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Effect of ionic gums and dry heating on physicochemical, morphological, thermal and pasting properties of water chestnut starch

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ABSTRACT

Starch from water chestnuts (*Trapa natans*) was isolated and modified by dry heating and hydrocolloids [carboxy methyl cellulose (CMC) and sodium alginate]. Native and modified starches were evaluated for their physicochemical, pasting, thermal and morphological properties. Pasting and thermal properties were studied using Rapid Visco Analyzer (RVA) and Differential Scanning Calorimeter (DSC) respectively. Morphological properties were studied by Scanning Electron Microscopy (SEM). Modification of the starch by dry heating with and without gums reduced paste clarity and increased the water and oil binding capacity; solubility and swelling power decreased. Dry heating of native starch increased peak viscosity; however, with addition of CMC, peak viscosity decreased. Starch modified with CMC and 4 h heating exhibited lowest gelatinization temperature (T_0). Pasting characteristics of native water chestnut starch were largely affected by the addition of gums and/or heat treatment. Overall onset gelatinization temperature reduced with heat treatment and addition of gums. Morphological studies revealed no significant variation in starch granule size. Starch granules were seen agglomerated because of leaching of amylose and granule interspacing decreased with addition of gums.

1. Introduction

Water chestnut (*Trapa natans*), locally known as 'Singhara', is an edible aquatic angiospermic plant found commonly on the water surfaces of lakes and ponds. Water chestnut kernel, triangular in shape, is covered with dark brown skin with small spikes at the top. The outer cover of the kernel is hard making it difficult to peel off to obtain the white meat (edible portion) inside. Water chestnut is an important commodity in food industry because of its unique taste (Parker & Waldron, 1995). Importance of water chestnut in Kashmir dates back to times of Sir Walter Lawrence; when the main crop of the valley was destroyed due to floods in 1893 the flour of '*Singhara*' (water chestnut) saved people from starvation (Lawrence, 1895, pp. 160–165). The fruit is used as a substitute for cereals in Indian subcontinent during fasting days. The fruits are usually eaten raw at tender stage and sometimes after boiling and roasting. Lot of research has been carried out on starch from corn, rice, wheat, potato starches (Medcalf & Giles, 1965; Raina, Singh, Bawa, & Saxena, 2006; Sandhu, Singh, & Lim, 2007; Singh & Singh, 2001; Svegmark & Hermanson, 1993), etc. Starch industry is continuously looking for new sources (Kaur, Ariffin, Bhat, & Karim, 2012; Kong, Kasapis, Bao, & Corke, 2009; Wani et al., 2013; Wani, Sogi, Wani, Gill, & Shivhare, 2010) to offset the production costs and to meet growing demand for novel starches in food, cosmetic and pharmaceutical applications. The demand of starch has increased enormously in recent years as starch is being widely used in production of ethanol and biodegradable plastics (Wani et al., 2012) apart from being used in food processing industries. Hence, search for novel starches is always a focus of the starch industry.

Water chestnut, an underutilised starch source, has been poorly understood for modification and utilization in food industry. Water chestnuts are cheaply available and promising with regards to the starch content. The bulk of the edible region of water chestnut consists of starch-rich thin walled storage parenchyma similar in appearance to potato, interspersed with vascular strands. However, in contrast to other sources like potato and rice,

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water chestnut is notable for its ability to maintain a firm and crunchy texture after considerable heat treatment during canning or cooking (Singh, Singh, Bawa, & Saxena, 2009). Water chestnuts principally having large quantities of starch can be used as a source of starch for industrial applications in food and allied industries. A detailed knowledge of the characteristics of water chestnut starch would facilitate its utilization in industries; enable tailoring of the properties by physical or chemical modification to specific applications and bring economic benefit to the people. Native starch has got some limitations with their use in food industry. To overcome the shortcomings, native starch is modified to increase its usefulness in industrial applications. Therefore, focus of the study was to analyze the effects of modification with ionic gums (CMC & sodium alginate) and heat treatment on water chestnut starch.

2. Material & methods

Fully mature water chestnuts were procured from Wular Lake, Asia's largest fresh water lake in Bandipora, Jammu and Kashmir, India. Samples were collected at the time of harvest and stored at 4 °C till further use. Carboxy methyl cellulose was procured from Central Drug House (CDH) Laboratory Reagents, New Delhi and sodium alginate was procured from S. D. Fine Chemicals Ltd, Mumbai, India.

2.1. Isolation of starch

Starch was isolated from water chestnuts with slight modifications to the method described by Vanna, Khajee, and Thanachan (2004). The hard skin of water chestnuts was removed manually and white kernels obtained were dipped in 0.1 g/100 g aqueous potassium metabisulphite (KMS) solution for 30 min. After grading to obtain fruits of same size, selected fruits were peeled, washed and cut into small pieces. Representative samples of 1 kg were ground in a blender with 2 L of 0.2 g/100 g sodium hydroxide. The homogenate was filtered through a 75 μm mesh sieve and centrifuged at 3000×*g* for 30 min at 10 °C (C-24, BL; Remi Laboratory Industries, Mumbai, India).

The sediment was recovered and again suspended with two volumes of water and centrifuged. Washing steps were repeated until clear supernatant and traces of alkali were no longer found. Starch solution was filtered through a buchner funnel under vacuum to remove the water. The filtered cake obtained was dried in an oven at 40 °C to less than 10 g/100 g moisture content. Starch was ground gently with mortar and pestle and passed through 75 μm sieve, packed in airtight plastic bags and stored in refrigerated conditions at 4 °C.

2.2. Modification of starch

Modification of water chestnut starch, shown in Table 1, was carried out by the method as described by Lim, BeMiller, Han, and Lim (2002). Modification of starch was carried out by dry heating of starch with and without ionic gums (sodium alginate and carboxy methyl cellulose (CMC)). Initially sodium alginate & CMC (0.4 g) was slowly added in distilled water (70 ml) separately with vigorous stirring using a magnetic stirrer. Starch (39.6 g) was added to the prepared gum solutions, and the dispersion was stirred continuously for 30 min at room temperature. Separately prepared dispersions were transferred into a glass dish and dried at 45 °C in an oven to a moisture content of <10 g/100 g, based on starch. The starch gum mixture was heated in an electric oven at 130 °C for 2 and 4 h separately in two lots. The starch sample itself was concurrently heat treated without gums under identical conditions.

Table 1
Treatments for modification of starch with ionic gums and dry heating.

Sample	Starch (g)	Treatments			
		CMC (g/100 g)	Sodium alginate (g/100 g)	Heating temperature (°C)	Heating duration (h)
B_0	50	–	–	–	–
B_2	50	–	–	130	2
B_4	50	–	–	130	4
C_0	39.6	1	–	–	–
C_2	39.6	1	–	130	2
C_4	39.6	1	–	130	4
S_0	39.6	–	1	–	–
S_2	39.6	–	1	130	2
S_4	39.6	–	1	130	4

2.3. Physicochemical properties

2.3.1. Moisture and ash

Moisture content (g/100 g) and ash content (g/100 g) were determined by A.O.A.C (1995) methods.

2.3.2. Total carbohydrate content

Total carbohydrate was quantified by phenol sulphuric acid method as described by Dubois, Gilles, Hamilton, Rebers, and Smith (1956) and as modified by Wankhede and Tharanthan (1976).

Starch sample (0.5 g, dry weight basis) was weighed in a test tube and kept in ice water bath for few minutes followed with addition of 2 ml cold sulphuric acid (72 ml/100 ml) with gentle stirring. The viscous paste was prepared by pinching with glass rod and it was diluted with distilled water (23 ml) to obtain a final concentration 2 ml equi/L with respect to acid. It was then hydrolyzed at 98 °C in a water bath for 3–4 h. The sample was filtered and the volume was made to 100 ml. One ml was taken and volume make up to 50 ml was done. Further, one ml from 50 ml sample solution was taken and 0.2 ml of 5 ml/100 ml phenol was added.

The standard glucose solution was prepared by weighing 100 mg of glucose in a beaker in which 25 ml of distilled water were added. The standard working solution was made by diluting a known amount of stock glucose solution to prepare calibration curve.

2.3.3. Amylose content

The amylose content was determined by using the method described by Scott, Hugh, and Colin (1998). The reagents used were distilled ethanol, 1 ml equi/L NaOH, 0.1 ml/100 ml phenolphthalein, iodine reagent (dissolved 10 g KI + 1 g iodine in water and made up to 500 ml), potato standard amylose (dissolved 0.1 g amylose in 10 ml 1 ml equi/L NaOH made volume up to 100 ml with demineralized water).

Starch sample (0.1 g) in the powdered form was weighed. To this 1 ml of distilled ethanol was added. Then 10 ml of 1 ml equi/L NaOH was added and left overnight. On the following day, the volume was made up to 100 ml with distilled water. Extract, 2.5 ml, was taken and about 20 ml distilled water was added followed by three drops of phenolphthalein indicator. To this, 0.1 ml equi/L HCl drop by drop was added until the pink colour just disappeared. One ml iodine reagent was added, volume was made up to 50 ml and colour was read at 590 nm. Standard amylose 0.2, 0.4, 0.6, 0.8, and 1 ml was taken and the colour was developed as in the case of sample for preparing standard curve.