J Food Sci Technol (May–June 2010) 47(3):273–278
DOI: 10.1007/s13197-010-0042-0

ORIGINAL ARTICLE

Functional, thermal and pasting characteristics of flours from different lentil (*Lens culinaris*) cultivars

Maninder Kaur · Kawaljit Singh Sandhu

Revised: 11 November 2009 / Accepted: 15 December 2009

Abstract Flours from four lentil cultivars ('LL-912', 'LL-699', 'LL-56', and 'LL-147') were characterized for their functional, thermal and pasting properties. Results showed that water and oil absorption capacity of flours were 1.5–1.7 and 0.92–1.13 g/g, respectively. The minimum concentration of flours needed for gelation was 12 to 14% while the foaming capacity was 33.9–47.3%. The transition temperatures (T_o, T_p and T_c) and enthalpies (ΔH_{gel}) associated with gelatinization varied significantly among different lentil cultivars. Several significant correlations were observed among different flour properties as revealed by Pearson correlation and principal component analysis (PCA). PCA showed that 'LL 56' and 'LL 147' cultivars differed greatest degree in the properties of their flours. The pasting properties of flours showed considerable variation when studied by rapid visco analyzer.

Keywords Flour · Lentil · *Lens culinaris* · Physicochemical · Functional · Thermal

Kaur M. [1] · Sandhu K. S.[2]
[1]Department of Food Science and Technology, Guru Nanak Dev University, Amritsar - 143 005, India
[2]Department of Food Science and Technology, Chaudhary Devi Lal University, Sirsa, India

M. Kaur (✉)
E-mail: mandyvirk@rediffmail.com

Introduction

Lentil is an important legume crop in developing countries and is exclusively used in human foods (Hoover and Manuel 1995). India is the largest producer of lentil in the world. Like most legumes, lentil seeds are composed of about two-thirds carbohydrates and 24–30% proteins. Both the starch and protein fractions of lentils offer a new source of novel ingredients (Lee et al. 2007). Lentil proteins have been studied for their composition (Bhatty et al. 1976) and functional properties (Hsu et al. 1982, Kaur et al. 2007). The functional properties, which affect the sensory characteristics of foods, play important roles in the physical behavior of food. Variations in functional properties of flours may be ascribed to the relative ratio of different constituents like proteins, carbohydrates and lipids. Studies have been made on functional properties of lima bean (Chel-Guerrero et al. 2002), mung bean (Dzudie and Hardy 1996), chickpea (Kaur and Singh 2005), black gram (Kaur and Singh 2007) and pigeon pea (Oshodi and Ekperigin 1989) flours. Sosulski et al. (1976) investigated the functional properties of ten legume flours, and found some properties of mung bean flour to be comparable with soybean flour. Henshaw et al. (1996) reported that the functionality of cowpea flour can be attributed to its chemical components as determined by the genetic architecture of seed and post-harvest conditions of storage and processing.

Gelatinization is an energy absorbing process that can be followed by differential scanning calorimetry (DSC). Gelatinization is an order-disorder phase transition that involves diffusion of water into the starch granules, hydration and swelling, uptake of heat, loss of birefringence and crystallinity, and amylose leaching (Biliaderis et al. 1980). Henshaw et al. (1996) reported that flour contains other substances such as protein, lipid, and minerals that may interact with starch to varying degrees and affect the paste characteristics. The variation in flour properties between lentil cultivars have not been the subject of a detailed study as differences in physico-chemical properties will affect the functional and thermal properties of flours and their suitability in different food applications. Therefore, the functional, thermal and pasting properties of flours from four lentil cultivars grown at the same location and in the same year in India were investigated. Also the correlations between different flour properties were also studied.

Materials and methods

Four improved red lentil (*Lens culinaris*) cultivars (‘LL 912’, ‘LL 699’, ‘LL 56’ and ‘LL 147’) were obtained from Punjab Agricultural University, Ludhiana, India. Seeds from the cultivars were ground to pass through sieve Nr 72 (British sieve standards) to obtain flour. The flour samples were defatted by solvent extraction using n-hexane, dried at 40°C in a hot air oven for 3 h and was packed after cooling in air tight containers.

Proximate composition: Flour samples were analyzed for moisture, ash, fat, protein (N %×6.25) and fiber contents (AOAC 1990). Carbohydrate content was calculated by difference.

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

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

The L* value indicates the lightness, 0–100 representing dark to light. The a* value gives the degree of the red-green color, with a higher positive a* value indicating more red. The b* value indicates the degree of the yellow-blue color, with a higher positive b* value indicating more yellow (Kaur and Singh 2005).

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

Functional properties: Functional properties, viz, water absorption capacity (WAC) (Sosulski 1962), oil absorption capacity (OAC) and foaming capacity (FC) (Lin et al. 1974), least gelation concentration (LGC) (Sathe et al. 1982) of lentil flours were determined.

Thermal properties: Thermal characteristics of flours were analyzed using a Differential Scanning Calorimeter-821^e (Mettler Toledo, Switzerland). 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 Hamilton micro syringe to achieve a flour-water suspension containing 70% water. Samples were hermetically sealed and allowed to stand for 1 h at room temperature (20°C) before heating in 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).

Pasting properties: Pasting properties of flours were studied by using rapid visco analyzer (Newport Scientific Pty Ltd, Warriewood NSW 2102, Australia) as described previously (Kaur and Singh 2005). Viscosity profiles of flours were recorded using flours suspensions (10% 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.

Statistical analysis: The data in triplicate were subjected to statistical analysis using Minitab statistical software (Minitab Inc, State College, PA, USA). Pearson correlation coefficients (*r*) for relationships between various flour properties were calculated. A principle component analysis (PCA) of measured flour properties was carried out to provide a ready means of visualizing the differences and similarities among four lentil flours in terms of these properties.

Results and discussion

Physico-chemical and functional properties: The flours had ash and fat content of 2.5–2.8% and 1.7–1.9%, respectively (Table 1). The protein content of the flours varied from 23.6 to 25.1%, indicating that lentil flours could be a valuable protein supplement in food products. The fiber and carbohydrate contents (calculated by difference) of the flours were 3.7–3.8% and 66.6–68.2%, respectively. Sosulski and Youngs (1979) observed ash, fat, protein and fiber contents of 2.8, 1.1, 23.9 and 3.8% in lentil flours. The bulk density (BD) of lentil flours varied from 0.516 to 0.548 g/ml (Table 1). BD is a reflection of the load the sample can carry if allowed to rest directly on another (Onimawo and Asugo 2004). BD of 0.536–0.571 g/ml in chickpea flours (Kaur and Singh 2005) and 0.600 g/ml in green mung bean (Dzudie and Hardy 1996) have been reported. ‘LL 699’ had the highest ash and BD, whereas ‘LL 56’ flour showed the highest fat and the lowest ash, protein and BD.

The L* and a* values of the flours were 74.0–76.1 and 1.3–1.9, respectively. Flours from all lentil cultivars showed positive a* value, which indicated their reddish

Table 1 Physico-chemical, thermal and pasting properties of flours from different lentil cultivars

Parameter	Cultivars			
	'LL 912'	'LL 699'	'LL 56'	'LL 147'
Physico-chemical				
Ash, %	2.7 ± 0.10^{b}	2.8 ± 0.09^{c}	2.5 ± 0.14^{a}	2.5 ± 0.16^{ab}
Crude fat, %	1.7 ± 0.06^{a}	1.9 ± 0.07^{b}	1.9 ± 0.06^{c}	1.7 ± 0.05^{a}
Protein, %	24.0 ± 0.63^{ab}	24.9 ± 0.72^{ab}	23.6 ± 0.81^{a}	25.1 ± 0.69^{b}
Crude fiber, %	3.7 ± 0.09^{a}	3.8 ± 0.11^{ab}	3.8 ± 0.13^{ab}	3.8 ± 0.14^{b}
Carbohydrate, %	67.8^{ab}	66.6^{a}	68.2^{b}	66.8^{a}
Bulk density, g/ml	0.542 ± 0.020^{bc}	0.548 ± 0.015^{c}	0.516 ± 0.020^{a}	0.529 ± 0.010^{b}
Hunter L colour	76.1 ± 1.11^{b}	74.0 ± 1.08^{a}	76.0 ± 1.21^{b}	74.1 ± 1.19^{a}
a	1.7 ± 0.06^{bc}	1.7 ± 0.02^{b}	1.3 ± 0.03^{a}	1.9 ± 0.04^{c}
b	14.7 ± 0.12^{ab}	15.7 ± 0.11^{b}	14.9 ± 0.10^{ab}	14.6 ± 0.13^{a}
ΔE value	57.2 ± 0.8^{b}	55.5 ± 0.9^{a}	57.4 ± 1.0^{b}	55.4 ± 0.9^{a}
WAC, g/g	1.5 ± 0.11^{ab}	1.7 ± 0.13^{b}	1.5 ± 0.11^{a}	1.5 ± 0.12^{ab}
OAC, g/g	0.94 ± 0.09^{a}	0.92 ± 0.07^{a}	1.10 ± 0.08^{b}	1.13 ± 0.09^{b}
FC, %	47.3 ± 1.5^{d}	42.4 ± 1.3^{c}	38.3 ± 1.4^{b}	33.9 ± 1.2^{a}
LGC, %	14^{b}	12^{a}	12^{a}	14^{b}
Thermal properties				
T_o, °C	63.1 ± 0.5^{ab}	62.9 ± 0.6^{a}	62.7 ± 0.4^{a}	63.9 ± 0.5^{b}
T_p, °C	71.9 ± 0.2^{a}	71.9 ± 0.3^{a}	71.8 ± 0.2^{a}	72.1 ± 0.3^{b}
T_c, °C	79.0 ± 0.6^{b}	78.7 ± 0.3^{ab}	78.4 ± 0.5^{a}	79.1 ± 0.7^{b}
ΔH_{gel}, J/g	3.4 ± 0.2^{a}	3.6 ± 0.1^{ab}	3.7 ± 0.2^{b}	3.4 ± 0.3^{a}
PHI	0.383 ± 0.003^{a}	0.405 ± 0.004^{ab}	0.407 ± 0.002^{b}	0.409 ± 0.003^{b}
R	15.9 ± 0.5^{b}	15.8 ± 0.4^{ab}	15.7 ± 0.5^{ab}	15.2 ± 0.5^{a}
Pasting properties				
PT, °C	73.4 ± 0.10^{a}	73.5 ± 0.13^{a}	73.5 ± 0.12^{a}	74.0 ± 0.11^{b}
PV, cP	1764 ± 19^{d}	1455 ± 16^{a}	1681 ± 18^{b}	1732 ± 20^{c}
BV, cP	386 ± 19^{b}	293 ± 16^{a}	479 ± 21^{c}	406 ± 24^{bc}
FV, cP	2318 ± 29^{d}	1797 ± 19^{a}	1897 ± 20^{b}	2135 ± 26^{c}

Mean ± SD with different superscripts in a row differ significantly ($p < 0.05$) ($n = 3$) WAC: Water absorption capacity, OAC: Oil absorption capacity, FC: Foaming capacity, LGC: Least gelation concentration, T_o: Onset temperature, T_p: Peak temperature, T_c: Conclusion temperature; ΔH_{gel}: Enthalpy of gelatinization (dwb, based on starch weight); R : Gelatinization range (T_c–T_o); PHI: Peak height index $\Delta H_{gel}/(T_p-T_o)$, PT: Pasting temperature, PV: Peak viscosity, BV: Breakdown viscosity, FV: Final viscosity

color. The b* value ranged from 14.58 to 15.73, whereas ΔE (total color difference) ranged from 55.4 to 57.4 for the flours. Flour from 'LL 699' showed the lowest L* and the highest b* value, indicating its comparatively darker and yellow color, whereas 'LL 912' flour showed the highest L* value, indicating its significantly lighter color as compared to other lentil flours.

The WAC of different lentil flours ranged between 1.5-1.7 g/g, lowest for 'LL 56' and highest for 'LL 699' flour was observed (Table 1). The differences in WAC between the flours can be attributed to their different protein and carbohydrate fractions. WAC of 2.2 g/g for soybean flour (Akubor 2007), 1.3–1.5 g/g for chickpea flour (Kaur and Singh 2005), 2.1 g/g in green mung bean flour (Dzudie and Hardy 1996), 2.4 g/g for moth bean flour (Pawar and Ingle 1988), 2.2 g/g for soybean meal (Sharma and Subramanian 1994) and 2.4 g/g for raw cowpea flour (Abbey and Ibeh 1988) have been reported earlier. These WAC values, especially the high value of 'LL 699' flour makes lentil flours as useful ingredients in the preparation of comminuted products and to improve handling characteristics of bread dough.

The Maximum oil absorption capacity (OAC) of 1.1 g/g was observed in 'LL 147' while the least value of 0.92 g/g was recorded in 'LL 699' flour. These values are comparable with those reported for chickpea (1.0–1.2 g/g), soybean (1.2 g/g), pigeon pea (1.2 ml/g), soybean meal (1.1 g/g), and great northern bean flour (1.0 g/g) by Kaur and Singh (2005), Akubor (2007), Mizubuti et al. (2000), Sharma and Subramanian (1994) and Sathe and Salunkhe (1981), respectively. Pawar and Ingle (1988), Dzudie and

Hardy (1996), and Abbey and Ibeh (1988) reported OAC of 2.4 g/g in moth bean, 1.9 g/g in green mung bean, and 2.9 g/g in raw cowpea, respectively, which were higher than the values observed in the present study. Adebowale and Lawal (2004) reported that flours with good OAC are potentially useful in flavor retention, improvement of palatability and extension of shelf life particularly in bakery or meat products where fat absorption is desired.

The LGC for various lentil flours ranged between 12 and 14% (Table 1). Protein gelation is vital in the preparation and acceptability of many foods, including vegetables and other products. Previous studies have indicated LGC of 10-14% in chickpea flours (Kaur and Singh 2005), 10% in great northern bean flour (Sathe and Salunkhe 1981) and 10% in pigeon pea flour (Onimawo and Asugo 2004).

The foams produced by lentil flours were relatively thick with FC between 33.9 and 47.3% (Table 1). Foams are used to improve texture, consistency and appearance of foods (Onimawo and Asugo 2004). The good foaming ability of lentil flours makes them useful in food systems that require aeration for textural and leavening properties. Our observations on FC agree with those reported for jackbean (52%), bambarra groundnut (57.1%) and mucuna bean (41.0%) flours by Adebowale and Lawal (2004). In our work on black gram flour (Kaur and Singh 2007) the FC was 36.2 to 49.2%, with an average of 41.9%.

Thermal properties: T_o, T_p and T_c of flours were 62.7–63.9, 71.8–72.1 and 78.4–79.1°C, respectively (Table 1). ‘LL 56’ showed the lowest transition temperatures, whereas ‘LL 147’ flour showed the highest values for the same. The differences in transition temperature among different flours may be attributed to the difference in size, form and distribution of starch granules in the flours (Kaur and Singh 2005). T_o, T_p and T_c in the range 65.4–67.9, 70.6–73.3 and 77.0–79.4°C, respectively in chickpea flours (Kaur and Singh 2005) and average value of 73.0, 78.1 and 84.1°C, respectively in black gram flours (Kaur and Singh 2007) has been reported earlier. ΔH_{gel} of lentil flours ranged from 3.35 to 3.70 J/g. The lowest and highest ΔH_{gel} values among the flours were recorded for 147’ and ‘LL 56’ flours, respectively. The gelatinization enthalpy values of starches have been reported to be affected by factors such as granule shape, percentage of large and small granules, and the presence of phosphate esters (Yuan et al. 1993). The gelatinization temperature was highest (15.9) in ‘LL 912’ flour, while lowest (15.2) was observed in ‘LL 147’ flour.

Pasting properties: Pasting temperature (PT) of the flour was 73.4–74.0°C, the lowest for ‘LL 912’ and the highest for ‘LL 147’ flour were observed (Table 1). PT of 73.1–75.2°C in chickpea (Kaur and Singh 2005), 68.9–81.1°C in black gram (Kaur and Singh 2007), and 78–83°C in cowpea flour (Henshaw et al. 1996) have been reported. The high pasting temperature of ‘LL 147’ flour indicates the presence of starch in this flour that is highly resistance to swelling and rupturing. The PT obtained with RVA was consistent with the gelatinization temperatures obtained with DSC. All the flours showed gradual increase in viscosity with the increase in temperature (Fig. 1). Peak viscosity (PV) and trough viscosity (TV) of different lentil flours varied from 1455 to 1764 cP, and 1162 to 1378 cP, respectively. Lowest breakdown (BV) was observed in ‘LL 699’ flour thereby indicating its paste stability. Final viscosity (FV) and set-back (SV) of the flours varied from 1797 to 2318 and 635 to 940 cP, respectively. Flour from ‘LL 912’ had the highest PV, TV, SV and FV, while ‘LL 699’ flour showed the lowest values for the same. The highest SV of ‘LL 912’ flour indicates its higher tendency to retrograde. Flour with high hot paste viscosity would be advantageous in products requiring viscosity increase after cooking such as soups, sauces, and puddings (Henshaw et al. 1996). Although starch is quantitatively major component to control the pasting /thermal properties, temperature induced changes in non starchy polysaccharides and proteins also contribute to the gelling, and pasting properties by way of swelling, denaturation and unfolding. Henshaw et al. (1996) reported that flour contains other substances such as protein, lipid, and minerals that may interact with starch to varying degrees and influence the paste characteristics of flour.

Pearson correlation and principal component analysis (PCA): L* and ΔE were negatively correlated to protein content (r= –0.957 and –0.981, respectively) (Table 2). Negative correlations of OAC with WAC (r = –0.724) and BD (r = –0.874) have been revealed as analyzed by Pearson correlation analysis. A statistically significant negative correlation of FC with OAC was observed (r = –0.884, p <0.05). The correlation coefficients of FC with protein and BD were –0.376 and 0.627, though not statistically

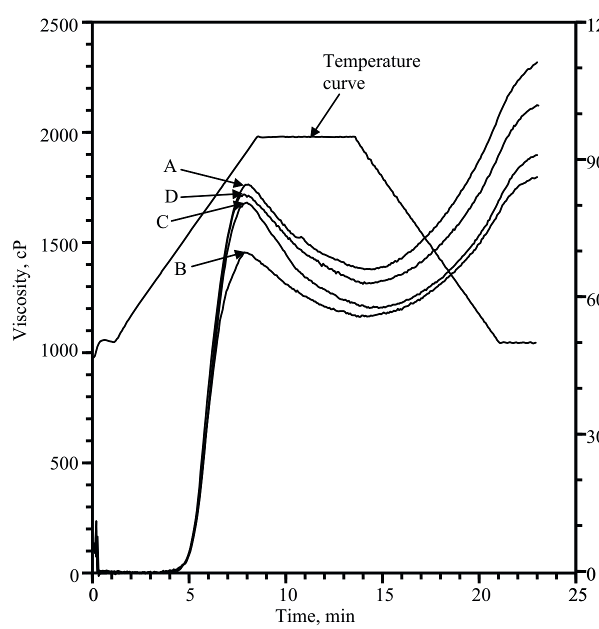

Fig. 1 RVA profiles of flours from different lentil cultivars (A) ‘LL 912’, (B) ‘LL 699’, (C) ‘LL 56’ and (D) ‘LL 147’

Table 2 Pearson correlation coefficients between various physico–chemical, thermal and pasting properties of flours from lentil cultivars

	FC	WAC	OAC	T_o	T_p	T_c	ΔH_{gel}	R	PV	TV	FV
WAC	0.316										
OAC	–0.884*	–0.724									
T_o	–0.529	–0.115	0.444								
T_p	–0.508	0.069	0.338	0.982**							
T_c	0.013	0.086	–0.049	0.842*	0.838*						
ΔH_{gel}	–0.015	0.197	–0.089	–0.808*	–0.748	–0.955**					
R	0.908**	0.281	–0.800*	–0.836*	–0.809*	–0.407	0.395				
PV	–0.085	–0.850*	0.483	0.411	0.237	0.412	–0.661	–0.277			
TV	0.177	–0.435	0.088	0.587	0.476	0.792	–0.931**	–0.188	0.844*		
FV	0.277	–0.432	0.015	0.492	0.379	0.743	–0.892*	–0.077	0.839*	0.933**	
SV	0.350	–0.427	–0.042	0.416	0.302	0.699	–0.855*	0.008	0.827*	0.980**	0.996**

WAC, OAC, FC, LGC, $T_{o,}$ $T_{p,}$ $T_{c,}$ $\Delta H_{gel,}$ R, PHI, PT, PV, BV, FC, FV: As in Table 1

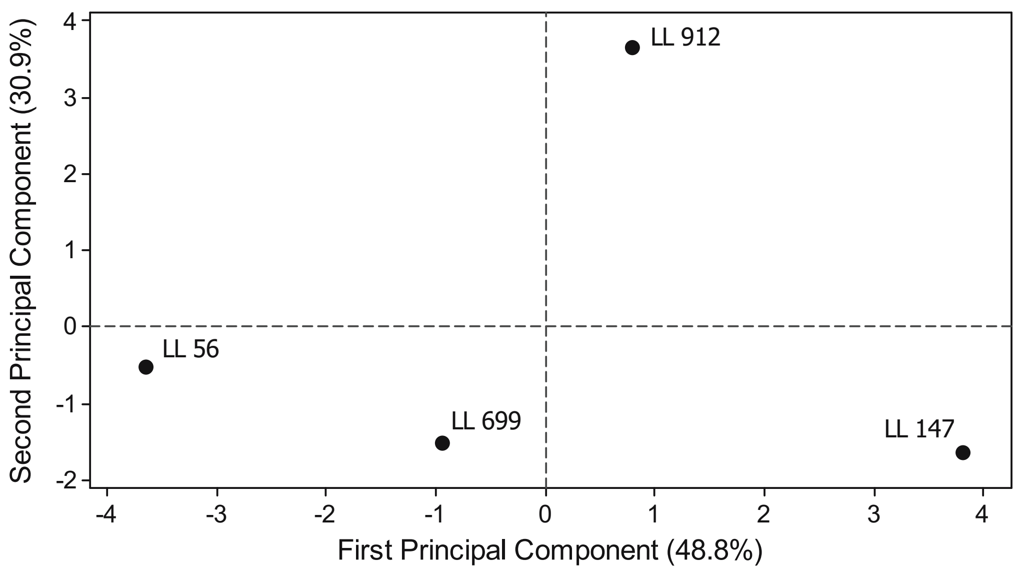

Fig. 2 Principal component analysis: score plot of first principal component (PC1) and second principal component (PC2) describing the overall variation among flours from different lentil cultivars

significant. T_o was positively correlated to T_p (r = 0.982, p <0.01) and T_c (r = 0.842, p <0.05) whereas ΔH_{gel} showed a negative correlation with T_o, T_p and T_c. Several significant interrelationships between DSC and RVA parameters were observed. Pearson correlation analysis revealed a positive correlation of PV with TV (r = 0.844, p <0.05), FV (r = 0.839, p <0.05) and SV (r = 0.827, p <0.05, Table 2). These results are in agreement with those reported earlier for corn flour (Sandhu et al. 2007). Negative correlation was shown by ΔH_{gel} with PV, TV, FV and SV. The results of the PCA are shown in Fig. 2. The PCA plots provide an overview of the similarities and differences between various lentil flours. The distance between the locations of any two flours on the score plot is directly proportional to the degree of difference or similarity between them. The first and the second principal components (PC) described 48.8 and 30.9% of the variance respectively. Together, the first two PCs represent 79.6% of the total variability. 'LL 147' flour was located at the far right of the score plot with a large positive score in PC1, while 'LL 56' flour had a large negative score (Fig. 2). Overall, these two flours exhibited the greatest differences in their properties.

Conclusion

Significant variations in the functional, thermal and pasting properties of flours from different lentil cultivars were observed, which could be ascribed to the ratio of starch to protein and other constituents in the flour. 'LL 56' differed significantly from all other flours with respect to its composition, color parameters, bulk density and WAC. 'LL 56' flour also showed the lowest T_o, T_p, T_c, and the highest ΔH_{gel} and BV. The correlation analysis of the thermal and pasting properties of the flours provided valuable information on the mechanisms contributing to the functional properties of the flours.

References

Abbey BW, Ibeh GO (1988) Functional properties of raw and heat processed cowpea (*Vigna unguiculata*, Walp) flour. J Food Sci 53:1775–1791

Adebowale KO, Lawal OS (2004) Comparative study of the functional properties of bambarra groundnut (*Voandzeia subterranean*), jack bean (*Canavalia ensiformis*) and mucuna bean (*Mucuna pruriens*) flours. Food Res Int 37:355–365

Akubor PI (2007) Chemical, functional and cookie baking properties of soybean/maize flour blends. J Food Sci Technol 44: 619–622

AOAC (1990) Official methods of analysis, 15th edn, Association of Official Analytical Chemists, Washington DC

Bhatty RS, Slinkard AE, Sosulski FW (1976) Chemical composition and protein characteristics of lentils. J Can Plant Sci 56: 787–794

Biliaderis CG, Maurice TJ, Vose JR (1980) Starch gelatinization phenomena studied by differential scanning calorimetry. J Food Sci 45:1669–1674, 1680

Chel-Guerrero L, Perez-Flores V, Bentacur-Ancona D, Davila-Ortiz G (2002) Functional properties of flours and protein isolates from *Phaseolus lunatus* and *Canavalia ensiformis* seeds. J Agric Food Chem 50:584–591

Dzudie T, Hardy J (1996) Physico-chemical and functional properties of flours prepared from common beans and green mung beans. J Agric Food Chem 44:3029–3032

Henshaw FO, McWatters KH, Oguntunde AO, Phillips RD (1996) Pasting properties of Cowpea flour: effects of soaking and decortication method. J Agric Food Chem 44:1864–1870

Hoover R, Manuel H (1995) A comparative study of the physicochemical properties of starches from two lentil cultivars. Food Chem 53:275–284

Hsu DL, Leung HK, Morad MM, Finny PL, Leung CT (1982) Effect of germination on electrophoretic, functional and bread making properties of yellow pea, lentil and fava bean protein isolates. Cereal Chem 59:344–350

Kaur M, Singh N (2005) Studies on functional, thermal and pasting properties of flours from different Chickpea *(Cicer arietinum* L.*)* cultivars. Food Chem 91:403–411

Kaur M, Singh N (2007) Relationships between various functional, thermal and pasting properties of flours from different Indian black gram (*Phaseolus mungo* L.) cultivars. J Sci Food Agric 87:974–984

Kaur M, Singh N, Sandhu K (2007) Preparation and characterization of protein isolates from different lentil (*Lens culinaris*) cultivars. J Food Sci Technol 44:327–329

Krueger BR, Knutson CA, Inglett GE, Walker CE (1987) A differential scanning calorimetry study on the effect of annealing on gelatinization behavior of corn starch. J Food Sci 52:715–718

Lee HC, Htoon AK, Uthaya Kumaran S, Paterson JL (2007) Chemical and functional quality of protein isolated from alkaline extraction of Australian lentil cultivars: ‘Matilda’ and ‘Digger’. Food Chem 102:1199–1207

Lin MJY, Humbert ES, Sosulski FW (1974) Certain functional properties of sunflower meal products. J Food Sci 39:368–370

Mizubuti IY, Junior OB, Souza LWD, da Silva RSDF, Ida EI (2000) Functional properties of pigeon pea (*Cajanus cajan* (L.) Millsp) flour and protein concentrate. Arch Latinoam Nutr 50: 274–280

Onimawo IA, Asugo S (2004) Effects of germination on the nutrient content and functional properties of pigeon pea flour. J Food Sci Technol 41:170–174

Oshodi AA, Ekperigin MM (1989) Functional properties of pigeon pea (*Cajanus cajan)* flour. Food Chem 34:1–5

Pawar VD, Ingle UM (1988) Functional properties of raw and cooked moth bean (*Phaseolus aconitifolius* Jacq) flours. J Food Sci Technol 25:186–189

Sandhu KS, Singh N, Malhi NS (2007) Some properties of corn grains and their flours. I. Physicochemical, functional and chapati-making properties of flours. Food Chem 101:938–946

Sathe SK, Deshpande SS, Salunkhe DK (1982) Functional properties of lupin seeds (*Lupinus mutabilis*) proteins and protein concentrates. J Food Sci 47:491–497, 499–500

Sathe SK, Salunkhe DK (1981) Functional properties of great northern bean proteins: emulsion, foaming, viscosity and gelation properties. J Food Sci 46:71–75

Sharma YK, Subramanian N (1994) Comparative studies on functional properties of soymeals from ‘Kalitur’ and ‘Bragg’ varieties. J Food Sci Technol 31:27–31

Singh U (2001) Functional properties of grain legume flours. J Food Sci Technol 38:191–199

Sosulski FW (1962) The centrifuge method for determining flour absorption in hard red spring wheats. Cereal Chem 39: 344–350

Sosulski FW, Garratt MD, Slinkard AE (1976) Functional properties of ten legume flours. J Can Inst Food Sci Technol 9: 66–69

Sosulski FW, Youngs CG (1979) Yield and functional properties of air classified protein and starch fractions from eight legume flours. J Am Oil Chem Soc 56:292–295

Vasanthan T, Bhatty RS (1996) Physico-chemical properties of small and large granule starches of waxy, regular, and high amylose barleys. Cereal Chem 73:199–207

Yuan RC, Thompson DB, Boyer CD (1993) Fine structure of amylopectin in relation to gelatinization and retrogradation behavior of maize starches from three wx-containing genotypes in two inbred lines. Cereal Chem 70:81–89