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ORIGINAL ARTICLE

Effect of cooking methods on selected physicochemical and nutritional properties of barlotto bean, chickpea, faba bean, and white kidney bean

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Abstract The effects of atmospheric pressure cooking (APC) and high-pressure cooking (HPC) on the physicochemical and nutritional properties of barlotto bean, chickpea, faba bean, and white kidney bean were investigated. The hardness of the legumes cooked by APC or HPC were not statistically different ($P>0.05$). APC resulted in higher percentage of seed coat splits than HPC. Both cooking methods decreased Hunter "L" value significantly ($P<0.05$). The "*a*" and "*b*" values of dark-colored seeds decreased after cooking, while these values tended to increase for the light-colored seeds. The total amounts of solid lost from legume seeds were higher after HPC compared with APC. Rapidly digestible starch (RDS) percentages increased considerably after both cooking methods. High pressure cooked legumes resulted in higher levels of resistant starch (RS) but lower levels of slowly digestible starch (SDS) than the atmospheric pressure cooked legumes.

Keywords Cooking methods · Pressure cooking · Domestic cooking · Legumes · Starch digestibility · Solid loss · Color change

Introduction

Legumes are rich source of protein, carbohydrate, dietary fiber, some vitamins and minerals. Inclusion of legumes in the daily diet has many beneficial physiological effects in controlling and preventing various metabolic diseases such as diabetes mellitus, coronary heart disease, and colon cancer (Tharanathan and Mahadevamma, 2003). Legumes are generally consumed after various processes like soaking, cooking, milling, roasting, puffing, and germinating. However, soaking followed by cooking is the most common way of the production of edible legume products. Soaking is carried out below the gelatinization temperature and intended for increasing the water content to accelerate the following cooking step. Cooking is done above the gelatinization temperature for gelatinizing starch and to produce a tender edible product, to develop aroma and to improve the overall acceptability of the legumes (Tharanathan and Mahadevamma, 2003; Chavan et al., 1986). It also increases the bioavailability of the nutrients by inactivating the antinutritional factors (Chau et al., 1997). The main conventional cooking methods of dry or soaked legume seeds are boiling in water for an extended period of 1–2 h in an open pan or for 10–15 min under pressure (Chavan et al., 1986). Pressure cooking has the advantages of faster cooking and requires less energy than boiling in open pan. With pressure cooking, heat is very evenly, deeply, and quickly distributed. Effect of cooking methods on some of the quality parameters of the finished products has been studied by different researchers. Nisha et al. (2005) reported that the order of magnitude of retention of riboflavin was the same in open pan cooking and pressure cooking methods of green gram (*Vigna radiata* L.). Cooking of soaked dry bean seeds at atmospheric pressure caused more reductions in antinutrients contents than pressure cooking (Nergiz and Gökgöz, 2007). It was reported that pressure cooking had the most pronounced effect in improving the in vitro protein digestibility of presoaked moth bean seeds compared to ordinary cooking, soaking or sprouting (Khokhar and Chanhan, 1986). Rao (1974) has reported a reduction in the available lysine of chickpea by increasing the time and temperature of

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processing. However, very limited information is available about the effect of cooking methods on the nutritional and physicochemical properties of barlotto bean.

Therefore, the present study was undertaken to investigate the effect of traditional cooking procedures on some important physicochemical and nutritional properties of barlotto bean, chickpea, faba bean, and white kidney bean, the four commonly consumed legumes in Turkey. The cooking methods used in the study were the ones practiced at homes, which are cooking in boiling water at atmospheric pressure (APC-Atmospheric Pressure Cooking) and at high-pressure (HPC-High Pressure Cooking). The physicochemical and nutritional properties investigated in this study were the percentage of seed coat splits, the changes in the surface color, the percentage loss of total carbohydrate and total proteins of the cooked legume seeds. In addition, nutritionally important starch fractions, namely rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS), of the raw and cooked legumes were also investigated.

Materials and methods

Legume samples

Barlotto bean (*Phaseolus vulgaris* L.), chickpea (*Cicer arietinum* L.), faba bean (*Vicia faba* L.), and white kidney bean (*Phaseolus vulgaris* L.), were obtained from a legume processing company in Mersin, Turkey. They were all harvested in 2006. Legume seeds were manually cleaned to remove foreign materials and damaged grains. All seeds were stored in moisture tight plastic bags to avoid moisture fluctuations.

Physicochemical properties of the legumes

The moisture of the seed flours was determined by drying at 130 °C in an oven for 3 h (Method No: 44-15A) (AACC, 1995). Protein contents were determined by the Kjeldhal Method with a protein conversion factor of 6.25 (Method No: 46–30) (AACC, 1995). Lipids were determined by the gravimetric method after extraction with petroleum ether on a Soxhlet system (Method No: 30–25) (AACC, 1995). Ash was determined by using Method No: 08–01 of the Approved Methods of AACC (AACC, 1995). The carbohydrate content was calculated by difference on dry basis [Carbohydrate% = 100–(ash% + lipid% + protein%)]. The seed coat percentage of the grains was determined according to the method described by Giami (2001). All the above analyses were done in triplicate and the results reported on dry matter basis. The seed dimensions (length, width and thickness) and seed coat thickness of 25 seeds for each legume were measured using a digital micrometer (Mitutoyo 0.001 mm, Japan). Seed coats were removed from the grains according to the method given by Sayar et al. (2001).

Processing and analysis of the processed legumes

Soaking and cooking Fresh deionized water was used in all soaking experiments. Soaking of legumes was conducted at 22 °C for 16 h (seeds/water ratio = 1/20). Hydration and swelling capacities of the soaked seeds were determined according to the methods given by Williams et al. (1983). Cooking at atmospheric pressure (APC) of the soaked legume were carried out in boiling water in a beaker while cooking of soaked legume seeds at high pressure (HPC) were carried out in a laboratory type retort (OMS Lab 20, Osmanlı Makina, Balıkesir, Turkey). In both methods the seeds were cooked until chewable softness or until the disappearance of the white core in the endosperms (Williams et al., 1983). Therefore, barlotto bean, chickpea, faba bean, and white kidney bean were cooked for 60, 65, 85, and 55 min by APC method, respectively. In the case of HPC, retorting was carried out at 120 °C for 15 min for barlotto bean, chickpea and white kidney bean and 20 min for faba bean.

Hardness of the seeds Hardness of the cooked seeds was analyzed by using a Texture Analyzer (Model XT2i; Stable Micro Systems Ltd., England). Seeds were placed at its natural rest position on the heavy duty platform of the texture analyzer and a compression cycle test was performed with an aluminum cylinder probe of 5 cm diameter for 60% of compression at a test speed of 1.0 mm. min^{-1}. The peak force required to compress the samples was used as a measure of hardness. At least 10 seeds were analyzed for each legume and for each treatment.

Percentage of seed coat splits The percentage of seed coat splits was determined according to Wu et al. (2005) to evaluate seed coat integrity after the cooking process. The results were given as the average of the three determinations conducted in three individual cooking experiments.

Colour of the seeds The surface color of the seeds were determined by HunterLab colorimeter (ColorQuest XE, Hunter Associates Laboratories, Inc., Reston, VA) using the 50 mm light path optical cell. A white tile (HunterLab, CQ X3397) were used to standardize the instrument. The cooked seeds were washed and drained before analysis. The number of replicates was six for each legume and each treatment.

Determination of the solid loss Percent solid lost after cooking was determined by drying a known amount of the cooking water at 105 °C until constant mass as given by Wang et al. (1979). Carbohydrate and protein content of the cooking water was also determined. Protein content of the water was determined according to Lowry et al. (1951) using bovine serum albumin (BSA) as the standard. The carbohydrate content in the water was determined as given in Dobois et al. (1956). Reagent grade chemicals (Sigma Chemical Co., St. Louis, MO) were used in the experiments. The percentage of the carbohydrate or protein loss (L,%) was calculated from

$$L,\% = \frac{M_L}{M_0} \times 100 \quad (1)$$

where, M_L and M_0 are the total amounts (g) of carbohydrate or protein in the cooking water, and in the raw seeds, respectively.

Determination of starch fractions Rapidly digestible starch (RDS), slowly digestible starch (SDS), and resistant starch (RS) were determined using the method of Englyst et al. (1992). Raw seeds were ground/pulverized using a laboratory type grinder which has a 0.5 mm screens. Cooked legume samples were mashed to paste form so as to pass through a kitchen strainer. Then 0.5 g legume flour or 0.8 g paste (weighed exactly) and 10 mL water were added to 50-mL screw-capped polypropylene centrifuge tubes and mixed by vortexing for 5 min. After mixing, 50 mg guar gum, 10 glass beads, and 10 mL sodium acetate buffer (pH 5.2) were added to each tube. The tubes were then incubated with pancreatin (8X USP specifications, Sigma-Aldrich Co., St. Luis, MO) and amyloglucosidase (from *A. niger*, 3,260 U/ml on soluble starch, Megazyme Ltd, Co. Wicklow, Ireland) mixture (5 mL) according to Englyst et al. (1992) at 37 °C. After 20 and 120 min of incubation 0.5 mL aliquots of hydrolyzate were removed and added to 10 mL of 80% ethanol to stop the enzymatic reaction. The glucose released in each measurement was determined by using a glucose oxidase peroxidase diagnostic kit (Megazyme Ltd, Co.Wicklow, Ireland). The RDS, SDS, and RS percentage of the total starch were determined according to Englyst et al. (1992).

Statistical analysis

Results were analyzed by using a statistical analysis software system (SPSS Version 12.0, SPSS Inc., IL). Differences among legumes or treatments were compared by using a least significant difference (LSD) test with a probability level (α) of 0.05.

Results and discussion

Table 1 summarizes the selected quality parameters, physical properties, and proximate chemical compositions of the legume samples used in the study. Comparison of seed weights and dimensions indicates that faba bean has the largest seed. Seed coat thicknesses ranged from 0.08 to 0.16 mm, and seed coat content from 3.74 to 14.28%, where chickpea seeds have the thinnest seed coat and also the lowest seed coat content among the samples used in this study. Legumes used in this study did not significantly differ in the quality parameters commonly used for legumes, i.e. hundred seed weight, hydration capacity, and swelling capacity (Williams et al., 1983; Antunes and

Table 1 Selected quality parameters, physical properties, and proximate chemical compositions of the legume samples[a]

Parameters	Barlotto bean	Chickpea	Faba bean	White kidney bean
100-seed weight, g	56.8±0.1c	48.16±0.29b	138.47±1.96d	35.46±0.89a
Seed coat thickness, mm	0.11±0.01b	0.08±0.01a	0.16±0.01c	0.10±0.01ab
Seed coat content,%	6.01±0.16b	3.74±0.13a	14.28±0.28d	7.01±0.22c
Dimensions, mm				
Length	16.43±0.95c	9.72±0.49a	23.25±2.3d	12.49 ±0.51b
Width	8.50±0.40b	7.48±0.20a	15.56±1.7c	7.46±0.31a
Thickness	6.80±0.52ab	7.42±0.19b	5.64±0.70a	5.61±0.40a
Hydration capacity, g water/g dry seed	1.10±0.04a	1.07±0.01a	1.09±0.04a	1.00±0.06a
Swelling capacity, g water/g dry seed	1.49±0.04ab	1.53±0.10b	1.42±0.03ab	1.34±0.04a
Protein content,% (db)	26.68±1.03b	23.83±0.05a	29.09 ±0.48c	25.63±0.35b
Ash content,% (db)	3.55±0.02d	2.38±0.01a	3.02±0.03b	3.45±0.01c
Lipid content,% (db)	1.44±0.04c	5.82±0.01d	0.94±0.05a	1.30±0.02b
Carbohydrate content,% (db)	68.32±0.72b	67.97±0.07b	66.95±0.51a	69.62±0.38c

[a] Values are given as means±standard deviation. Values in a row followed by the same letter (a-d) are not significantly different ($P>0.05$)

Table 2 Hardness values and mean percentages of seed coat splits of the cooked legume seeds[a]

Properties	Barlotto bean		Chickpea		Faba bean		White kidney bean	
	APC	HPC	APC	HPC	APC	HPC	APC	HPC
Hardness, N	1.8±0.2b	2.0±0.3b	1.1±0.2a	1.0±0.1a	2.2±0.3bc	2.6±0.6c	1.0±0.1a	0.8±0.1a
Split,%	26±2ab	24±1ab	32±4bc	20±4a	39±4c	22±2a	54±5d	38±3c

[a] Values are given as means±standard deviation. Values in a row followed by the same letter (a-d) are not significantly different ($P>0.05$)

Sgarbieri, 1979; Nasar-Abbas et al. 2008). Proximate chemical compositions of the samples were comparable with the values reported in previous publications (Chavan et al., 1986; Antunes and Sgarbieri 1979; Youssef et al., 1982). These similarities mean that the values in Table 1 are typical to barlotto bean, chickpea, faba bean and white kidney bean and the outcomes of this study can be used in related investigations on these legumes.

Hardness values of the cooked legume seeds are given in Table 2. Although, the hardness of barlotto and faba bean was significantly higher ($P<0.05$) than chickpea and white kidney bean, the hardness of each legume cooked with APC or HPC method was statistically the same ($P>0.05$). Therefore, it is quite important to consider that the following results in this study were interpreted for each legume cooked using different methods but has the same hardness, which is acceptable texture for human consumption.

The mean percentages of seed coat splits from the legume samples are presented in Table 2. Among the legumes studied, white kidney bean had the highest percentage of seed coat splits in both APC and HPC. This indicated that the seed coat of white kidney bean was the most susceptible to thermal processing, compared to the other legumes. The mineral composition of the seed coat is reported to affect the splitting properties of legume seeds (Wu et al., 2005). They had observed in a previous study that higher concentrations of calcium, sodium, and iron in seed coats maintains the integrity of seed coat and results in fewer split during thermal processing of kidney bean. APC caused significantly higher% split than HPC, for chickpea, faba bean, and white kidney bean (Table 2). Taking into account that cooking time was longer with APC than HPC, this could be explained that the splitting tendency of legumes depends more on cooking time rather than cooking temperature.

The visual appearance of both dry and cooked legumes is one of the most important determinants of acceptance by the consumers. The surface color properties of the dry and cooked legumes studied are given in Table 3. The "*L*" values of all legume seeds significantly decreased ($P<0.05$) after APC or HPC indicating that seeds darkened after processing. Darkening of barlotto bean and faba bean was not significantly affected by type of cooking. However, high pressure cooked chickpea and white kidney beans were darker than the atmospheric pressure cooked ones. Nleya et al. (2002) has indicated that kabuli type chickpea seeds become darker after canning process. Darkening of beans during heat treatments may be attributed to the presence of copper and iron in the cooking medium. Thus addition of up to 165 ppm Na_2 EDTA to canned beans is permitted by U.S. Standards of Identity and food additive regulations to preserve the color (Downing, 1996).

There were no distinct trend on the changes of "*a*" and "*b*" values of the seeds after APC and HPC (Table 3). The "*a*" (redness) and "*b*" (yellowness) values of barlotto bean and faba bean, the dark-colored seeds used in this study, decreased after cooking. Conversely, the "*a*" and "*b*" values of chickpea and white kidney bean, the light-colored seeds, tended to increase after cooking. APC significantly decreased redness and yellowness of barlotto bean than HPC, where redness and yellowness of both atmospheric and high pressure cooked faba bean were not significantly different ($P>0.05$). Canning process, applied to different Canadian chickpea cultivars by Nleya et al. (2002), and soaking process applied to soybean by Bayram et al. (2004)

Table 3 The surface color properties of the raw and cooked legume seeds[a]

		Raw	APC	HPC
Barlotto bean	L	57.79±1.10b	41.21±0.71a	40.57±0.75a
	a	9.32±0.13c	6.41±0.25a	7.48±0.27b
	b	11.03±0.23c	5.64±0.67a	6.73±0.31b
Chickpea	L	60.75±1.97c	57.05±0.81b	53.51±0.81a
	a	6.77±0.20a	7.62±0.12b	7.01±0.15ab
	b	16.14±0.67a	22.59±0.91b	17.71±0.44a
Faba bean	L	40.05±1.33b	35.23±0.56a	34.42±0.53a
	a	6.19±0.81b	2.82±0.24a	2.44±0.48a
	b	4.67±1.33b	1.01±0.20a	0.85±0.55a
W. kidney bean	L	73.72±2.01c	64.71±0.18b	57.55±0.29a
	a	1.14±0.03a	2.66±0.18b	5.88±0.31c
	b	12.92±1.33a	16.16±1.05b	15.73±0.23b

[a] Values are given as means±standard deviation. Values in a row followed by the same letter (a-d) are not significantly different ($P>0.05$)

Table 4 The total amount and the main composition of the solid lost from legume seeds[a]

Components lost (g/100 g dry seed)	Barlotto bean		Chickpea		Faba bean		White kidney bean	
	APC	HPC	APC	HPC	APC	HPC	APC	HPC
Total	11.3±1.6bc	12.3±0.7c	10.0±0.4b	14.5±0.8d	8.6±0.5a	9.8±1.0b	9.1±1.2b	12.4±0.9c
Carbohydrate	8.7±0.9bc	9.6±0.6c	7.3±0.2b	11.5±0.6d	5.6±0.4a	7.4±0.5b	7.0±0.8ab	9.7±0.6c
Protein	0.9±0.2c	0.8±0.1bc	0.7±0.0abc	0.8±0.0bc	0.6±0.1ab	0.6±0.1ab	0.5±0.1a	0.6±0.0ab
Other[a]	1.7±0.3a	1.9±0.1ab	2.0±0.1ab	2.2±0.2ab	2.4±0.3b	1.8±0.3ab	1.6±0.3a	2.1±0.2abc

[a] Values are given as means±standard deviation. Values in a row followed by the same letter (a-d) are not significantly different ($P>0.05$)

also increased redness and yellowness of the seeds, supporting the findings in this study. Bayram et al. (2004) summarized the factors that can affect the color of foods during processing. The most common ones are pigment degradation, browning reactions, ascorbic acid oxidation, acidity, and heavy metal contamination. The decrease in redness and yellowness of dark-colored seeds used in this study (barlotto bean and faba bean) might be explained by the degradation of color pigments during cooking, while the darkening process caused by metal contamination during cooking might results as increase in redness and yellowness of the light-colored seeds (chickpea and white kidney bean).

Soluble solid loss into cooking water generally decreases the nutritional and economic value of the final product and it is one of the quality indicators of the cooked legumes. The amounts of solids lost from legume seeds, used in this study, were in the range of 8.7 to 14.5% of the dry seed weight (Table 4). The total solids loss was reported to be between 2 and 19% of the dry legume seeds during soaking and cooking, depending on the water temperature, type of seed, and physiochemical defects on seed (Kon, 1979; Wang et al., 1979; Seena and Sridhar, 2005). In the current study, HPC tended to increase the solid loss for all legume seeds. Main components of the solids lost into the cooking water are known to be carbohydrates and proteins (Wang et al., 1979). The share of carbohydrates and proteins in the total amounts of solids loss was 71–85% in this study. The carbohydrate loss during HPC was higher than APC for each legume studied (Table 4). The difference was statistically significant for chickpea, faba bean, and white kidney bean ($P<0.05$). However, the amount of protein and other components (vitamins, minerals, lipids, etc.) lost from atmospheric pressure or high pressure cooked seeds were

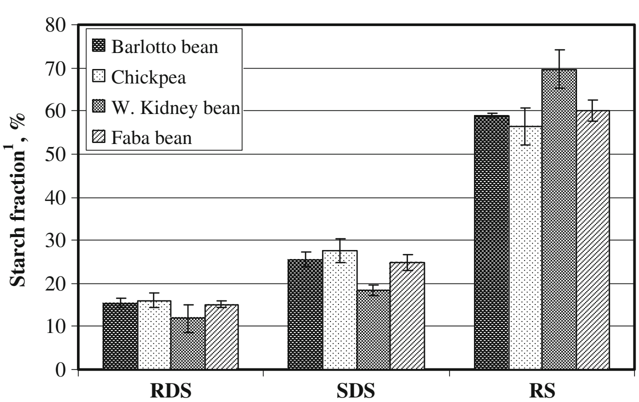

Fig. 1 Rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS) fractions of the total starch in raw legumes ([(1)] Percentage of the total amount of starch)

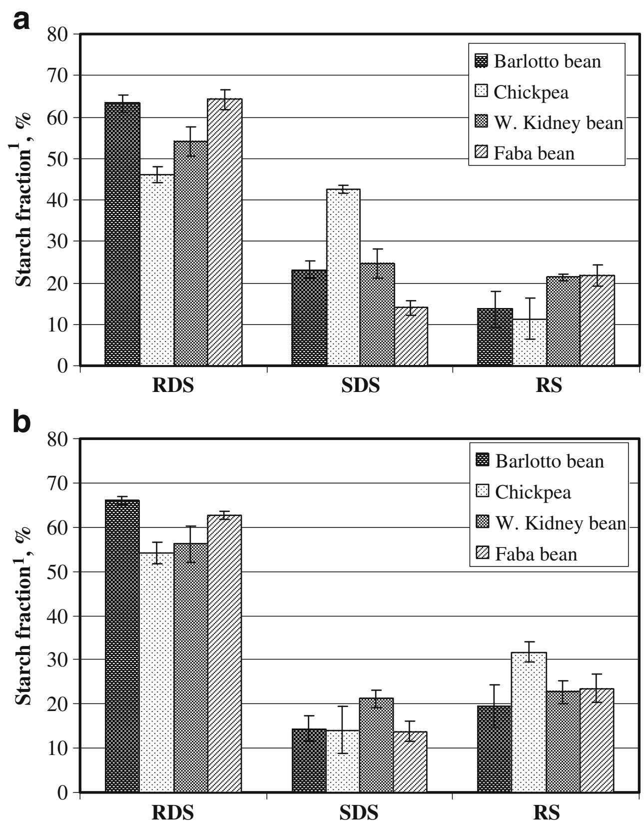

Fig. 2 Rapidly digestible starch (RDS), slowly digestible starch (SDS) and resistant starch (RS) fractions of the total starch in (**a**) atmospheric pressure cooked (APC) legumes, and (**b**) in high pressure cooked (HPC) legumes ([(1)] Percentage of the total amount of starch)

not significantly different ($P>0.05$, Table 4). The results indicated that the solubility of carbohydrates is sensitive to temperature increase during cooking, whereas the solubility of proteins or other components is not affected by the APC or HPC conditions. Kaur and Kawatra (2000) also observed that the total amount of soluble sugars lost from whole rice bean (*Vigna umbellata*) was higher in the case of pressure cooking than open pan cooking.

Food legumes are generally considered to contain starch with lower digestibility compared to cereal starches (Tharanathan and Mahadevamma, 2003). In the current study the RDS, SDS, and RS levels of the raw and cooked legume samples are presented in Figs. 1 and 2. As expected, raw legume samples have the highest RS and lowest RDS levels (Fig. 1). RDS percentages of the four raw legume samples were in the range of 12–16%, which were not significantly different ($P>0.05$). Raw white kidney bean had significantly lower ($P<0.05$) SDS but higher RS content than barlotto bean, chickpea and faba bean. Uniform granule size and granule surface properties, high amount of B-type crystals, and low amount of bounded lipids were indicated to be the possible factors that increase the resistance of legume starches to enzyme hydrolysis (Ratnayake et al., 2001; Tharanathan and Mahadevamma, 2003). Both APC and HPC process increased the RDS levels of legumes around four-fold (Fig. 2) shows that cooking caused a dramatic increase in susceptibility of starch to digestion by pancreatic α-amylase. Comparison of the effects of cooking methods on nutritionally important starch fractions shows that pressure cooked legumes tended to have higher levels of RS but lower levels of SDS than the atmospheric pressure cooked ones. Pressure cooked rice was also reported to have higher level of RS compared to boiled rice (Rashmi and Urooj, 2003). The sum of SDS and RS, the nutritionally beneficial starch fractions, levels were in the range of 33.9–53.9% of the total starch present in the cooked legume samples. The highest total amount of these two fractions was determined in chickpea after both APC and HPC. Chickpea has the highest amount of lipid among all legumes studied (Table 1). Therefore, formation of greater amount of amylase-lipid complex after cooking might be the possible reason of reduced starch digestibility. SDS and RS are considered to be beneficial in the human diet (Lehmann and Robin, 2007; Nugent, 2005). SDS has the advantage of a slow increase of postprandial blood glucose levels, and sustained blood glucose levels over time compared to RDS with its fast and high peak and fast decline (Lehmann and Robin, 2007). Thus, SDS has moderate impact on the Glycemic Index (GI). It was indicated that low GI diets are associated with decreased risk of diabetes and cardiovascular diseases (Lehmann and Robin, 2007). On the other hand, RS escapes the digestion in the small intestine and becomes a substrate for the colonic flora where it is fermented and results in the production of gas and short-chain fatty acids (SCFA). It is reported that SCFA may protect against colon carcinogenesis, and aid in cholesterol and glucose metabolism (Cummings, 1981). In addition, lower pH resulting from production of SCFA may lead to a lower formation rate of secondary bile acids, which may be involved in large-bowel carcinogenesis (Cummings, 1981). Therefore, although cooking process increases the starch digestibility, the cooked legumes still retain a considerable amount of SDS and RS and these foods might be considered nutritionally beneficial for human diet.

Conclusions

This study demonstrated that cooking methods influence the physicochemical and nutritional properties of legumes. APC gave significantly higher% split than HPC. The Hunter "L" values of the legume seeds studied significantly decreased ($P<0.05$) after APC or HPC, indicating that seeds darkened after cooking. Darkening of chickpea and white kidney beans were higher in the case of HPC. The "*a*" (redness) and "*b*" (yellowness) values of dark-coloured seeds (barlotto bean and faba bean) decreased after cooking, while these values tended to increase for the light-colored seeds (chickpea and white kidney bean). Additionally, HPC tended to increase the solid loss for all the legume seeds. The results from this study also showed that APC or HPC process led to dramatic increase in RDS levels of legumes. HPC resulted in higher levels of RS but lower levels of SDS than the APC.

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