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TRENDS IN FOOD SCIENCE & TECHNOLOGY

Review

Physicochemical properties, molecular structure, and uses of sweetpotato starch

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Interests in sweetpotato production and utilization are surging in recent years. The major carbohydrate of sweetpotato root is starch which accounts up to around 80% of the dry matter, with a large and cheap potential supply. This review summarizes the recent advances in physicochemical properties, structure, modifications, and uses of sweetpotato starches, and provides suggestions for further research to improve the utilization.

Introduction

Sweetpotato (*Ipomoea batatas* Lam.) is a dicotyledonous plant that belongs to the family Convolvulaceae. It can grow at altitudes from sea level to 2500 m, and comes in varieties with skin and flesh colours from white to yellow, orange, and deep purple. Globally, sweetpotato is the sixth most important food crop after rice, wheat, potatoes, maize, and cassava. It is the fifth most important food crop in developing countries, playing a critical role in food security. The global annual production accounts up to more than 105 million metric tons (International Potato Center, 2013).

There are diverse health benefits of sweetpotato consumption due to the presence of various functional components such as dietary fibres, carotenoids, phenolic acids, anthocyanins, vitamins, and minerals (International Potato Center, 2013; Zhu, Cai, Yang, Ke, & Corke, 2010). The major component of sweetpotato root is starch which can account up to around 80% of the dry matter (Zhang, 2001). The growing cycle of sweetpotato can be short (3.5 months) and the potential supply of starch is large and cheap (Ramirez, 1992). In recent years, interests in the production, characterization, and utilization of sweetpotato starch are surging. More genetic resources from various biogeographic locations and also genetic modifications were explored and provide sweetpotato starches with novel properties (Kitahara *et al*., 2007; Takahata *et al*., 2010). Structural analysis further revealed the molecular basis for these functional novelties (Noda *et al*., 2009). The functional properties of starch naturally-obtained were further diversified by chemical/physical/enzymatic modifications (Lee, Choi, Shin, Park, & Moon, 2008; Gunaratne & Corke, 2007). These novel structural and physicochemical features of starch in turn have greatly expanded their food and industrial applications.

Previous reviews dated until roughly a decade ago summarized data on the composition, physiochemical properties, and structure of sweetpotato starch (Hoover, 2001; Moorthy, 2002; Tian, Rickard, & Blanshard, 1991). The last decade saw a great increase in our understandings of sweetpotato starch, facilitated by the development of the experimental tools and conceptual breakthrough. This review summarizes recent advances in the structure, functional properties, and industrial and food uses. Suggestions for further research to improve the utilization of sweetpotato starch are outlined.

Physical changes of starch granules in the presence of water during heating and cooling

Starch granules are made up of alternating amorphous and semi-crystalline shells as 'growth rings' with a thickness between 100 and 400 nm. Within the semi-crystalline shells, crystalline and amorphous lamellae are found with a periodicity of about 9–10 nm as revealed by X-ray diffraction investigations (Pérez & Bertoft, 2010). When heated in the presence of water, starch granules absorb water and swell while starch components leach out and solubilise. Further heating and water absorption lead to the rupture of granules and disordering of the organization of the chains. This process is in general termed gelatinization. Upon cooling, the amorphous chains undergo molecular interactions through hydrogen bonding.

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Table 1. Swelling and solubility of granular starch.

No.	Parameter	Temperature (°C)				References
		55	65	75	85	
21	SP		7.8–31.1 (60)			Aina *et al.*, 2012
21	S		1.5–9.5			
2	SP	3.5–4.1 (50)	5.0 (60)	5.0–28.1	31.4–33	Jangchud, Phimolsiripol, & Haruthaithanasan, 2003
2	S	1–1.6	2.2–2.4	3.2–11.6	20.4–20.7	
25	WSI	0.1–0.3 (RT)				Waramboi *et al.*, 2011
11	SP	2.0–3.2	2.8–6.5	14.5–22.1	13.3–20.4	Zhu, Yang, *et al.*, 2011
	WSI	0.2–0.8	9.2–18.3	22.5–61.2	53.4–85.8	

No., number of genotypes tested in the specific study; SP, swelling power (g/g); S, solubility (%); WSI, water soluble index (%); figures in the parenthesis indicate actual temperature used; RT, room temperature.

The re-association and re-ordering of starch chains are termed retrogradation (Hoover, 2001).

The water content, amylose–amylopectin ratio, structures of amylose and amylopectin, the packing of amylose and amylopectin chains in the granules, the presence of minor components (e.g., phosphorous and lipids), the environment (e.g., pressure, heating and cooling rates) have great influence on the physical changes of starch during heating and cooling (Hoover, 2001; Srichuwong & Jane, 2007). There are various methods to measure diverse aspects of the physical changes of starch granules during heating, as outlined below.

Swelling and solubilisation

The extent of granular swelling during heating can be quantified as swelling power (SP) (measures both inter- and intra-granular water), and the solubilisation of starch components is characterized as solubility (S) (%) or water soluble index (WSI) (%) (Hoover, 2001; Tester & Morrison, 1990; Zhu, Yang, Cai, Bertoft, & Corke, 2011). Great diversity in swelling and solubilisation properties was observed among different genotypes from various studies (Table 1). Correlation between SP and WSI was observed ($r^2 = 0.88$) (Zhu, Yang, *et al.*, 2011).

Pasting

Pasting properties of sweetpotato starch are commonly measured by Rapid visco-analyzer (RVA), Brabender viscograph (BV), or Brabender amylograph (BA) (Table 2). The starch content of the sample has a great effect on the pasting behaviour, and thus should be noted when comparing the results from different studies. Great genetic diversity in pasting properties as reflected by peak viscosity, breakdown, and setback was recorded. Novel genotypes with lower pasting temperatures were generated by the means of breeding (Katayama *et al.*, 2002) or genetic manipulations (i.e., inhibition of starch synthase II expression) (Takahata *et al.*, 2010). Increased amounts of very short

Table 2. Pasting properties.

No.	Method	Starch content (%)	Peak viscosity	Breakdown	Setback	Pasting temp. (°C)	References
21	RVA	10	143–288	29–163	15–79	73.5–87.7	Aina *et al.*, 2012
3	RVA	6	133–152	18–37	42–59	77.6–80.8	Wickramasinghe, Takigawa, Matsuura-Endo, Yamauchi, & Noda, 2009
1	RVA	10	465			78	Tetchi *et al.*, 2007
1	RVA	9	281		73	72.4	Peroni *et al.*, 2006
20	RVA	7		85–206	106–176	53.8–66.6	Kartayama, Tamiya, & Ishiguro, 2004
2	RVA	10	381.9–433.4	197.5–237.3	125.4–176.4	74.8–80.5	Jangchud *et al.*, 2003
2	BA	10	240–275		380–405	75–79.5	Osundahunsi, Fagbemi, Kesselman, & Shimoni, 2003
7	RVA	8	275–330	124–154	32–68	73.5–77.6	Noda *et al.*, 2002
25	RVA	10	145–1260			73.5–81.1	Waramboi *et al.*, 2011
11	RVA	8.9	268–469	149–247	51–76		Zhu, Yang, *et al.*, 2011
5	BV	6	666–887	37–417	275–396	54.9–73.6	Kitahara *et al.*, 2005
8	RVA	8	348–385	128–189	69–98	74.1–77.2	Toyama, Ishiguro, Noda, Kumagai, & Yamakawa, 2003
4	RVA	7				52.6–73.6	Katayama *et al.*, 2002
		10				51.4–72.6	
9	RVA	7	126–190	33–84	119–199	60.4–76.0	Takahata *et al.*, 2010

No., number of genotypes tested in the specific study; RVA, Rapid visco-analyzer; BA, Brabender amylograph; BV, Brabender viscograph; Viscosity unit of peak viscosity, breakdown, and setback for RVA, BA, and BV are RVU, AU, and BU, respectively.