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Physicochemical and functional properties of modified sweet potato starch

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Abstract

Sweet potato (*Ipomoea batatas* L. (Lam)) is an important source of starch and it is a biopolymer composed of anhydroglucose units. The physico-chemical properties and functional characteristics of starch systems and their uniqueness in various food products vary with starch biological origin. The cooking, textural and rheological properties of potatoes are related to the physicochemical, morphological, thermal and rheological properties of their starch. Sweet potato starch is used in many products including noodles, cakes, bread, biscuits, desserts, alcoholic and non-alcoholic drinks, puddings and confectionery products. Applications of starch in food systems are primarily governed by gelation, gelatinization, pasting, solubility, swelling, colour and digestibility. This study investigated the physicochemical and functional properties of sweet potato starch extracted with water (control) and modified with sodium hypochlorite. The control method had moisture (13.24%), protein (0.45%), fat (0.89%), ash (1.87%), crude fiber (0.67%), purity (82.885), water absorption capacity (0.76ml/g), oil absorption capacity (0.20 ml/g), light transmittance (7.2%) and pH (6.1). The modified starch had significantly lower moisture (12.23%), protein (0.21%), fat (0.32%), ash (0.93%) and crude fiber (0.41%) content. So the percent purity (85.9 %) was higher than control method. The water absorption capacity (0.91ml/g), oil absorption capacity (0.39ml/g) and pH (6.8) were higher than control method. Light transmittance (28.4%) was also better in sodium hypochlorite modified starch.

Keywords: sweet potato, root crop, starch, solubility

1. Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam) is a starchy root crop grown in tropical and subtropical countries like China, USA, India, Japan, Indonesia, Philippines, Thailand, Vietnam, and Nigeria. In India it is cultivated in almost all the states. Sweet potato is considered as a 'poor man's rich food' in many parts of India. In India, sweet potato is largely grown in three states: Orissa, Uttar Pradesh, and West Bengal (Attaluri, *et al.* 2010) [5]. The functionality of starches in any application is governed by its physicochemical properties (Chen *et al.*, 2003) [8]. Industrial interest in new value added starch products has resulted in many investigations being carried out on the characterization of starches isolated from sweet potato roots of different genotypes and botanical sources. These starches are known to differ in their physicochemical properties and these differences have been attributed to variation in amylose / amylopectin ratio in starch granules, granule size distribution, mean granule size, mineral content and the presence of naturally occurring non carbohydrate impurities in the starches (Zhu *et al.*, 2011; Oduro *et al.*, 2000; Aina *et al.*, 2010) [21, 16, 4]. Chemical modification brings about structural alterations and the introduction of new functional groups, thus affecting the physicochemical properties of the starch and making it fit for various industrial uses. Oxidation causes depolymerisation of the starch and introduces carboxyl and carbonyl functional groups. Oxidised starches are used in food products where neutral-tasting, low-viscosity starch is required, such as in lemon curd, salad cream and mayonnaise. The low non-starch components of the starch like low protein content make them valuable in the production of syrups with high glucose content compared to the native starch. Therefore, this study is aimed at investigating the physicochemical and functional properties of sweet potato starch extracted with water (control) and modified with sodium hypochlorite.

2. Materials and Methods**Materials**

The sweet potatoes were procured from local vegetable market, Chittorgarh, Rajasthan.

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Starch isolation

The starch was isolated by slightly modified method of Peshin (2001) [17]. In brief, sweet potatoes were washed to remove adhering soil, followed by peeling to remove the thin outer skin. The eyes and all bruises were pitted. Immediately after peeling, the sweet potatoes were cut into small pieces and one kg of the material was crushed for 3-4 min in a mixer at room temperature using one litre of distilled water. The slurry was filtered through muslin cloth. The residue left on the muslin cloth was washed with distilled water, until only small amounts of starch were passing the muslin cloth. Filtrate was collected in a glass beaker and residue left on the muslin cloth was discarded. The beaker containing filtrate was kept undisturbed for 2 h. A solid layer of starch settled down. The sedimented starch was washed 3 to 4 times with distilled water followed by sieving through 120 size mesh sieve until the wash water became clear and free of suspended impurities. The pure starch extracted was dried in hot air oven at a temperature of $40\pm 5^\circ\text{C}$ overnight, then ground, sieved through a 150 size mesh screen, dried starch used for further use. This method considered as standard control method for starch extraction.

Starch modification by sodium hypochlorite

Sweet potato starch was isolated using method of Forssell *et al.* (1995) with slight modifications. One kg tubers were washed, cut into small pieces, placed in blender, and then blended in an electric blender for 3-4 min. Added 10 g sodium hypochlorite solution in ground slurry of sweet potato for 30 min to avoid browning with constant stirring while maintaining a pH range of 9.0 – 9.5. The reaction was allowed for 10 min after all the NaOCl had been added and then filter through muslin cloth. Subsequently, the pH was adjusted to 7.0 with 1M H_2SO_4 . The filtrate was washed extensively with distilled water in order to separate starch and sweet potato cell debris. The residues containing the starch grains were further washed for 4 times and allowed to settle for 2 h. The starch sediment was dried in oven at $40\pm 5^\circ\text{C}$ overnight, then ground and sieved through a 150 size mesh screen. The dried starch used for further test.

The starch extracted by different methods was analysed for the various parameters. The parameters like moisture content, crude ash content, crude fiber, crude fat (using Soxhlet apparatus) were estimated using A.O.A.C. (2006) [1] method. Crude protein was also estimated using Micro-Kjeldhal method (A.O.A.C., 2006) [1]. Water absorption capacities of native and modified starches were determined using the method of Beuchat *et al.* (1977) [6] with slight modification. 1 g of starch sample was weighed in 50 ml centrifuge tubes and about 50 ml of water added. The centrifuge tube was stoppered tightly. The suspension was allowed to shake in incubator cum shaker at temperature ($30\pm 2^\circ\text{C}$) for 1 h. The suspension was centrifuged at 3000 rpm for 10 min. The volume of water on the sediment was measured and was decanted. The weight of wet starch paste (sediment) was taken. The water absorbed by starch expressed as g/g water absorption based on the original sample weight. Light transmittance of starch paste from sweet potato starch was measured by Craig *et al.* (1989) [9] method with slight modification. An aqueous suspension of starch (1%) was heated in a water bath at 90°C for 1 h with constant stirring. The starch paste was cooled for 1 h at 30°C , and the light transmittance was measured at 640 nm. The samples were

stored for 5 days at 4°C in a refrigerator and transmittance was determined every 24 h with a VIS spectrophotometer (Labtronics Model LT-39, India). The swelling power and solubility of sweet potato starch was determined by using the method of Waliszewski *et al.* (2003) [20] with slight modification. Starch sample (1.0 g) was accurately weighed and transferred into clean dried centrifuged tubes and weighed (W_1). The starch was then dispersed in 50 ml of distilled water using glass rod. The slurry obtained was heated for 30 min at two temperatures 80°C and 90°C respectively with constant stirring with the help of glass rod. The mixture was cooled to room temperature and centrifuged for 15 min at 3000 rpm. The residue obtained after centrifugation in the centrifuged tube was weighed (W_2). Aliquots of the supernatant were dried into an evaporating dish of known weight to a constant weight at 110°C . The residue obtained after drying weighed. The supernatant represented the amount of starch solubilized in water. The pH of sweet potato starch was also determined by using pH meter.

3. Results and Discussion

Physiochemical properties of control and modified starch isolated from sweet potato are presented in Table 1. Modified sweet potato starch had significantly lower moisture content than control method. The range of moisture varied from 12.23% to 13.24%. The moisture content of a starch powder plays a significant role in the flow and other mechanical properties (Adebowale and Lawal, 2003) [3]. Although it largely depends on the method, extent of drying and the humidity in the surrounding atmosphere.

Table 1: Physiochemical properties of control and modified sweet potato starch

Starch	Moisture	Protein	Fat	Crude fiber	Ash	Purity
Control starch	13.24	0.45	0.89	0.67	1.87	82.88
Modified starch	12.23	0.21	0.32	0.41	0.93	85.90
C.D. at 5%	0.37	0.09	0.11	.06	0.08	0.46

The modified starch resulted in significantly lower protein content than control method (0.45%). Fat and protein located on the surface of starch granules that are crucial for maintaining their structural stability (Chan *et al.*, 2010). The modified starch resulted in significantly lower fat, crude fiber and ash content than control method. This reduction can be attributed to the possible chemical degradation of the starch during modification and is in agreement with reports by (Lawal, 2004) [15] and (Adebowale and Lawal, 2003) [3]. Reductions observed in fat, protein and ash content could also be attributed to various degradative processes during modifications of the starch and it might be due to washing of degraded starch molecule after modifications. Low moisture and fat contents in modified starch play a vital role in long storage but high moisture levels could be deleterious because it would favour microbial growth and cause the starch to become discoloured especially if moisture content level exceeds 18% (Adebowale *et al.*, 2002) [2]. The purity of modified starch is more (85.9%) than control starch (82.8%). The purity of the starch as indicated by the low nitrogen and low ash levels (Gunaratue and Hoover, 2002). The effect of both methods of extraction on water absorption capacity, oil absorption capacity, light transmittance and pH of the extracted starch is presented in Table 2.

Table 2: functional properties of control and modified sweet potato starch

Starch	Water absorption capacity (ml/g)	Oil absorption capacity (ml/g)	Light transmittance (%)	pH
Control starch	0.76	0.20	7.2	6.1
Modified starch	0.91	0.39	28.4	6.8
C.D. at 5%	0.13	0.09	1.2	0.2

Significantly higher water absorption capacity (0.91 ml/g) was recorded in modified sweet potato starch than control starch (0.76 ml/g). This behavior of oxidized starches could be due to introduction of functional groups on the starch molecules which facilitate a more enhanced binding capacity than the native starch. Increase of water retention capacity of modified starches as compared to native starch could be due to increase in the availability of water binding sites (Jyothi *et al.*, 2005) [12]. Oil absorption capacity (OAC) (ml/g) had also found same trend. Significantly higher OAC (0.39 ml/g) was recorded in modified starch than control starch (0.20 ml/g). The pH of the sweet potato starch extracted by modified method is also significantly higher (6.8 pH) as compare to control method (6.1 pH). Light transmittance (%) on 5th day was recorded significantly higher (28.4%) in modified starch method as compare to control method (7.2%). Increase light transmittance after oxidation indicates low levels of retrogradation in oxidized starches as compared to their native counterparts. The increase in light transmittance (%) after oxidation may be due to the chemical substitution of the hydroxyl groups in the starch molecules by carbonyl and carboxyl functional groups. This causes repulsion between adjacent starch molecules and apparently reduces inter-chain association which facilitates improved transmittance (Lawal, 2004) [15]. The effect of both methods of extraction on swelling power of the extracted starch at both temperatures (80°C and 90°C) is presented in Table 3.

Table 3: Swelling power and solubility of control and modified sweet potato starch

Starch	Swelling power (g/g)		Solubility (%)	
	80°C	90°C	80°C	90°C
Control starch	14.83	17.25	1.74	2.83
Modified starch	21.56	29.56	4.52	8.62
C.D. at 5%	0.96	1.12	0.68	0.87

Both extraction methods resulted in significant variations in swelling power of the extracted starch at both temperatures (80°C and 90°C). The swelling power of sweet potato starch increased when temperature increased from 80°C to 90°C in respect of both extraction methods. At 90°C, the maximum swelling power (29.56 g/g) was recorded by modified method which is significantly higher than control method (17.25 g/g). The solubility of sweet potato starch also increased when temperature increased from 80°C to 90°C in respect of both extraction methods. At 90°C, the maximum solubility (8.62 %) was recorded by modified method which is significantly higher than control method (2.83 %). Swelling power is very important phenomenon of starch because it results in higher viscosity in starch-water systems. Similar results were also reported by (Singh *et al.*, 2004) [19] in modified white sorghum starch and by Lawal (2004) [15] for cocoyam starch. The rise in swelling power could be due to the gelatinization of starches which unfolds the structure of starch granules. The swelling power of oxidized starches improved due to insertion of functional groups. Since carboxyl and carbonyl groups are introduced in oxidized starch, therefore it demonstrated the highest improvement in swelling power. Increase in solubility

of modified starches as compared to native starch may be due to increase in leaching of amylose from the starch granules. Similarly, increase in temperature resulted in leaching of higher amount of amylose from the starch, as granules gelatinize at higher temperature. Starch swelling occurs concomitantly with loss of birefringence and proceeds solubilization (Singh *et al.*, 2004) [19]. Oxidised starch had wide applications in food industries, such as, coating and sealing agents in confectionery, as emulsifier (Khan *et al.*, 2014) [13], dough conditioner for bread, as gum Arabic replacer and binding agent in some applications (Kuakpetoon and Wang, 2001) [14]. The film forming property of oxidized starch makes it a suitable excipient for tablet (Sanchez-Rivera *et al.*, 2005) [18].

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