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RVA analysis of mixtures of wheat flour and potato, sweet potato, yam, and cassava starches

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Abstract

Rapid visco analysis (RVA) was performed to study the pasting properties of mixtures of wheat flour and tuber starches, i.e., potato starch (PS), sweet potato starch (SPS), yam starch (YS), and cassava starch (CS), at 10–50% starch in the mixtures. Lower phosphorus and higher amylose contents were observed in CS, followed by YS, SPS, and PS. The peak, breakdown, final, and setback viscosities of the control wheat flour were lower than those of the control PS, SPS, YS, and CS. The peak viscosity of wheat–PS mixtures was higher than those of the wheat–SPS, wheat–YS, and wheat–CS because of the higher phosphorus and lower amylose content of PS, which resulted in higher swelling of PS than that of SPS, YS, and CS. The breakdown viscosities increased as the starch content of the PS, SPS, and CS in the mixtures increased to up to the 50%, and the values tended to decrease in the wheat–YS mixture. The setback viscosities of wheat–SPS, wheat–YS, and wheat–CS increased significantly as the starch content increased from 10% to 50%, and that of wheat–PS dropped dramatically at 50%. The findings in this work provide evidence that tuber starches could be used as a partial substitute for wheat flour in some wheat-based products.

Keywords: Wheat flour; Potato starch; Sweet potato starch; Yam starch; Cassava starch; Mixture; Pasting properties

1. Introduction

Commercial starches are obtained from grains, such as corn, wheat, and rice, and from tubers and roots of particularly potato, sweet potato, and cassava (Whistler & BeMiller, 1997). Starch is the major carbohydrate in roots, ranging from 73.7% to 84.9% of the root dry weight (Sriburi, Hill, & Mitchell, 1999). Starch is a very important raw material used in the food industry because of its properties, such as a low gelatinization temperature and a low tendency to retrodrade. Furthermore, it has no residual proteinaceous material or soil residues. It lacks a cereal flavor; it has high viscosity and a high water binding capacity. In addition, it has a blend taste, translucent paste, and it is relatively stability. Matveev et al. (2001) concluded that the melting thermodynamic properties of starches were directly correlated to their amylose content. X-ray diffraction patterns have been used to reveal the characteristics of the crystalline structure of starch granules (Zobel, 1988). Most of the root and tuber starches exhibit a typical B-type X-ray pattern (Hoover, 2001).

Among the most important functional properties of starches are their thermal and pasting properties. The pasting behavior is usually studied by observing changes in the viscosity of a starch system based on rheological principles. From the pasting curve, several parameters can be observed that indicate the extent of disintegration and whether there is retrogradation. In general, root and tuber starches show weaker associative intragranular forces. Root and tuber starches gelatinize at relative low tempera-

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tures, with rapid and uniform swelling of granules. They also exhibit a high viscosity profile and high paste clarity compared to cereal starches, although root and tuber starches retrograde easily (Craig, Maningat, Seib, & Hoseney, 1989).

Wheat starch has higher phospholipids and produces a starch paste with lower transmittance than potato, whose starch has a lower content of phospholipids (Singh, Singh, Kaur, Sodhi, & Gill, 2003). On the other hand, among all the commercial starches, potato starch exhibits the highest swelling power and gives the highest viscosity of pasting properties (Mitch, 1984). Highly swelled starches increase the smoothness and thereby reduce the firmness and elasticity of some noodles (Konik, Mikkelsen, Moss, & Gore, 1994; Ross, Quail, & Crosbie, 1997), consequently, lowering the total texture quality. Phosphorus, a non-carbohydrate constituent, is found in potato starch with relatively high values and may affect the functional properties of the starch. A relatively high degree of phosphate substitution in potato starch leads to starch gels with high viscosity (Noda et al., 2006a; Suzuki, Shibanuma, Takeda, Abe, & Hizukuri, 1994; Wiesenborn, Orr, Casper, & Tacke, 1994). However, the properties of the native potato starches may not be desirable for all applications. Thus, studying the possibility of substituting the potato, sweet potato, yam, and cassava starches in wheat flour may be important to meet the requirements of carbohydrate-based food products.

The possibility of using potato and sweet potato starches in noodles and other wheat-based foods has been investigated by different researchers (Chen, Schols, & Voragen, 2003; Noda et al., 2006a). To determine the suitability of sweet potato flour for specific requirements, knowledge of the functional and physico-chemical characteristics of its starch is essential. Sweet potato starch can be used as an ingredient in bread, biscuits, cake, juice, and noodles (Zhang & Oates, 1999). However, the extent of the changes in the pasting behavior when substituting sweet potato starch in other types of flour has not been reported.

The yam (*Dioscorea* spp.) is a valuable food crop because of its high starch content, about 70–80% of dry matter, and small but valuable protein fraction of approximately 1–3/100 g (wet basis) (Zhang & Oates, 1999). Root and tuber starches have unique physico-chemical properties, primarily, due to their amylose and amylopectin ratio (Jenkins & Donald, 1995). Yam starch has been reported as an alternative source because of several desirable properties of its starch, such as viscosity stability to high temperature and low pH (Alves et al., 2002). The high retrogradation of yam starch gel is disadvantageous when it is applied to food systems. However, yam starches have fewer commercial applications than other starches. Hoover and Vasanthan (1994) observed that the apparent amylose content in yam starch is 27.1%, very similar to that of wheat starch and higher than that of potato starches. While cassava, also rich in starch, has received more attention over the years, the important role of yams for ensuring adequate food supply is being increasingly recognized, and their popularity is increasingly growing (Orkwor, 1998).

Whistler and BeMiller (1997) compared the general properties of some starch granules and pastes. They observed the formation of a translucent gel with high viscosity and a medium tendency to retrograde in cassava starch. Cassava (*Manihot esculenta* Crantz) is an important vegetable crop in tropical regions. On a food energy production basis, it ranks fourth after rice, wheat, and corn as a source of complex carbohydrates (Moorthy & Mathew, 1998). Cassava roots are prepared and consumed in many different ways, including boiled, similarly to potatoes. Starch is the major component of the dry matter in cassava, and, during hydrothermal treatment gelatinization may play an important role in defining the final characteristics of the cooked product (Beleia, Butarelo, & Silva, 2006). However, cassava starch does not show certain characteristics that introduce an unacceptable level of variability or process limitations in foods manufactured from this starch (Sriburi et al., 1999).

Since starch is quantitatively the most important component of potato, sweet potato, yam, and cassava, and, it is possible that the pasting properties of these starches could change during heat treatment. However, very limited research on the RVA analysis of mixtures of wheat flour and tuber starches has been reported, and, hence, it is interesting to study the pasting characteristics of the mixtures. The objective of this work was to study the pasting properties of substituting tuber starches in wheat flour using a rapid visco-analyzer (RVA). Thus, the effect of the amylose, phosphorus, protein, and lipid contents and granule size on the pasting properties was observed. The study should help to better understand the functionalities of starch properties during mixing with wheat-based foods.

2. Materials and methods

2.1. Materials

Commercial hard-wheat flour milled from the Japanese cultivar, Kitanokaori, was purchased from the Ebetsu Flour Milling Co. Ltd., Ebetsu, Japan. Potato starch (PS) (*Solanum tuberosum* L.) and sweet potato starch (SPS) (*Ipomoea batatas*) were purchased from Toukouren, Urahoro, Hokkaido, Japan, and the Haraigawa Starch Factory, Kimotsuki Agricultural Cooperative Association, Kanoya, Kagoshima, Japan, respectively. Cassava starch isolated from cassava tubers (CS) (*M. esculenta*) grown in Thailand was obtained from the Nippon Starch Chemical Co. Ltd., Osaka, Japan. Yam starch (YS) was isolated from the fresh yam tubers (*Dioscorea opposite* spp.), which were obtained from the Kawanishi Agricultural Cooperative Association, Obihiro, Hokkaido, Japan. The tubers were washed carefully with distilled water and cut into cubes of about 1 cm. The diced sample was homogenized in a mixture with twofold of ethanol. The slurry was centri-

fuged, and the resulting supernatant was decanted. The procedure was repeated until the viscosity of the slurry was low. The starch-containing pellets were washed with water and the slurry was successively filtered through 250 and 106 μm metallic sieves, allowing most of the starch granules to pass. The slurry was centrifuged and the resulting supernatant was decanted. The pellet obtained was treated with three times with a 2% sodium dodecyl sulphate solution containing 2% mercaptoethanol to remove the residual protein. The remaining starch pellets were washed with water three times in succession and then dried at 25 °C.

2.2. Analytical methods

The moisture content of the samples was determined using a moisture analyzer, model no. MX-50 (A & D Co. Ltd., Tokyo). The granule size of the samples was measured using sympatec HELOS particle-size analysis. The phosphorus content of the samples was determined using an energy dispersive X-ray fluorescence method according to Noda et al. (2006b). The mean diameter, based on the volume distribution, was measured according to Noda et al. (2004). The blue value (BV) of wheat starch of 0.411 was calculated according to the equation of Shibanuma, Takeda, and Hizukuri (1994). They determined that the average BVs at 680 nm of amylose and amylopectin of five wheat starches were 1.24 and 0.10, respectively. These BVs were used in the calculation of the amylose content (%) of wheat starch. The BVs of PS, SPS, YS, and CS were 0.485, 0.474, 0.524, and 0.417, respectively, estimated at 680 nm according to Noda, Takahata, Sato, Kumagai, and Yamakawa (1998a) and Noda et al. (1998b) using intact starch rather than defatted starch. The amylose content (%) was calculated from the BV according to the equation of Takeda, Takeda, and Hizukuri (1983). The BVs of amylose and amylopectin isolated PS were 1.38 and 0.24, respectively, determined by Suzuki et al. (1994). These BVs were used in the calculation of the amylose content (%) of PS. Similarly, the BVs of amylose and amylopectin isolated from SPS were 1.48 and 0.167, respectively, as determined by Takeda, Hizukuri, and Juliano (1986). These BVs were used in the calculation of the amylose content (%) of SPS. The BVs of amylose and amylopectin isolated from YS were 1.55 and 0.168, respectively, as determined by Suzuki, Kanayama, Takeda, and Hizukuri (1986). These BVs were used in the calculation of the amylose content (%) of YS. Finally, the BVs of amylose and amylopectin isolated from CS were 1.3 and 0.06, respectively, as determined by Thitipraphunkula, Uttapap, Piyachomkwan, and Takeda (2003). These BVs were used in the calculation of the amylose content (%) of CS.

The protein content of the samples was determined using the micro-Kjeldhahl distillation method. The Soxhlet extraction method was used to determine the fat content and petroleum ether (bp 40–60 °C) was used to extract fat (AOAC, 1990).

2.3. Preparation of blend

Wheat flour was blended with PS, SPS, YS, and CS individually in ratios of 0/100 (potato starch: wheat flour), 10/90, 20/80, 30/70, 40/60, 50/50, and 100/0. Mixing was on a weight basis as described by Zaidul, Yamauchi, Kim, Hashimoto, and Noda (2007).

2.4. Determination of pasting properties using the RVA

The RVA parameters were determined using the RVA-4 (Newport Scientific Pvt. Ltd., Australia) according to Noda et al. (2004). Each sample of control wheat, PS, SPS, YS, and CS was added to 25 ml of distilled water to prepare a 6% suspension on a dry weight basis (w/w). The mixtures of wheat–PS, wheat–SPS, wheat–YS and wheat–CS were also added to 25 ml of distilled water to prepare 8% suspension on a dry weight basis (w/w). Each suspension was kept at 50 °C for 1 min and then heated up to 95 °C at 12.2 °C/min and held for 2.5 min at 95 °C. It was then cooled to 50 °C at 11.8 °C/min and kept for 2 min at 50 °C.

2.5. Statistical analysis

The determinations of amylose content were performed in triplicate. Other experiments were carried out in duplicate. The averages and Duncan *t*-test were computed to measure variations in wheat flour and different tuber starches of PS, SPS, YS, and CS, and their mixtures. The least significant difference at the 5% probability level ($P < 0.05$) was calculated for each parameter.

3. Results and discussion

3.1. Physico-chemical analysis

The median granule size and the phosphorus, amylose, protein, fat, and moisture contents of the samples are shown in Table 1. The median granule size of wheat flour was found to be larger than that of all other starches used in the experiments. Wheat flour had the highest phosphorus content, followed by PS, SPS, YS, and CS. The protein and fat contents of wheat flour were 13.2% and 1.4%, respectively, whereas a negligible amount of protein and fat was present in PS, SPS, YS, and CS.

3.2. Pasting properties of control wheat, PS, SPS, YS, and CS

The RVA properties of control wheat flour and tuber starches, namely PS, SPS, YS, and CS, are shown in Table 2. A lower peak, trough, breakdown, final, and setback viscosities were exhibited in wheat flour than in tuber starches. However, the higher peak viscosity and breakdown of PS resulted in a lower setback than those of SPS, YS, and CS. The results of the pasting behaviors of

Table 1
Componential characteristics of wheat flour, potato starch (PS), sweet potato starch (SPS), yam starch (YS), and cassava starch (CS)

Sample	Granule size* (μm)	Phosphorus* (ppm)	Amylose* (%)	Protein* (%)	Fat (%)	Moisture (%)
Wheat	59.3[a]	1138.1[a]	27.2 ± 0.9[b]	13.2	1.4	15.0
PS	35.2[b]	847.2[b]	21.5 ± 1.1[e]	<0.1	neg.[A]	15.6
SPS	19.4[d]	231.3[c]	23.4 ± 1.0[d]	<0.1	neg.[A]	15.9
YS	22.8[c]	166.1[d]	25.8 ± 0.5[c]	<0.1	neg.[A]	16.9
CS	15.7[e]	97.0[e]	28.8 ± 0.7[a]	<0.1	neg.[A]	13.4

[A] neg., negligible.
* Values followed by the different lower letters in the same column are significant at a $P < 0.05$ level.

Table 2
RVA properties of control wheat flour, potato starch (PS), sweet potato starch (SPS), yam starch (YS), and cassava starch (CS)

Control sample	Peak viscosity (RVU)	Trough (RVU)	Break down (RVU)	Final viscosity (RVU)	Setback viscosity (RVU)	Peak time (°C)	Pasting temp. (°C)
Wheat	33.3	21.8	11.5	41.8	20.1	5.0	—
PS	543.9	165.4	378.5	204.8	39.4	3.0	69.1
SPS	132.8	96.8	36.0	139.1	42.3	4.5	81.5
YS	224.1	172.2	51.9	239.7	67.4	4.4	71.1
CS	134.9	75.9	59.0	122.5	46.6	4.3	72.7

RVA parameters are the mean of two determinations of the control samples, where the maximum standard deviation was ±0.08, ±2.62, ±2.14, ±1.88, and ±0.41 for wheat, PS, SPS, YS, and CS, respectively.

PS showed that a lower amylose content was associated with a higher peak viscosity and a lower pasting temperature for SPS, YS, and CS. Similar trends were observed in SPS, YS, and CS (Table 2). Our observation was supported by the study of Blennow, Bay-Smidt, and Bauer (2001), in which they found that the higher-amylose starches of cassava, sorghum and *Curuma zedoaria* had low viscosities and very small differences between the peak and final viscosities. Blennow et al. (2001) found that the starches extracted from potato tubers had high viscosities, while the sorghum, cassava and *Curuma zedoaria* starches had relatively low viscosities. Noda et al. (2006c) also reported that starches with lower phosphorus contents tended to exhibit lower peak viscosity and breakdown than those with higher phosphorus contents. In addition, our observations agree with those of Huang, Lin, and Wang (2006), who studied the pasting properties of various yam starches. When the temperature was cooled down to 50 °C, the final viscosity in YS increased to 239.7 RVU (Table 2). Ragaee and Aal (2006) found lower values of the RVA parameters in hard-wheat flour due to the lower rate of absorption and swelling of wheat starch granules.

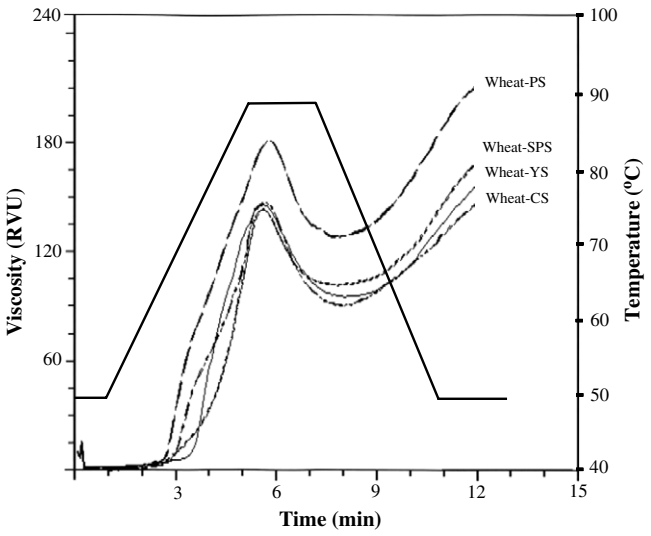

Fig. 1. Typical RVA pasting curves for the mixtures of wheat–PS, wheat–SPS, wheat–YS, and wheat–CS at 30% starch in the mixture.

3.3. Pasting properties of wheat–PS, wheat–SPS, wheat–YS, and wheat–CS mixtures

Fig. 1 shows the typical RVA pasting curves for the mixtures of wheat–PS, wheat–SPS, wheat–YS, and wheat–CS mixtures at 30% starch. Fig. 2a shows the peak viscosity of wheat–PS, wheat–SPS, wheat–YS, and wheat–CS mixtures at 10–50% starch. The peak viscosities increased significantly ($P < 0.05$) with an increase in the starch content in the mixtures. The peak viscosity of the wheat–PS mixture was significantly higher than those of wheat–SPS, wheat–YS, and wheat–CS mixtures. The higher peak viscosity of the wheat–PS mixtures was attributed to the higher phosphorus and lower amylose content of PS (Table 1), which caused the higher swelling of PS than of SPS, YS, and CS. However, the amylose content of PS was lower than that of wheat flour (Table 1); thus, the viscosity of the wheat–PS mixture was higher than that of the control wheat (Table 2) because the wheat starch was diluted by the tuber starch in the mixtures. Although the peak viscosity tended to increase with an increase of SPS, YS, and CS in the mixture, the differ-

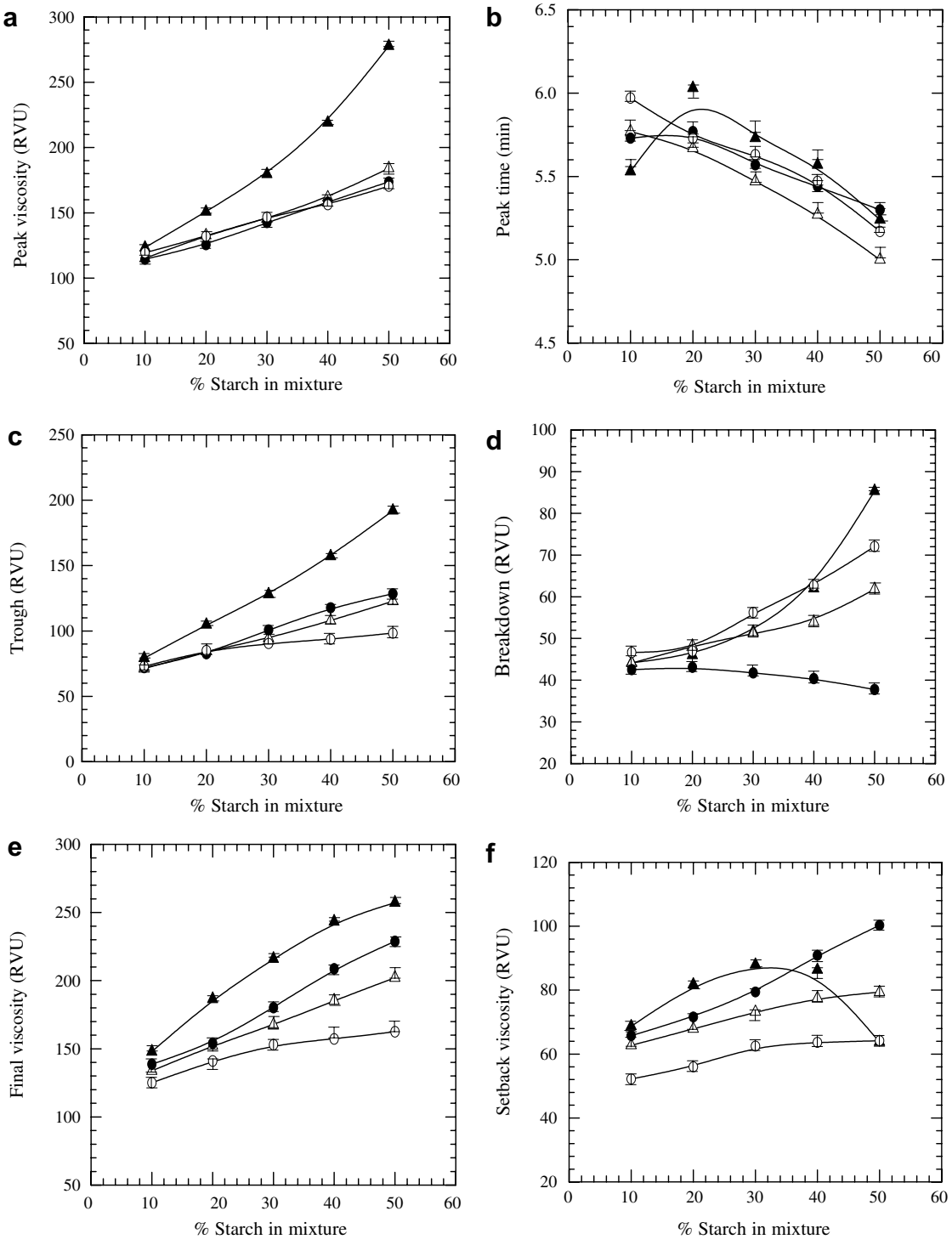

Fig. 2. (a) Peak viscosity for the mixtures of wheat–PS (▲), wheat–SPS (△), wheat–YS (●), and wheat–CS (○) at different % of starch. (b) Peak time for the mixtures of wheat–PS (▲), wheat–SPS (△), wheat–YS (●), and wheat–CS (○) at different % of starch. (c) Trough for the mixtures of wheat–PS (▲), wheat–SPS (△), wheat–YS (●), and wheat–CS (○) at different % of starch. (d) Break down viscosity for the mixtures of wheat–PS (▲), wheat–SPS (△), wheat–YS (●), and wheat–CS (○) at different % of starch. (e) Final viscosity for the mixtures of wheat–PS (▲), wheat–SPS (△), wheat–YS (●), and wheat–CS (○) at different % of starch. (f) Setback viscosity for the mixtures of wheat–PS (▲), wheat–SPS (△), wheat–YS (●), and wheat–CS (○) at different % of starch.

ences were not significant among wheat–SPS, wheat–YS, and wheat–CS. Thus, the peak time tended to be shorter with an increase of starch content in the mixtures (Fig. 2b). However, the peak time of wheat–PS and wheat–YS increased from 10% to 20%, and the differences were not significant. The peak time decreased significantly with an increase in the starch content from 20% to 50% in the wheat–PS, wheat–SPS, wheat–YS, and wheat–CS mix-

tures (Fig. 2b). The peak viscosity was too low in the control wheat and was of out of ranges (Table 2). Thus, it would appear advantageous to combine the starches with wheat flour for optimize the viscosity temperature. Zaidul, Karim, Manan, Norulaini, and Omar (2003) observed similar trends in the peak viscosity characteristics in the blend of sago starch and wheat flour with 10–50% sago in the mixtures. Fig. 2c shows a trough that was directly correlated to the peak viscosity. The addition of the trough and breakdown values represented an equal value of the peak viscosity. The breakdown viscosities of wheat–PS and wheat–SPS increased significantly with an increase of starch content up to 50% in the mixtures (Fig. 2d). On the other hand, in the wheat–YS mixture, the breakdown viscosities remained similar at 10% and 20% YS and then tended to decrease with an increase of YS from 20% to 50% (Fig. 2d). However, the differences in the breakdown values of wheat–YS were not significant. On the other hand, the breakdown viscosities of wheat–CS also increased significantly with an increase of CS, and the values were significant at 20–50% CS in the mixtures (Fig. 2d). The final viscosities of the of wheat flour and tuber starch mixture increased significantly with an increase in the starch content from 10% to 50% in the mixture (Fig. 2e). However, the wheat–PS mixture showed a higher final viscosity, followed by the wheat–YS, wheat–SPS, and wheat–CS mixtures. These trends were similar to those of mixtures of wheat flour and various amylose and potato starches with varying contents of phosphorus studied by Zaidul et al. (2007). Finally, the setback viscosities (Fig. 2f) of wheat–PS increased significantly at 10–30% starch and then tended to decrease dramatically at 50% PS in the mixture. Thus, PS could substitute wheat flour up to 50%. On the other hand, the setback viscosities of wheat–SPS, wheat–YS, and wheat–CS increased significantly with a 10–50% increase in the starch content in the mixture. However, the setback viscosities of wheat–CS were not significant with 30–50% starch in the mixture. Zaidul et al. (2003) reported that the setback reflects the retrogradation tendency of starch, which inhibited the increase of the minimum viscosity upon cooling. It was observed that the peak viscosity of control PS was too high compared to those of SPS, YS, and CS, which was attributed to the higher peak viscosities in the wheat–PS mixtures than in all other wheat flour and tuber starch mixtures at 10–50% starch. The dramatic increase in the peak viscosity at 40% and 50% PS was attributed to the lower setback viscosities with 40% and 50% PS in the mixtures. This conclusion was also supported by the observations of wheat–potato and sago–wheat mixtures studied by Zaidul et al. (2003) and Zaidul et al. (2007), respectively. However, such dramatically higher peak viscosities were not be observed with increased amounts of other tuber starches in the mixtures due to the relatively lower amounts of phosphorus and higher amounts of amylose of SPS, YS, and CS. In this case, the protein content of wheat flour directly affected the peak viscosities of wheat–SPS, wheat–YS, and wheat–CS. Olkku and Rha (1978) reported that protein forms complexes with the starch granule surface, preventing the release of exudates and lowering the peak viscosity. Eliasson, Carlson, Larsson, and Miezis (1981) reported that protein bound to granule surfaces at 1.5–4.7 mg/g. In addition, the lipids of wheat flour may affect the viscosities, as stated by Russell (1987). The peak and setback viscosities of a wheat–PS mixture were affected by the protein and lipid contents of wheat flour, similar to other mixtures of wheat–SPS, wheat–YS, and wheat–CS. The effect of the protein and lipid contents on wheat–PS mixtures was negligible due to the presence of higher amounts of phosphorus in PS than in SPS, YS, and CS; thus, the peak and setback viscosities were dramatically increased and decreased, respectively. The differences in the concentrated PS and wheat flour systems cannot be solely ascribed to the protein and lipids present in wheat flour.

The peak viscosities were observed within 5–6 min (Fig. 2b) for all wheat–PS, wheat–SPS, wheat–YS, and wheat–CS mixtures, and the wheat–PS mixtures showed the highest peak viscosity of all mixtures (Figs. 1 and 2a). This result indicated that the wheat–PS mixture has higher swelling power than the wheat–SPS, wheat–YS, and wheat–CS mixtures. However, the peak viscosity prior to disruption of the swollen granules was determined from the volume occupied by these swollen granules. This observation was supported to the study of swelling characteristics of Korean ginseng starch granules conducted by Koo, Park, Jo, Kim, and Baik (2005).

The strong swelling power of starch granules makes it easy for them to reach their maximum viscosity, and they are likely to breakdown easily because of their weak intermolecular force, thus become more sensitive to the shear force as the temperature increases. Therefore, the starch granules were easily broken down by the shear force, which had been increased by the swelling power (Kim, Lee, & Seok, 1999). This result suggested that the wheat–SPS, wheat–YS, and wheat–CS mixtures showed lower peak viscosity at the same initial pasting temperature and had a denser structure or higher crystallinity than the wheat–PS mixture. The breakdown is regarded as the measure the degree of disintegration of granules or paste stability (Dengate, 1984; Newport Scientific, 1995). At breakdown, the swollen granules disrupt further, and amylose molecules generally leach into the solution (Newport Scientific, 1995; Whistler & BeMiller, 1997). At 50% starch in the mixtures the wheat–PS mixture showed the highest breakdown (Fig. 2d) in association with higher peak viscosities (Fig. 2a), which, in turn, were related to the degree of swelling of the starch granules during heating (Ragaee & Aal, 2006). This means that the wheat–SPS, wheat–YS, and wheat–CS mixtures were more resistant to heat and shear force than the wheat–PS mixture. The setback that of the final viscosity and holding strength indicated that the value of obtained from the formation of rearrangement of excreted

amylose molecules from starch granules after swelling. The setback reveals the gelling ability or retrogradation tendency of amylose (Newport Scientific, 1995). The highest setback was observed in wheat–PS up to 30% and in wheat–YS at 40% and 50% starch in the mixtures, suggesting that the highest amylose retrogradation occurred in those mixtures at those of concentrations.

Our conclusions was also supported by the observations of Hopkins and Gormley (2000), Kim, Wiesenborn, Orr, and Grant (1995), Noda et al. (2006a, 2006b, 2006c, 2004), and Wiesenborn et al. (1994). They indicated that a higher phosphorus content was associated with a higher peak viscosity and breakdown. Noda et al. (2006c) reported that the RVA parameters of peak viscosity and breakdown were positively correlated with the phosphorus content. The peak viscosity and breakdown were negatively correlated with the amylose content (Noda et al., 2004) and the correlation between the peak viscosity and the amylose content was not so significant (Hopkins and Gormley, 2000; Wiesenborn et al., 1994).

4. Conclusions

Blending tuber starches with wheat flour resulted in acceptable and better RVA properties. The RVA properties of the peak viscosity, breakdown viscosity, final viscosity, and setback viscosity of control PS, SPS, YS, and CS were higher than those of control wheat flour. Thus, in the mixtures of wheat–PS, wheat–SPS, wheat–YS, and wheat–CS, the peak viscosity and final viscosity increased with an increase in the starches from 10% to 50%. However, the peak and final viscosities of wheat–PS were significantly higher than those of the wheat–SPS, wheat–YS, and wheat–CS mixtures. This conclusion was reached because the higher phosphorus and lower amylose content of PS resulted in higher swelling of PS than of SPS, YS, and CS. The observation of a setback of wheat–PS shows that PS could be recommended for substituting wheat flour up to the 50%. The result of this work could encourage substituting tuber starches for part of the wheat flour used in wheat-based food products, e.g., noodles, breads, biscuits, and crackers. However, further studies are needed to determine the interaction between wheat flour and tuber starches. Thus, studies of the rheological properties of the thermal and textural analysis of gel-containing wheat flour and tuber starch mixtures using differential scanning calorimeter and rheoner, respectively, are required.

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