J Food Sci Technol (July 2014) 51(7):1401–1405
DOI 10.1007/s13197-012-0638-7

ORIGINAL ARTICLE

Bulgur processes increase nutrition value: possible role in *in-vitro* protein digestability, phytic acid, trypsin inhibitor activity and mineral bioavailability

Nilgün Ertaş · Selman Türker

Revised: 23 October 2011 / Accepted: 24 January 2012 / Published online: 18 February 2012

Abstract Changes in the chemical constituents and nutritive quality of chickpea bulgur process, were studied in seeds that were soaked at different time (2, 8 and 12 h), different soaking water pH (pH 4, 6 and 8). Soaking in pH 8 soaking water and 12 h soaking time significantly ($p<0.05$) reduced the ash content of chickpea bulgur samples. Compared to the raw material, the protein content and in-vitro protein digestibility increased, but starch, crude fiber, fat and energy values decreased and trypsin inhibitor activity was completely eliminated by bulgur process. As the soaking time increased, the phytic acid content also decreased. The highest total phenolic content was determinated with bulgur samples soaked in pH 4 soaking water. The P, Ca, and K values decreased with increasing soaking time. The HCl-extractability of P, Ca, Mg, Fe and K present in chickpea bulgur samples were significantly higher than the raw chickpea seeds.

Keywords Chickpea · Bulgur · Soaking · Minerals · Phytic acid · Soaking time

Introduction

Legumes, including beans and chickpeas, are rich sources of complex carbohydrates, protein, vitamins and minerals. In the world, chickpea (*Cicer arietinum L.*) is the 4th largest grain legume crop over the total grain production (FAO STAT 2005). They have some benefits like lower glysemic index for people with diabetes, increased satiation, cancer prevention and protection against cardiovascular diseases due to their dietary fiber content (Hangen and Bennink 2002).

Bulgur is a valuable cereal product and a very famous industrially processed ancient wheat product. And also bulgur is a very important pre-cooked wheat product due to its storability, high nutritional value, ease preparation and low cost (Bayram et al. 2004). Bulgur is usually produced from different cereals by soaking, cooking, dehulling, drying and grinding (Bayram et al. 2004). Generally, durum wheat is preferred for bulgur production, but some researchers choosed to use oats, corn, triticale, barley, rye and soybean instead of durum wheat (Singh and Dodda 1979; Elgün et al. 1990; Köksel et al. 1999; Bayram et al. 2004). Soaking, cooking, dehulling and the other food processing methods not only improves flavor of legumes but also increases the bioavailability of nutrients by destroying antinutritional factors, and improves the protein digestibility (Martin-Cabrejas et al. 2004).

Before the cooking process, soaking is a preliminary step, it causes soften texture and decreases the cooking time. Soaking is widely applied at household and industrial scale. Soaking could decrease the soluble antinutrients which can be eliminated with the discarded soaking solution (Abdus Sattar et al. 1989). Researchers developed the methods to decrease the cooking time of legumes have largely depended on soaking prior to cooking (Pujola et al. 2007; Shimelis and Rakshit 2007).

There is only one published research on chickpea bulgur, and therefore the objectives of this study are to introduce the processing treatments of chickpea bulgur and to investigate the effects of the soaking time and soaking water pH on chemical and nutritional properties of chickpea bulgur.

N. Ertaş (✉) · S. Türker
Faculty of Agriculture, Department of Food Engineering,
Selçuk University,
42049 Konya, Turkey
e-mail: nilgun.ertas@hotmail.com

Materials and methods

Materials Seeds of Gökçe chickpea variety were obtained from Sarayönü Vocational School of Higher Education in Konya, Turkey.

Preparation of bulgurs Chickpea samples free from cracks, dust and other foreign materials were soaked at different soaking time (2, 8 and 12 h) and different soaking medium (soaking water pH 4, 6 and 8). The seed-to solution ratio was 1:5 (w/v). Soaking water was prepared with 0.01 N NaOH and 0.01 N HCl solutions. After soaking, the water was drained off and chickpea seeds cooked at 121 °C, 20 min in autoclave (1:2 w/v) (Hirayama AT-HVA-85, Saitama Japan). The cooked materials were dried at 50±5 °C to 10% moisture content in a dryer (Nüve FN-500, Ankara, Turkey). The dried seeds were conditioned with 2% additional water by mixing for 10 min, milled into course grist on the disk mill (Bastak, Ankara, Turkey) so that all the material passed though a 3.55 mm sieve and 1.6 mm sieve, and aspirated to remove bran material.

Physical analysis One thousand seed weight, 1000 seed volume were determined according to Williams et al. (1983) with some modifcations. Seed weight was calculated as the mean weight of 1000 undamaged chickpea seeds. For the determination of seed volume, seeds were transferred to a 250 ml measuring cylinder, and 100 ml distilled water was added. Seed volume was determined as total volume minus 100. Samples were analyzed for density, using the following formula;

$$Density = seed\ volume/seed\ weight$$

A digital micrometer (0.001 mm, Mitutoyo, inoto-Ku, Tokyo, Japan) was used to measure three dimensions (length, width and thickness) of the chickpea seeds. The sphericity and diameter ratio were found using the formula by Mohsenin (1968).

$$Sphericity = geometric\ mean\ diameter/major\ diameter$$

$$= (L \times W \times T)^{1/3}/L$$

$$Diameter\ ratio = length/width = L/W$$

Color measurement was performed using a Minolta Chroma Meter CR-400 (Minolta, Osaka, Japan). The L*, a* and b* color measurements were determined according to the CIE Lab color space system, where L* corresponds to light/dark chromaticity (changing from 0% dark to 100% light), a* to green/red chromaticity (changing from −60% green to 60% red) and b* to blue/yellow chromaticity (changing from −60% blue to 60% yellow). The instrument was calibrated with a white reference tile (L*=97.10, a*=−4.88, b*=7.04) before the measurements.

Chemical analysis The AACC methods were used for the determination of moisture (method 44–19), crude ash (method 08–01), crude fat (method 30–25), crude fiber (method 32–10), and crude protein (method 46–12) contents of the raw material and bulgur samples (ACCC 1990). Starch contents were determined by using the polarimeter (Elgün et al. 2005). Gross energy (kcal) was estimated by multiplying the percentages of crude protein, lipid and carbonhydrates by the factors 4, 9 and 4, respectively.

In the analysis of minerals, a microwave system was used for acid digestion of all the samples. The samples were dried in a forced stove until dry weight. For the determination of mineral concentrations, the samples were preliminarily digested by means of a closed pressurized system microwave oven, using MARS 5 CEM Corporation. Within 15 min, completely clear and colourless solutions were obtained which were subsequently diluted with double-distilled water. Samples were prepared in triplicate runs (Anonymous 1998). Total mineral and HCl extractable mineral concentrations were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES) (VARIAN-CCD Simultaneous ICP-AES, Australia) with an automatic sampler system. HCl extractabilities of the minerals were carried out according to Saharan et al. (2001). HCl extractable minerals and HCl extractable ash were extracted in 0.03 N HCl for 3 h at 40 °C and digested in diacid mixture.

Trypsin inhibitor activity was essentially determined according to Kakade et al. (1974). TIA (trypsin inhibitor activity) was calculated as units/mg sample, and one TI unit was defined as an increase in absorbance of 0.01 absorbance unit at 410 nm in 10 min by the reaction mixture of volume 10 ml.

Phytic acid content was determined by the method of Haugh and Lantzsch (1983). In-vitro protein digestibility (IVPD) was determined by the methods given by Bookwalter et al. (1987). The total phenolic content was determined by the Folin-Ciocalteu method using a Shimadzu UV 160A spectrophotometer.

Statistical analysis A commercial software program (MINITAB and MSTAT) was used to perform statistical analyses. Data were assessed by analysis of variance. Duncan's multiple-range test was used to separate means. Significance was accepted at $P<0.05$ throughout the analysis. The data reported in all the tables are an average of triplicate observations.

Results and discussion

Analytical results The average 1000 kernel weight, 1000 kernel volume, density, lenght, width, thickness, sphericity, diameter ratio, L*, a* and b* values were found as 417.12 g, 328.38 ml, 1.27 g/ml, 9.72 mm, 7.80 mm, 7.62 mm, 0.857, 1.247, 51.56, 6.03, 15.65, respectively. The sphericity values

Table 1 Changes in chemical and nutritional composition of chickpea bulgur samples due to soaking treatments

A) Proximate composition (g/100 g) and energy (kcal/100 g)

		Crude ash	Crude protein	Starch	Crude fiber	Crude fat	Energy
Raw chickpea		2.4	18.0	49.2	3.7	6.5	327.5
Soaking time (hour)	2	1.6±0.07[a]	19.5±0.85[a]	48.4±0.97[a]	2.7±0.09[a]	6.0±0.09[a]	317.7±8.81[a]
	8	1.5±0.02[a]	19.3±0.47[a]	48.0±1.42[b]	2.7±0.07[a]	6.0±0.11[a]	315.5±8.74[a]
	12	1.5±0.04[b]	19.3±0.83[a]	47.0±1.35[c]	2.7±0.16[a]	6.0±0.11[a]	315.4±4.26[a]
Soaking water pH	4	1.6±0.04[ab]	20.0±1.37[a]	48.0±1.26[b]	2.8±0.10[a]	6.0±0.12[a]	322.3±5.74[a]
	6	1.6±0.12[a]	19.5±0.43[a]	47.2±1.43[c]	2.7±0.15[a]	6.0±0.12[a]	313.3±6.08[a]
	8	1.5±0.05[b]	18.4±0.89[b]	48.3±1.17[a]	2.7±0.07[a]	6.0±0.09[a]	313.0±6.27[a]

B) Nutritional and antinutritional constituents

		IVPD (g/100 g)	TPC (mg GAE/g)	Phytic acid (mg/100 g)
Raw chickpea		64.5	1.8	936.0
Soaking time (hour)	2	77.6±5.98[a]	1.11±0.10[a]	492.4±48.93[a]
	8	76.2±0.90[b]	1.06±0.12[b]	465.0±52.55[b]
	12	77.6±1.88[a]	1.10±0.10[a]	414.6±42.92[c]
Soaking water pH	4	74.8±2.94[c]	1.2±0.06[a]	460.5±59.19[a]
	6	76.8±0.73[b]	1.1±0.06[b]	457.2±42.03[a]
	8	79.9±4.11[a]	1.0±0.16[c]	454.3±73.76[a]

C) Total mineral contents (mg/100 g) and HCl-extractability of minerals (g/100 g)

		Total P	HCl-Ext. P	Total Ca	HCl-Ext. Ca	Total Mg	HCl-Ext. Mg
Raw chickpea		338.4	31.1	138.6	67.4	131.1	65.2
Soaking time (hour)	2	287.3±20.45[a]	38.5±2.50[a]	102.8±8.22[a]	71.1±1.76[a]	110.4±2.08[a]	74.6±3.60[b]
	8	282.0±27.52[a]	40.8±1.27[a]	101.1±7.73[a]	70.2±1.84[a]	108.7±4.20[a]	78.8±2.07[a]
	12	267.2±35.77[b]	36.1±2.24[b]	92.7±2.96[b]	72.2±1.42[a]	108.0±3.39[a]	82.3±1.86[a]
Soaking water pH	4	282.4±27.73[a]	39.7±1.98[a]	98.3±7.93[b]	71.9±1.98[a]	108.2±3.10[ab]	77.7±2.75[a]
	6	280.2±18.41[ab]	36.8±3.82[b]	101.8±5.74[a]	70.1±1.59[a]	111.1±2.75[a]	79.4±2.95[a]
	8	273.9±39.52[b]	39.0±1.43[a]	96.4±9.65[c]	71.5±1.53[a]	107.8±3.43[b]	78.4±6.13[a]

D) Total mineral contents (mg/100 g) and HCl-extractability of minerals (g/100 g)

		Total Zn	HCl-Ext. Zn	Total Fe	HCl-Ext.Fe	Total K	HCl-Ext. K
Raw chickpea		2.1	52.8	6.8	35.6	1060.9	71.0
Soaking time (hour)	2	1.74±0.11[b]	56.6±2.72[c]	5.5±0.13[b]	41.7±3.94[b]	768.3±29.03[a]	72.9±1.88[c]
	8	1.71±0.18[c]	60.8±2.10[b]	5.6±0.17[ab]	43.0±8.51[ab]	758.6±30.53[b]	77.9±4.33[b]
	12	1.86±0.07[a]	64.1±1.40[a]	5.7±0.07[a]	47.3±8.19[a]	757.9±31.70[b]	83.8±1.44[a]
Soaking water pH	4	1.75±0.16[b]	60.0±4.45[b]	5.6±0.18[ab]	49.0±6.95[a]	765.7±19.99[b]	79.6±5.63[a]
	6	1.80±0.13[a]	59.3±4.24[b]	5.7±0.07[a]	37.7±4.40[b]	784.3±11.15[a]	78.8±3.21[a]
	8	1.75±0.15[b]	62.2±2.16[a]	5.5±0.12[b]	45.3±5.30[a]	744.8±40.49[c]	76.2±6.76[b]

[a] Variables were determined by the two- way ANOVA model, means with different superscripts in the same column are significantly different ($p<0.05$), ($n=3$)

[b] *IVPD* In-vitro protein digestibility, *TPC* Total phenolic content, *HCl-Ext.* HCl-extractability, *P* Phosphorus, *Ca* Calcium, *Mg* Magnesium, *HCl-Ext.* HCl-extractability, *Zn* Zinc, *Fe* Iron, *K* Potassium

[c] Protein = N × 6.25

were higher than the findings of Zia-Ul-Haq et al. (2007); Kaur et al. (2005). The density values were similar with reported by Zia-Ul-Haq et al. (2007) and Kaur et al. (2005).

Chemical properties of chickpea bulgurs The effects of bulgur processes as soaking time and soaking water pH on the chemical properties on chickpea samples are shown in Table 1 (A). Soaking time significantly ($p<0.05$) reduced the ash content between 32.7 and 37.8% when compared with the raw chickpea seed. Similar results have been reported by some researchers who showed that soaking and cooking reduce the ash content because of the certain minerals diffusion into the soaking and cooking water (Köksel et al. 1999; Wang et al. 2010). The lowest ash content was obtained with soaked in pH 8 soaking water. The protein content tends to rise, while the starch, crude fiber and crude fat tend to fall compared to

raw material. This is in agreement with data given by Wang et al. (2010) but contradict the results of Habiba (2002). The starch content was found to decrease from 49.2 to 46.93% with increase in soaking time from 2 to 12 h. Energy values of chickpea seeds decreased with bulgur process.

Nutritional properties of chickpea bulgur samples Table 1 (b) summarises the nutritional properties of chickpea bulgurs. IVPD values were significantly affected by soaking treatments and increased with bulgur processes which include soaking, cooking and dehulling. The results agree with those of previous studies, Shimelis and Rakshit (2007) and Nestares et al. (1996), who reported that soaking and cooking increased the IVPD of beans and chickpeas. Soaking time had a significant effect on TPC (total phenolic content) ($p<0.01$), phytic acid ($p<0.01$), HCl-extractable ash ($p<0.01$), and soaking water pH had a significant effect on TPC ($p<0.01$) and HCl-extractable ash ($p<0.01$). The average trypsin inhibitor activity value in chickpea seeds was 8.27 mg/kg. TIA was completely eliminated after bulgur process. The reduction in TIA in chickpea bulgurs would be due to destruction of protease inhibitors during pressure cooking. Phytic acid content decreased by 47.4 to 55.71% with increase in soaking time from 2 to 12 h. Changing soaking water pH did not affect the phytic acid content of the samples significantly. Bilgiçli (2009) reported that phytic acid reduction ratios from raw seed to bulgur were 25.2–32.0% for common bean bulgur and 31.2–39.5% for chickpea bulgur, respectively. The lowest TPC content was determinated in the chickpea bulgur samples with soaked at 8 h and soaked in pH 8 soaking water. This is in agreement with data given by Nergiz and Gökgöz (2007), but contradicts the result of Siddhuraju et al. (2002), who reported that total phenolic content of *Sesbania ssp* and *Vigna radiata* seeds increased by the soaking process. The HCl-extractability of ash content of chickpea bulgur samples was increased by bulgur process. The highest HCl-extractability of ash content was measured in the bulgur samples with soaked pH 6 soaking water. Figure 1 points at the effect of soaking time and soaking water pH on the HCl-extractability of ash content. In pH 8 soaking water, HCl-extractability of ash content significantly increased between 2 and 8 h soaking time because of the destroying the antinutritional factors such as phytic acid. As observed by Habiba (2002), cooking resulted in decreasing total and HCL-extractablity of ash in peas.

Total mineral content and HCl-extractability of minerals Total mineral content and HCl-extractability of minerals of raw chickpea and chickpea bulgur samples are presented in Table 1(c and d). Bulgur process resulted in decrease of all minerals. The minerals leached from chickpea samples into soaking and cooking water during soaking and cooking treatments. As observed by some researchers, cooking (in boiling water and autoclave) caused great losses of K (20–24%), Ca (11%), P (6%), Mg (21%), and Fe (8–19%) (Haytowitz and Matthews 1983; and Mubarak 2005). The P, Ca, Mg and K values decreased with increasing soaking time. Duhan et al. (2002) reported that Fe content of pea samples decreased while soaking time increased. But in this study, Fe content of chickpea seeds increased while increasing soaking time. And the lowest P, Ca, Mg, Fe and K values of chickpea bulgur samples were measured by soaked with pH 8 soaking water in all different soaking water pH. Fagbemi et al. (2005), reported that boiling resulted in 16.3 to 44.0% losses of total P content. Habiba (2002) reported that cooking resulted in decrease total phosphorus in peas. The HCl-extractability of P, Ca, Mg, Fe and K present in chickpea bulgur samples were significantly ($p<0.05$) higher than that of the raw whole chickpea seeds. Soaking the chickpea seeds for 12 h enhanced the HCL-extractability of Fe, Ca, P by 33.06; 7.15; 16.21 g/100 g over the raw samples, respectively. Similar results have been reported by Saharan et al. (2001), who reported HCl-extractability of Ca content of faba bean samples soaked at 12 h increased by 4 g/100 g. The average value of HCl-extractability of Mg (78.56 g/100 g) of chickpea bulgur samples had the highest values over the minerals.

Conclusions

The present work about chickpea bulgur samples made by different soaking treatments has demonstrated chemical differences, nutritional differences among the chickpea bulgur samples. Turkish people may esteem legume products because of the lower cost and higher protein content of the legumes, higher prices of animal products and the reduced incomes of majority of Turkish people. Bulgur process affected the composition of chickpeas. The protein content rised, while the starch, crude fiber and crude fat decreased by bulgur process. Energy values decreased with bulgur process. Soaking time significantly ($p<0.05$) reduced the ash content of chickpea

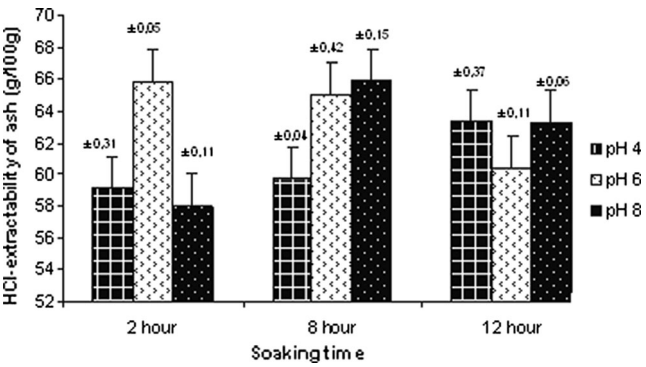

Fig. 1 Effect of soaking time and soaking water pH on the HCl-extractability of ash content (g/100 g) ($n=3$)

bulgur samples. IVPD values were significantly affected by soaking treatments and increased with bulgur process which includes soaking, cooking and dehulling. TIA was completely eliminated after bulgur process. Soaking time had a significant effect on TPC ($p<0.01$). The P, Ca, Mg and K values decreased with increasing soaking time. The HCl-extractability of P, Ca, Mg, Fe and K present in chickpea bulgur samples were significantly ($p<0.05$) higher than that of the raw whole chickpea seeds.

Acknowledgement We are grateful to the Commission for the Scientific Research Projects (BAP: 07101029) at Selcuk University for supporting and funding this research study.

References

Abdus Sattar A, Durrani SK, Mahmood F, Ahmed A, Khan I (1989) Effect of soaking and germination temperatures on selected nutrients and antinutrients of mungbean. Food Chem 34:111–120

ACCC (1990) Approved methods of the American Association of cereal chemists, 8th edn. AACC International, St. Paul

Anonymous (1998) Mineral matter analysis. CEM Corporation, 3100 Smith Farm Road Mtthews, NC

Bayram M, Kaya A, Öner MD (2004) Changes in properties of soaking water during production of soy-bulgur. J Food Eng 61(2):221–230

Bilgiçli N (2009) Effects of cooking and drying processes on physical, chemical and sensory properties of legume based bulgur. J Food Process Pres 33:590–604

Bookwalter GN, Kırleis AW, Mertz ET (1987) In vitro digestibility of protein in milled sorghum and other processed cereals with and without soy fortification. J Food Sci 52(6):1577–1579

Duhan A, Khetarpaul N, Bishnoi S (2002) Content of phytic acid and HCl-extractibility of calcium, phosphorus and iron as affected by various domestic processing and cooking methods. Food Chem 78:9–14

Elgün A, Ertugay Z, Certel M (1990) Corn bulgur: effects of corn maturation stage and cooking from on bulgur making parameters and physical and chemical properties of bulgur products. Cereal Chem 67(1):1–6

Elgün A, Türker S, Bilgiçli N (2005) Tahıl ve Ürünlerinde Analitik Kalite Kontrolü. SU Agricultural Faculty food Engineering Department Konya Turkey pp

Fagbemi TN, Oshodi AA, Ipinmoroti KO (2005) Processing effects on some antinutritional factors andı n vitro multienzyme protein digestibility (IVPD) of three tropical seeds: breadnut (*Artocarpus altilis*), cashewnut (*Anacardium occidentale)* and fluted pumpkin (*Telfairia occidentalis*). Pakistan J Nutr 4(4):250–256

Habiba RA (2002) Changes in anti-nutrients, protein solubility, digestibility, and HCl-extractibility of ash and phosphorus in vegetable peas as affected by cooking methods. Food Chem 77:187–192

Hangen L, Bennink MR (2002) Consumption of black beans and navy beans (*Phaseolus vulgaris*) reduced azoxymethane-induced colon cancer in rats. J Nutri Cancer 44:60–65

Haugh W, Lantzsch HJ (1983) Sensitive method for the rapid determination of phytate in cereals and cereal product. J Sci Food Agr 34:1423–1426

Haytowitz DB, Matthews RH (1983) Effect of cooking on nutritive retention of legumes. Cereal Foods World 28:326–364

Kakade ML, Rackis JJ, McGhee JE, Puski G (1974) Determination of trypsin inhibitor activity of soy bean products: a collaborative analysis of an improved procedure. Cereal Chem 51:376–382

Kaur M, Singh N, Sodhi NS (2005) Physicochemical, cooking, textural and roasting characteristics of chickpea (*Cicer arietinum L.)* cultivars. J Food Eng 69:511–517

Köksel H, Edney MJ, Özkaya B (1999) Barley bulgur: effect of processing and cooking on chemical composition. J Cereal Sci 29:185–190

Martin-Cabrejas MA, Vidal A, Sanfiz B, Molla E, Esteban R, Lopez-Andreu FJ (2004) Effect of fermentation and autoclaving on dietary fiber fractions and antinutritional factors of beans (*Phaseolus vulgaris L.*). J Agric. Food Chem 52:261–266

Mohsenin NN (1968) Physical properties of plant and animal materials. Gordon and Breach, New York

Mubarak AE (2005) Nutritional composition and antinutritional factors of mung bean seeds (*Phaseolus aureus*) as affected by some home traditional process. Food Chem 89:489–495

Nergiz C, Gökgöz E (2007) Effects of traditional cooking methods on some antinutritients and in vitro protein digestibility of dry bean varietes (*Phaseolus vulgaris L.*) grown in Turkey. Int J Food Sci Tech 42:868–873

Nestares T, Lopez-Frias M, Barrionuevo M, Urbano G (1996) Nutritional assesment of raw and processed chickpea (*Cicer arietinum L.*) protein in growing rats. J Agric Food Chem 44 (9):2760–2765

Pujola M, Farreras A, Casanas F (2007) Protein and starch content of raw, soaked beans (*Phaseolus vulgaris L.)*. Food Chem 102:1034–1041

Saharan K, Khetarpaul N, Bishnoi S (2001) HCl-extractibility of minerals from ricebean and fababean: influence of domestic processing methods. Inno Food Sci Em Technol 2:323–325

Shimelis EA, Rakshit SK (2007) Effect of processing on antinutrients and in vitro protein digestibility of kidney bean (*Phaseolus vulgaris L.*) varietes grown in East Africa. Food Chem 103:161–172

Siddhuraju P, Osoniyi O, Makkar HPS, Becker K (2002) Effect of soaking and ionising on various antinutritional factors of seeds from different species of an unconventional legume, Sesbabia and a common legume, green gram (*Vigna radiata*). Food Chem 79:273–281

Singh B, Dodda LM (1979) Studies on the preparation and nutrient composition of bulgur from triticale. J Food Sci 44:449–452

Wang N, Hatcher DW, Tyler RT, Toews R, Gawalko EJ (2010) Effect of cooking on the composition of beans (*Phaseolus vulgaris L.)* and chickpeas (*Cicer arietinum L.*). Food Res Int 43:589–594

Williams P, Nakoul H, Singh K (1983) Relationship between cooking time and some physical characteristics in chickpeas (*Cicer arietinum L.*). J Sci Food Agric 34:492–496

Zia-Ul-Haq M, Iqbal S, Ahmad S, Imran M, Niaz A, Bhanger MI (2007) Nutritional and compositional study of desi chickpea (*Cicer arietinum L.*) cultivars grown in Punjab, Pakistan. Food Chem 105:1357–1363