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Nutritional and compositional study of Desi chickpea (*Cicer arietinum* L.) cultivars grown in Punjab, Pakistan

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Abstract

Four indigenous Desi chickpea (*Cicer arietinum* L.) cultivars grown in the Punjab Province of Pakistan have been analyzed to determine and compare their nutritional and compositional properties and to assess their role in human nutrition. Variability was observed among investigated cultivars in terms of physical characteristics of seeds, such as seed size, seed volume, seed density, hydration capacity, hydration index, swelling capacity and swelling index. Mineral composition showed that sufficient amounts of Ca, P, K, Cu, Zn and Mg were present to meet the macronutrient and micronutrient demand in human diets. Despite variations, potassium and manganese were noted as being present in highest and lowest concentrations, respectively, in all cultivars. The distribution patterns of various amino acids in these cultivars suggested sulfur-containing amino acids as limiting amino acids. Fatty acid profile indicated unsaturated fatty acids as major fatty acids in all cultivars. The levels of some of the anti-nutritional factors were also determined. The analysis showed almost similar proportions of biochemical constituents among all cultivars. The data show that, in terms of both quality and quantity, the Desi chickpea cultivars can serve as a significant source of essential amino acids, essential fatty acids and trace minerals to meet the demand of populations living in Punjab Province of Pakistan.

Keywords: Nutritional; Composition; Desi chickpea (*Cicer arietinum* L.) cultivar; Punjab; Pakistan

1. Introduction

The chickpea is considered to be a healthy vegetarian food and it is one of the most important human and domestic animal foods in south Asia. It is a cheap source of high quality protein in the diets of millions in developing countries, who cannot afford animal protein for balanced nutrition. In addition to proteins, it is a good source of carbohydrates, minerals and trace elements (Duke, 1981; Huisman & Van der Poel, 1994; Williams & Singh, 1988). Chickpea, like other legumes, not only brings to the cereal staple a variety of taste and texture but adds nutrients (carbohydrates, minerals) to the staple dish which ensure a balanced diet, meeting all nutrient requirements (Duhan, Khetarpaul, & Bishnoi, 1999). Its flour, called *Besan*, is used in many ways for cooking, e.g. mixed with wheat flour to make roti or chapatti. Young plants and green pods are eaten like spinach. A small proportion of canned chickpea is also used in Turkey and Latin America (Duke, 1981).

On the medicinal side, chickpea seed is used as a tonic, stimulant and aphrodisiac (Pandey & Enumeratio, 1993). The seed is used as an appetizer and also has anthelmintic properties. It also alleviates thirst and burning sensation.

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Seeds are mainly used for the treatment of bronchitis, leprosy, skin diseases, blood disorders and biliousness (Sastry & Kavathekar, 1990). Seeds are also used for the treatment of diseases of the liver and spleen; seeds enrich the blood and cure skin diseases and inflammation of the ear (Warner, Nambiar, & Remankutty, 1995). Among food legumes, chickpea is the most hypocholesteremic agent, and germinated chickpea is reported to be effective in controlling cholesterol level in rats (Geervani, 1991).

Inspite of a good nutritional profile, as well as reported medicinal properties, chickpea has several nutritional and processing problems, such as the presence of antinutrients, prolonged cooking time, hard-to-cook phenomenon and poor digestibility. Its chemical composition is subject to fluctuations, depending on various factors, e.g. cultivar and maturity stage, environment (mostly weather conditions), and agrotechnics. Some reports have also underlined variations in the physical as well as the chemical composition of these legumes (Rupperez, 1998). These variations can be either due to intrinsic factors (mainly genetics, which are partly responsible for differences between cultivars and varieties) or to extrinsic factors, such as storage, type of soil, agronomic practices, climatic factors and technological treatments (Paolini, Colla, Saccardo, & Campiglia, 2003).

Despite published works (Amjad, Khalil, Ateeq, & Khan, 2006; Badshah, Ahmad Aurangzeb, Bibi, Mohammad, & Khan, 1987; Khattak, Khattak, Mahmood, Bibi, & Ihsanullah, 2006) describing the chemical and nutritional composition of chickpea, overall information in this area, particularly about Desi chickpea (*Cicer arietinum* L.) cultivars, is fragmentary and a comprehensive knowledge of the nutritional value of such food crops in the Punjab, particularly describing cultivar influence on nutritional quality, is lacking. The present study presents an attempt to close this knowledge gap by physicochemical and nutritional evaluation of seeds of Desi chickpea (*Cicer arietinum* L.) cultivars grown and used currently in Punjab, Pakistan.

2. Materials and methods

2.1. Seed material

Five kilogrammes of seeds of each Desi chickpea (*Cicer arietinum* L.) cultivar, grown and harvested under similar environmental and climatological conditions, were obtained from the Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Punjab. The seeds were hand-cleaned to render them free of dust and then stored in an air-tight opaque plastic container at room temperature until used.

2.2. Physical characteristics of seeds

A reported procedure (Khattak et al., 2006) was followed for making physical measurements. Three random samples of 100 seeds from each cultivar per replication were weighed and the values converted to grammes per seed. Seed volume was determined by transferring 100 seeds into a 100 ml measuring cylinder, and 50 ml of distilled water were added. The gain in volume divided by 100 was taken as the seed volume. Seed density was calculated as seed weight divided by seed volume. Hydration capacity was recorded as gain in weight after overnight soaking in distilled water. Hydration index was calculated as hydration capacity divided by original seed weight. The swelling capacity was determined as gain in volume after overnight soaking in water, and swelling index was calculated as swelling capacity divided by original seed volume (Table 1).

2.3. Mineral analysis

The samples were incinerated at 450 °C for 12 h in a muffle furnace and acid digest was prepared by oxidizing each sub-sample with a nitric/perchloric acid (2:1) mixture. Aliquots were used to estimate Na and K by flame photometer (Flame Photometer Model-EEL). The minerals, such as calcium, manganese, magnesium, zinc, iron and copper, were determined with an atomic absorption spectrophotometer (Perkin–Elmer Model 5000) while Phosphorus was determined by the phosphovanado-molybdate (yellow) method (AOAC, 1990) (Tables 2 and 3). The samples were quantified against standard solutions of known concentration that were analyzed concurrently.

2.4. Amino acid analysis

Samples (300 mg), in triplicate from each cultivar, were hydrolyzed with 6 N HCl in an evacuated test tube for 24 h at 105 °C. The dried residue was dissolved in citrate buffer (pH 2.2) after flash evaporation. Aliquots were analysed in an automatic amino acid analyser (Hitachi Perkin–Elmer Model KLA 3B), using the buffer system described earlier (Zarkadas, Voldeng, Yu, & Minero-Amador, 1993). Methionine and cystine were analysed separately after performic acid treatment and subsequent hydrolysis with HCl (Khalil & Durani, 1990). Tryptophan was determined after alkali (NaOH) hydrolysis by the colorimetric method (Freidman & Finely, 1971) (Table 3).

Essential amino acids score was calculated with reference to the FAO/WHO reference amino acid pattern (FAO/WHO, 1985) (Table 4).

$$\text{Amino acid score} = \frac{\text{Test amino acid} \times 100}{\text{Reference amino acid}}.$$

2.5. Fatty acid contents

Fatty acid methyl esters (FAMEs) of the chickpea flour samples were assessed by employing the method of Garces and Mancha (1993). Samples of 50 mg, together with respective fatty acids (AOCS, Merck, Germany) as the internal standards, were placed in tubes with teflon-lined

Table 1
Physical characteristics of Desi chickpea seeds

Parameter	CM72	Bittal98	Punjab91	Punjab2000
Seed weight (g/seed)	0.189 ± 0.004	0.239 ± 0.005	0.195 ± 0.007	0.223 ± 0.009
Seed volume (ml/seed)	0.159 ± 0.006	0.144 ± 0.009	0.125 ± 0.003	0.137 ± 0.011
Seed density (g/ml)	1.18	1.65	1.56	1.62
Hydration capacity (g/seed)	0.213 ± 0.003	0.232 ± 0.012	0.197 ± 0.006	0.209 ± 0.003
Hydration index	1.126	0.970	1.01	0.937
Swelling capacity (ml/seed)	0.196 ± 0.004	0.203 ± 0.004	0.186 ± 0.007	0.179 ± 0.005
Swelling index	1.232	1.416	1.488	1.306

Each value is the mean ± SD of three independent determinations.

Table 2
Mineral constituents of Desi chickpea seeds

Minerals (mg/100 g)	CM72	Bittal98	Punjab91	Punjab2000	NRC/NAS pattern for infants (1989)
Sodium	96 ± 1.74	107 ± 4.57	103 ± 2.56	107 ± 3.21	120–200
Potassium	1236 ± 3.12	1137 ± 5.91	1272 ± 7.82	1109 ± 4.49	500–700
Phosphorus	246 ± 4.08	239 ± 8.11	263 ± 2.13	259 ± 4.13	500
Calcium	194 ± 2.31	219 ± 3.65	203 ± 4.63	185 ± 3.12	600
Iron	3.7 ± 0.17	2.4 ± 0.13	4.1 ± 0.29	3.4 ± 0.09	10
Copper	10.7 ± 0.59	11.3 ± 0.47	12.2 ± 0. 17	11.9 ± 0.23	0.6–0.7
Zinc	5.7 ± 0.63	3.5 ± 0.76	6.0 ± 0.33	4.9 ± 0.59	5
Manganese	2.3 ± 0.09	1.2 ± 0.11	1.9 ± 0.21	1.5 ± 0.17	0.3–1
Magnesium	4.3 ± 0.11	4.6 ± 0.21	5.0 ± .0.09	4.3 ± 0.14	–
Na:K ratio	0.07	0.09	0.08	0.09	–
Ca:P ratio	0.79	0.91	0.77	0.71	–

Each value is the mean ± SD of three determinations.

Table 3
Amino acid profile of Desi chickpea seeds

Amino acids (g/100 g protein)	CM72	Bittal98	Punjab91	Punjab2000
Essential amino acids				
Arginine	8.5 ± 0.21	8.3 ± 0.21	8.0 ± 0.03	8.3 ± 0.06
Histidine	3.2 ± 0.03	3.0 ± 0.03	3.0 ± 0.05	2.9 ± 0.08
Isoleucine	4.8 ± 0.03	4.8 ± 0.03	4.6 ± 0.05	4.5 ± 0.06
Leucine	8.5 ± 0.03	8.1 ± 0.08	8.4 ± 0.05	8.2 ± 0.06
Lysine	7.0 ± 0.03	7.0 ± 0.04	6.9 ± 0.03	6.7 ± 0.07
Methionine	1.1 ± 0.04	1.1 ± 0.04	0.9 ± 0.02	0.8 ± 0.04
Phenylalanine	5.3 ± 0.04	5.1 ± 0.06	5.2 ± 0.12	5.0 ± 0.12
Threonine	3.0 ± 0.04	3.0 ± 0.05	2.9 ± 0.04	2.7 ± 0.05
Tryptophan	0.9 ± 0.02	0.9 ± 0.02	0.8 ± 0.03	0.8 ± 0.11
Valine	4.4 ± 0.03	4.6 ± 0.06	4.5 ± 0.05	4.1 ± 0.08
Total	46.1	46.2	45.1	44.0
Non-essential amino acids				
Alanine	5.2 ± .03	4.97 ± 0.03	4.7 ± 0.07	5.0 ± 0.06
Aspartic acid	11.5 ± .04	11.0 ± 0.08	10.9 ± 0.12	11.3 ± 0.10
Cystine	0.6 ± 0.06	0.6 ± 0.03	0.7 ± 0.04	0.4 ± 0.07
Glutamic acid	17.8 ± .08	17.3 ± 0.06	17.5 ± 0.07	17.6 ± 0.05
Glyine	3.6 ± 0.03	3.7 ± 0.01	3.6 ± 0.03	3.4 ± 0.09
Proline	4.1 ± 0.05	3.8 ± 0.13	3.8 ± 0.10	3.9 ± 0.09
Serine	3.5 ± 0.02	3.7 ± 0.06	3.2 ± 0.10	3.3 ± 0.08
Tyrosine	2.8 ± 0.06	2.8 ± 0.05	3.1 ± 0.09	2.6 ± 0.07
Total	49.1	47.7	47.4	47.5
E:NE amino acid ratio	0.93	0.96	0.95	0.92

Values are the means ± SD of three determinations.
E:NE means essential and non-essential amino acids.

caps and methylated with a mixture containing methanol: benzene:2,2-dimethoxypropane (DMP):H_2SO_4 (37:20:5:2) (v/v). 2.1 ml of the mixture and heptane, upto volume of 5 ml, were added to the sample and the whole incubated in a water bath (80 °C for 2 h). On cooling, the tubes were shaken to separate out two phases. A sample (1 μl) of upper layer, consisting of FAMEs, was injected into a GLC (Shimadzu GC-14A) capillary column (Silar, 10%) packed with ethylene glycol succinate (5%) on Supelcoport 80/100 isothermically (200 °C). Conditions maintained for analysis included: carrier gas, N_2; injector temperature, 225 °C; FID detector temperature, 265 °C; oven temperature, 200 °C; flow rate: N_2, 35 ml min^{-1}, H_2, 30 ml min^{-1}, O_2, 75 ml min^{-1}. A comparison between the retention times of the samples and authentic standard mixture (Sigma, St. Louis, MO, USA; 99% purity specific for GLC), run on the same column under the same conditions, was made to facilitate identification (Table 5).

2.6. Antinutritional contents

Tannins were determined by the vanillin-HCl method (Burns, 1971). Test sample (1 g) was treated with methanol, (28 °C, 12 h) with occasional shaking. Decanted methanol was made upto 25 ml and filtered (Whatman No. 1). One ml of the extract was treated with 5 ml of reagent mixture (1:1, 4% vanillin in methanol and 8% concentrated HCl in methanol). The colour developed was read at 500 nm after

Table 4
Amino acid score of of Desi chickpea seeds

Amino acids	Reference pattern[a] FAO/WHO (1985)	CM72	Bittal98	Punjab91	Punjab 2000
Histidine	1.9	168	158	163	158
Lysine	5.8	121	121	119	115
Leucine	6.6	129	123	127	124
Isoleucine	2.8	171	171	161	161
Methionine + cystine	2.5	68	68	64	48
Phenylalanine + tyrosine	6.3	129	125	132	121
Threonine	3.4	88	88	85	79
Tryptophan	1.1	82	84	72	72
Valine	3.5	126	131	129	117
Limiting amino acids	–	S[b]	S	S	S

[a] FAO/WHO (1985) amino acid reference pattern of protein for children (2–5 years old) diet. Values are % of protein. Each amino acid in the reference pattern was presumed to score a value = 100.Values for each cultivar are expressed relatively to the reference pattern.
[b] S means sulfur-containing amino acids.

Table 5
Fatty acids profile of oil of Desi chickpea seeds

Fatty acids (% in oil)	CM72	Bittal98	Punjab91	Punjab2000
Palmitic (C16:0)	19.8 ± 0.08	20.4 ± 0.12	18.9 ± 0.11	19.5 ± 0.14
Palmitoleic (16:1)	0.5 ± 0.02	0.5 ± 0.06	0.3 ± 0.05	0.4 ± 0.05
Stearic (C18:0)	1.5 ± 0.04	1.4 ± 0.02	1.7 ± 0.09	1.3 ± 0.06
Oleic (C18:1)	21.9 ± 0.11	22.2 ± 0.16	22.0 ± 0.15	21.6 ± 0.17
Linoleic (C18:2)	56.2 ± 0.15	55.0 ± 0.13	54.7 ± 0.18	54.8 ± 0.10
Linolenic (C18:3)	0.7 ± 0.03	0.9 ± 0.05	0.5 ± 0.05	0.8 ± 0.04
Arachidic (C20:0)	1.4 ± 0.02	1.0 ± 0.04	1.1 ± 0.05	1.2 ± 0.03
O/L	0.39	0.41	0.40	0.39

O/L means oleic acid/linoleic acid.
Data represent means ± SD of three determinations.

Table 6
Antinutrient contents of Desi chickpea seeds

Antinutrient contents (mg/100 g)	CM72	Bittal98	Punjab91	Punjab2000
Phytic acid	151 ± 8.42	138 ± 9.87	171 ± 7.98	162 ± 6.93
Tannins	740 ± 0.74	763 ± 1.42	756 ± 1.07	748 ± 2.59

Values are the means ± SD of three determinations.

20 min, using catechin as a standard, with a spectrophotometer. The tannin contents were then determined from standard curves. Phytic acid was extracted in 0.5 M nitric acid by shaking at room temperature for 3 h and determined spectrophotometrically at 512 nm (Davies & Reid, 1979) (Table 6).

2.7. In vitro protein digestibility

A multienzyme technique was used to measure the *in vitro* protein digestibility (Ekpenyong & Borchers, 1979). Fifty ml of glass-distilled water were added to the seed flour (amount of sample was adjusted so as to contain 6.25 mg/ml) and kept for 1 h at 5°C to hydrate. The sample suspension was adjusted to pH 8.0 with 0.1 N HCl and/or 0.1 N NaOH while stirring in a water bath maintained at 37 °C for 15 min. The multienzyme solution (1.6 mg trypsin, 3.1 mg chymotrypsin and 1.3 mg peptidase/ml maintained in an ice bath at pH 8.0) was added (5 ml) to the protein suspension while stirring at a constant temperature of 37 °C. Exactly 10 min after the addition of multienzyme solution, the pH of the hydrolysate was measured and the percentage of *in vitro* protein digestibility was calculated from the formula given below (Hsu, Vavak, Satterlee, & Miller, 1977).

$$Y = 210.464 - 18.103X,$$

where $X =$ pH of protein suspension after digestion (10 min) with multienzyme solution and $Y =$ percentage of digestibility (Table 7).

2.8. In vitro starch digestibility

Ten millilitres of HCl–KCl buffer, with a pH of 1.5, were added to 50 mg of flour samples. Then 0.2 ml of a solution containing 1 g of pepsin in 10 ml of HCl–KCl buffer was added to each sample, and the samples were incubated at 40 °C for 1 h in a shaking water bath. Volume was completed to 25 ml with Tris-maleate buffer, pH 6.9. Five ml of α-amylase solution (2.6 UI) in Tris-maleate buffer were added to each sample. Samples were then incubated at 37 °C in a shaking water bath for 3 h. From this, a 1 ml aliquot was taken and placed in a tube that was shaken vigorously at 100 °C for 5 min to inactivate the enzyme. Then 3 ml of 0.4 M sodium acetate buffer, pH 4.75, were added to the aliquot, and 60 μl of amyloglucosidase were used to hydrolyze the digested starch to glucose over 45 min at 60 °C in a shaking water bath. Volume was adjusted from 10–100 ml with distilled water. Triplicate aliquots of 0.5 ml were incubated with glucose oxidase/peroxidase reagent. The glucose was converted into starch by multiplying by 0.9 (Goni, Garcia-Alonso, & Saura-Calixto, 1997). Percentage of starch digestibility was calculated as percent starch hydrolyzed from the total starch content of the sample (Table 7).

2.9. Statistical analysis

Results were expressed as mean values ± standard deviations of three separate determinations. Data were statistically analyzed using the Statistica programme, version 5.1. The significant differences between means were calculated

Table 7
In vitro protein and starch digestibility of Desi chickpea seeds

Digestibility %	CM72	Bittal98	Punjab91	Punjab2000
In vitro protein digestibility	33.0 ± 1.05	39.0 ± 1.14	37.1 ± 0.09	42.1 ± 1.07
In vitro starch digestibility	49.0 ± 0.69	37.1 ± 0.13	46.0 ± 0.32	52.1 ± 0.43

Values are the means ± SD of three determinations.

by one-way analysis of variance (ANOVA) using Duncan's multiple-range test at $p < 0.05$.

3. Results and discussion

The fast demographic growth and the low economic resources in developing countries create the necessity to look for new protein sources that can substitute animal proteins, complement the nutritional value of cereal-based foods and prevent malnutrition. Legumes are the major source of protein and they constitute an important supplement to the predominantly cereal based diet of Asians. Legumes are able to fix nitrogen from air (through their symbiotic association with the rhizobium bacteria) and they are also adaptable to a variety of cropping systems.

Physical characteristics of seeds (Table 1) show considerable variations and each cultivar excelled over other cultivars in one or other aspect. Bittal98 and CM72 had largest (0.239 g) and smallest (0.189 g) seed weight respectively, while CM72 had the largest seed volume (0.159) and Punjab91 had the least (0.125). Bittal98 excelled over other cultivars in terms of seed density (1.65 g/ml), hydration capacity (0.232) and swelling capacity (0.203) and the same was true for hydration index (1.126) for CM72 cultivar. Punjab91 had the largest swelling index (1.488). The results are close to those already reported (Amjad et al., 2006; Khattak et al., 2006). The differences observed may be due to variety, cultivar and agronomic practice differences.

Mineral constituents of chickpea (Table 2), varied among the cultivars, but potassium constituted the major mineral. Potassium content ranged from 1109 mg/100 g in Punjab2000 to 1236 mg/100 g in CM72. Sodium (96 mg/100 g) was found in lower quantity in CM72 while Bittal98 had the lowest iron (2 mg/100 g) content. All cultivars contained good amounts of calcium, zinc and copper. The results correspond to those already reported for chickpea in Pakistan (Amjad et al., 2006). These results revealed that chickpea may provide a sufficient amount of minerals to meet the human mineral requirement (Recommended Dietary Allowance) (NRC/NAS, 1989). However, excess of one mineral may prevent others being absorbed and utilized properly. The mean Ca:P ratio in chickpea seed was 0.7. This ratio should not be less than 1.0 (Amjad et al., 2006). The results closely match those reported earlier (Amjad et al., 2006; Ereifej, Alkaraki, & Hemmouri, 2001). Mineral supplementation can be used as an alternative approach to correct this imbalance.

Amino acid composition generally indicates the nutritive value of a protein source (Bodwell, Satterlee, & Hackler, 1980). The chemical score and amino acid index are widely used for screening potential protein foods. Essential amino acid score was computed with reference to the FAO/WHO (1985) standard amino acid profile established for humans. The data (Tables 3 and 4) indicated that all essential amino acids, except S-containing types and tryptophan, are present in excessive amounts in all the cultivars analyzed. Amino acid profile showed methionine and cystine as the limiting amino acids. Surprisingly, tryptophan was not observed to be the limiting amino acid in chickpea (72–84). Results are comparable to those of earlier workers (Amjad et al., 2006). Amino acid deficiency can be met by consuming large amounts of legumes, or by taking a mixture of legumes, or by employing the complementarity that exists between high sulphur amino acid cereals and legumes, especially the soybean.

Data about the qualitative and quantitative composition of fatty acids are summarized in Table 4. Fatty acid profile of all chickpea cultivars reveals the lipids as a good source of the nutritionally essential linoleic and oleic acids. Linoleic acid was the dominating fatty acid, followed by palmitic acid and oleic acid. The nutritional value of linoleic acid is due to its metabolism at tissue levels which produce the hormone-like prostaglandins. The activity of these prostaglandins includes lowering of blood pressure and constriction of smooth muscle (Aurand, Woods, & Wells, 1987). Linoleic and linolenic acids are the most important essential fatty acids required for growth, physiological functions and maintenance (Pugalenthi, Vadivel, Gurumoorthi, & Janardhanan, 2004). Most of the fatty acids were unsaturated fatty acids, while saturated fatty acids (mainly, palmitic acid) contributed little of the total fatty acids content. The fatty acid composition and high amounts of unsaturated fatty acids make chickpea a special legume, suitable for nutritional applications. The presence of high levels of unsaturated fatty acids, in all the presently studied cultivars, is nutritionally desirable and results are comparable with some edible legumes. The O/L ratio of oils of chickpea, are lower in comparison with the averages suggested earlier (Attia, Aman, El tabey shehata, & Hamza, 1996).

Phytic acid content ranged from 138 mg/100 g in Bittal98 to 171 mg/100 g in the Punjab91. The results are comparable with those reported earlier (Amjad et al., 2006; Badshah et al., 1987). The phytate molecule is negatively charged at the physiological pH and is reported to bind nutritionally important essential divalent cations, such as iron, zinc, magnesium and calcium. This binding forms insoluble complexes, thereby making minerals unavailable for absorption and utilization (Van der Poel, 1990). Tannins ranged from 740 mg/100 g for CM72 to 763 mg/100 g in Bittal98. Tannins inhibit the utilization of nutrients through astringency, enzyme inhibition and reduced forage digestibility. As phenolics and tannins are water-soluble, they may be eliminated by decortication-soaking or cooking (Reddy, Pierson, Sathe, & Salunkhe, 1985).

The *in vitro* starch digestibility of flour from the four cultivars was in the range of 37–52%, with the lowest in CM72 (37%) and highest in Punjab2000 (52%). The digestibility of chickpea starch is relatively higher than other legumes, e.g. black gram. Compared with cereals, which have 15–20% amylose and are easily digestible (over 70%), legume starches are generally known to contain more amylose and are less digestible (Madhusudhan & Tharanathan, 1996). Moreover, the digestibility of legume starch is also affected by the cell–wall structural features and antinutrients, such

as amylase inhibitors, phytates and tannins (Yadav & Khetarpaul, 1994). Legume starches, to a certain extent, are rather refractory to enzymatic digestion and contribute to flatulence and discomfort. This can be overcome by consumption of the whole legume (alongwith husk), wherein the dietary fibre helps in reducing the intestinal transit time and also in supporting bowel motility. Reduced digestibility lowers glucose release into the blood stream, which is advantageous to diabetic patients (Jenkins et al., 1988). Chickpea must be cooked before consumption to make it palatable and to destroy these antinutritional factors (Ahmad, Chaudhry, & Chaudhry, 1975).

In vitro protein digestibility data revealed that values are lowest in CM72 and highest in Punjab2000. A considerable variation has been reported for chickpea protein digestibility in the literature (Mansour, 1996). The digestibility of legume proteins is relatively low, due to the presence of antiphysiological and antinutritional factors, such as trypsin inhibitors, phytates, and tannins and structural characteristics of the storage proteins (Duranti & Gius, 1997). Chickpea protein digestibility is the highest among the dry edible legumes. Digestibility of legume proteins is poor. However, it can be improved through heat-treatments, e.g. cooking, autoclaving and roasting.

4. Conclusions

This study about chickpea in Punjab has demonstrated biochemical differences among the cultivar samples. Previous reports have also underlined differences, both physical and biochemical, among various cultivars. The lower cost of the legumes and the reduced incomes of the majority of people of Pakistan, together with the high prices of animal products, may justify these efforts. This may be of potential importance for breeding studies in selecting for improved legumes with zero antinutritional content and high nutrient quality. Cooking quality and consumer acceptability criteria should be evaluated, preferably in the early stages of development of cultivars in a breeding programme and methods should be developed for rapid evaluation of these attributes.

References

Ahmad, S. U., Chaudhry, F. H., & Chaudhry, M. S. (1975). Effect of cooking on the essential amino acid content and net protein utilization (NPU) of common pulses. *Pakistan Journal of Scientific and Industrial Research, 18*, 175–178.

Amjad, L., Khalil, A. L., Ateeq, N., & Khan, M. S. (2006). Nutritional quality of important food legumes. *Food Chemistry, 97*, 331–335.

AOAC (1990). In K. Helrich (Ed.), *Official methods of analysis* (15th ed.). Arlington, VA/Washington, DC, USA: Association of Official Analytical Chemists.

Attia, R. S., Aman, M. E., El tabey shehata, A. M., & Hamza, M. A. (1996). Effect of ripening stage and technological treatments on the lipid composition, lipase and lipooxygenase activities of chickpea. *Food Chemistry, 56*, 123–129.

Aurand, L. W., Woods, A. E., & Wells, M. R. (1987). *Food composition and analysis*. New York, USA: Van Nostrand Reinhold Company.

Badshah, A., Ahmad Aurangzeb, M., Bibi, N., Mohammad, T., & Khan, I. (1987). Relationship between physicochemical characters and cooking time in chickpeas. *Pakistan Journal of Science and Industrial Research, 30*, 795–798.

Bodwell, C. E., Satterlee, L. D., & Hackler, L. R. (1980). Protein digestibility of the same protein preparations by human and rat assays and by in vitro enzymatic digestion methods. *American Journal of Clinical Nutrition, 33*, 677–686.

Burns, RR. (1971). Methods for estimation of tannin in grain Sorgham. *Agronomic Journal, 63*, 511–512.

Davies, N. T., & Reid, H. (1979). An evaluation of phytates zinc, copper, iron and manganese content of and availability from soya based textured vegetable protein. *British Journal of Nutrition, 41*, 579–582.

Duhan, A., Khetarpaul, N., & Bishnoi, S. (1999). in starch digestibility (in vitro) of various pigeonpea cultivars through processing and cooking. *Ecology of Food and Nutrition, 37*, 557–568.

Duke, J. A. (1981). *Handbook of legumes of world economic importance*. New York, USA: Plenum Press, pp. 52–57.

Duranti, M., & Gius, C. (1997). Legume seeds: Protein content and nutritional value. *Field Crops Research, 53*, 31–45.

Ekpenyong, T. E., & Borchers, R. L. (1979). Digestibility of proteins of winged bean seed. *Journal of Food Science and Technology, 16*, 92–95.

Ereifej, K. I., Alkaraki, G. N., & Hemmouri, M. K. (2001). Seed chemical composition of improved cultivars grown under semi arid mediterranean conditions. *International Journal of Food Properties, 4*, 239–246.

FAO/WHO/UNU. (1985) *Energy and protein requirements*. WHO Technical Report Series No. 724, Geneva.

Freidman, M., & Finely, J. W. (1971). Methods of tryptophan analysis. *Journal of Agriculture Food Chemistry, 19*, 626–631.

Garces, R., & Mancha, M. (1993). One-step lipid extraction and fatty acid methyl esters preparation from fresh plant tissues. *Analytical Biochemistry, 211*, 139–143.

Geervani, P. (1991). Utilization of chickpea in India and scope for novel and alternative uses. In *Uses of Tropical Grain Legumes, Proceedings of Consultants Meeting* (pp. 47–54). 1989, ICRISAT Center, Patancheru, Andhra Pradesh, India.

Goni, I., Garcia-Alonso, A., & Saura-Calixto, F. A. (1997). A starch hydrolysis procedure to estimate glycemic index. *Nutrition Research, 17*, 427–437.

Hsu, H. W., Vavak, D. L., Satterlee, L. D., & Miller, G. A. (1977). A multienzyme technique for estimating protein digestibility. *Journal of Food Science, 42*, 1269–1271.

Huisman, J., & Van der Poel, A. F. B. (1994). Aspects of the nutritional quality and use of cool season food legumes in animal feed. In F. J. Muehlbauer & W. J. Kaiser (Eds.), *Expanding the production and use of cool season food legumes* (pp. 53–76). Dordrecht: Kluwer Academic Publishers.

Jenkins, D. J. A., Wolever, T. M. S., Buckley, G., Lam, K. Y., Giudici, S., Kalmusky, J., et al. (1988). Low-glycemic-index starchy foods in the diabetic diet. *American Journal of Clinical Nutrition, 48*, 248–254.

Khalil, LA., & Durani, F. R. (1990). Haulm and Hull of peas as a protein source in animal feed. *Sarhad Journal of Agriculture, 6*, 219–225.

Khattak, A. B., Khattak, G. S. S., Mahmood, Z., Bibi, N., & Ihsanullah, I. (2006). Study of selected quality and agronomic characteristics and their interrelationship in Kabuli-type chickpea genotypes (*Cicer arietinum* L.). *International Journal of Food Science and Technology*(Supplement 2), 1–5.

Madhusudhan, B., & Tharanathan, R. N. (1996). Structural studies of linear and branched fractions of chickpea and finger millet starches. *Carbohydrate Research, 184*, 101–109.

Mansour, E. H. (1996). Biological and chemical evaluation of chickpea seed proteins as affected by germination, extraction and α-amylase treatment. *Plant Foods for Human Nutrition, 49*, 271–282.

NRC/NAS, B. (1989). *Recommended dietary allowances* (10th ed.). Washington DC, USA: National Academy Press, p. 302.

Pandey, G., & Enumeratio, G. (1993). *Planta Medica Gyanendra Ausadhiya Padapavali*. Delhi, India: Spring, p. 116.

Paolini, R., Colla, G., Saccardo, F., & Campiglia, E. (2003). The influence of plant crop density on the efficacy of mechanical and reduced chemical weed in lentil (*Lens culinaris* Medik). *Italian Journal of Agronomy, 7*, 85–94.

Pugalenthi, M., Vadivel, V., Gurumoorthi, P., & Janardhanan, K. (2004). Comparative nutritional evaluation of little known legumes, *Tamarindus indica*, *Erythrina indica* and *Sesbania bispinosa*. *Tropical and Subtropical Agroecosystems, 4*, 107–123.

Reddy, N. R., Pierson, M. D., Sathe, S. K., & Salunkhe, D. K. (1985). Dry bean tannins – A review of nutritional implications. *Journal of American Oil Chemistry Society, 62*, 541–549.

Rupperez, P. (1998). Oligosaccharides in raw and processed legumes. *Food Research and Technology, 206*, 130–133.

Sastry, C. S. T., & Kavathekar, K. Y. (1990). *Plants for reclamation of wastelands*. New Delhi, India: Council of Scientific and Industrial Research, p. 684.

Van der Poel, A. F. B. (1990). Effect of processing on antinutritional factors and protein nutritional value of dry beans. *Animal Feed Science and Technology, 2*, 179–208.

Warner, P. K. W., Nambiar, V. P. K., & Remankutty, C. (1995). *Indian medicinal plants*. Chennai, India: Orient Longman, p. 773.

Williams, P. C., & Singh, U. (1988). Quality screening and evaluation in pulse breeding. In R. J. Summerfield (Ed.), *World crops, cool season food legumes* (pp. 445–457). Dordrecht, The Netherlands: Kulwer Academic Publishers.

Yadav, S., & Khetarpaul, N. (1994). Indigenous legume fermentation: Effect on some antinutrients and in vitro digestibility of starch and protein. *Food Chemistry, 50*, 403–406.

Zarkadas, C. G., Voldeng, H. D., Yu, Z., & Minero-Amador, A. (1993). Assessment of the protein quality of new high-protein soya bean cultivars by amino acid analysis. *Journal of Agricultural and Food Chemistry, 41*, 616–623.