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

I.S.M. Zaidul [a,*], N.A. Nik Norulaini [b], A.K. Mohd. Omar [c], H. Yamauchi [a], T. Noda [a,*]

[a] Memuro Upland Farming Research Station, National Agricultural Research Center for Hokkaido Region, Shinsei, Memuro, Kasai, Hokkaido 082-0071, Japan
[b] School of Distant Education, University Sains Malaysia, 11800 Pulau, Pinang, Malaysia
[c] School of Industrial Technology, University Sains Malaysia, 11800 Pulau, Pinang, Malaysia

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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-

* Corresponding authors. Tel.: +81 155 62 9278; fax: +81 155 62 2926.
E-mail addresses: zaidul@naro.affrc.go.jp (I.S.M. Zaidul), noda@affrc.go.jp (T. Noda).

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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-