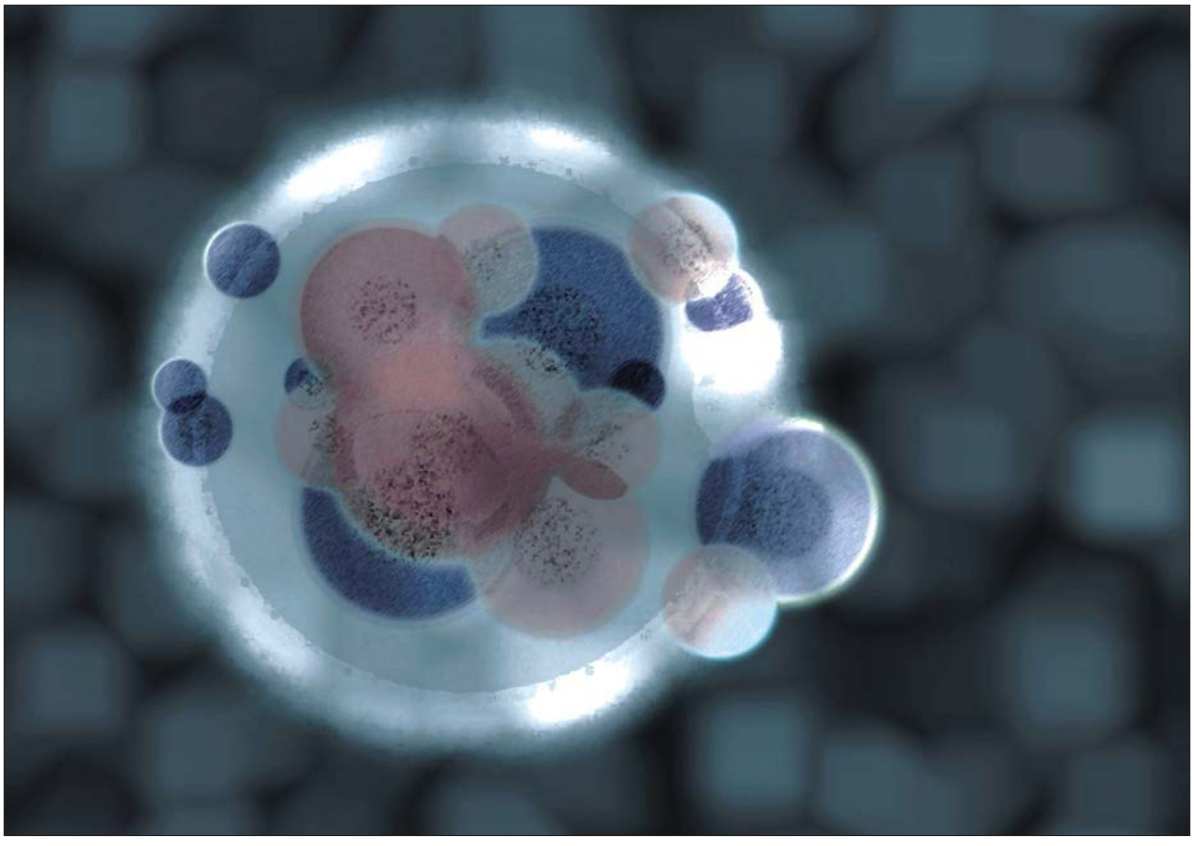

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Influence of Traditional Processing Methods on the Nutritional Composition and Antinutritional Factors of Red Peanuts (*Arachis hypogea*) and Small Red Kidney Beans (*Phaseolus vulgaris*)

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Abstract: Comparative effects of traditional processing methods such as germination, roasting and germination followed by roasting on nutritional composition and reduction of antinutritional factors in red peanuts (*Arachis hypogea*) and small red kidney beans (*Phaseolus vulgaris*) were studied. The seeds were germinated at 28-30°C in the dark for 96 h for peanuts, 72 h for beans and roasted at 140°C for 20 min. Raw and processed peanuts showed the highest levels of energy, fat and proteins, while beans showed the highest levels of antinutritional factors such as phytates, condensed tannins, trypsin and α-amylase inhibitors. Dehulling caused a significant increase ($p<0.05$) in energy and protein and totally eliminated condensed tannins in both legumes. The combination of germination and roasting was the best method in reducing antinutritional factors in both legumes when compared to germination and roasting.

Key words: Peanut, kidney bean, antinutritional factors, proximate composition, processing

INTRODUCTION

Legume seeds such as small red peanuts and red kidney beans are good sources of proteins, complex carbohydrates and some minerals. Additionally, peanuts are a good source of energy due to their high content of fat, close to 50%[1]. However, peanuts and red kidney beans contain some antinutritional factors such as phytates, condensed tannins, trypsin and α-amylase inhibitors, that may limit their usage and nutritional value.

Traditional processing methods such as germination and roasting could effectively improve the nutritional value of legume seeds[2,3]. Alonso *et al.*[3] reported an increase in protein content and a decrease in phytic acid level, condensed tannins, trypsin and α-amylase inhibitors, after 72 h germination of kidney beans in an aired and dark incubator at 25°C. A decrease in trypsin inhibitors in traditional germinated beans and in germinated and boiled black beans has been reported in previous studies, but traditional processing methods did not affect iron, zinc and calcium contents[4,5]. In peanuts, some authors have reported changes on the chemical composition and lipid content as a result of roasting and germination[6-8], but information on the effect of traditional processing on peanuts remains scarce.

The aim of this study was first to investigate the efficiency of processing methods on nutritional composition, mineral and vitamin changes and on the reduction or elimination of antinutritional factors in peanuts and beans and secondly to investigate processing methods for an optimal nutritional quality of end products. An emphasis has been placed on identifying the most effective methods to reduce antinutritional factors in peanuts and beans at a domestic level.

MATERIALS AND METHODS

Materials: Red peanuts (*Arachis hypogea*) and small red kidney beans (*Phaseolus vulgaris*) were purchased at a local market at Yaoundé, Cameroon and the study was carried out in Joseph-Rhéaume's laboratory (Laval University, Sainte-Foy, Quebec from June to September 2002). Extraneous materials and broken seeds were removed by hand sorting. The whole seeds (raw) were divided into two portions, one portion being designated as control and stored in a cold room at 4°C. The remaining seeds were processed by germination and/or roasting.

Experimental procedures:
Raw samples: Bean seeds were milled in a Tecator 1093 cyclotec sample mill (Germany) to pass through a 1 mm sieve. A Porkert manual iron plate disc mill (Czech Republic) was used to produce raw peanut paste. One

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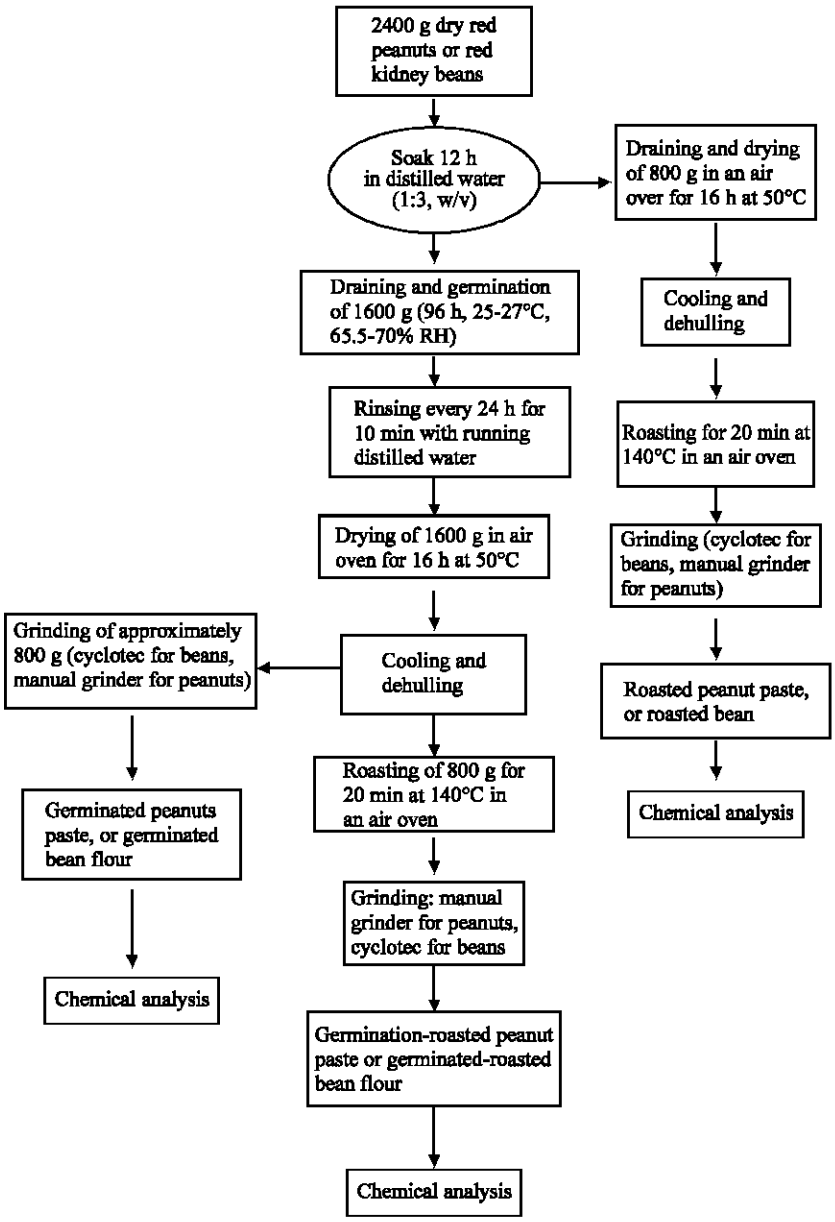

Fig. 1: Flow diagram of the production process of germinated, roasted and germinated-roasted peanut paste or bean flour

part of the bean flour or peanut paste was immediately analyzed for thiamin and riboflavin. The remaining were packed, sealed in polyethylene bags and stored in a Fisher Scientific desiccator in a cold room at 4°C until further analysis.

Germination, roasting and dehulling: Germination and roasting were performed in a dark room at 25-27°C and 65.5-70% relative humidity, following the modified method of Griffith *et al.*[9] (Fig. 1). Washed peanut and bean seeds were divided into three equal portions and soaked for 12 h in distilled water (1:3, w/v). Soaking time was optimized to ensure maximum germination with minimum loss of dry matter through leaching. The water was then discarded and one third of each of the three portions were dried at 50°C for 16 h, dehulled manually and then roasted in a market forge air circulation oven (Everett, MA, USA) at 140°C for 20 min. Roasted peanuts and beans were milled as raw samples.

The remaining of each portion of the soaked seeds were spread on moist filter papers (Whatman No .1) on a large plastic screen. The seeds were then covered with filter papers, to reduce evaporation rate. The screen was

placed in a perforated plastic container and the seeds were kept at 28-30°C in the dark for 72 h (beans) or 96 h (peanuts), to germinate. The seeds were splashed every 24 h with running distilled water for 10 min to avoid mold contamination. At the end of the germination period, non-germinated seeds were discarded, germinated seeds were dried in an air circulation oven at 50°C for 16 h, dehulled manually and one half was milled. The other half of germinated dried and dehulled seeds were roasted and milled. All processed and milled seeds were immediately analyzed for vitamin. The remaining samples were kept in a cold room at 4°C in a desiccator until further analysis.

Analytical methods

Proximate and mineral composition: The moisture and ash contents were determined by standard AOAC method 925.10[10]. Nitrogen was determined by AOAC Kjeldahl method 979.09[10] using a nitrogen auto analyzer (Foss Electric, Denmark) and crude protein content was calculated (N×6.25). Lipid content was determined by the AOAC Goldfish method 945.16[10] and total carbohydrate and fiber was calculated by difference.

The Fe, Zn and Ca contents were simultaneously determined by flame atomic absorption spectrophotometry (Perkin-Elmer Analysis 100, USA) following wet digestion of sample with HNO_3 and $HClO_4$[11].

Energy value: Gross Energy (GE) was determined with an automatic adiabatic bomb calorimeter (Parr, model 1720, Il, USA).

Thiamin and riboflavin: The measurement of thiamin and riboflavin was simultaneously made by an HPLC system equipped with a Millipore pump (Waters 501, Milford, MA), a reversed phase column (LiCrospher ® 100 RP-18, 5 μm endcapped) and a LiChrocart ® Cartridge 250-4 both from Hewlett Packard (Waldbronn, Germany). A short body μBondapak C18 Sep-Pak Classic cartridges (Waters, Milford, MA) and Minisart® (Sartorius, Goettingen, Germany) were used for sample condensation and purification, respectively. Sample preparation and extraction procedure were carried out according to Fellman *et al.*[12].

Phytates: Phytates were extracted with 2.4% HCl (1:20, w/v). The mixture was centrifuged at 400 g (Sorvalle®-rotor GSA, Newton, USA) for 10 min and the supernatants were collected and diluted (4 to 20%). Bio-Rad (medium size) columns were filled with AG1-X8 200-400 mesh resin to effect phytate purification. To assess total phytate content, Wade solution was used as described by Latta and Eskin[13].

Condensed tannins: Condensed tannins were extracted with acidified HCl (HCl 1% v/v) for 1 h with mechanical shaking at 20°C. The mixture was centrifuged at 4800 g for 10 min at 20°C. Aliquots were immediately analyzed for condensed tannins using a modified 1% vanillin assay[14].

Trypsin inhibitor activity: Trypsin inhibitor activity was measured by the method described by Alonso *et al.*[3] based on the test developed by Kakade *et al.*[15] with modifications and limitations[16,17]. The method used α-N-benzoyl-DL-arginine-p-nitroanilide hydrochloride (BAPNA) as a substrate for trypsin. Trypsin inhibitor from bovine pancreas was used to release P-nitroanilide. The absorbency was measured at 410 nm against a reagent blank and Trypsin Inhibitory Activity (TIA) expressed as Trypsin Inhibitory Units (TIU)/mg Dry Matter (DM) was calculated. One trypsin unit was defined as 0.01 increase in absorbency unit.

α-amylase inhibitor activity: α-amylase inhibitor activity was evaluated according to Deshpande *et al.*[18] with some modifications[19-21]. A 1 g sample was extracted with 10 mL deionized water for 16 h at 4°C, centrifuged at 5000 g (Sorvalle SS-34 8000 rpm, Newton, USA) for 20 min and the supernatant was tested for α-amylase Inhibitor Activity (AIA). The absorbency was recorded at 540 nm. One unit of enzyme activity was defined as that which liberates, from soluble starch, one micromole of reducing groups (calculated as maltose) per three minutes at 37°C and pH 7.0.

Statistical analysis: Treatments were conducted in three repetitions. Macronutrients, micronutrients and antinutritional factors analysis were performed in triplicate for each treatment repetition, with two readings for vitamins and four readings for enzyme inhibitor activity (α-amylase and trypsin). The statistical analysis were done using SAS system Copyright © 1989-1996 by SAS Institute Inc., Cary, NC, USA. Results were given as treatment means plus or minus Standard Deviations (SD). Analysis of Variance (ANOVA) was used to test for significant effects of treatments at $p<0.05$. Duncan's New Multiple-Range Test was used to separate the means.

RESULTS AND DISCUSSION

Energy value: Table 1 shows the results for energy content of peanuts and beans as affected by processing. In peanuts, energy value significantly increased by 3.71, 6.87 and 2.2% after dehulling, roasting and germination-roasting, respectively, compared to the raw seeds.

Table 1: Energy value and proximate composition of raw and processed red peanuts and small red kidney beans

			Processing methods			
	Elements	Raw	Dehulling	Germination and dehulling	Roasting and dehulling	Germination-roasting and dehulling
Peanuts	Moisture (%)	1.45±0.29^{d}	4.52±0.1^{a} (211.72↑)	2.95±0.4^{b} (103.45↑)	1.37±0.1^{d} (5.51↓)	2.03±0.2^{c} (40.0↑)
	Gross energy (Kcal/100 g DM)	671.06±1.80^{d}	695.96±1.8^{b} (3.71↑)	656.5±8.2^{e} (2.17↓)	717.19±2.3^{a} (6.87↑)	685.84±2.8^{c} (2.20↑)
	Ash (%)	2.45±0.13^{a}	2.11±0.08^{b} (13.88↓)	2.42±0.08^{a} (1.22↓)	2.4±0.07^{a} (2.04↓)	2.55±0.05^{a} (4.08↑)
	Carbohydrate and fiber (%)	21.02±2.40^{a}	14.87±0.5^{c} (29.25↓)	19.8±1.5^{ab} (5.80↓)	17.6±1.4^{b} (16.27↓)	19.86±0.4^{ab} (5.52↓)
	Fat (%)	44.39±1.90^{a}	45.17±0.8^{a} (1.75↑)	41.25±0.8^{b} (7.07↓)	44.68±1.2^{a} (0.65↑)	40.3±0.9^{b} (9.21↓)
	Crude protein (N x 6.25)	30.03±0.10^{e}	31.19±0.4^{d} (3.86↑)	32.33±0.2^{c} (7.66↑)	33.34±0.4^{b} (11.02↑)	34.42±0.7^{a} (14.65↑)
Beans	Moisture (%)	6.56±0.60^{b}	8.41±0.1^{a} (24.08↑)	5.33±0.4^{c} (18.75↓)	1.42±0.7^{d} (78.35↓)	1.36±0.3^{d} (79.27↓)
	Gross energy (Kcal/100 g DM)	414.57±1.20^{d}	457.18±1.4^{a} (10.28↑)	423.52±1.1^{b} (2.16↑)	417.35±2^{c} (0.67↑)	421.34±1.6^{b} (1.63↑)
	Ash (%)	3.51±0.30^{b}	4.71±0.3^{a} (34.19↑)	3.93±0.2^{b} (11.97↑)	3.67±0.1^{b} (4.56↑)	4.09±0.3^{b} (16.24↑)
	Carbohydrate and fiber (%)	68.14±0.60^{a}	59.06±0.2^{d} (13.32↓)	62.26±0.4^{c} (8.62↓)	68.0±1^{a} (0.04↓)	65.98±0.7^{b} (3.16↓)
	Fat (%)	1.03±0.10^{e}	1.29±0.04^{b} (25.24↑)	1.55±0.03^{a} (50.49↑)	1.27±0.02^{b} (23.30↑)	1.63±0.04^{a} (58.25↑)
	Crude protein (%)	20.77±0.10^{e}	26.52±0.03^{b} (27.68↑)	26.92±0.2^{a} (29.61↑)	25.63±0.5^{b} (23.4↑)	26.95±0.1^{a} (29.75↑)

Results are the means of 3 determinations±SD, Means within the same row followed by the same letter are not statistically significant using the Duncan's New Multiple Range Test ($p< 0.05$), Figures in parentheses indicate the percent increase↑/decrease↓ over the corresponding raw seeds

After dehulling, germination and the combination of germination and roasting, energy value in beans significantly increased by 10.28, 2.16 and 1.63%, respectively ($p<0.05$), compared to the raw seeds. Findings regarding the effect of germination, roasting and germination-roasting could partly be explained by the influence of dehulling after germination and before roasting of peanuts and beans. Cotyledons, which have greater weight than the hull or seed coats, contribute the major amount of macronutrients to the whole seed[3], which automatically results in a relative increase in energy value in dehulled raw seeds compared to raw seeds. The seed coats in the present study represented 3.6 and 9.4% of the total seed weight for peanuts and beans, respectively. Energy contents were 671 (raw peanuts) and 415 (raw beans) Kcal/100 g DM versus 696 (dehulled raw peanuts) and 457 (dehulled raw beans) Kcal/100 g DM, representing an increase of 3.71 and 10.28% for peanuts and beans, respectively. On the other hand, germination which is the process of soaking and steeping dry seeds in water, involves chemical changes due to the hydrolysis by the amylolytic enzymes α- and β-amylases, of complex macromolecules such as starch and proteins into low-molecular-weight and more digestible, molecules[22,23]. In addition, degradation and oxidation of starch observed during respiration provide energy for the increased metabolic functions in the germinated seeds. That may explain the decrease in energy value observed in both legumes after germination and the combination of germination and roasting, compared to the dehulled raw seeds as opposed to energy value in roasted peanuts (717±2 Kcal/100 g DM) which showed a significant increase of 7 and 3% compared to raw and dehulled raw peanuts, respectively (Table 1).

Proximate composition: On germination of peanuts, ash and total carbohydrate and fiber levels did not change significantly, but there was a significant decrease of 7 and 9% in the fat content of germinated and germinated-roasted peanuts, respectively compared to raw peanuts (Table 1). Offem *et al.*[8] reported a drastic decrease of 84.68% in lipid content of groundnut cotyledons (brunch variety) from 496 to 76 g kg^{-1} wet mass of cotyledon after 132 h germination in the dark. It has been suggested that the decrease in lipid content during germination was due to the conversion of fatty acids into carbohydrates through the glyoxylate cycle[8]. Such a conversion could explain the higher levels of carbohydrate and fiber in germinated and germinated-roasted peanuts (19.8 and 19.9 g/100 g DM, respectively) observed compared to 17.6 and 14.9 g/100 g DM for roasted and dehulled raw peanuts, respectively.

There were no significant effect of roasting on ash and fat content of peanuts compared to raw seeds (Table 1). Those findings are in agreement with those of Sekhon *et al.*[7] who reported no significant effect of

roasting peanuts at 150°C for ½ h on ash and on oil content. However, Khalil and Chughtai[1] have shown an increase of 3.2 and 54.2% in fat and ash content, respectively in roasted peanuts at 150°C for ½ h. Although some studies have been made on chemical changes of peanuts after germination[8] or roasting[1,6-8,24], the present study constituted a comprehensive investigation on the influence of dehulling on the effect of germination, roasting, germination-roasting in peanut processed through the procedure described in Fig. 1.

Table 1 shows that dehulling of the seeds significantly ($p<0.05$) increase ash levels in beans by 34% compared to raw seeds. Siddhuraju *et al.*[25] obtained 31.1% increase in ash content in dehulled white variety of velvet beans (Marthandam germplasm). Carbohydrate-fiber level in beans decreased significantly with dehulling (13.32%), germination (8.6%) and germination-roasting (3.2%), but there were no changes on roasting compared to raw seeds. There was a significant increase of fat content in germinated (50%), roasted (23%) and germinated-roasted beans (58%) compared to raw seeds. Siddhuraju *et al.*[25] reported 6% increase of lipid in dehulled white variety of velvet beans (Salem germplasm) compared to whole seeds. The average fat levels of 1.37 g/100 g DM in processed beans were comparable to 1.8 g/100 g DM fat in black beans reported by Donangelo *et al.*[4]. The processes by which fat contents in beans increased with germination remain unclear. However nutrient distribution after dehulling may explain the increase in fat content in germinated, roasted and germinated-roasted beans compared to raw seeds (Table 1).

Protein levels were significantly greater in processed peanuts and beans, compared to the raw seeds, due to both dehulling and germination (Table 1). Although the increase in protein was more important in dehulled and processed beans than in dehulled and processed peanuts, the values remained higher in peanuts compared to beans. Alonso *et al.*[3] observed significant increases in protein levels in kidney beans after dehulling (6%) and after 72 h germination (3%). Mubarak[26] also reported a 9.1% increase in protein content in mungbean seeds compared to raw seeds, but Njitang *et al.*[2] reported an average decrease in protein content in dehulled bean flour due to germination (27 vs 25% for ungerminated vs germinated dehulled bean flour). However the changes in protein content observed in the present study were more important than those observed in previous studies[2,3].

Protein content of germinated and germinated-roasted beans were significantly higher compared to roasted beans, but roasting did not significantly affect protein levels compared to dehulling (Table 1). Increase in protein contents observed after germination of peanuts and beans could partly be attributed to the utilization of carbohydrates as a source of energy, changing the nutrient distribution within the seeds[3,9].

The changes in carbohydrate and fiber, fat and protein were probably due to both dehulling and germination. Before germination, the seeds were first soaked in water, which stimulates metabolic activity as the seeds start to grow. Complex chemical changes that may occur will affect nutrient content. Those chemical changes that occur are basically the breakdown of materials such as starch and protein, into a more usable form for the growing seeds, the transport of materials from one part of the seed to another and the synthesis of new substances such as vitamins. On the other hand, some leaching of substances, notably water-soluble vitamins to the surrounding water may also occur[22]. The changes may vary due to the varietal differences of the seeds and the germination technique used.

Minerals (iron, zinc and calcium): As shown in Table 2, processing did not significantly affect iron, zinc and calcium, contents in peanuts, except for roasted peanuts, where a significant decrease of 17% was observed for iron compared to raw peanuts. Khalil and Chughtai[1] reported an average of 1, 5 and 53 mg/100 g Dry Weight (DW) in raw peanuts for iron, zinc and calcium, respectively, versus 1, 5 and 60 mg/100 g DW in roasted peanuts. In the present study, iron, zinc and calcium content in raw peanuts were 4, 3 and 66 mg/100 g DM, respectively; versus 3, 3 and 68 mg/100 g DM in roasted peanuts (Table 2).

Iron, zinc and calcium content were significantly affected by germination, roasting and germination-roasting of beans (Table 2). It could be assumed that the changes were mainly due to dehulling, with calcium showing the most important decrease. Calcium was not measured in dehulled raw beans due to the accidental loss of samples, but Siddhuraju *et al.*[25] reported a drastic decrease of 56, 44 and 56% of calcium levels in dehulled white variety of Marthandam, white variety of salem and black variety of marthandam germplasms, respectively compared to raw seeds. Singh *et al.*[27] also reported a considerable reduction of calcium during dehulling of chickpea cotyledons.

Thiamin and riboflavin: Thiamin levels decreased by 40% with roasting of peanuts due to heat, but did not change after germination, whereas, the increase of 33% after germination-roasting could not be explained (Table 2). On germination of beans, thiamin increased by 12%, but a decrease was observed after roasting (9%) and

Table 2: Mineral and vitamin content of raw and processed red peanuts and small red kidney beans

			Processing methods			
	Elements	Raw	Dehulling	Germination and dehulling	Roasting and dehulling	Germination-roasting and dehulling
Peanuts	Iron (mg/100 g DM)	3.63±0.2^{a}	3.77±1.2^{a} (3.86↑)	3.63±0.2^{a} (0)	3.01^{b}±0.1 (17.08↓)	3.86±0.3^{a} (6.34↑)
	Zinc (mg/100 g DM)	3.49±0.2^{a}	3.62±0.2^{a} (3.72↑)	3.53±0.2^{a} (1.15↑)	3.48±1.9^{a} (0.3↓)	3.57±0.2^{a} (2.29↑)
	Calcium (mg/100 g DM^{c})	65.89±4.6^{a}	-	70.71±5.6^{a} (7.31↑)	68.08^{a}±0.8 (3.32↑)	70.64±0.4^{a} (7.21↑)
	Thiamin (mg/100 g DM)	1.77±0.05^{b}	-	1.71±0.1^{b} (3.39↓)	1.06±0.02^{c} (40.11↓)	2.35±0.4^{a} (32.77↑)
	Riboflavin (mg/100 g DM)	0.14±0.02^{b}	-	0.24±0.02^{a} (71.43↑)	0.037±0.006^{d} (73.57↓)	0.087±0.01^{c} (37.86↓)
Beans	Iron (mg/100 g DM)	6.22±0.2^{c}	6.85±0.2^{ab} (10.13↑)	7.01±0.05^{a} (12.07↑)	6.60^{b}±0.2 (6.10↑)	7±0.18^{a} (12.54↑)
	Zinc (mg/100 g DM)	2.68±0.2^{c}	2.94±0.2^{bc} (9.70↑)	3.34±0.2^{a} (24.63↑)	2.98^{b}±0.02 (11.19↑)	3.21±0.2^{ab} (19.78↑)
	Calcium (mg/100 g DM)	179.12±4.8^{a}	-	72.16±3^{e} (59.71↓)	52.07^{d}±5.2 (70.93↓)	56±0.4^{c} (68.74↓)
	Thiamin (mg/100 g DM)	0.34±0.07^{b}	-	0.38±0.1^{a} (11.76↑)	0.31±0.07^{c} (8.82↓)	0.27±0.05^{d} (20.6↓)
	Riboflavin (mg/100 g DM)	0.19±0.06^{d}	-	1.01±0.06^{a} (431.58↑)	0.4±0.03^{c} (110.53↑)	0.82±0.05^{b} (331.58↑)

Results are the means of at least 3 determinations±SD, Means within the same row followed by the same letter(s) are not statistically significant using the Duncan Multiple Range Test ($p<0.05$), Figures in parentheses indicate the percent increase↑/decrease↓ over the corresponding raw seeds

germination-roasting (21%) (Table 2). As it is generally known, steeping in water and germination could increase thiamin in dry seeds[22] as the result of chemical changes.

Table 2 shows a significant increase in riboflavin after germination of peanuts (71%) and a decrease occurred after roasting (74 and 38% for roasting and germination-roasting, respectively), compared to raw peanuts. Riboflavin in peanuts was partly destroyed by roasting. Heat processing may have destroyed some of the riboflavin in beans as well.

Riboflavin showed a drastic significant increase of 432% with germination of beans, compared to the raw seeds (Table 2), probably due to dehulling and 12 h steeping of the seeds in water before germination. Thiamin and riboflavin in dehulled raw beans and peanuts were not measured.

Riboflavin in peanuts has been seen to be more heat-labile than riboflavin in beans, probably due to the differences in the structure and the physiology of the seeds. The activity of enzymes involved in the synthesis of riboflavin during germination and seed coat weight could also affect riboflavin in both seeds. The present study showed that germination involves a number of complex chemical changes[22], which could affect the chemical composition of peanuts and beans in many ways. The effect of germination and roasting on the nutritional value of peanuts and beans needs more investigation.

Antinutritional factors

Phytates: There was a significant decrease ($p<0.05$) in phytate after germination, roasting and germination-roasting of peanuts when compared to raw seeds and to dehulled raw seeds (Table 3). The elimination of peanuts seed coat did not make a significant difference in the phytate content in dehulled raw seeds compared to raw seeds, as opposed to beans. In beans, the combination of germination and roasting significantly reduced phytate levels by 12% compared to raw seeds. Significant changes in phytate content were not observed after germination and after roasting of beans compared to raw seeds. Phytate reduction was greater in both peanuts and beans when germination was combined with roasting, compared to germination alone and roasting alone (Table 3). Alonso *et al.*[3] observed 5.66, 30.2 and 21.4% decrease ($p<0.05$) of phytate in kidney beans due to 12 h soaking at 30°C, 72 h germination and extrusion at 156°C, respectively. Apata and Ologhobo[28] reported a 17% decrease in phytate after roasting of kidney beans for 30 min at 105°C. The decrease in phytates in beans and peanuts observed with germination-roasting was probably the result of the combined effect of an increase in phytase activity during germination, the leaching-out effect during 12 h steeping[3] and the hydrolysis and heat destruction of some molecules of inositol hexaphosphate to penta, tetra and triphosphate[3]. Increase of phytates in dehulled raw seeds was 4 and 13% for peanuts and kidney beans, respectively compared to raw seeds, but dehulling did not significantly change phytate distribution in dehulled raw peanuts compared to raw peanuts probably due to the low ratio seed coat weight/whole seed weight.

Condensed tannins: Condensed tannins significantly decreased ($p<0.05$) in both legumes by 100%. The

Table 3: Antinutritional factors in raw and processed red peanuts and small red kidney beans

			Processing methods			
	Elements	Raw	Dehulling	Germination and dehulling	Roasting and dehulling	Germination-roasting and dehulling
Peanuts	Phytates (mg/g DM)	14.66±0.5^{a}	15.2±0.5^{a} (3.68↑)	11.29±0.06^{c} (22.94↓)	12.78±0.4^{b} (12.76↓)	8.45±0.9^{d} (42.32↓)
	Tannins (CE) mg/100 g DM	0.09±0.01^{a}	0^{b} (100↓)	0^{b} (100↓)	0^{b} (100↓)	0^{b} (100↓)
	Trypsin (TIU/mg DM)	16.31±1.2^{b}	17.9±1.2^{b} (9.75↑)	21.7±0.5^{a} (33.04↑)	12.6±0.8^{c} (22.75↓)	16.78±1.2^{b} (2.88↑)
	α-amylase (AIU/g DM)	62.5±5.4^{a}	46.9±3^{b} (24.96↓)	27.8±1.8^{c} (55.52↓)	19.1±0.7^{d} (69.44↓)	18±0.3^{d} (71.2↓)
Beans	Phytates (mg/g DM)	16.58±0.4^{b}	18.68±1.6^{a} (12.67↑)	16.8±0.5^{b} (1.33↑)	16.32±0.4^{b} (1.57↓)	14.65±0.6^{c} (11.64↓)
	Tannins (CE) mg/100 g DM	0.24±0.01^{a}	0^{b} (100↓)	0^{b} (100↓)	0^{b} (100↓)	0^{b} (100↓)
	Trypsin(TIU/mg DM)	65.73±4.1^{bc}	77.18±5.1^{a} (17.42↑)	69.43±3.4^{ab} (5.63↑)	73.33±4.5^{ab} (11.56↑)	58.44±6.1^{c} (11.09↓)
	α-amylase (AIU/g DM)	448.7±16.3^{b}	593.1±18^{a} (32.18↑)	342.0±8.2^{c} (23.78↓)	188.5±25.3^{d} (58↓)	120.2±8.2^{e} (73.21↓)

Results are the means of at least 3 determinations±SD, Means within the same row followed by the same letter(s) are not statistically significant using the Duncan's New Multiple Range Test ($p<0.05$), Figures in parentheses indicate the percent increase↑/decrease↓ over the corresponding raw seeds, CE = Catechin equivalent, TIU = Trypsin Inhibitor Units, AIU = α-amylase Inhibitor Units

decrease reported by Alonso *et al.* was 72% after 72 h germination and 84% after extrusion, compared to raw seeds of *Phaseolus vulgaris*. In the present study the seeds were dehulled after germination, roasting and germination-roasting and that may have changed the distribution of condensed tannins in the seeds.

Phytic acid is accumulated in legumes in the globoids located in the cotyledons, which is one of the inclusions of the protein body. Major amounts of condensed tannins in legumes are located in the seed hull or testa with low or negligible amounts located in the cotyledons. The physical removal of testa or seed coats by dehulling could have changed phytate distribution in dehulled raw beans as opposed to dehulled raw peanuts and consequently may have increased phytate content in dehulled raw beans and at the same time eliminated condensed tannins in dehulled raw beans and peanuts.

Trypsin and α-amylase inhibitors: α-amylase inhibitor activity decreased significantly ($p<0.05$) after roasting and germination-roasting in both peanuts and beans and trypsin inhibitor activity significantly decreased ($p<0.05$) after roasting in peanuts and after germination-roasting in beans, compared to raw seeds (Table 3). On the other hand, dehulling significantly increased ($p<0.05$) trypsin inhibitors in raw beans due to the seed coat weight. The reduction of trypsin and α-amylase inhibitor should be viewed in light of their location in the seeds. Trypsin and α-amylase inhibitors are proteins mainly located in the seed cotyledons. The removal of seed coats produced increased trypsin and α-amylase inhibitors in dehulled raw beans as in phytate and there was an additional increase on trypsin and α-amylase inhibitors due to the 12 h steeping of the raw seeds prior to dehulling and processing.

It is generally known that heat treatments, especially hydrothermal treatments are very effective in destroying protease-inhibiting activity[3]. On peanuts, reduction of trypsin inhibitors was effective after roasting (23%) compared to raw seeds and in beans after the combination of germination and roasting (11%) compared to raw seeds, but the dehulling effect may have influenced the changes in antinutritional factors observed in both seeds (Table 3). Perkins and Toledo[29] reported a 100% inactivation of trypsin inhibitors after a treatment at 120°C for 150 min, but the heat treatment seemed to be too long and may have destroyed other important nutrients. Comparable findings i.e. 86% reduction of trypsin inhibitors in extruded kidney beans compared to raw seeds, have been reported by Alonso *et al.*[3].

α-amylase inhibitors, which are generally known to be heat sensitive, were reduced not only by roasting, but also by germination (Table 3). In both legumes, the combination of germination-roasting showed the most important decrease in α-amylase inhibitors; 71% in peanuts and 73% in beans compared to raw seeds. Alonso *et al.*[3] reported the reduction of α-amylase inhibitor activity by 156°C extrusion (100%) and 72 h germination (33.8%) of red kidney beans.

When comparing raw seeds, peanuts had the highest energy value, crude protein and fat. Some minerals, especially calcium were probably lost by dehulling, but could also be more bioavailable due to the reduction of antinutritional factors. Calcium was severely lost in beans,

but dehulling could remove all condensed tannins. The use of whole beans should be investigated by increasing the steeping period prior to processing, in order to eliminate condensed tannins by leaching in steeping water, to reduce the loss of calcium. Dehulling before roasting and after germination significantly increased phytates, trypsin and α-amylase inhibitors concentration in beans but had proven to be a beneficial step to be incorporated in the processing methods used in the present study, because it eliminated condensed tannins, increased energy value and protein level, in both peanuts and beans and fat content in beans. The combination of germination and roasting was the most effective processing method in reducing antinutritional components in both peanuts and beans, except for trypsin inhibitors in peanuts. There were some similarities in the effect of processing on peanuts and beans in view of the elements assessed, but antinutritional factors levels remained higher in processed red kidney beans, making them apparently less advantageous than processed peanuts. However since moist heat is more effective in reducing digestive enzyme inhibitors than dry heat, it is assumed that wet cooking will effectively inactivate trypsin and α-amylase inhibitors, although the present study did not investigate this aspect.

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