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Structural, thermal and rheological properties of starches isolated from Indian quinoa varieties

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In this study starches isolated from Indian quinoa varieties were examined for physicochemical, morphological, thermal and rheological properties. Among isolated starches V_1 showed higher starch yield and lower purity (48.45% and 98.32%) than V_2 (41.28 and 98.53%). The amylose content was higher for V_1 (12.10%) than V_2 (9.46%). Swelling powers and solubility of the starches increased with increasing temperature. Peak viscosity (386.4 RVU) was higher for V_1. In contrast V_2 showed higher pasting temperature (72.85 °C). Low setback viscosity of the starches suggests that they can be profitably used in frozen and refrigerated foods. Starch granules from both varieties were irregular, angular and polygonal in shape. The starch granule size obtained by SEM was 1.23 μm for V_1 and 1.19 μm for V_2. Both starches showed a typical A-type diffractrometric pattern with varying crystallinity. Further V_1 showed lower transition temperatures (To, Tp and Tc) than V_2. FTIR spectroscopy showed higher intensity and broader shape of V_2 at O—H stretch which can be due to its higher crystallinity. Increased interest is shown in quinoa starch because of its unique microcrystalline granules. Higher yield and purity values suggest that both varieties can be exploited for commercial starch utilization.

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1. Introduction

Pseudo-cereals belong to class dicotyledonae and produce seeds having high proportion of starch Chenopodium quinoa, amaranth and buckwheat are the three most important pseudo-cereals. Quinoa has origiAnated from South America, and belongs to the family Chenopodiaceae and order caryophyllales. Quinoa has grabbed much attention as a new food source because of its nutritional value and tolerance to stress conditions like drought, frost and salinity [1]. The production of quinoa was 45,782 t in Bolivia, 800 t in Ecuador and 44,213 t in Peru [2]. Quinoa has been successfully cultivated in the drought-prone area of Andhra Pradesh under the "Project Ananta" [3,4]. There is no widespread cultivation of quinoa in India hence; FAO data for cultivation of this crop in India is not available. Quinoa can be termed 'underutilized' for India, as despite of its wide adaptability, and nutritional superiority, its commercial potential has remained untapped [5]. Quinoa grain is a starchy raw material with large content of carbohydrates, consisting of starch and a small percentage of sugars. Starch is the major component of quinoa, and varies from 50 to 62% with a granule diameter of less than 3 μm [6,7]. There is a growing demand of starch, as the new food processing industries are increasingly dependent on both native and modified starches for the manufacture of various fabricated foods. This demand has created interest in finding the new sources of this polysaccharide. Starch has been widely used for improving moisture retention and maintenance of the quality of stored food products [8]. There have been few studies on the functional and industrial potentials of quinoa starches from different countries, but there is a complete dearth of such information about Indian quinoa starch (IQS). The limited publications on quinoa mainly deal with its chemical composition, granule morphology and pasting properties a systematic documentation of functional, structural and textural properties of quinoa starches is still to be conducted. Further the study on amplitude sweep and temperature sweep (rheological properties) is absconding. Hence, the aim of this study was to characterize the physicochemical, morphological, thermal and rheological properties of Indian Quinoa Starches. The properties of the starch were then compared with that of quinoa starch Q-J.Grano (already available in literature) and denoted as "V3" [9].

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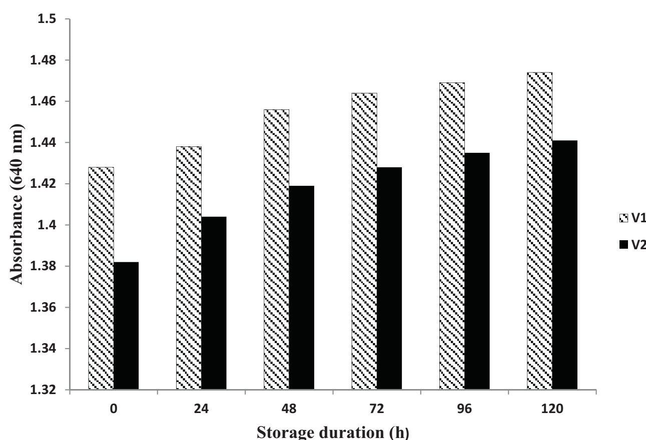

Fig. 1. Effect of storage duration on turbidity (absorbance at 640 nm) of gelatinized starches from Indian Quinoa starches stored at 4 °C.

2. Materials and methods

2.1. Raw material

Two germplasms of Quinoa IC-411824 (V_1) and EC-507739 (V_2) used in this study were obtained from the National Bureau of Plant Genetic Resources (NBPGR), located in Shimla. The seeds were then cultivated at the experimental farm of Sant Longowal Institute of Engineering and Technology. Both varieties were planted in the month of December and were harvested manually in the month of April. The quinoa was planted in the holes almost 40 cm deep with a plant spacing of about 35 cm per plant. Both the varieties matured in almost 140–151 days. The seeds were dried at room temperature and stored in plastic bags until processing for starch extraction. All the reagents used in the study were obtained from Sigma Aldrich, St. Louis, USA. All measurements were done in triplicates.

2.2. Starch isolation

Starch was isolated from the quinoa varieties by using alkaline steeping method given by Ahamed et al. (1998) [10] with slight modifications from the standardised procedure (Jan K.N et al. unpublished data). Flour (500 g) was dispersed in a NaOH solution 0.25 g/100 mL (0.25% w/v) by mixing manually at room temperature for few minutes before steeping. The flour-to-water ratio used during steeping was 1:6 and the steeping time was 24 h. The slurry was then centrifuged at 5500 rpm for 15 min, supernatant was collected for the recovery of protein and the residue was subjected to wet milling with addition of de-ionized water. The resultant slurry was then filtered by passing through a series of BSS sieves (100,200 and 300 mesh size). The material left over the sieves was washed thoroughly with de-ionized water and filtrate was centrifuged at 6500 rpm for 15 min. The top yellow layer was scrapped off from the residue and the starch was re-suspended in the water, while the supernatant was collected and combined with the initial one for the protein recovery. Starch was washed repeatedly (five times) for purification and then dried in hot air oven at 40 °C for 12 h. The dried starch thus obtained was ground with a lab scale blender (Philips electric appliance company) and stored under refrigerated conditions in air tight containers for further analysis.

2.3. Physico-chemical properties

2.3.1. Proximate composition

Starch Recovery from both quinoa varieties was expressed as percent yield. Starches were chemically analyzed for their moisture, ash, lipids, and crude protein contents (N × 6.25) according to the methods described in AOAC (2006) [11]. Purity was expressed as total starch content (100–% protein + % fat + % fibre + % ash). The samples were tested in triplicate.

2.3.2. Color

Hunter colorimeter (Model i5 Green Macbeth, USA) was used for determination of color values of Quinoa starches. Data was recorded as L*, a* and b* values. More appropriate color measurement was obtained from the Calculation of hue angle [$h^\circ = \tan^{-1}(b^*/a^*)$] and Chroma [$C^* = (a^{*2} + b^{*2})^{0.5}$]. Where $h^\circ = \tan^{-1}(b^*/a^*)$ when $a^* > 0$ and $b^* > 0$; $h^\circ = 180 + \tan^{-1}$

(b^*/a^*) when $a^* < 0$ and $h^\circ = 360 + \tan^{-1}(b^*/a^*)$ when $a^* > 0$ and $b^* < 0$.

2.3.3. Amylose

Colorimetric determination of amylose content of native starch samples was done by using the method described by Morrison and Laignelet (1983) [12]. Urea and DMSO (UDMSO) solution 10 mL (90% DMSO, 10% 6 M urea in water) was mixed with 70 mg starch sample and heated for 10 min in boiling water bath with intermittent mixing. The solution was transferred to oven at 100 °C for 1 h and then cooled to room temperature. The aliquot of 0.5 mL of the solution was taken into volumetric flask containing 25 mL distilled water + 1 mL of I_2-KI (0.2 g I_2 and 2 g KI in 100 mL distilled water) and final volume was made up to 50 mL with distilled water. Absorbance was measured at 635 nm 15 min after addition of the I_2-KI reagent and UDMSO-I_2-KI (except sample) was used as blank. Amylose content was calculated from the blue value and determined in triplicates. Amylopectin was esimated by difference (100-amylose%).

$$\text{Bluevalue} = \frac{\text{Absorbance} \times 100}{2 \times \text{gsolution} \times \text{mgstarch}} \times 10$$

$$\%\text{Amylose} = \text{Blue value} \times 28.414$$

2.3.4. Turbidity

Transmittance of starch sample was measured as described by Perera and Hoover (1999) [13]. A 1% aqueous starch suspension was made by heating 0.4 g starch in 40 mL of de-ionized water in a water bath at 90 °C for 1 h with thorough shaking after every 5 min. The sample were then cooled to room temperature and stored at 4 °C for five days. The absorbance was measured after every 24 h at 640 nm against a water blank using a spectrophotometer (Cole-parker, Germany).

2.3.5. Swelling power & solubility

Swelling power (SP) and solubility were determined according to the method of Lin et al. (2011) with some modifications [14]. Starch suspension 1%, (0.4 g in 40 mL w/v) was taken in centrifuge tubes and placed on a vortex mixer for 10 s. The samples were heated in a water bath at 55° to 95 °C (at 10 °C intervals) for 30 min; and were left for cooling to room temperature. Samples were then centrifuged at 3000 rpm for 15 min using a REMI PR-24 centrifuge (VCDL-4890; M/s. Remi Electrotechnik Limited, Maharashtra, India). The supernatant was dried in a pre-weighed Petri plate to a constant weight at 120 °C. All measurements were done in triplicates. The SP (g/g) and Solubility (%) were calculated as;

$$\text{Solubility}\,(\%) = \frac{\text{Weigth of dried supernatent}}{\text{Weight of sample}} \times 100$$

$$\text{Swelling power}\,\left(g/g\right) = \frac{\text{Weigth of sediment paste} \times 100}{\text{Weight of samlpe} \times (100 - \%\text{Solubilty})}$$

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