

Physicochemical and functional properties of *Chenopodium quinoa* starch

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Starch isolated from lysine-rich high protein *Chenopodium quinoa* grains was studied for physicochemical and functional properties. In contrast to corn starch which showed a two-stage swelling, *C. quinoa* showed a single-stage swelling in the temperature range of 65–95°C. However, *C. quinoa* starch had a lower solubility and lower viscosity than corn starch at same concentration. The unique property of *C. quinoa* starch was its unusual freeze–thaw stability, a fact difficult to explain. The opaque nature of *C. quinoa* starch paste suggests applications in emulsion food products such as salad dressings. Utilization of *C. quinoa* starch has advantages, since the grain as such has limited acceptability, attributed to the presence of bitter saponins. Copyright © 1996 Elsevier Science Ltd

INTRODUCTION

Chenopodium quinoa has been recently identified to have promising potential in overcoming world's food shortage. Its lysine-rich high protein grains (Gonzalez *et al.*, 1989; Dini *et al.*, 1992; Ruales & Nair, 1992; Ranhotra *et al.*, 1993), coupled with a desirable fatty acid composition (Przybylski *et al.*, 1984; Ruales & Nair, 1993) and high calcium and phosphorus contents (National Research Council, 1989) make it a unique food source. An added advantage is the nutritional quality of vegetable chenopods (Weber, 1978; Prakash *et al.*, 1993). The presence of bitter saponins, located primarily in the outer layer of the seed prevented it from attaining global importance (Reichert *et al.*, 1986; Muzui *et al.*, 1988; Ridout *et al.*, 1991).

The main constituent of *Chenopodium* grain is the small granule sized ($< 1 \mu\text{m}$) starch, having about 11% amylose (Lorenz, 1990). Such starches having small sized starch granules have unique applications such as dusting starches, for example, in cosmetics, candy dusting, rubber tyre mould release agents (Pomeranz, 1985), and as flavour carriers (Zhao & Whistler, 1994). The fact that *Chenopodium* starch can be isolated in saponin-free form also qualifies it in food applications. Its industrial potential, however, remains untapped. The present work reports on the functional properties such as swelling and solubility behaviour and paste properties such as viscosity, freeze–thaw stability and paste clarity. Corn starch has been included for comparison.

MATERIALS AND METHODS

Corn starch was obtained from M/S Laxmi Starch, Mazgoan, Bombay. *Chenopodium* grain was obtained from the National Botanical Research Institute, Lucknow, and starch isolated from it by the alkali steeping method (Yanez & Walker, 1986) as detailed in Fig. 1. The following experiments were carried out:

Determination of swelling power and solubility

These were determined over a temperature range of 65–95°C according to the method of Leach *et al.* (1959). 0.35±0.001 g of the starch sample was taken in a 15 ml graduated centrifuge tube. To this was added 12.5 ml of distilled water. The tube was capped quickly and the contents of the tube were mixed on a vortex mixer. Any delay in this stage caused clumping of starch. The tube was then placed in a constant temperature water bath maintained at 65°C, mixed by inverting twice at several intervals (20 s) for 15 min. The tube was cooled rapidly in iced water to approximately 25°C and centrifuged at 1000 rpm for 20 min. The supernatant was carefully pipetted, evaporated and dried at 105°C for 5 h till constant weight. A duplicate was carried out to ensure reproducibility. Similar sets of experiments were also carried out 75, 85 and 95°C. Swelling power and solubility were calculated using the following relations:

$$\% \text{ Solubility} = \frac{\text{Weight of the soluble starch (g)}}{\text{Weight of the sample (dry basis), (g)}} \times 100$$

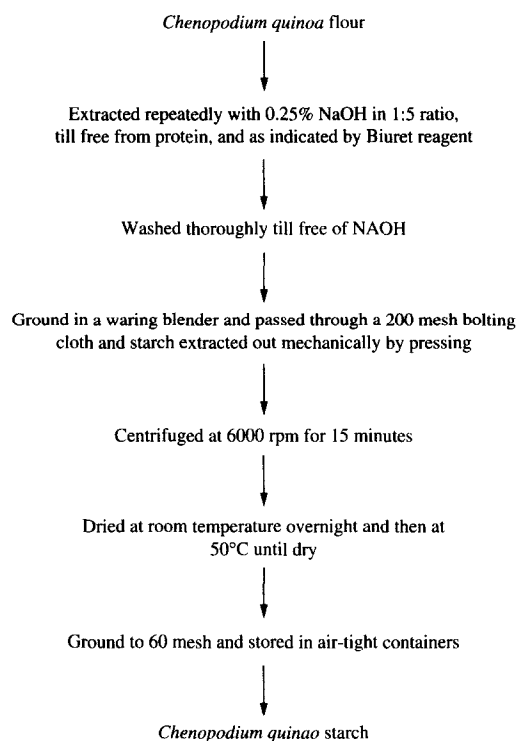


Fig. 1.

$$\text{Swelling power} = \frac{\text{weight of the sedimental paste, g}}{\text{weight of the sample (dry basis), g} \times (100 - \% \text{ Solubles on dry basis})}$$

Brabender amylogram profile of *C. quinoa* starch

The paste viscosity of *C. quinoa* starch was evaluated by using Brabender Viscoamylograph at 5%, 7% and 10% concentrations. The paste viscosity of corn starch was also evaluated at 5% level for comparison. The starches were heated from room temperature (28°C) to 95°C at a rate of 1.5°C/min, held at 95°C for 10 min, and then cooled back to 40°C at a rate of 1.5°C/min.

Freeze-thaw stability of *C. quinoa* starch

The freeze-thaw stability of *C. quinoa* and corn starch was studied by subjecting 5% starch pastes to repeated cycles of freezing and thawing, and measuring the amount of water separated on centrifuging the thawed paste. The starches were kept for freezing at -10°C for 18 h and was then thawed at room temperature for 6 h. The starch suspensions were then centrifuged at 3000 rpm for 10 min. The freeze-thaw stability was expressed as the percentage of water separated after each freeze-thaw cycle (Schoch, 1959; Kite *et al.*, 1963).

Paste clarity of *C. quinoa* starch

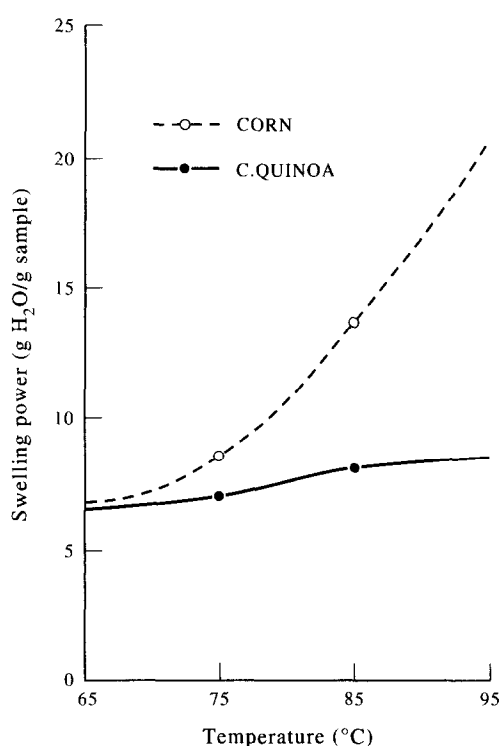
The paste clarity was studied as a function of starch concentration (0.5–5.0%) by measuring the percentage

of light transmitted at 660 nm (Schoch, 1959; Kite *et al.*, 1963).

RESULTS AND DISCUSSION

Figure 2 gives the swelling power of corn and *C. quinoa* starch in the temperature range of 65–95°C. Corn starch shows a two-stage swelling at 65–75°C and 85–95°C, while *C. quinoa* shows a single-stage swelling from 65–95°C. The swelling power of corn and quinoa starch at 95°C is 21.0 and 8.54, respectively. A two stage swelling, indicates that there are two types of forces which require different energy inputs to cause relaxation. A single stage swelling on the other hand indicates relaxation of binding forces within starch granules over one range and not at different temperature range (Soni & Agarwal, 1983). Various other workers have reported a two-stage swelling for corn starch (Srivastava *et al.*, 1970; Soni *et al.*, 1987, 1989, 1990). Besides corn starch, other starches such as *Careya arboria*, wheat (Medcalf & Gillers, 1966), mango (Srivastava *et al.*, 1970), *Aesculus assamica* (Soni *et al.*, 1989), *Dioscorea alata* (Rosenthal *et al.*, 1972) are also known to give two stage swelling. Similarly, mucuna starch (Rosenthal & Lodson, 1969), jack bean (Rosenthal *et al.*, 1970), chick pea (Srivastava *et al.*, 1970) are known to give single stage swelling.

Comparison of swelling power of *C. quinoa* starch with other starches like barley, wheat, rice, amaranth

Fig. 2. Swelling power of corn and *C. quinoa* starches.

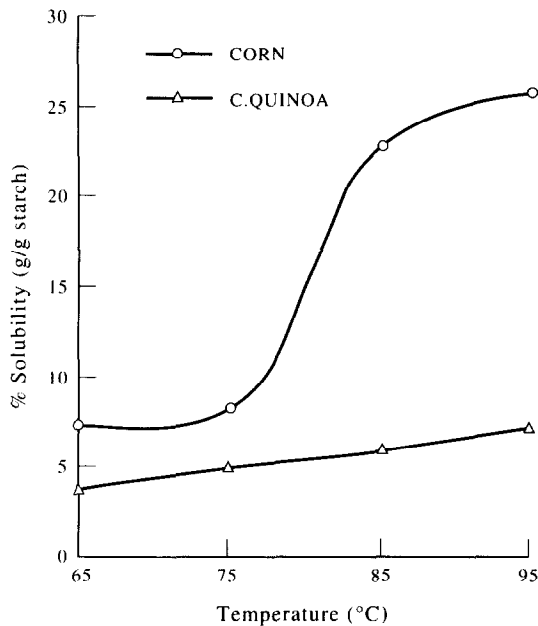


Fig. 3. Comparative account of solubility behaviour of *C. quinoa* and corn starches.

and potato has been reported (Lorenz, 1990). However, there has been no mention about the behaviour of corn starch. A much higher swelling power for *C. quinoa* was observed as compared to the other above mentioned starches.

Percent solubilities of corn and *C. quinoa* starches in the pasting temperature range of 65–95°C is shown in Fig. 3. It can be seen from Figs 2 and 3, that the nature of the curves for swelling power and solubility are almost similar. Here also, the solubilization pattern of *C. quinoa* starch is indicative of uniform strong binding forces, whereas patterns for corn starch exhibit two sets of binding forces within the granular structure. It is believed that the presence of weak intragranular binding and loose linking of the linear amylose fraction with the rest of the macromolecular structure contributes to high solubility (Soni *et al.*, 1987). Higher solubility of corn starch may be attributed to the higher amylose content of 23–24% in corn starch as compared to 11% in quinoa starch (Soni *et al.*, 1990).

A plot of swelling power vs solubility of corn and *C. quinoa* starch is shown in Fig. 4. For both the starches, it can be seen that the solubility increases with the swelling power. This is clearly evident in corn starch as compared to *C. quinoa* starch. This could be explained by assuming that a part of linear component is involved in micellar network, while the rest is free from enlargement and is able to leach out after hydration (Soni & Agarwal, 1983). Corn starch having a higher amylose is presumably involved in hydration capacity after leaching. There it has a higher swelling power as well as higher solubility as compared to *C. quinoa*.

The Brabender characteristics of *C. quinoa* starch

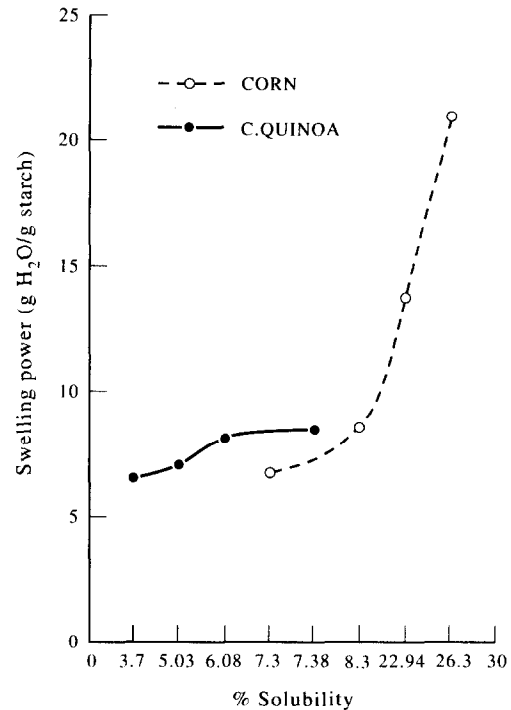


Fig. 4. Comparative account of swelling power vs solubility of *C. quinoa* and corn starch.

pastures at 5, 7 and 10% as compared to corn starch paste at 5% is as given in Table 1. It can be seen that *C. quinoa* starch had a lower gelatinization temperature of about 71°C as compared to 85°C for corn starch. Gelatinization temperature for other starches are as follows: wheat starch, 65–67.5°C; potato, 56.7–62.5°C; tapioca, 62.5–68.7°C; rice, 58.7–61.2°C (Radley, 1968). The low swelling power of *C. quinoa* starch is also clear from the peak viscosity values of the starches at 5% concentration. However, at 7% and 10% concentration, *C. quinoa* starch showed a much higher peak viscosity. Similar trend was observed with respect to viscosity at 95°C, viscosity after holding at 95°C for 10 min and cold paste viscosity at 40°C. A dramatic change in these values is seen, when the concentration of *C. quinoa* starch increases from 5% to 7% to 10%. Lorenz (1990) compared *C. quinoa* starch with wheat, barley, wild rice, amaranth and potato. However, corn starch was not included in the study. According to this study, *C. quinoa* starch showed much higher viscosity than wheat or barley starch at all reference points. These results would suggest corn starch to be a better thickener in food products as compared to *C. quinoa* starch, but the comparative effect of other ingredients on the pasting properties of the starch in the formulation need to be ascertained.

Figure 5 shows the freeze–thaw stability of corn and *C. quinoa* starches at 5% level. An unusual freeze–thaw stability for *C. quinoa* starch was observed. While the percentage separation of water after six cycles was 60%

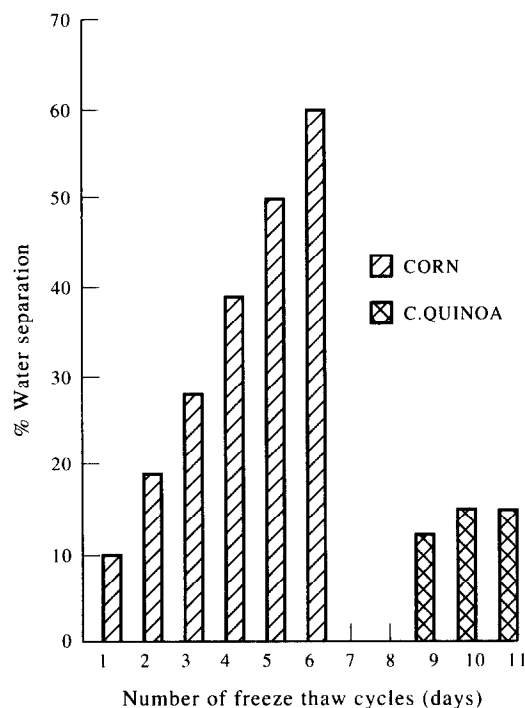


Fig. 4. Comparative freeze-thaw stability of 5% *C. quinoa* and corn starches.

for corn starch, there was no separation for *C. quinoa* starch upto the eighth cycle. It was only in the ninth cycle that 12% separation was observed. This indicated that *C. quinoa* starch paste is resistant to retrogradation, suggesting applications in frozen food products (Leitch & Rhodes, 1963), and in emulsion type of food products such as salad dressings. Other applications where poor retrogradation can be industrially exploited are sauces and cream soups, pie fillings, etc. The unusual freeze-thaw stability of *C. quinoa* starch is difficult to explain, specially in view of the fact that it does contain about 8–10% amylose. Waxy starches devoid of amylose as well as certain modified starches are known for their good freeze-thaw stability. Waxy rice starch shows best freeze-thaw stability. It is stable for about twenty cycles (Merca & Juliano, 1981). No convincing explanation for this behaviour has been offered to date.

Figure 6 represents the light transmitted at 660 nm as a function of *C. quinoa* and corn starch concentration. At all the concentrations ranging from 0.5–5.0%, *C. quinoa* starch showed lower paste clarity. Visual observation of this function was also noticed. The smaller size of *C. quinoa* starch granule (< 1.0 μm) could be a reason for this phenomenon. The opaque nature of this starch is a desirable characteristic for salad dressing, where it can be utilized.

In conclusion, a good freeze-thaw stability of *C. quinoa* starch suggests applications as a thickener in frozen food products. Its small granule size and opaque nature of its pastes are other properties which could be commercially tapped and beneficially utilized.

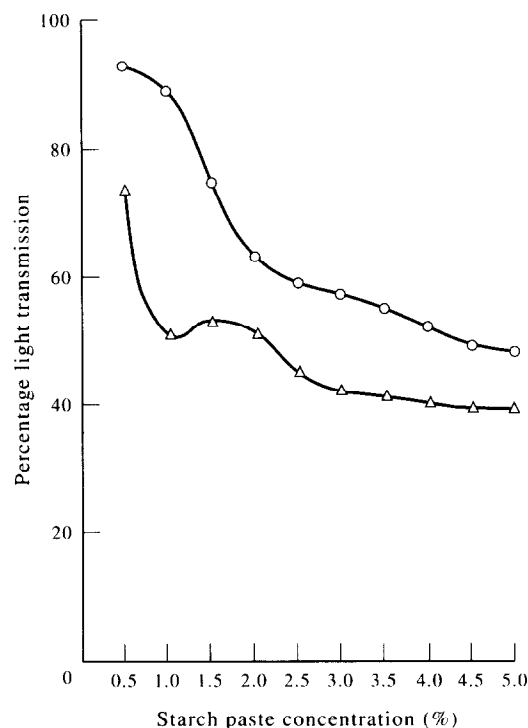


Fig. 6. Percent light transmission vs starch paste concentration.

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