that 439S (221.21 RVU) had the highest breakdown and followed by 804S (140.60 RVU), SWS (83.13 RVU) and HWS (71.46 RVU) respectively. As the mixture cools, there is a decrease in kinetic energy, which allows the starch molecules to reassociate and form network. This short-term re-association results in

textural changes of cooked paste. Longer storage induces reversible re-crystallization of amylopectin, which increases the rigidity of the swollen granules embedded in the continuous amylose network (Miles *et al.*, 1985; Ring *et al.*, 1987). During the reassociation process, it could cause the final viscosity (FV) to increase (Figure 2 A) and it is also known as setback. Figure 2 A shows that the setback value of SWS (164.75 RVU) was the highest and then 804S (156.73), HWS (147.54) and 439S (137.67) respectively. The setback also correlates to retrogradation and reordering of starch molecules (Ragaee, and Abdel-Aal, 2006). Therefore, 439S should have lowest rate of starch retrogradation and less syneresis than other starches due to its lowest setback. Furthermore, the protein presence in flour could affect pasting viscosity and properties of starch (Batey and Curtin, 2000 and Ragaee, and Abdel-Aal, 2006) as shown in Figure 2 B. In the presence of protein, the results have shown that the PV of flours was lower than those of starches. It may be because the protein presence in flour could inhibit swelling of starch granules. Moreover, the breakdown values of 439F and 804F were lowered significantly. When compared among flours, 804F (9.56 RVU) had the lowest breakdown and followed by 439F (56.83), SWF (57.96) and HWF (75.50). All flour types had lower setback as compared to starch; therefore,
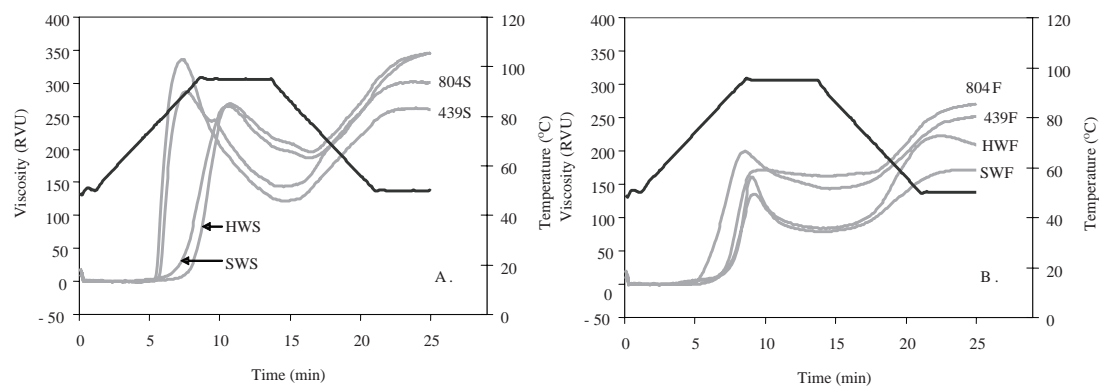

Figure 2 Pasting profiles of sorghum and wheat starch (A), and flour (B).

flour could withstand to shear and had lower rate of retrogradation than starch. When compare among flours, setback value of HWF (126.08 RVU) was the highest and SWF (92.50) was the lowest. It could also imply that HWF had the highest rate of retrogradation and vice versa for SWF.

CONCLUSION

Sorghum flour and starch (KU439 and 804) were different from wheat flour and starch (hard and soft) according to their chemical composition, yield, swelling power, solubility and RVA pasting properties. In the presence of protein in flour, it could inhibit the swelling of starch as it lowered the swelling power and peak viscosity. The information obtained from this research could be used for modifying or improving sorghum flour and starch in order to substitute or replace wheat flour and starch in gluten-free products.

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