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Physicochemical properties and amylopectin chain profiles of cowpea, chickpea and yellow pea starches

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Abstract

Starches from cowpea and chickpea seeds were isolated and their properties were compared with those of commercial yellow pea starch. Amylose contents were 25.8%, 27.2%, and 31.2%, and the volume mean diameter of granules, determined in the dry state, were 15.5, 17.9, and 33.8 μm for cowpea, chickpea and yellow pea starches, respectively. All three legume starches showed a C-type X-ray diffraction pattern and two-stage swelling pattern. Amylopectin populations were isolated and the unit chain profiles were analyzed by HPLC after debranching with pullulanase. The degree of polymerization (DP) of short chain populations was about 6–50 and the populations of long chain had a DP of 50–80. Cowpea showed a lower weight ratio of short:long chains than chickpea and yellow pea starches. The larger portion of long side chains in cowpea amylopectin can be correlated with a higher gelatinization temperature, greater pasting peak and a slight difference in crystalline structure found for cowpea starch. Chickpea and yellow pea starches exhibited similarity in unit chain profile of amylopectin as well as in gelatinization temperature and pasting profile, while they differed in amylose content, particle size and syneresis. It is assumed that the chain length distribution of amylopectin has a large influence on starch properties.
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1. Introduction

Legumes are important ingredients of a balanced human diet in many parts of the world, due to their high protein and starch contents (Czuchajowska, Otto, Paszczynska, & Baik, 1998). Cowpea (*Vigna unguiculata*), native to Asia and Africa, has a number of commonly used names, e.g. southern pea, black-eyed pea and crowder pea (Prinyawiwatkul, McWatters, Beuchat, & Phillips, 1997). Chickpea (*Cicer arietinum*), also known as garbanzo (Schoch & Maywald,

1968) and Bengal gram, is cultivated in the Mediterranean Basin, North America and Asia. Yellow pea (*Pisum sativum*), which is also known as field pea (Sosulski, Hoover, Tyler, Murray, & Arntfield, 1985), garden pea and smooth pea (Boyer, 1981; Gernat, Radosta, Damaschun, & Schierbaum, 1990; Li & Vasanthan, 2003), is a yellow seeded cultivar of *Pisum sativum*, very common in northern Europe.

Cowpea, chickpea and yellow pea have been historically consumed as whole seeds or ground flour. The utilization of their components as new ingredients in the food industry has drawn the attention of researchers. The protein contents of cowpea, chickpea and yellow pea are in the range of 15–35% (Arora & Das, 1976; Clemente, Sanchez-Vioque,

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Vioque, Bautistab, & Millan, 1998; Jirapa, Normah, Zamaliah, Asmah, & Mohamad, 2001; Longe, 1980; Rangel, Domont, Pedrosa, & Ferreira, 2003; Soetrisnot & Holmes, 1992; Sosulski et al., 1985). These values are much higher than the levels found in cereal grains and root crops. Consequently, cowpea, chickpea and yellow pea have been subjected to protein studies (Okechukwu & Rao, 1997; Rangel et al., 2003; Sanchez-Vioque, Clemente, Vioque, Bautista, & Millan, 1999; Soetrisnot & Holmes, 1992) aimed to satisfy the demand for new sources of plant proteins. Protein production can only be economic when the other major component – starch – is utilized simultaneously.

Information on structure–property relationships of these legume starches is essential for predicting their functionality and subsequent end-use in foods. There are some studies on gelatinization, gel and rheological behaviours of cowpea starch, but few systematic studies on its physicochemical properties or amylopectin structure. There is more information for chickpea starch, but this does not cover the relationship between molecular structure of amylopectin and starch properties. An attempt was made to relate the properties of cowpea and chickpea starches to the chain profiles of their amylopectin fractions. Characteristics of chickpea starch exhibit considerable variability in the literature; so do those of yellow pea starch. Therefore, the physicochemical properties and the chain length distributions of amylopectin populations of chickpea and yellow pea starches were investigated, together with cowpea starch, in this study.

2. Materials and methods

2.1. Materials

Cowpea and chickpea starches were prepared in the laboratory from cowpea and chickpea seeds kindly supplied by AVEBE Food Innovation Centre, Asia Pacific (Shanghai, China). Yellow pea starch was a gift from COSUCRA (Warcoing, Belgium). Pullulanase (EC 3.2.1.41) (M2, from *Bacillus licheniformis*, 400 U/mL) was purchased from Megazyme (Ireland).

2.2. Starch isolation from cowpea and chickpea

Starches were isolated from cowpea and chickpea according to the method of Schoch and Maywald (1968) with some modifications. Peas were steeped in deionized water at 4 °C for 24 h (cowpea) and 48 h (chickpea). The steep water was decanted, and the softened legumes were ground in a blender (Waring, New Hartford, USA) for 3 min in deionized water (4 °C) at low speed. The ground slurry was sieved through a 0.450 mm sieve on a AS200 digit shaker (Retsch GmbH & Co., Haan, Germany). The residual pulp was again ground for 3 min in the blender with fresh water, and sieved again. The combined starch suspension was then sieved through a set of sieves

(0.250 and 0.063 mm). The starch was allowed to settle overnight at 4 °C. The supernatant was drained off, and the upper non-white layer was removed. The starch layer was resuspended in cold 0.2% NaOH and kept at 4 °C for 17 h (cowpea) and 2 h (chickpea). Then starch slurries were neutralized with 2 mol/L HCl to pH 6 and centrifuged at 100g (cowpea) and 1500g (chickpea) at 4 °C. The starch layer was suspended in deionized water and centrifuged 6–7 times, until the settled starch gave a firm, dense deposit on the bottom and was substantially free of fine fibre (as examined by microscopy). The final sediment was suspended in cold deionized water and screened through a 0.032 mm sieve. The starch was recovered by filtration, and drying at 40 °C for 72 h and ground into powder using a blender.

2.3. Chemical characteristics of materials

Cowpea and chickpea were milled with an ultra centrifugal mill (ZM200, Retsch GmbH & Co., Haan, Germany) into fine powder. The moisture contents and lipid contents of two raw materials and three starch samples were determined according to Chen, Schols, and Voragen (2003a). The starch contents of cowpea, chickpea seeds and three starches were determined using the enzymatic Roche starch test kit (Boehringer Mannheim, Darmstadt, Germany). The amylose contents of cowpea, chickpea and yellow pea starches were tested using the enzymatic amylose/amylopectin assay kit (Megazyme International Ireland Ltd., Co., Wicklow, Ireland). Nitrogen contents were determined according to Chen, Schols, and Voragen (2003b). Phosphorus contents of the starches were measured according to the method of Rameau and Have (1951).

2.4. Physical properties of starch

Particle size distribution of starch was measured, both in dry state and in water, with a laser diffraction system (H1140, Sympatec Inc., New Jersey, USA). The analysis of the crystalline structure of the starches was carried out using a Philips diffractometer (PW 1830, Almelo, the Netherlands). Degree of relative crystallinity was calculated by the method of van Soest, Tournois, de Wit, and Vliegenthart (1995) with the equation: Relative crystallinity (%) = $A_c/A_t \times 100$, where A_c is the area of crystalline peak and A_t is total area measured from the baseline, which was a straight line from 7° 2-theta in the X-ray diffractogram as shown in Fig. 1.

The temperature range of gelatinization was measured using a differential scanning calorimeter (Perkin–Elmer DSC-7, Norwalk, CT, USA). Starches (10 mg) and 40–50 mg deionized water were weighed, sealed and held for 5 min at 10 °C, then heated from 10 to 150 °C at a rate of 10 °C/min. The PE Pyris Series – DSC7 software was used for data handling. The enthalpy of the endothermic peak was expressed on the basis of dry material (J/g dry starch).
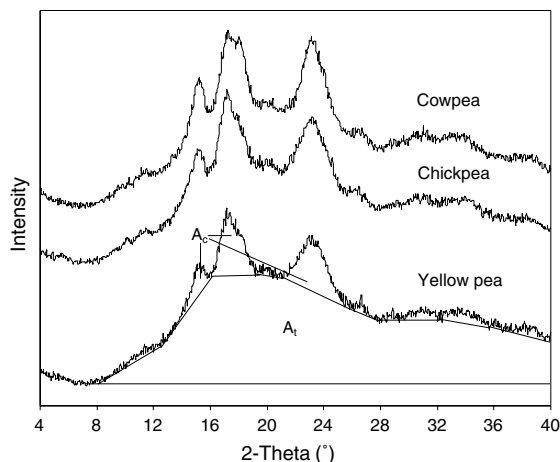
Fig. 1. X-ray diffractograms of cowpea, chickpea and yellow pea starches. A_c is the area of crystalline peak and A_t is total area measured from the baseline.

Swelling volume was determined by the method of Collado and Corke (1999). The sample (0.20 g, dry substance) was mixed with 10 ml deionized water, equilibrated at 25 °C for 30 min and heated for 30 min at 10 °C intervals between 50 and 90 °C with continuous mixing. The sample was cooled to 25 °C and then centrifuged at 1000g for 15 min. For less than 2 ml of gel volume, the volume was adjusted to 10 ml. The supernatant was removed gently and measured with a graduated cylinder. The gel volume was then calculated as: ml of gel = 10 ml − ml of supernatant (Prinyawiwatkul et al., 1997). Swelling volume was calculated as gel volume per unit dry weight of the sample.

2.5. Characteristics of starch pastes and gels

The pasting behaviours of the starches were measured using a Rapid Visco Analyzer (RVA-4, Newport Scientific Pty. Ltd., Warriewood, NSW, Australia) in a defined programme: 28 g of 6% (w/w) starch suspensions were stirred with a paddle speed of 160 rpm/min and heated from 30 to 90 °C at 15 °C/min, held at 90 °C for 5 min, cooled to 30 °C at −15 °C/min and held at 30 °C for 7 min.

Freeze–thaw stability was tested according to the method of Yuan and Thompson (1998) with some modifications. Starch suspensions of 5% (w/v) were mixed and equilibrated at 25 °C for 30 min; then, 1 ml starch slurry was dispensed into 2 ml tubes with vigorous stirring. After heating in a boiling water bath for 30 min while stirring, the samples were kept at −20 °C for 24 h and thawed at 30 °C for 1.5 h. Free water was removed by putting the gel on 16 layers tissue paper for 5 min. Five freeze–thaw cycles were considered. The extent of syneresis was calculated as the ratio of exuded water weight to the original paste weight. The synereses of the starch gels without freeze–thaw treatments were measured by storing at 2 °C for 5 days. Every 24 h, the exuded water was measured after the starch gel was centrifuged at 1000g for 10 min.

2.6. Amylopectin structure

The separation of amylopectin and the digestion of pullulanase were conducted according to Chen, Schols, and Voragen (2004). The purity of the separated amylopectin was checked by high-performance size-exclusion chromatography (HPSEC) after pullulanase treatment according to Kobayashi, Schwartz, and Lineback (1985). The unit chain profile was analyzed by HPSEC and HPAEC (high-performance anion-exchange chromatography). HPSEC and HPAEC were performed as described in Chen, Huang, Suurs, Schols, and Voragen (2005), except that a CarboPac PA1 column (2×250 mm) with guard column (Dionex, USA) was operated at a flow rate (0.3 ml/min) in the HPAEC analysis.

3. Results and discussion

3.1. Chemical compositions of raw materials and starches

Cowpea and chickpea starches were isolated from commercial cowpea and chickpea seeds. Analyses on these two raw materials showed that starch was the most abundant component (Table 1), as found by others (Arora & Das, 1976; Ereifej, Al-Karaki, & Hammouri, 2001; Longe, 1980; Oluwatosin, 1998; Sosulski et al., 1985). Their protein contents were similar, while the lipid level in cowpea was about one quarter of that in chickpea. The chemical characteristics of isolated starches from cowpea, chickpea and the commercial yellow pea starch are summarized in Table 2. It is rather difficult to obtain pure starches from legumes, due to their high protein contents (Moorthy, 2004; Schoch & Maywald, 1968). The isolation process of cowpea starch is one of the most difficult because of the fine fibre, slowing down the sedimentation and co-settling with the starch to give a light, loose deposit. The purities of isolated cowpea and chickpea starches were above 93%. The lipid contents in chickpea, cowpea and yellow pea starches were low and at the same level as in tuber starches and much lower than in cereal starches (1%, Eliasson & Wahlgren, 2004). Their phosphorus contents were lower than that in potato starch (0.08%, Chen et al., 2003a). Legume starches have been characterized by high amylose contents (Czuchajowska et al., 1998; Singh, Sandhu, & Kaur, 2004). The amylose levels of three starches were within the ranges in the literature (20.9%–48.7% for cowpea, 20.7%–42.2% for chickpea, and 22.0%–49.6% for yellow pea starches) (Arora & Das, 1976; Hoover & Ratnayake, 2002; Ratna-

Table 1
The chemical composition of cowpea and chickpea seeds (w/w, %)

Source	Moisture	Starch content (db)[b]	Protein (db)	Lipid (db)
Cowpea	11.0 ± 0.0[a]	49.6 ± 0.1	23.1 ± 0.16	1.3 ± 0.26
Chickpea	10.6 ± 0.0	50.4 ± 1.3	23.0 ± 0.23	5.8 ± 0.09

[a] Standard deviation of triplicate.
[b] Dry basis.

Table 2
Composition (w/w, %) of cowpea, chickpea and yellow pea starches

Starch	Moisture	Starch (db)	Amylose (db)[b]	Protein (db)	Lipid (db)	Phosphorus (db)
Cowpea	11.5 ± 0.42[a]	93.1 ± 0.48	25.8	0.49 ± 0.03	0.15 ± 0.05	0.022
Chickpea	11.9 ± 0.23	94.0 ± 0.39	27.2	0.57 ± 0.01	0.10 ± 0.01	0.012
Yellow pea	11.3 ± 0.12	92.3 ± 0.56	31.2	0.52 ± 0.02	0.07 ± 0.01	0.007

[a] Standard deviation of triplicate.
[b] Dry basis.

yake, Hoover, Shahidi, Perera, & Jane, 2001; Saini & Knights, 1984; Won, Choi, Lim, Cho, & Lim, 2000).

3.2. Physical properties of starch

3.2.1. Size distribution

The granule size distributions of cowpea and chickpea starches were unimodal, while, for yellow pea starch, there was a slight shoulder at high granule diameters (Fig. 2). In the dry state, the VMDs (volume mean diameters) were 15.5, 17.9 and 33.8 μm for cowpea, chickpea and yellow pea starches, respectively. When measured in water, the starches had a shift toward larger granule sizes, indicating slight swelling of the granules in cold water. The size of cowpea starch granules was smaller than that reported by Okechukwu and Rao (1996a, 1996b) (range, 3–64 μm; mean, 19 μm). A similar result for chickpea starch (6–31 μm), using microscopy, has been observed by Hoover and Ratnayake (2002) and Singh et al. (2004). Hoover and Ratnayake (2002) reported that the starch granule size ranged from 14 to 37 μm for smooth pea.

3.2.2. Crystalline structure

Three different types of crystal structures have been identified and classified by Katz and Itallie in 1930. C-type starches actually consist of a mixture of A-type and B-type (Donald, 2004). Crystals in cowpea, chickpea, and yellow pea starches, determined by X-ray diffraction, were all C-type (Fig. 1), which is known as the characteristic pattern
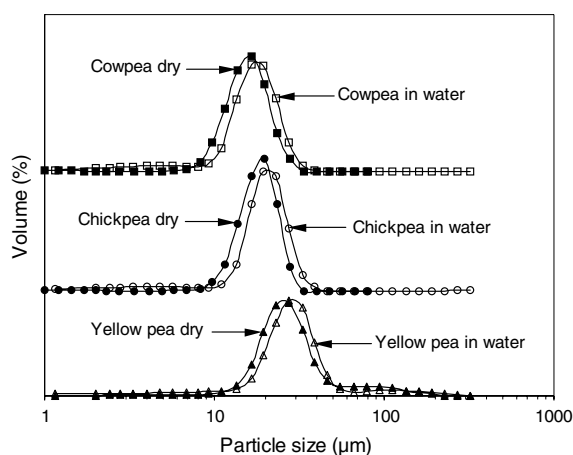
of legume starches (Donald, 2004). All three starches showed peaks at 15.2°, 17.2° and 23.2° 2-theta, corresponding to d-spacings of 0.58, 0.52 and 0.38 nm, respectively. Cowpea starch showed an extra peak at 18.0° 2-theta (d-spacing 0.49 nm). This indicates that the crystalline structure in cowpea starch is slightly different from that in chickpea and yellow pea starches. The relative crystallinity of yellow pea starch was lower than those of cowpea and chickpea starches (Table 3). This may be explained by the fact that yellow pea starch had the highest amylose content among three starches. The double helical content decreases with increasing amylose content (Cheetham & Tao, 1997). A C-type X-ray pattern has been reported for chickpea and smooth pea starches (Davydova, Leont'ev, Genin, Sasov, & Bogracheva, 1995; Gernat et al., 1990; Hoover & Ratnayake, 2002). However El Faki, Desikachar, Paramahans, and Tharanathan (1983) reported cowpea starch as A-type and chickpea starch as B-type. The X-ray diffraction pattern may depend on the starch origin as well as the environmental growth conditions.

3.2.3. Thermal properties

DSC was used to study the thermal properties of the starches. Chickpea and yellow pea starches showed similar onset and completion temperatures of gelatinization, which were much lower than that of cowpea starch (Table 3). The gelatinization temperature ranges and enthalpies of chickpea and yellow pea starches were higher than that of cowpea starch. The higher gelatinization temperature was an indication of more perfect crystals (Sasaki & Matsuki, 1998; van Soest, Bezemer, de Wit, & Vliegenthart, 1996) or a higher co-operative unit, that is, longer chains in the crystal or a larger crystal size (Matveev et al., 2001). Chickpea and yellow pea starches showed single endothermic peaks, while cowpea starch showed a slightly double peak (results not shown). This confirms the findings from the

Fig. 2. Particle size distributions of cowpea, chickpea and yellow pea starches measured in the dry state and in water.

Table 3
Properties of cowpea, chickpea and yellow pea starches

Starch	Gelatinization temperature, °C (DSC)[a]				Enthalpy (J/g dry starch) (DSC)[a]	Relative crystallinity % (X-ray)
	T_o[b]	T_p	T_c	ΔT		
Cowpea	70.5	75.4	81.0	10.5	15.2	26
Chickpea	57.9	63.5	70.4	12.5	17.6	26
Yellow pea	58.2	65.1	70.4	12.2	16.1	21

[a] Differential Scanning Calorimeter.
[b] T_o = onset temperature, T_p = peak temperature, T_c = completion temperature, $\Delta T = T_c - T_o$.

X-ray measurement, that the crystalline structure in cowpea starch is different from those of the other two legume starches. Double peaks represented two transitions, the melting of B polymorphs and the melting of A polymorphs (Bogracheva, Morris, Ring, & Hedley, 1998).

The onset gelatinization temperatures, 65–71, 59.4–66 and 60.8–64 °C, have been reported for cowpea, chickpea and yellow pea starches, respectively (Czuchajowska et al., 1998; El Faki et al., 1983; Hoover & Ratnayake, 2002; Kerr, Ward, McWatters, & Resurreccion, 2000; Okechukwu & Rao, 1996a, 1997; Ratnayake et al., 2001; Schoch & Maywald, 1968; Singh et al., 2004; Sosulski et al., 1985). The gelatinization temperature seems to be influenced by the molecular architecture of the crystalline region rather than the amylose content (proportion of crystalline region) of starch (Bao & Bergman, 2004). In addition, the isolation procedures may have an impact on the value.

3.2.4. Swelling volume

When starch is heated in enough water, hydrogen bonds stabilizing the structure of the double helices in crystallites are broken and replaced by hydrogen bonds with water (Tester & Karkalas, 1996), the starch granule swells and its volume increases. The swelling volume of cowpea starch increased slightly from 50 to 70 °C (Fig. 3). At 80 °C, the value was about 10 times as high as that at 70 °C, indicating that, only after the temperature reaches the onset gelatinization point does the starch granule undergo rapid swelling. Similar relationships between swelling behaviour and gelatinization temperature were found for chickpea and yellow pea starches. A two-stage swelling pattern has been reported by Agunbiade and Longe (1999) for cowpea starch and Gujska, Reinhard, and Khan (1994) for field pea starch, and is considered to be the typical swelling pattern of legume starches (Oates, 1991; Ratnayake et al., 2001). The higher swelling volume at 90 °C indicates that amylopectin chains within crystalline regions are more strongly associated in cowpea starch than in the other two legume starches, as suggested by Hoover, Li, Hynes, and Senanayake (1997) for mung bean starch. Swelling volume of starch was affected by amylose content and the structure of amylopectin (Sasaki & Matsuki, 1998).

3.3. Characteristics of starch pastes and gels

3.3.1. Pasting behaviour

Pasting temperature is a measure of the temperature at which a starch starts to thicken. In a RVA curve, the point at which viscosity starts to increase is considered to be the pasting temperature. Cowpea starch showed much higher pasting temperature (80.7 °C) than chickpea (70.9 °C) and yellow pea (70.5 °C) starches. The results were in accordance with the gelatinization temperatures obtained with DSC (Table 3). According to the classification of Schoch and Maywald (1968), chickpea and yellow pea starches showed type C pasting profiles (Fig. 4), presenting no pasting peak; the viscosity remained constant during cooking and increased during cooling. The maximum value at 90 °C was reported as peak viscosity (Agunbiade & Longe, 1999). Cowpea starch had a type B viscosity, with a peak viscosity (PV) of 1440 cP and setback (SB = final viscosity − peak viscosity) of 2535 cP, which were much higher than those of chickpea (PV, 871 cP; SB, 1071 cP) and yellow pea (PV, 724 cP; SB, 643 cP) starches. The fast retrogradation tendency of cowpea starch, indicated by its high setback value, is favourable for food products such as gluten-free oriental noodles (Czuchajowska et al., 1998). Type B viscosity pattern for cowpea starch and Type C viscosity pattern for chickpea and field pea starches have been observed (Agunbiade & Longe, 1999; El Faki et al., 1983; Li & Vasanthan, 2003; Singh et al., 2004; Tolmasquim, Correa, & Tolmasquim, 1971). Pasting properties of chickpea, cowpea and yellow pea starches were influenced by granule swelling, as pointed out by Ratnayake et al. (2001). Cowpea starch showed the highest swelling volume at 90 °C, and the highest viscosity, during cooking at 90 °C, among the starches.
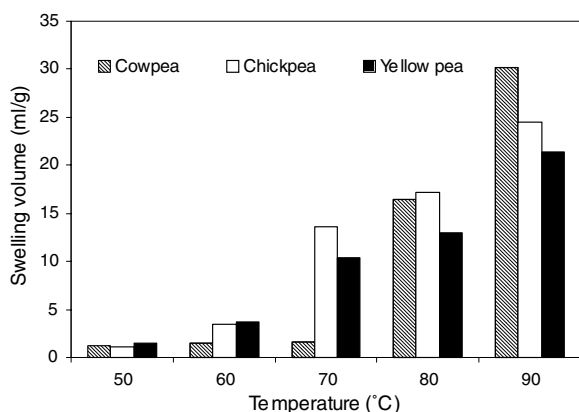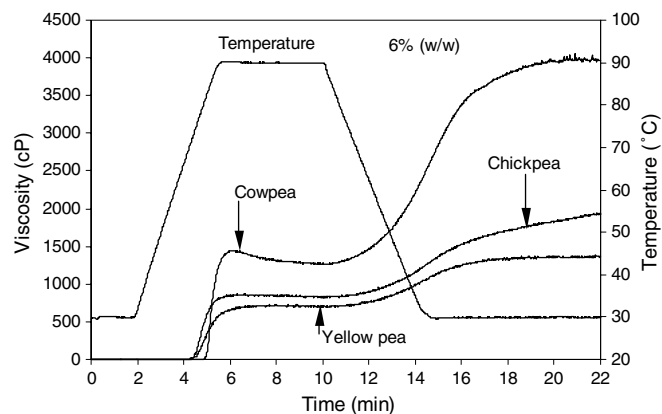

Fig. 3. Swelling volume of cowpea, chickpea and yellow pea starches influenced by temperature. Swelling volume was calculated as gel volume per unit dry weight of starch.

Fig. 4. RVA pasting curves of cowpea, chickpea and yellow pea starches. RVA, rapid visco analyzer; cP, centipoises.

3.3.2. Syneresis

Freeze–thaw stability of gelatinized starch pastes is a desired property for the use of starch by the food industry (Jobling, Westcott, Tayal, Jeffcoat, & Schwall, 2002). The syneresis occurred rapidly in the first two cycles and slowed down in the next three cycles; it did not increase steadily with increasing number of the freeze–thaw cycle (Fig. 5). Similar findings for waxy maize, amaranth, wheat, corn, rice and potato starches have been reported (Baker & Rayas-Duarte, 1998; Jobling et al., 2002; Yuan & Thompson, 1998). Our results confirm the finding of Yuan and Thompson (1998) that the estimation of freeze–thaw stability of starch pastes should be based on data obtained from several freeze–thaw cycles. The lowest rate of syneresis observed for cowpea starch suggested that it could be more suitable for use in products that are stored frozen and thawed for consumption. As the procedure to determine freeze–thaw stability of starch has not been standardized (Karim, Norziah, & Seow, 2000), the syneresis values obtained by others were quite variable, namely 33.2% after three freeze–thaw cycles, 50% and 30% after five freeze–thaw cycles, with amylose contents of 27.9%, 21.2% and 43.7% for cowpea, chickpea and field pea starches, respectively (Chung et al., 1998; Hoover & Ratnayake, 2002; Ratnayake et al., 2001).

When stored at 2 °C for five days, yellow pea starch showed the highest syneresis (Fig. 5). The separation of phases caused by α-glucan chain re-association is a sign of starch retrogradation (Jobling et al., 2002). The retrogradation tendencies measured by the syneresis with and without freeze–thaw treatment were not in agreement with each other, as reported by Chen et al. (2003a). The difference in the rates of syneresis for all the three starches between two types of treatments may be explained by the fact that, as water freezes, it increases in volume. As the water freezes and expands, the gel network may be broken by ice crystals. The weaker the starch gel, the stronger physical damage appeared to be in the gel network, and the higher the rate of syneresis. Chickpea and yellow pea starches had weaker gels and the networks were destroyed more by freeze–thaw treatment than was cowpea starch. Singh et al. (2004) reported that the syneresis of chickpea starch, with amylose content 34.3%, at 2% starch concentration, was 18.5% after storage at 4 °C for 120 h.

3.4. Chain length distribution of amylopectin

Properties of starch depend on the molecular structure of its components. Amylopectin predominated in cowpea, chickpea and yellow pea starches and played an important role in their properties. Biliaderis, Grant, and Vose (1981) and Chung et al. (1998) found that studies on isolated amylopectin can give more precise chain length information than using the whole starch sample. Structural investigation of amylopectin, using pullulanase, was carried out to explain the differences in the properties of the cowpea, chickpea and yellow pea starches at a molecular level.

After treatment with pullulanase, only smaller polysaccharide fragments appeared and no other peaks were detected in HPSEC chromatograms. Therefore, the amylopectin populations isolated from cowpea, chickpea and yellow pea starches were believed to be pure.

All three amylopectin samples displayed two populations: long chains (fraction I) and short chains (fraction II) in the HPSEC chromatogram (Fig. 6). The bimodal chain distribution profiles have been reported for cowpea amylopectin based on study of the whole starch sample, and for isolated chickpea and smooth pea amylopectin (Biliaderis et al., 1981; Chung et al., 1998). The weight ratio of short:long chains of chickpea amylopectin (4.4:1) was close to that of yellow pea (4.2:1). The results were in agreement with data found by Biliaderis et al. (1981) on the molar ratio of short:long chains of chickpea (8.0) and smooth pea (7.7) amylopectin. Cowpea amylopectin had a lower weight ratio of short:long chains (3.1:1), which was the evidence for the higher amount of long chains that
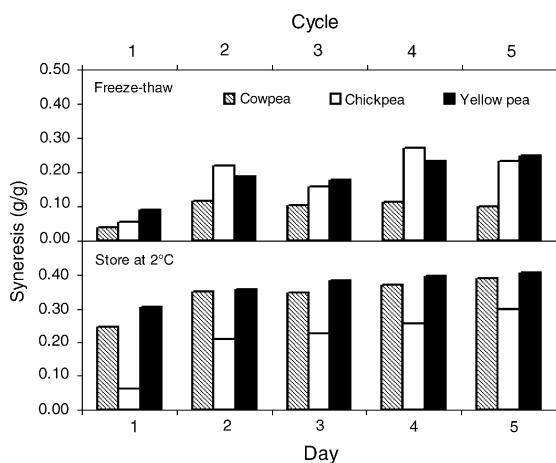

Fig. 5. Syneresis of cowpea, chickpea and yellow pea starches during freeze–thaw cycles and when stored at 2 °C. The extent of syneresis was calculated as the weight ratio of exuded water to the original paste.
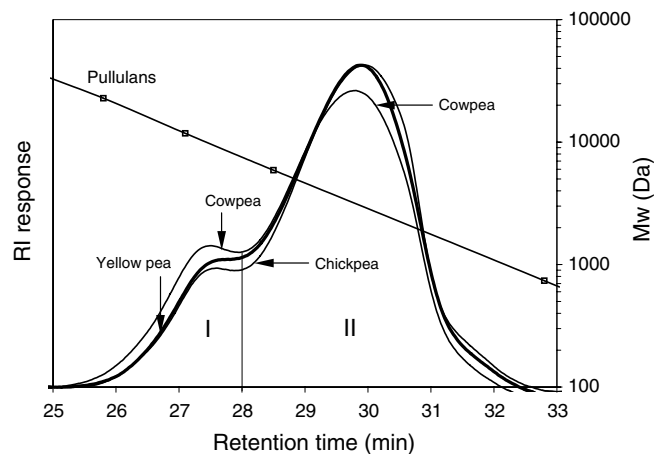

Fig. 6. HPSEC elution profiles of the pullulanase hydrolysates of the amylopectin populations isolated from cowpea, chickpea and yellow pea starches. RI, refractive index.
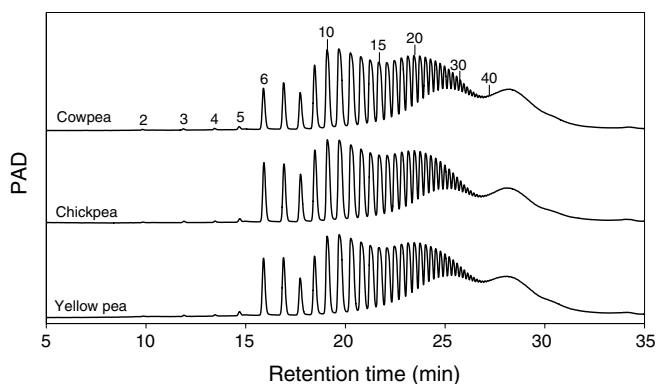
Fig. 7. HPAEC elution profiles of the pullulanase hydrolysates of the amylopectin populations isolated from cowpea, chickpea and yellow pea starches. Numbers indicate degree of polymerization. PAD, pulsed amperometric detection.

accounted for higher gelatinization temperature, greater pasting peak, and better stability in freeze–thaw cycles of cowpea starch than those of chickpea and yellow pea starches. It was evident that the chickpea and yellow pea starches were very similar in some properties as well as in chain length profiles. The shortest chain in all three samples was DP 6, as revealed by HPAEC (Fig. 7), which was also reported by Ratnayake et al. (2001) for field pea starch and mentioned to be a general feature of all amylopectins described so far (Bertoft, 2004). Individual chains up to DP 40 were recognized in the HPAEC pattern. Considering the data sets from HPSEC and HPACE together, the DP (degree of polymerization) of short chains was about 6–50, and of long chains, about 50–80.

4. Conclusions

From our results of the physicochemical properties and the unit chain profiles of cowpea, chickpea and yellow pea starches, it can be proposed that the higher gelatinization temperature, slight difference in crystalline structure and higher peak viscosity of cowpea starch, is partly provided by its higher amount of long chains in amylopectin molecules compared with those of chickpea and yellow pea starches. Similarity in chain length distribution between chickpea and yellow pea starches correlated with the nearly identical gelatinization temperatures, similar X-ray diffraction patterns and RVA profiles. Their different swelling and syneresis behaviours can be explained by the difference in amylose content and particle size distribution. Smaller granule size, lower amylose level and larger degree of swelling at 90 °C suggest that the crystallites in cowpea starch are of a higher order of stability and that amylopectin chains within crystalline regions were more strongly associated than they were in chickpea and yellow pea starches. The significantly higher setback value for cowpea starch indicates that this starch may be suitable for food products where fast retrogradation is necessary, e.g. glass noodle.

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