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Thermal heat processing effects on antinutrients, protein and starch digestibility of food legumes

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Abstract

Thermal heat processing effects were investigated on antinutrients, protein and, starch digestibility of black grams, chick peas, lentils, red and white kidney beans. The tannin and phytic acid contents in these five food legumes ranged from 770–1100 mg/100 g to 970–1440 mg/100 g, respectively, whereas protein and starch digestibilities of the raw food legumes were 33.0–37.6% and 36.8–42.0%, respectively. Reduction in the levels of antinutrients, along with an improvement in protein and starch digestibility, was observed after cooking these food legumes. Antinutrient, including tannin (33.1–45.7%) and phytic acid (28.0–51.6%) contents, were reduced by different thermal heat treatments (121AC10, 121AC20, 121AC40, 121AC60, 121AC90, 128AC20). Maximum improvement in protein (95.7–105%) and starch (117–138%) digestibilities was observed on cooking these food legumes at 121 °C for 10 min (121AC10). However, ordinary cooking resulted in improvement of protein and starch digestibilities of the food legumes by 86.0–93.3% and 84.0–90.4%, respectively.

Keywords: Thermal heat processing; Antinutrients; Protein digestibility; Starch digestibility

1. Introduction

Food legumes are commonly used as a source of protein and carbohydrates in human diet in Pakistan and many other countries of the world. Poor nutritive values of the food legumes, due to the presence of some antinutritional substances, have been reported (Morrow, 1991). Tannins inhibit the digestibility of protein, whereas phytic acid reduces the bioavailability of some essential minerals (Duhan, Chauhan, & Kapoor, 1989; Van der Poel, 1990). It has been observed, by earlier workers, that different cooking methods improve the nutritional quality of food legumes to various extents (Chi-Fai, Peter, & Shing, 1997; Nielson, 1991). Improvement in protein quality of pigeon pea has been reported after the partial removal of polyphenols as a result of a simple boiling method (Singh, 1993). Rehman and Shah (2001) observed an improvement in protein digestibility of black grams due to removal of tannins after pressure cooking. Kataria, Chauhan, and Punia (1989) reported that pressure cooking was more effective than ordinary cooking in reducing the antinutrients of black grams and mung beans. The findings of Kadam, Smithard, Eyre, and Armstrong (1987) revealed that boiling and autoclaving in water improved the protein quality of winged beans due to reduction in the levels of antinutrients. Mbofung, Rigby, and Waldron (1999) reported that starch digestibility of cowpea was distinctly improved as a result of a steam cooking method, whereas in an earlier study, Yu-Hui (1991) found that a simple boiling method improved the protein and starch digestibilities of cowpeas to some extent.

Food legumes are usually cooked either by simple boiling or in a pressure cooker. The literature is replete

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with reports that simple boiling improves the nutritional quality of food legumes due to reduction in antinutrients. However, there is scarce information in the literature about the improvement in nutritional quality of food legumes as a result of cooking in a pressure cooker under different conditions. In fact, cooking of food legumes is related to heating temperature and time, initial moisture and amount of water added during the cooking process. Therefore, the present work was undertaken to study the thermal heat processing effects on antinutrients, and protein and starch digestibilities of food legumes subjected to different heating conditions.

2. Materials and methods

2.1. General

Red kidney beans, Black grams (Punjab91), Chick Pea (CP-98), lentils (Nayyab2002), White Kidney Beans (WK-70), and Red Kidney Beans (Chkwal99) were obtained from Ayub Agriculture Research Institute, Faisalabad (Pakistan). The samples were cleaned to remove broken seeds, dust and other foreign matter manually. About 5 kg lots of each sample were placed in air-tight plastic containers of uniform size at room temperature for further processing.

Two hundred and fifty gramme of samples of each food legume were soaked in 1250 ml of distilled water for 4 h at room temperature. After soaking, the seeds were removed from the soaking water and then cooked in an autoclave (American/Laboratory sterilizer AMSCO Type LS 2036 Eric (PA)) with five times their weight of distilled water at 121 °C for 10, 20, 40, 60, 90 min and 128 °C for 20 min (121AC10, 121AC20, 121AC40, 121AC60, 121AC90, 128AC20, respectively). After autoclaving, legumes were dried in a hot air drier at 60 °C overnight, and ground to pass a 40 mesh size screen using a Wiley mill. Portions of soaked legumes were also cooked by boiling, keeping a seed to water ratio of 1:5 (ordinary cooking). The legumes cooked by the ordinary method were also dried and ground to pass a 40 mesh screen.

2.2. Chemical analysis

Protein contents of raw and cooked legume samples were estimated after digestion with concentrated sulphuric acid according to the micro-Kjeldalal method, as described in AOAC (1990), whereas starch contents were determined on a spectrophotometer at 620 nm using 0.1 N iodine solution after extraction with boiling water, as described by Elemo, Oladimeji, Adu, and Olayeye (1999). Protein digestibility was estimated after digestion with pepsin–HCl solution at 37.5 °C for 24 h (Price, Butter, Rogler, & Featherson, 1979) and starch digestibility in vitro was measured after digestion with pancreatic alpha amylase in 0.1 M phosphate buffer (pH 6.9) at 37 °C for 2 h (Costas, 1982). Phytic acid was extracted in 0.5 M nitric acid by shaking at room temperature for 3 h and determined spectrophotometrically at 512 nm, as, described by Davies and Reid (1979). Tannin contents of the samples were estimated by spectrophotometer, at 760 nm, using the Folin–Denis reagent after extraction with 1% hydrochloric acid in methanol (AOAC, 1990). All determinations were carried out in triplicate and standard derivations (SD) were calculated according to the method of Steele and Dickey (1996). Duncan's multiple range test was used to determine significant differences ($p < 0.05$).

3. Results and discussion

Table 1 summarizes the tannin and phytic acid contents of raw and cooked black grams, chickpeas, lentils, red and white kidney beans. Reductions of tannin and phytic acid contents were observed, to various extents, depending on the cooking conditions of these food legumes. About 20.8–26.8% tannin and 24.0–35.1% phytic acid contents were reduced upon cooking by the ordinary boiling method.

However, reduction of these antinutrients was significantly greater upon cooking the food legumes in an autoclave at 121 and 128 °C. Reductions of tannin and phytic acid contents were 33.1–45.7% and 28.0–51.6%, respectively, as a result of cooking food legumes in a autoclave at 121 °C for different time periods. However, almost the same amounts of these antinutrients were reduced when food legumes were cooked in an autoclave at 128 °C for 20 min (128AC20) and at 121 °C for 90 min (121AC90). These results are consistent with the findings of other workers who found reductions in tannins and other antinutrients on cooking faba beans (Sharma & Sehgal, 1992; Singh, 1993).

Protein and starch contents were also reduced up on cooking the food legumes but to lesser extents than antinutrients (tannins and phytic acid) (Table 2). About 0.86–2.63% of protein and 0.86–3.38% of starch contents were lost on cooking these food legumes by the ordinary method, whereas 1.33–4.58% of protein and 1.09–6.66% of starch contents were lost when food legumes were cooked in an autoclave at 121 °C for 18–90 min (121AC10, 121AC20, 121AC40, 121AC60, 121AC90) and at 128 °C for 20 min (128 AC 20). The losses in protein could be attributed to partial removal of certain amino acids, along with other nitrogenous compounds, on heating as has already been reported by other workers (Clawson & Taylor, 1993; Monica, Tovin, & Theresia, 1992). However, losses in starch con-

Table 1
Thermal heat processing effects on tannin and phytic acid contents of food legumes

Cooking treatments	Tannins (mg/100 g)					Phytic acid (mg/100 g)				
	Black grams	Chick peas	Lentils	Red kidney beans	White kidney beans	Black grams	Chick peas	Lentils	Red kidney beans	White kidney beans
Raw	$890^{a} \pm 0.79$	$770^{a} \pm 0.86$	$915^{a} \pm 0.76$	$1100^{a} \pm 0.89$	$980^{a} \pm 0.90$	$1100^{a} \pm 0.88$	$970^{a} \pm 0.69$	$1250^{a} \pm 0.75$	$1440^{a} \pm 0.99$	$1230^{a} \pm 0.93$
Ordinary cooking	$680^{b} \pm 0.61$	$610^{b} \pm 0.79$	$700^{b} \pm 0.88$	$805^{b} \pm 0.65$	$740^{b} \pm 0.73$	$740^{b} \pm 0.77$	$630^{b} \pm 0.93$	$950^{b} \pm 0.81$	$1100^{b} \pm 0.75$	$930^{b} \pm 0.60$
121AC10	$580^{b} \pm 0.73$	$515^{b} \pm 0.63$	$610^{b} \pm 0.74$	$665^{b} \pm 0.81$	$615^{b} \pm 0.80$	$740^{b} \pm 0.94$	$665\ ^{b} \pm 0.70$	$900^{b} \pm 0.76$	$910^{b} \pm 0.80$	$800^{b} \pm 0.88$
121AC20	$565^{b} \pm 0.63$	$505^{b} \pm 0.69$	$595^{b} \pm 0.70$	$640^{b} \pm 0.77$	$600^{b} \pm 0.73$	$725^{b} \pm 0.89$	$628^{b} \pm 0.72$	$870^{b} \pm 0.68$	$880^{b} \pm 0.66$	$740^{b} \pm 0.83$
121AC40	$545^{c} \pm 0.94$	$490^{c} \pm 0.91$	$580^{c} \pm 0.69$	$632^{c} \pm 0.79$	$588^{c} \pm 0.88$	$708^{c} \pm 0.80$	$600^{c} \pm 0.79$	$845\ ^{b} \pm 0.69$	$805^{b} \pm 0.77$	$700^{b} \pm 0.77$
121AC60	$530^{c} \pm 0.88$	$470^{c} \pm 0.80$	$568^{c} \pm 0.74$	$620^{c} \pm 0.58$	$580^{c} \pm 0.94$	$600^{c} \pm 0.99$	$588^{c} \pm 0.86$	$748^{c} \pm 0.87$	$760^{c} \pm 0.90$	$635^{c} \pm 0.84$
121AC90	$525^{c} \pm 0.76$	$460^{c} \pm 0.89$	$560^{c} \pm 0.89$	$610^{c} \pm 0.89$	$532^{c} \pm 0.99$	$540^{c} \pm 0.75$	$520^{c} \pm 0.58$	$670^{c} \pm 0.89$	$71\ 5^{c} \pm 0.95$	$595^{c} \pm 0.76$
128AC20	$565^{b} \pm 0.84$	$480^{c} \pm 0.76$	$585^{b}s \pm 0.91$	$628^{c} \pm 0.70$	$575^{c} \pm 0.77$	$545^{c} \pm 0.80$	$540^{c} \pm 0.69$	$715^{c} \pm 0.88$	$740^{c} \pm 0.79$	$640^{c} \pm 0.71$

Mean values ± SD of triplicate determinations.
Mean values within a column with different superscripts are significantly different at $p \leqslant 0.05$.

Table 2
Thermal heat processing effects on protein and starch contents of food legumes

Cooking treatments	Protein (%)					Starch (%)				
	Black grams	Chick peas	Lentils	Red kidney beans	White kidney beans	Black grams	Chick peas	Lentils	Red kidney beans	White kidney beans
Raw	$24.7^{a} \pm 1.11$	$24.6^{a} \pm 1.09$	$23.1^{a} \pm 133$	$25.0^{a} \pm 1.29$	$25.3^{a} \pm 1.16$	$41.1^{a} \pm 1.44$	$43.5^{a} \pm 1.76$	$42.8^{a} \pm 1.68$	$44.0^{a} \pm 1.38$	$47.9^{a} \pm 1.28$
Ordinary cooking	$24.1^{a} \pm 1.63$	$24.0^{a} \pm 1.37$	$22.7^{a} \pm 1.28$	$24.5^{a} \pm 1.53$	$25.1^{a} \pm 1.66$	$40.0^{a} \pm 1.37$	$42.8^{a} \pm 1.33$	$42.4^{a} \pm 1.64$	$43.6^{a} \pm 1.39$	$46.4^{a} \pm 1.40$
121AC10	24.2 ± 1.08	$24.0^{a} \pm 1.33$	$22.7^{a} \pm 1.20$	$24.5^{a} \pm 1.74$	$25.0^{a} \pm 1.46$	$40.0^{a} \pm 1.58$	$42.7^{a} \pm 1.38$	$42.3^{a} \pm 1.17$	$43.2^{a} \pm 1.61$	$46.4^{a} \pm 1.77$
121AC20	$24.1^{b} \pm 1.64$	$23.8^{b} \pm 1.50$	$22.4^{b} \pm 1.51$	$24.2^{b} \pm 1.66$	$24.9^{b} \pm 1.91$	$39.7^{b} \pm 1.22$	$42.6^{b} \pm 1.70$	$42.0^{b} \pm 1.60$	$43.0^{b} \pm 1.18$	$46.3^{b} \pm 1.38$
121AC40	$24.0^{b} \pm 1.22$	$23.7^{b} \pm 1.65$	$22.3^{b} \pm 1.44$	$24.1^{b} \pm 1.70$	$24.9^{b} \pm 1.46$	$39.6^{b} \pm 1.46$	$42.3^{b} \pm 1.15$	$41.8^{b} \pm 1.66$	$42.5^{b} \pm 1.51$	$46.2^{b} \pm 1.80$
121AC60	$23.9^{b} \pm 1.44$	$23.7^{b} \pm 1.39$	$22.1^{b} \pm 1.73$	$24.1^{b} \pm 1.11$	$24.8^{b} \pm 1.59$	$39.0^{b} \pm 1.51$	$42.0^{b} \pm 1.66$	$41.5^{b} \pm 1.91$	$42.2^{b} \pm 1.80$	$46.0^{b} \pm 1.72$
121AC90	$23.8^{c} \pm 1.08$	$23.7^{c} \pm 1.40$	$22.1^{c} \pm 1.88$	$24.0^{c} \pm 1.49$	$24.7^{c} \pm 1.50$	$38.9^{c} \pm 1.53$	$41.8^{c} \pm 1.24$	$41.0^{c} \pm 1.18$	$42.2^{c} \pm 1.50$	$45.9^{c} \pm 1.50$
128AC20	$23.8^{c} \pm 1.55$	$23.6^{c} \pm 1.71$	$22.1^{c} \pm 1.43$	$22.8^{c} \pm 1.51$	$24.6^{c} \pm 1.88$	$38.4^{c} \pm 1.77$	$41.7^{c} \pm 1.58$	$41.0^{c} \pm 1.75$	$42.2^{c} \pm 1.59$	$45.8^{c} \pm 1.74$

Mean values ± SD of triplicate determinations.
Mean values within a column with different superscripts are significantly different at $p \leqslant 0.05$.

tents could be the result of solubilization of soluble starch from food legumes during cooking.

Significant improvement in protein and starch digestibility was observed on cooking the various food legumes (Table 3). However digestibility of protein was distinctly higher in the case of different thermal heat treatments than ordinary cooking. Treatment 121AC10 showed the highest protein digestibility (68.0–76.0%) while the food legumes cooked by the ordinary boiling method showed the second highest protein digestibility (63.0–72.0%). However, protein digestibility of uncooked food legumes ranged from 33.8 to 37.6%. Therefore, on the basis of these results, it is concluded that protein digestibility was improved by 86.0–93.3% after cooking the food legumes by the ordinary boiling method, whereas thermal heat treatment (121AC10) caused maximum, improvement in protein digestibility, by 95.7–105%. It is apparent from Table 3 that food legumes cooked at 121 °C showed a decrease in protein digestibility when cooking time was increased from 10 to 90 min, (121AC20, 121AC40, 121AC60, 121AC90). Similarly, cooking food legumes at 128 °C for 20 min (128AC20) also decreased the digestibility of protein. Wu et al. (1994), reported that availability of certain amino acids, especially lysine, was decreased with increasing temperature and time, which might be the reason for the in vivo reduction of protein digestibility. Higher protein digestibility after heat treatment may be due to increased accessibility of the protein to enzymatic attack. However, this effect could also be due to inactivation of proteinaceous antinutritional factors (Van der Poel, Gravandecl, & Boer, 1991).

Starch digestibility of the uncooked food legumes was 36.8–42.0% which became 70.0–77.3% after ordinary cooking and 87.4–91.0% after thermal heat treatment (121AC10). No further increase in starch digestibility was observed when cooking time (from 10 to 90 min) and temperature (from 121 to 128 °C) were increased during different thermal heating treatments (121AC20, 121AC40, 121AC60, 121AC90 and 128AC20). In fact, ordinary cooking and 121AC10 treatment improved starch digestibility by 81.0–90.4% and 117–138%, respectively. It seems that the combination of cooking temperature and time for 121AC10 was optimal for providing the highest protein and starch digestibility. Improvement in starch digestibility could be attributed due to hydrolysis of starch as a result of heat treatments. However, earlier workers also reported that cooking improves the digestibility of starch through gelatinization and destruction of antinutrients (Mbofung et al., 1999; Rehman, Salariya, Yasin, & Zafar, 2001; Yu-Hui, 1991). In fact, partial removal of tannins and phytic acid probably created a large space within the matrix, which increased the susceptibility to enzymatic attack and consequently improved the digestibility of protein and starch after the cooking process.

Table 3
Thermal heat processing effects on protein and starch digestibilities of food legumes

Cooking treatments	Protein digestibility (%)					Starch digestibility (%)				
	Black grams	Chick peas	Lentils	Red kidney beans	White kidney beans	Black grams	Chick peas	Lentils	Red kidney beans	White kidney beans
Raw	$34.8^{a} \pm 1.33$	$36.0^{a} \pm 1.09$	$37.6^{a} \pm 1.25$	$33.8^{a} \pm 1.11$	$34.0^{a} \pm 1.30$	$40.4^{a} \pm 1.78$	$42.0^{a} \pm 1.29$	$41.0^{a} \pm 1.40$	36.8 ± 1.44	$39.0^{a} \pm 1.53$
Ordinary cooking	$65.0^{b} \pm 1.80$	$69.0^{b} \pm 1.77$	$72.7^{b} \pm 1.44$	$64.1^{b} \pm 1.28$	$63.6^{b} \pm 1.64$	$75.0^{b} \pm 1.96$	$77.3^{b} \pm 2.11$	$76.4^{b} \pm 1.88$	$70.0^{b} \pm 1.68$	$73.5^{b} \pm 1.70$
121AC10	$68.0^{c} \pm 1.49$	$72.5^{c} \pm 1.60$	$76.0^{c} \pm 1.58$	$68.3^{c} \pm 1.39$	$69.8^{c} \pm 1.27$	$89.3^{c} \pm 1.55$	$91.0^{c} \pm 1.64$	$90.0^{c} \pm 1.92$	$87.4^{c} \pm 1.74$	$88.0^{c} \pm 1.90$
121AC20	$64.5^{b} \pm 1.45$	$68.5^{b} \pm 1.19$	$72.0^{b} \pm 1.93$	$64.0^{b} \pm 1.78$	$63.0^{b} \pm 1.91$	$89.1^{c} \pm 1.70$	$90.9^{c} \pm 1.42$	$89.1^{c} \pm 1.77$	$87.0^{c} \pm 1.61$	$87.8^{c} \pm 1.39$
121AC40	$62.8^{b} \pm 1.60$	$67.0^{b} \pm 1.94$	$70.8^{b} \pm 1.70$	$62.4^{b} \pm 1.22$	$61.4^{b} \pm 1.64$	$89.0^{c} \pm 1.88$	$90.8^{c} \pm 1,70$	$89.3^{c} \pm 1.09$	$87.1^{c} \pm 1.57$	$87.4^{c} \pm 1.49$
121AC60	$62.0^{b} \pm 1.49$	$65.7^{b} \pm 1.27$	$68.0^{b} \pm 1.79$	$61.0^{b} \pm 1.52$	$60.0^{b} \pm 1.01$	$89.0^{c} \pm 1.92$	$90.5^{c} \pm 1.33$	$88.9^{c} \pm 1.89$	$86.9^{c} \pm 1.44$	$87.5^{c} \pm 1.26$
121AC90	$61.8^{b} \pm 1.66$	$64.9^{b} \pm 1.56$	$67.8^{b} \pm 1.80$	$60.5^{b} \pm 1.39$	$59.9^{b} \pm 1.74$	$88.9^{c} \pm 1.99$	$90.4^{c} \pm 1.80$	$88.6^{c} \pm 1.46$	$86.8^{c} \pm 1.39$	$87.9^{c} \pm 1.61$
128AC20	$62.4^{b} \pm 1.30$	$65.0^{b} \pm 1.58$	$68.0^{b} \pm 1.27$	$61.8^{b} \pm 1.70$	$61.0^{b} \pm 1.35$	$89.1^{c} \pm 1.46$	$90.7^{c} \pm 1.28$	$88.9^{c} \pm 1.40$	$87.3^{c} \pm 1.73$	$87.9^{c} \pm 1.66$

Mean values ± SD of triplicate determinations.
Mean values within a column with different superscripts are significantly different at $p \leqslant 0.05$.

4. Conclusion

Maximum improvement in protein and starch digestibility was observed on cooking the black grams, chickpeas, lentils, red and white kidney beans in an autoclave at 121 °C for 10 min. However, gradual decline in protein digestibility was observed, whereas starch digestibility remained unchanged when cooking time (from 10 to 90 min) and temperature (from 121 to 128 °C) were increased during different thermal heat processings. Reduction in the levels of anti-nutrients from different food legumes were also observed as a result of different thermal heat treatments. In view of these results, it is suggested that food legumes should be cooked in an autoclave at 121 °C for 10 min for maximum improvement in protein and starch digestibility.

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