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Food Chemistry 91 (2005) 403–411
Food Chemistry
www.elsevier.com/locate/foodchem

Studies on functional, thermal and pasting properties of flours from different chickpea (*Cicer arietinum* L.) cultivars

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Received 23 February 2004; received in revised form 8 June 2004; accepted 8 June 2004

Abstract

The variability in physicochemical, functional, thermal, and pasting properties of flours from five desi (PBG-1, PDG-4, PDG-3, GL-769 and GPF-2) and one kabuli type (L-550) chickpea cultivars were studied and related to each other. Physicochemical (water solubility index, water absorption index, hunter colour parameters and bulk density) and functional properties (water absorption, oil absorption, least gelation concentration, foaming, and emulsification properties) of desi and kabuli chickpea flours were determined. Significant differences between properties of flours from kabuli and desi chickpea cultivars were observed. Flour from kabuli chickpea cultivar was significantly different from desi chickpea flours in its highest L^*, ΔE value, bulk density, oil absorption capacity, and emulsion stability. The kabuli and desi chickpea flours showed significant differences in transition temperatures (T_o, T_p, and T_c) and enthalpy of gelatinization (ΔH_{gel}). T_o, T_p, T_c and ΔH_{gel} of chickpea flours ranged from 65.4 to 67.9, 70.6 to 73.3, 77.0 to 79.4 °C, and 3.5 to 4.9 J/g, respectively. L-550 flour (kabuli type) differed significantly from all other chickpea flours in exhibiting lowest T_o, T_p, T_c, ΔH_{gel}, and PHI. Pasting properties of chickpea flours, measured using a rapid visco analyzer (RVA), also differed significantly. Pasting temperatures, peak, final and setback viscosities of flours from different chickpea cultivars ranged from 73.1 to 75.2 °C, 112.3 to 180.3, 126.3 to 225.3, and 19.8 to 62.8 Rapid Visco Units (RVU), respectively. Kabuli chickpea flour showed a low pasting temperature (73.9 °C), and highest peak (180.3 RVU), trough (162.5 RVU), final (225.3 RVU), and setback (62.8 RVU) viscosities.

Keywords: Chickpea flour; Physicochemical; Functional; Thermal; Pasting

1. Introduction

Chickpea (*Cicer arietinum*) is a crop of economic importance and also an important source of protein in the diet of people in India as well as other countries (Singh & Jambunathan, 1981). Chickpea and other food legumes contribute significant amounts of protein, carbohydrate, vitamins and minerals to the diets of people living in the Mediterranean region (Bahl, 1990; Singh, Bejiga, & Malhotra, 1993). Chickpea is the fifth in importance of crops world wide, India being the country which contributes about 75% of the total world production, followed by Turkey, Pakistan, and Mexico as main exporters of high quality grain (Grelda, Farlas, Moreno-Valencia, Falcon-Villa, & Barron-Hoyos, 1997). The total production of chickpea in India was 5,320,000 Mt. (FAO, 2002). Chickpea cultivars are broadly divided into two groups, desi and kabuli. Kabuli seeds are large and light coloured beans, and are characterized by their larger size, ram-head shape and low fibre content (Singh, Subrahmanyam, & Kumar, 1991). The seeds of desi cultivars are small, wrinkled at beak, with brown, black or green colour.

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doi:10.1016/j.foodchem.2004.06.015

The ultimate success of utilizing plant proteins as ingredients depends largely upon the beneficial qualities they impart to foods. In recent years there has been increasing interest in the functional potential of plant proteins. Legumes have been the focal point of this interest since they contain 18–25% protein (Pawar & Ingle, 1988). In view of the increasing utilization of grain legumes in composite flours for various food formulations, their functional properties are assuming greater significance (Singh, 2001). Functional properties constitute the major criteria for the adoption and acceptability of proteins in food systems. The physical and chemical characteristics and interactions of proteins with other components in the food are the major contributors to the usefulness and success of proteins in food systems. These characteristics influence processing, preparation and quality attributes of foods (Kinsella, 1981). Functionality has been defined as any property of a food ingredient, except its nutritional value, that has a great impact on its utilization (Mahajan & Dua, 2002). Protein functional properties are determined to a large extent by a protein's physicochemical and structural properties (Damodaran, 1990). Protein solubility is an important prerequisite for food functional properties and it is a good index of potential applications of proteins (Kinsella, 1976). Hydration properties, dispersability, water absorption, binding, swelling and viscosity are known to directly influence the characteristics of a food system (McWatters, 1983). Hydration of proteins is vital for several functional properties, such as emulsion capacity, foaming, viscosity and gelation (Sathe & Salunkhe, 1981). The functional properties of legume flours are provided, not only by proteins, but also by the complex carbohydrates and other components, such as pectins and mucilages.

Gelatinization is an energy absorbing process that can be followed by differential scanning calorimetery (DSC). The process of gelatinization, which involves melting of crystalline and double helices is assisted by hydration and swelling of the starch granule amorphous regions (Adebowale & Lawal, 2003a). Starch transition temperatures and gelatinization enthalpies, determined by DSC, may be related to characteristics of the starch granule, such as degree of crystallinity (Krueger, Knutson, Inglett, & Walker, 1987). Evidence for the loss of an organized structure upon gelatinization includes irreversible granule swelling, loss of birefringence and crystallinity (Freitas, Paula, Feitosa, Rocha, & Sierakowski, 2004). Not much literature information was available on the comparison of properties of desi and kabuli chickpea flours. Therefore, the present investigation was undertaken to study and compare the physicochemical, functional, thermal and pasting properties of flours derived from different Indian chickpea cultivars.

2. Materials and methods

2.1. Materials

Representative samples of six improved commercial chickpea cultivars, namely PBG-1, PDG-4, PDG-3, GL-769, GPF-2 and L-550, from the 2002 harvest, were obtained from Punjab Agricultural University, Ludhiana, India. The cultivars PBG-1, PDG-4, PDG-3, GL-769, GPF-2 were of desi type while L-550 cultivar were kabuli type. Seeds of different chickpea cultivars were ground to pass through the sieve No. 72 (British Sieve Standards) to obtain flour. The flour samples were defatted by a solvent extraction process using *n*-hexane and then dried at 50 °C in a hot air cabinet drier and, after cooling, were packed in air-tight containers.

2.2. Proximate composition

Flour samples from different chickpea cultivars were estimated for their moisture, ash, fat, fibre and protein ($N \times 6.25$) contents by employing the standard methods of analysis (AOAC, 1984).

2.3. Physicochemical properties of chickpea flours

2.3.1. Colour characteristics of flours

Colour measurements of chickpea flour samples were carried out using a Hunter colorimeter Model D 25 optical Sensor (Hunter Associates Laboratory Inc., Reston, VA, USA) on the basis of L^*, a^* and b^* values. A glass cell containing chickpea flour was placed above the light source, covered with a white plate and L^*, a^* and b^* colour values were recorded. The instrument (45°/0° geometry, 10° observer) was calibrated against a standard red-coloured reference tile ($L_s = 25.54$, $a_s = 28.89$, $b_s = 12.03$). Total colour difference (ΔE) was calculated by applying the equation

$$\Delta E = [(L_s - L)^2 + (a_s - a)^2 + (b_s - b)^2]^{1/2},$$

where the L^* value indicates the lightness, 0–100 representing dark to light, the a^* value gives the degree of the red–green colour, with a higher positive a^* value indicating more red. The b^* value indicates the degree of the yellow–blue colour, with a higher positive b^* value indicating more yellow.

2.3.2. Water absorption index and water solubility index

Water absorption index (WAI) and water solubility index (WSI) of chickpea flours were determined by slightly modifying the method of Anderson, Conway, Pfeifer, and Griffin (1969). Flour sample (2.5 g) was dispersed in 30 ml of distilled water, using a glass rod, and cooked at 90 °C for 15 min in a water bath. The cooked paste was cooled to room temperature and transferred to tared centrifuge tubes, and then centrifuged at 3000*g* for 10 min. The supernatant was decanted for determination of its solid content into a tared evaporating dish and the sediment was weighed. The weight of dry solids was recovered by evaporating the supernatant overnight at 110 °C. WSI and WAI were calculated by the equations:

$$\mathrm{WAI} = \frac{\text{Weight of sediment}}{\text{Weight of dry solids}},$$

$$\mathrm{WSI}\ (\%) = \frac{\text{Weight of dissolved solids in supernatant} \times 100}{\text{Weight of dry solids}}.$$

2.3.3. Bulk density

The flour samples were gently filled into 10 ml graduated cylinders, previously tared. The bottom of the cylinder was gently tapped on a laboratory bench several times until there was no further diminution of the sample level after filling to the 10 ml mark. Bulk density was calculated as weight of sample per unit volume of sample (g/ml). Measurements were made in triplicate.

2.4. Functional properties of flours

2.4.1. Water and oil absorption

Water absorption of chickpea flours was measured by the centrifugation method of Sosulski (1962). The samples (3.0 g) were dispersed in 25 ml of distilled water and placed in preweighed centrifuge tubes. The dispersions were stirred occasionally, held for 30 min, followed by centrifugation for 25 min at 3000*g*. The supernatant was decanted, excess moisture was removed by draining for 25 min at 50 °C, and sample was reweighed. For the determination of fat absorption, the method of Lin, Humbert, and Sosulski (1974) was used. Samples (0.5 g) were mixed with 6 ml of corn oil in preweighed centrifuge tubes. The contents were stirred for 1 min with a thin brass wire to disperse the sample in the oil. After a holding period of 30 min, the tubes were centrifuged for 25 min at 3000*g*. The separated oil was then removed with a pipette and the tubes were inverted for 25 min to drain the oil prior to reweighing. The water and oil absorption capacities were expressed as grammes of water or oil bound per gramme of the sample on a dry basis.

2.4.2. Least gelation concentration

The least gelation concentration (LGC) of chickpea flours was determined by the method of Sathe, Deshpande, and Salunkhe (1981). Test tubes containing suspensions of 2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18% and 20% (w/v) of material in 5 ml distilled water were heated for 1 h in boiling water, followed by rapid cooling under cold running water. The tubes were further cooling at 4 °C for 2 h. LGC is the concentration above which the sample did not fall down or slip when the test tube was inverted.

2.4.3. Emulsion activity and stability

Emulsifying properties were determined according to the method given by Naczk, Diosady, and Rubin (1985). Flour sample (3.5 g) was homogenized for 30 s in 50 ml water in a homogenizer (Yorco, India) at high setting. Groundnut oil (25 ml) was added, and the mixture was homogenized again for 30 s. Then, another 25 ml of groundnut oil were added, and the mixture homogenized for 90 s. The emulsion was divided evenly into two 50 ml centrifuge tubes and centrifuged at 1100*g* for 5 min. Emulsifying activity was calculated by dividing the volume of the emulsified layer by the volume of emulsion before centrifugation × 100. The emulsion stability was determined using the samples prepared for measurement of emulsifying activity. They were heated for 15 min at 85 °C, cooled and centrifuged again 1100*g* for 5 min. The emulsion stability was expressed as the % of emulsifying activity remaining after heating.

2.4.4. Foaming capacity and foaming stability

The capacity and stability of foams were determined by the method of Lin et al. (1974); 50 ml of a 3% (w/v) dispersion of flour sample in distilled water were homogenized using homogenizer (Yorco, India), at high setting, for 2–3 min. The blend was immediately transferred into a graduated cylinder and the homogenizer cup was rinsed with 10 ml distilled water, which were then added to the graduated cylinder. The volume was recorded before and after whipping and measured as the % of volume increase due to whipping. The foaming activity was expressed as the % of volume increase. Foam volume changes in the graduated cylinder were recorded at intervals of 20, 40, 60, and 120 min of storage. To study the effect of concentration on foamability, 2%, 4%, 5%, 7% and 10% (w/v) aqueous suspensions of chickpea flours were whipped identically, as described above, and the final volume was noted in each case in a graduated cylinder.

2.5. Thermal properties

Thermal characteristics of flours from different chickpea cultivars were studied by using a differential scanning calorimeter – 821[e] (Mettler Toledo, Switzerland) equipped with a thermal analysis data station. Sample (3.5 mg, dry weight) was loaded into a 40 μl capacity aluminium pan (Mettler, ME-27331) and distilled water was added with the help of a Hamilton microsyringe to achieve a flour–water suspension containing 70% water. Samples were hermetically sealed and allowed to stand for 1 h at room temperature before heating in the

Table 1
Proximate composition of flours from different chickpea cultivars[a,b]

Chickpea flours	Moisture (%)	Ash (%)	Crude fat (%)	Protein (%)[c]	Crude fibre (%)	Carbohydrate (%)
Desi type						
PBG-1	8.59 ± 0.32bc	2.72 ± 0.17a	0.96 ± 0.06b	23.7 ± 0.61b	1.5 ± 0.15ab	62.5 ± 2.15b
PDG-4	8.03 ± 0.41b	2.77 ± 0.18a	0.53 ± 0.08a	20.6 ± 0.52a	1.8 ± 0.17b	66.3 ± 1.98c
PDG-3	8.02 ± 0.39b	2.83 ± 0.16ab	1.17 ± 0.09bc	23.9 ± 0.69b	1.6 ± 0.16ab	62.5 ± 2.09b
GL-769	8.90 ± 0.35c	2.84 ± 0.18ab	1.16 ± 0.08bc	24.3 ± 0.72bc	1.9 ± 0.17bc	60.9 ± 2.01a
GPF-2	6.64 ± 0.37a	2.88 ± 0.16b	1.17 ± 0.07bc	22.3 ± 0.54ab	2.1 ± 0.18c	64.9 ± 1.99bc
Kabuli type						
L-550	7.89 ± 0.34b	2.91 ± 0.15b	1.21 ± 0.09c	26.7 ± 0.84c	1.1 ± 0.15a	60.2 ± 2.11a

[a] Means followed by same letter within a column do not differ significantly ($P < 0.05$).
[b] Means (±SD) of triplicate analyses.
[c] Total nitrogen × 6.25.

DSC. The DSC analyzer was calibrated using indium and an empty aluminium pan was used as reference. Sample pans were heated at a rate of 10 °C/min from 20 to 100 °C. Onset temperature (T_o), peak temperature (T_p), conclusion temperature (T_c) and enthalpy of gelatinization (ΔH_{gel}) were calculated automatically. The gelatinization temperature range (R) was computed as ($T_c - T_o$), as described by Vasanthan and Bhatty (1996). Enthalpies were calculated on sample dry basis. The peak height index (PHI) was calculated by the ratio $\Delta H_{gel}/(T_p - T_o)$, as described by Krueger et al. (1987).

2.6. Pasting properties

Pasting properties of chickpea flours were studied by using a rapid visco analyzer (Newport Scientific Pty Ltd., Warriewood NSW 2102, Australia). Viscosity profiles of flours from different chickpea cultivars were recorded using flours suspensions (8%, w/w; 28 g total weight). The temperature–time conditions included a heating step, from 50 to 95 °C at 6 °C/min (after an equilibration time of 1 min at 50 °C), a holding phase at 95 °C for 5 min, a cooling step from 95 to 50 °C at 6 °C/min and a holding phase at 50 °C for 2 min. Each sample was analyzed in triplicate.

2.7. Statistical analysis

The data reported in all the tables are averages of triplicate observations. The data were subjected to statistical analyses using Minitab Statistical Software version 13 (Minitab Inc., USA).

3. Results and discussion

3.1. Proximate composition

Proximate composition varied significantly among flours from different chickpea cultivars. The ash, crude fat, protein and fibre contents of flours from different chickpea cultivars ranged from 2.72% to 2.91%, 0.53% to 1.21%, 20.6% to 26.7% and 1.1% to 2.1%, respectively (Table 1). Mean values for protein, carbohydrate, lipid, and ash content of 22.5%, 69.5%, 5.01% and 2.98%, respectively, for chickpea flours have been reported earlier (Milan-Carrillo, Reyes-Moreno, & Armienta-Rodelo, 2000). The carbohydrate content was highest for PDG-4 flour (66.3%), while it was lowest for L-550 flour (60.2%). Since the carbohydrate content was calculated by difference, the variation in carbohydrate content for flours from different chickpea cultivars is attributed to the differences in the contents of other constituents. L-550 flour (kabuli type) had the highest ash (2.91%), fat (1.21%), protein (26.7%) and lowest fibre (1.1%) and carbohydrate contents (60.2%). Among flours from desi chickpea cultivars, GPF-2 flour showed significantly higher ash, fat and crude fibre contents. The variation in chemical composition between flours from desi and kabuli chickpea cultivars in the present study could be due to inherited differences.

3.2. Physicochemical properties

Hunter colour values (L^*, a^*, b^* and ΔE) of flours from different chickpea cultivars are shown in Table 2. Varietal differences were observed for various Hunter colour parameters. L^* and a^* values of flours from different chickpea cultivars ranged from 81.64 to 85.41 and −0.72 to −1.10, respectively. The highest L^* parameter for L-550 flour indicated that it was lighter in colour than all other chickpea flours. Flours from all types of chickpea cultivars showed negative a^* values, which indicated a slight green tint in these samples. The b^* value, an indicator of (−) blue and yellow (+), for chickpea flours ranged from 14.12 to 20.75, lowest for PBG-1 and highest for GPF-2 flour. ΔE, which indicated total colour difference in different flours, ranged from 64.18 to 66.96 for various chickpea flours. Kabuli type chickpea flour showed the highest L^* and ΔE value, indicating

Table 2
Hunter colour values of flours from different chickpea cultivars[a,b]

Hunter colour values	Desi chickpea flours					Kabuli chickpea flour
	PBG-1	PDG-4	PDG-3	GL-769	GPF-2	L-550
L^*	85.39c	84.24b	84.68bc	84.23b	81.64a	85.41c
a^*	−1.07a	−0.72c	−1.10a	−0.90b	−1.05a	−0.86b
b^*	14.12a	15.57b	14.98ab	16.47d	20.75d	15.47b
ΔE value[c]	66.94c	65.84b	66.35bc	65.97a	64.18a	66.96c

[a] Means followed by same letter within a row do not differ significantly ($P < 0.05$).
[b] Means of triplicate analyses.
[c] Total colour difference.

Table 3
Physicochemical properties of flours from different chickpea cultivars[a,b]

Parameters	Desi chickpea flours					Kabuli chickpea flour
	PBG-1	PDG-4	PDG-3	GL-769	GPF-2	L-550
Bulk density (g/ml)	0.562 ± 0.01bc	0.559 ± 0.02b	0.554 ± 0.01ab	0.546 ± 0.01ab	0.536 ± 0.02a	0.571 ± 0.01c
WAI[c]	2.45 ± 0.04b	2.47 ± 0.03b	2.50 ± 0.05bc	2.55 ± 0.04bc	2.66 ± 0.05c	2.39 ± 0.03a
WSI (%)[d]	20.75 ± 0.90ab	22.28 ± 0.86bc	21.83 ± 0.92b	20.42 ± 0.84a	21.69 ± 0.88ab	22.89 ± 0.95c

[a] Means followed by same letter within a row do not differ significantly ($P < 0.05$).
[b] Means (±SD) of triplicate analyses.
[c] Water absorption index.
[d] Water solubility index.

its lighter colour than flours from desi type chickpea cultivars. Among desi chickpea flours, GPF-2 flour had lowest L^* (81.64), ΔE (64.18) and highest b^* (20.75) values, thereby indicating its dark colour. Milan Carrillo et al. (2000) reported Hunter L^* and ΔE values of 89.4 and 19.0, respectively, for chickpea flours, but they used a white standard in place of the red used in the present study. The differences in the colour characteristics of chickpea flours may be attributed to differences in coloured pigments of the flours, which in turn depends on the biological origin of the plant.

Significant differences were also observed for bulk density in flours from different chickpea cultivars (Table 3). The bulk density measurements for chickpea flours varied from 0.536 to 0.571 g/ml, the highest for L-550 flour and lowest for GPF-2 flour. The higher bulk density of L-550 flour suggests that it was denser than desi chickpea flours. The WAI for different chickpea flours ranged from 2.39 to 2.66, the highest for GPF-2 flour and lowest for L-550 flour (Table 3). WSI, that is related to the presence of soluble molecules, for flours from different chickpea cultivars, varied from 20.42% to 22.89%. L-550 flour showed significantly higher WSI (22.89%) and lower WAI (2.39%) than flours from desi chickpea cultivars.

3.3. Functional properties

The genotypes belonging to two distinct chickpea groups showed large differences in certain functional properties (Table 4). The water absorption capacity (WAC) of different chickpea flours ranged from 1.33 to 1.47 g/g. Water absorption characteristics represent the ability of a product to associate with water under conditions where water is limiting (Singh, 2001). Desi chickpea flours showed a significantly higher WAC than kabuli type flour (1.33 g/g). According to Hodge and Osman (1976), flours with high water absorption have more hydrophilic constituents, such as polysaccharides. Therefore, the higher water absorption of desi chickpea flours than kabuli chickpea flours could be attributed to the presence of greater amounts of hydrophilic constituents in them. The inherent proteins in desi chickpea flours may also have played some role in their higher WAC.

The oil absorption capacity (OAC) of flours is also important as it improves the mouth feel and retains the flavour (Kinsella, 1976). The OAC of desi chickpea flours ranged from 1.05 to 1.17 g/g. Kabuli chickpea flour (L-550) showed significantly higher OAC (1.24 g/g). According to Kinsella (1976), more hydrophobic proteins show superior binding of lipids, implying that non-polar amino acid side chains bind the paraffin chains of fats. Based on this suggestion, it could be inferred that kabuli chickpea flour, which showed higher OAC, had more available non-polar side chains in its protein molecules than did desi chickpea flours.

Emulsifying activity (EA) is defined as the ability of the flour to emulsify oil. Flours from various chickpea cultivars differed significantly in their abilities to emulsify groundnut oil (Table 4). Flours from kabuli chickpea cultivar showed significantly lower emulsion activity (58.2%) than did desi chickpea flours (59.6–68.8%). Emulsion stabilities of different chickpea flours ranged

Table 4
Various functional properties of flours from different chickpea cultivars[a,b]

Chickpea flours	Water absorption capacity (g/g)[c]	Oil absorption capacity (g/g)[d]	Emulsion activity (%)	Emulsion stability (%)
Desi type				
PBG-1	1.37 ± 0.07b	1.16 ± 0.09b	62.0 ± 1.96b	78.0 ± 2.3ab
PDG-4	1.38 ± 0.06b	1.13 ± 0.08ab	59.6 ± 1.88a	80.9 ± 2.1b
PDG-3	1.47 ± 0.05c	1.17 ± 0.07b	61.4 ± 1.91b	81.3 ± 2.4b
GL-769	1.34 ± 0.06a	1.05 ± 0.08a	65.2 ± 1.76bc	76.6 ± 2.3a
GPF-2	1.39 ± 0.05b	1.08 ± 0.06a	68.8 ± 1.63c	77.4 ± 2.2ab
Kabuli type				
L-550	1.33 ± 0.07a	1.24 ± 0.08c	58.2 ± 1.72a	82.1 ± 2.6c

[a] Means followed by same letter within a column do not differ significantly ($P < 0.05$).
[b] Means (±SD) of triplicate analyses.
[c] Grammes of water absorbed per gramme of flour.
[d] Grammes of oil absorbed per gramme of flour.

Table 5
Least gelation concentration of chickpea flours after heating in boiling water for 1 h followed by cooling for 2 h at 4 °C[a]

Concentration (%)	Desi type chickpea flours					Kabuli chickpea flour
	PBG-1	PDG-4	PDG-3	GL-769	GPF-2	L-550
2	–	–	–	–	–	–
4	–	–	–	–	–	–
6	–	–	–	–	–	–
8	–	–	–	–	–	–
10	–	–	Gel	Gel	–	Gel
12	–	Gel	Firm gel	Firm gel	Gel	Firm gel
14	Gel	Firm gel	Firm gel	Firm gel	Firm gel	Firm gel
16	Firm gel	Firm gel	Very firm gel	Very firm gel	Firm gel	Very firm gel
18	Very firm gel	Very firm gel	Very firm gel	Very firm gel	Very firm gel	Very firm gel
20	Very firm gel	Very firm gel	Very firm gel	Very firm gel	Very firm gel	Very firm gel

(–) Indicates no gelation.
[a] Means of triplicate determinations.

from 76.6% to 82.1%, the lowest for GL-769 flour and highest for L-550 flour. The difference in total protein composition (soluble plus insoluble), as well as components other than proteins (possibly carbohydrates), may contribute substantially to the emulsification properties of protein-containing products like legume flours (McWatters & Cherry, 1977).

Least gelation concentration (LGC) for various chickpea flours ranged from 10% to 14% (Table 5). Legume flours contain high protein and starch contents and the gelation capacity of flours is influenced by a physical competition for water between protein gelation and starch gelatinization (Singh, 2001). Flour from kabuli chickpea cultivar formed a relatively firm gel, at a significantly lower concentration (10%) relative to desi chickpea flours. This may be attributed to the variation in constituents such as protein, carbohydrate and lipids in its flour as compared to desi chickpea flours. According to Schmidt (1981), gelation in legume flours involves the formation of a protein–polysaccharide complex.

The foaming capacities (FC) and foam stabilities (FS) of flours from different chickpea cultivars also differed significantly. Proteins foam when whipped because they are surface active. The foams produced by flours from all chickpea cultivars were relatively thick with low foam volume but high foam stabilities. Foamability of all chickpea flours was observed to be concentration-dependent. All the flour samples showed progressive increasing foamability with increase in concentration of solids. There was a rapid increase in foam volume up to 7% (w/v) solids concentration with a maximum at 10% (w/v) solids concentration (Fig. 1). According to Adebowale and Lawal (2003b), increase in concentration enhances greater protein–protein interaction, which increases viscosity and facilitates formation of a multilayer cohesive protein film at the interface. So, the coalescence of bubbles is offered resistance by this film formation. Also, the increase in concentration could lead to formation of thicker films, which limits the effect of drainage of protein from films. Foam stability (3% w/v dispersion) for chickpea flours was determined by measuring the decrease in volume of foam as a function of time. Foam stability is important since the usefulness of whipping agents depends on their ability to maintain the whip as long as possible (Lin et al., 1974). All the chickpea flours showed very high foam stabilities

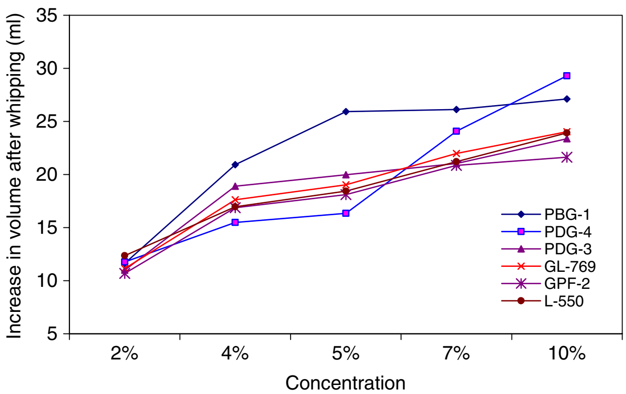

Fig. 1. Effect of flour concentration on foaming abilities of different chickpea cultivars.

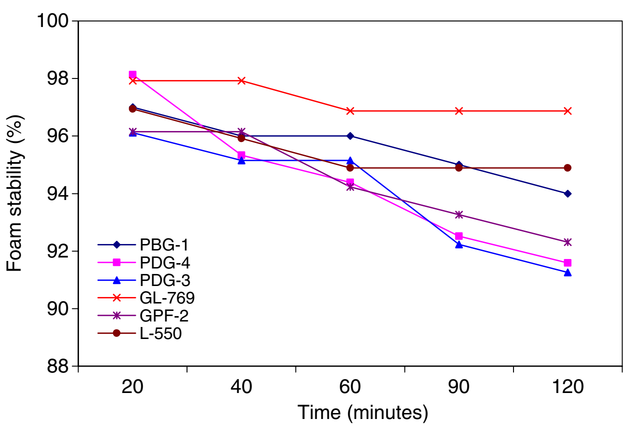

Fig. 2. Foam stability of flours from different chickpea cultivars after 20, 40, 60, 90 and 120 min of storage.

(>90%) after 120 min of storage (Fig. 2). Since foam stability is governed by the ability of the film formed around the entrapped air bubbles to remain intact without draining, it follows that stable foams can only be formed by highly surface-active solutes (Cherry & McWatters, 1981). The good foam stabilities of chickpea flours suggest that the native proteins that are oluble in the continuous phase (water) are very surface-active in chickpea flours.

3.4. Thermal properties

The gelatinization temperatures (onset, T_o, peak, T_p and conclusion, T_c), enthalpy of gelatinization (ΔH_{gel}), peak height index (PHI) and gelatinization range ($T_c - T_o$) for flours from different chickpea cultivars are presented in Table 6. Significant differences ($P < 0.05$) were observed in T_o, T_p and T_c among various chickpea flours. T_o, T_p and T_c for chickpea flours ranged from 65.4 to 67.9, 70.6 to 73.3 and 77.0 to 79.4 °C, respectively. PDG-4 (desi cultivar) flour had highest values of T_o, T_p and T_c, whereas L-550 (kabuli type) flour showed the lowest values for these. The differences in gelatinization temperature among different chickpea flours may be attributed to the differences in size, form and distribution of starch granules in the flours, and to the internal arrangement of starch fractions within the granule. ΔH_{gel} of flours from different chickpea cultivars ranged from 3.5 to 4.9 J/g, the highest for PDG-4, and lowest for L-550 flour. The gelatinization enthalpy value is affected by factors such as starch granule shape and percentage of large and small granules (Stevens & Elton, 1971; Yuan, Thompson, & Boyer, 1993). PHI is the ratio of ΔH_{gel} for gelatinization to the gelatinization temperature range and is a measure of uniformity in gelatinization. PHI values for various chickpea flours differed significantly, ranging from 0.67 to 0.93. L-550 flour (kabuli type cultivar) showed the significantly lowest T_o (65.4 °C), T_p (70.6 °C), T_c (77.0 °C), ΔH_{gel} (3.5 J/g), and PHI (0.67) as compared to desi chickpea flours. So, lesser energy is needed (fusion enthalpy) to break the intermolecular bonds in starch granules of this flour to achieve gelatinization. The gelatinization temperature range ($T_c - T_o$) among chickpea flours varied from 11.5 to 12.7. GPF-2 flour showed the greatest range whereas the lowest was observed for PDG-4 flour. The great range of GPF-2 flour suggests the presence of crystallites of varying stability within the crystalline domains of its starch granules.

3.5. Pasting properties

The results from the rapid visco analyzer (RVA) of chickpea flours are summarized in Table 7. Significant differences were observed in pasting characteristics of flours from different chickpea cultivars. Pasting curves of flours from different chickpea cultivars are shown in Fig. 3. Pasting temperature (temperature at the onset of rise in viscosity) of flours from different chickpea cultivars ranged from 73.1 to 75.2 °C. Pasting temperature provides an indication of the minimum temperature required to cook the flour. Highest pasting temperature was for GPF-2 and lowest for PBG-1 flour. The high pasting temperature of GPF-2 flour indicates the presence in this flour, of starch that is highly resistance to swelling and rupturing. Peak viscosity of different chickpea flours varied from 12.3 to 180.3 rapid visco units (RVU), the highest for L-550 and lowest for GPF-2 flour. All the flours showed a gradual increase in viscosity with increase in temperature. The increase in viscosity with temperature may be attributed to the removal of water from the exuded amylose by the granules as they swell (Ghiasi, Varriano-Marston, & Hoseney, 1982). Final viscosity (indicates the ability of the material to form a viscous paste) and setback (measure of retrogradation tendency or syneresis of flours upon cooling of cooked flour pastes) of chickpea flours ranged from 126.3 to 225.3 and 19.8 to 62.8 RVU, respectively. Breakdown

Table 6
Thermal properties of flours from different chickpea cultivars[a,b]

Chickpea flours	T_o (°C)	T_p (°C)	T_c (°C)	ΔH_{gel} (J/g)	PHI	R
Desi type						
PBG-1	66.1b	71.7ab	77.7ab	4.7bc	0.84c	11.6a
PDG-4	67.9c	73.3c	79.4c	4.9c	0.93d	11.5a
PDG-3	65.8a	71.8ab	78.1b	4.6bc	0.77b	12.3ab
GL-769	66.3b	72.1b	78.4bc	3.9b	0.68a	12.1ab
GPF-2	65.5a	71.3ab	78.2b	3.9b	0.69a	12.7b
Kabuli type						
L-550	65.4a	70.6a	77.0a	3.5a	0.67a	11.6a

T_o, onset temperature; T_p, peak temperature; T_c, conclusion temperature; ΔH_{gel}, enthalpy of gelatinization (dwb); PHI, peak height index $\Delta H_{gel}/(T_p - T_o)$; R, gelatinization range ($T_c - T_o$).
[a] Means of triplicate analyses.
[b] Means followed by same letter within a column do not differ significantly ($P < 0.05$).

Table 7
Pasting properties of flours from different chickpea cultivars[a,b]

Cultivars	Pasting temperature (°C)	Peak viscosity (RVU)	Trough viscosity (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)
Desi type						
PBG-1	73.1a	170.7c	153.0c	17.7cd	208.2cd	55.2c
PDG-4	74.3b	176.4cd	154.0c	22.4d	186.3c	32.3b
PDG-3	74.4b	147.6b	134.3bc	13.3c	169.8bc	35.5bc
GL-769	75.1bc	135.0ab	125.4b	9.6b	153.2b	27.8ab
GPF-2	75.2c	112.3a	106.4a	5.9a	126.3a	19.8a
Kabuli type						
L-550	73.9ab	180.3d	162.5d	17.8cd	225.3d	62.8d

[a] Means of triplicate analyses.
[b] Means followed by same letter within a column do not differ significantly ($P < 0.05$).

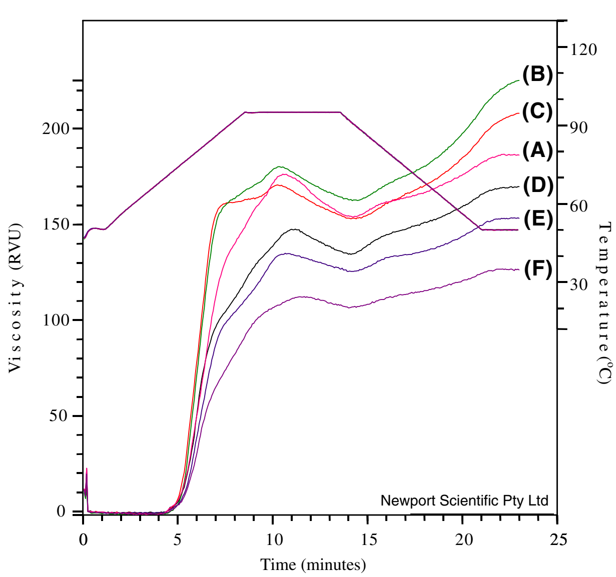

Fig. 3. RVA profiles of flours from different chickpea cultivars: (a) PBG-1; (b) L-550; (c) PDG-4; (d) PDG-3; (e) GL-769 and (f) GPF-2.

(measure of the ease with which the swollen granules can be disintegrated) values of flours from various chickpea cultivars ranged from 5.9 to 22.4 RVU. Lowest breakdown was observed in GPF-2 flour, thereby indicating its paste stability. Flour from kabuli chickpea cultivar had low pasting temperature (73.9 °C), highest peak viscosity (180.3), trough (162.5), final viscosity (225.3) and setback (62.8). Among desi chickpea flours, GPF-2 flour had highest pasting temperature (75.2 °C), lowest peak (112.3), trough (106.4), breakdown (5.9), final viscosity (126.3), and setback (19.8). The lowest setback value of GPF-2 flour indicates its lower tendency to retrograde. The smaller tendencies to retrograde are an advantage in food products such as soups and sauces, which undergo loss of viscosity and precipitation as a result of retrogradation (Adebowale & Lawal, 2003a).

4. Conclusion

Flours from desi and kabuli chickpea cultivars differed significantly in their physicochemical, functional, thermal and pasting properties. The variation in functional properties among legume flours can be ascribed to the ratio of protein to starch and other constituents in their flours. L-550 flour (kabuli chickpea cultivar) differed significantly from all other chickpea flours with respect to its water and oil absorption, gelation capacity, and emulsification properties. L-550 flour also showed lowest T_o, T_p, T_c, and ΔH_{gel} and highest peak, trough, final viscosity, and setback. The high setback value for kabuli flour indicated the higher tendency of this flour to retrograde.

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