Effect of different debittering processes on mineral and phytic acid content of lupin (*Lupinus albus* L.) seeds

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Abstract Lupin is a valuable ancient legume which contains high amount of protein, dietary fiber, oil, minerals and different functional components. Bitter lupin seeds cannot be consumed directly since its high toxic alkaloid content. Cooking and soaking are effective processes for removing these toxic substances and anti-nutrients as phytic acid, trypsin inhibitors and oligosaccharides. In this study, debittering process containing cooking and soaking up to 144 h was applied to lupin seeds. Raw lupin seeds had 3.3 % ash and 41.3 % protein content. Ash and protein content of debittered seeds changed between 2.1 and 2.5 %, 39.5 and 40.9 % respectively. After debittering process, significant ($p < 0.05$) decreases (between % 5.7 and 75.7) were observed in calcium, phosphorus, zinc, iron, magnesium and manganese contents of the lupin seeds. Phytic acid was removed from raw lupin seeds up to 71.4 % ratio by debittering processes, and soaking in distilled water at 55 °C and long soaking time (144 h) was found the most effective methods on phytic acid loss. While more lighter (L^*) seeds were obtained with soaking in distilled water at 25 °C, soaking in 0.5 % NaHCO_3 solution gave more yellowish (b^*) seed properties compared to other soaking methods. Soaking in 0.5 % NaHCO_3 solution at 144 h gave the most liked products in terms of sensorial evaluation.

Keywords Lupin · Mineral · Phytic acid · Debittering · Soaking · Cooking

Introduction

Lupin (*Lupinus albus* ssp.) is precious and old leguminous plant that can grow in different soils and climates. It has been used as food by people especially around the Mediterranean area (Evans and Bandemer 1967; Morrow 1991; Dervas et al. 1999). Similar to soy bean, lupin (*Lupinus albus* L.) seeds contain higher amount of protein ranging between 33 and 47 %. Beside its high dietary fiber, fat and ash content, it also has some functional properties like emulsifying and solubility (Huyghe 1997; Erbaş et al. 2005; Erbaş 2010; Yorgancılar and Bilgiçli 2012). In Turkey lupin seeds generally consumed as snack food after removing of alkaloids and then salted.

Many studies are conducted on various compounds (alkaloids, phytic acid (PA), trypsin inhibitors, oligosaccharides, phenolic compounds) of lupin species and other legumes (Kinghorn and Balandrin 1984; Błaszczuk et al. 1994; Gulewicz et al. 2002; Ertaş and Türker 2012; Yorgancılar and Bilgiçli 2012), which reduce efficiency of many body systems including circulatory, digestive, respiratory, immune and reproductive systems, and also cause toxic effects, flatulence and diarrhea in animals and humans (Birk 1993; Delzenne and Roberfroid 1994).

Legumes and some cereal grains are soaked before further processing in order to make them soften, to shorten the cooking time and remove the bitter taste and toxic substances of seeds. Previous studies have shown that cooking and soaking increase the nutritional properties such as ash, mineral and protein digestibility, and decrease antinutrients such as trypsin inhibitor, oligosaccharides and PA (Igbedioh et al. 1995; Awada et al. 2005; Fagbemi et al. 2005; Mubarak 2005; Afify et al. 2012). These processes also decrease the total

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phenols, flavonoids, soluble minerals, vitamin E and beta-carotene contents due to the leaching of these components into soaking/cooking water (Bilgiçli 2009; Afify et al. 2012; Ertaş and Türker 2012). Many varieties of lupin have high levels of alkaloids which give bitter and undesirable taste to seeds. These compounds are removed from the seeds by boiling and then washing under running water for several days (Rahma and Narasinga 1984). In a study conducted by Erbaş (2010), lupin seeds were boiled and then soaked in different conditions up to 144 h to debitter the lupin seeds, and found that total alkaloids, acidity and crude fiber content of debittered seeds were lower compared to the raw seeds.

During long debittering processes of lupin seeds, large amount of process water of soaking/cooking are removed as waste. These waste waters contain some soluble substances such as nitrogenous matters, minerals, vitamins, some functional components and toxic alkaloids. Waste treatment methods such as biomass, biogas/biofuel, composting, pyrolysis, gasification, combustion are used to alter the physical, chemical or biological properties of waste, to decrease its toxicity, and to make the waste safer for disposal (Arvanitoyannis and Tserkezou 2008; Arvanitoyannis and Varzakas 2008). The valuable components in waste water of lupin seeds can be separated by some waste treatment methods and can be used for different aims.

Phytic acid (myo-inositol 1,2,3,4,5,6-hexakis-dihydrogen phosphate) is a compound found in cereal grains, legumes, nuts and oilseeds, it is known as an antinutrient because it decreases bioavailability of minerals and protein in animal and humans. Mineral ions may bind with one or more phosphate groups in one or more PA molecules (Reddy et al. 1982; Torre et al. 1991; Rickard and Thompson 1997). During food processing some applications such as dehulling, grinding, soaking, cooking, fermentation and phytase addition reduce the PA content of the end product at variable degree depending on process condition (Lasztity and Lasztity 1990; Bilgiçli et al. 2006; Bilgiçli 2009). In legume seeds, long soaking process at suitable pH and cooking processes under atmospheric condition/pressure or by using microwave are effective methods for lowering the PA content of raw material (Bilgiçli 2009; Ertaş and Türker 2012).

In this research, we aimed to determine the effect of debittering process on mineral and PA content and also some physical and sensory properties of lupin seed.

Materials and methods

Material Lupin seeds were obtained from local pulses firm in Konya, Turkey. Sample was free of foreign material and broken kernels.

Methods Debittering process was conducted according to Erbaş (2010) with some modification. Lupin seeds were atmospheric cooked (seed: water, 1:5) at 80 °C for 75 min, drained and then soaked three different soaking mediums (distilled water at 25 °C; distilled water at 55 °C and 0.5 % NaHCO₃ solution at 25 °C) during 144 h. Soaking water was refreshed every 12 h. After cooking, color and chemical properties of the seeds were determined. During the 144 h of soaking, color, chemical and sensory properties were investigated in every 48 h period. After soaking processes, the seeds removed from the soaking water and also soaking water investigated for their color.

After cooking and soaking processes the seeds were dried at 50±5 °C to 10 % moisture content in an air-convection oven (Nüve FN-500, Ankara, Turkey). The dried seeds were milled in a hammer mill (FN-3100 Laboratory mill, Perten Instruments AB Huddinge, Sweden). Afterwards, the samples were kept in closed glass containers at room temperature until the analysis.

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

Raw and processed seed samples were analyzed for their moisture (method 44–19), crude ash (method 08–01), crude protein (according to Kjeldahl method) (method 46–12) using standard methods (AACC 1990).

Total minerals were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES) (Varian, Vista Model, Zug, Switzerland) (Skujins 1998). PA content was determined by the method of Haugh and Lantzsch (1983).

For sensory analysis, lupin seeds were served to 12 panelists after debittering processes. Sensory scores were evaluated in terms of color, taste, odor, bitterness, chewiness, hardness, and overall acceptability of lupin seeds. Lupin seed characteristics were rated on a 9 point hedonic scale: 1-Dislike extremely, 2-Dislike very much, 3-Dislike moderately, 4-Dislike slightly, 5-Neither like nor dislike, 6-Like slightly, 7-Like moderately, 8-Like very much, 9-Like extremely

Statistical analysis A commercial software programs (MINITAB and MSTAT) were 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. Analyze results are the average of triplicate measurements on the duplicate samples.

Results and discussion

Raw and cooked seed properties Chemical composition and color values of raw and cooked lupin seeds are given in Table 1. Crude ash, protein and PA content of the raw and cooked lupin seeds were found as 3.3 and 2.8 %, 41.3 and 39.3 % and 1486.8 and 1125.9 mg/100 g, respectively. Cooking process decreased ($p<0.05$) the crude ash and PA contents of raw seeds at 15.2 % and 24.3 % ratio, respectively. Yorgancılar and Bilgiçli (2010) reported ash loss (28.6 %) and PA loss (18.8 %) during bulgur process which contains cooking and dehulling of lupin seeds. Erbaş (2010) found significant ($p<0.01$) reduction in ash content from 2.57 % to 2.33 % of lupin seeds after debittering process. Compared to raw seeds all of the minerals (Ca, P, Zn, Fe, Mg and Mn) decreased with cooking process, but only decrease in Ca and Mg content were found significant ($p<0.05$). Generally cooking process causes organic and inorganic matter loss during cooking of different cereals and legumes. Bilgiçli (2009) reported significant ($p<0.05$) loss of Ca during bulgur process of common bean (28.5 %) and chickpea (27.0 %) according to raw legume seeds. There are some studies in literature on the effect of cooking on mineral loss of cereals and legumes (El-Adawy 2002; Mubarak 2005; Wang et al. 2008; 2010).

Table 1 Chemical compositions and color values of raw and cooked seeds^a ($n=3$)

Properties	Raw	Cooked ^b
Crude ash (%) ^c	3.3±0.03a	2.8±0.01b
Crude protein (%) ^{c,d}	41.3±0.71a	39.3±0.51a
Phytic acid (mg/100 g) ^c	1486.8±10.97a	1125.9±14.20b
Minerals (mg/100 g) ^c		
Ca	208.7±3.96a	186.3±3.34b
P	492.5±7.96a	472.8±8.67a
Zn	5.3±0.17a	4.9±0.13a
Fe	1.7±0.07a	1.5±0.13a
Mg	138.0±3.01a	119.0±3.73b
Mn	53.1±0.58a	52.4±0.34a
Color values		
L*	90.4±0.04a	88.0±0.03b
a*	-1.6±0.06b	-1.3±0.03a
b*	27.2±0.01b	33.2±0.00a

^a Means with different superscripts in the same row are significantly different ($p<0.05$) Values are the average of triplicate measurements on the duplicate samples.

^b Lupin seeds were atmospheric cooked (seed: water, 1:5) at 80 °C for 75 min

^c Based on dry matter

^d Protein=N×6.25

Color values of raw and cooked lupin seeds are shown in Table 1. Raw seeds had higher L* (lightness) and lower a* (greenness/redness) and b* (yellowness) values than that of cooked seeds. Cooking process caused darkening effect on seed color, and L* values decreased from 90.4 (raw) to 88.0 (cooked). Also, a* and b* values increased with cooking process. Güzel and Sayar (2012) reported decrement in L value after cooking of barlotto bean, chickpea, faba bean, and white kidney bean compared to raw legumes. They explained that the darkening of beans during heat treatments may be attributed to the presence of copper and iron in the cooking medium.

Soaking water properties Change in soaking water color values during the soaking at different soaking medium/soaking time are given in Table 2. ANOVA results showed that there were significant ($p<0.05$) effects of soaking medium/soaking time on color values of soaking water. Distilled water at 55 °C gave darker color compared to other soaking medium. This may be due to the adverse effect of high temperature of soaking water. Some researchers reported negative effect of high temperature cooking/soaking on product quality, which makes the products susceptible to color deterioration (Rhim et al. 1989; Barreiro et al. 1997; Lozano and Ibarz 1997; Avila and Silva 1999; Ibarz et al. 1999; Bayram et al. 2004). Usage of 0.5 % NaHCO₃ solution as soaking medium increased lightness and yellowness of the soaking water. As the soaking time increased from 48 h to 144 h, the lightness and yellowness values decreased significantly ($p<0.05$). The decrease in yellowness of soaking water may be explained that leaching of pigments and water soluble vitamins into the soaking water

Table 2 Effect of soaking medium and soaking time on Hunter color values of soaking water^a ($n=3$)

Soaking properties		L*	a*	b*
Soaking medium ^b	25 °C	60.1±3.29b	0.42±0.46a	1.5±0.85c
	55 °C	58.4±3.15c	0.42±0.82a	2.1±1.90b
	NaHCO ₃	63.4±3.52a	-0.54±1.02b	3.4±1.76a
Soaking time ^c	48 h	61.9±3.16a	-0.51±0.60c	3.7±1.21a
	96 h	61.1±5.66b	-0.02±1.03b	2.4±1.65b
	144 h	58.9±1.86c	0.82±0.15a	0.9±0.40c

^a Variables were determined by the two- way ANOVA model, means with different superscripts in the same column are significantly different ($p<0.05$). Experiments were conducted at 3 soaking mediums and 3 soaking times according to 3×3 factorial design. Values are the average of triplicate measurements on the duplicate samples

^b Soakig medium: distilled water at 25 °C; distilled water at 55 °C and 0.5 % NaHCO₃ solution at 25 °C

^c Soaking time; 48, 96 or 144 h in different soaking mediums (distilled water at 25 °C; distilled water at 55 °C and 0.5 % NaHCO₃ solution at 25 °C)

from lupin seeds was high at the beginning of the soaking. But the following days leaching was showed a declining trend. In addition, soaking water was refreshed every 12 h and yellowish pigments removed every water refreshments.

Soaked lupin properties Some chemical properties of soaked lupin seeds are given in Table 3. Ash and protein content of soaked lupin seeds changed between 2.1 and 2.5 %; 39.5 and 40.9 %, respectively. The highest ash loss was found in lupin seeds soaked by distilled water at 55 °C. The high temperature soaking might cause more leaching the soluble solid to the soaking water from the lupin seeds than low temperature soaking. Compared to distilled water at 25 or 55 °C with distilled water, 0.5 % NaHCO₃ solution significantly ($p<0.05$) increased the protein loss which occurs by the diffusion of soluble nitrogenous substances into the soaking water. Increasing soaking time caused more ash and protein loss from seeds. Mubarak (2005) studied the effect of some home traditional processes on the nutritional composition and antinutritional factors in mung bean seeds and reported that soaking for 12 h resulted in significant reductions in crude ash (12 %) and crude protein (2 %).

PA and PA loss of lupin seeds according to different soaking medium and soaking time changed between 425.7 and 998.5 mg/100 g; 32.3 and 71.4 %, respectively (Table 3). PA loss of processed seeds compared to the raw material were found as 24.3 % (cooked) and 71.4 % (cooked and 144 h soaked). These PA losses are compatible with previous studies on mung bean (soaking, 26.7 %) (Mubarak 2005), breadnut, cashewnut and fluted pumpkin seeds (boiling, 32.1–64.8 %) (Fagbemi et al. 2005) and common bean (traditional

cooking, 34.8 %) (Manez et al. 2002). These significant ($p<0.05$) decreases of PA during soaking and cooking treatment might be leaching out of PA into the soaking or cooking medium due to increased permeability of the seed coat in soaking or cooking water.

Table 3 shows color values of soaked lupin seeds. Significant differences ($p<0.05$) were observed in the color of lupin samples according to different soaking medium and soaking time. The highest lightness values were obtained by distilled water at 25 °C, however it decreases from 86.2 to 84.9 with increasing soaking time from 48 h to 144 h (Table 3). While the highest a^* values was obtained by distilled water at 55 °C, the highest yellowness was observed in 0.5 % NaHCO₃ solution soaking water at 25 °C.

Changes in mineral content of lupin seeds were shown in Table 4. The differences of mineral elements between different soaking mediums and soaking times were significant ($p<0.05$) for Ca, P, Zn, Fe, Mg and Mn ($p<0.05$). Mineral values changed between 90.7 and 172.5 mg/100 g for Ca, 344.7 and 400.4 mg/100 g for P, 2.8 and 4.1 mg/100 g for Zn, 1.23 and 1.36 mg/100 g for Fe, 33.8 and 54.5 mg/100 g for Mg and 31.5 and 50.1 mg/100 g for Mn according to different soaking medium and soaking time. Compared to raw lupin seeds, Ca, P, Zn, Fe, Mg and Mn content decreased 10.7 %, 4.0 %, 7.6 %, 11.8 %, 13.8 % and 1.3 % respectively, after cooking process (Table 1) and decreased between 17.3 and 56.5 %, 18.7 and 30.0 %, 23.2 and 46.4 %, 20.0 and 27.6 %, 60.6 and 75.5 % and 5.7 and 40.7 % respectively, according to different soaking medium/soaking time applications (Table 4). While the highest mineral contents were obtained by lupin seeds soaked in distilled water at 25 °C, distilled water at 55 °C gave the lowest mineral content probably due to the increased diffusion of the soluble minerals into the water brought

Table 3 Effect of soaking medium and soaking time on Hunter color values of lupin seeds^a ($n=3$)

Soaking properties		Crude ash (%)	Crude protein (%)	Phytic acid (mg/100 g)	Phytic acid loss (%)	Color		
						L*	a*	b*
Soaking medium ^b	25 °C	2.5±0.28a	40.9±2.85a	679.5±289.06b	54.3±19.44b	86.9±0.03a	−0.83±0.13c	34.4±0.40b
	55 °C	2.1±0.02c	40.8±3.52a	482.3±388.01c	67.6±26.10a	84.8±1.54b	−0.49±0.38a	31.3±1.66c
	NaHCO ₃	2.3±0.31b	39.5±0.41b	858.6±212.08a	42.3±14.26c	84.9±0.42b	−0.71±0.26b	34.5±0.95a
Soaking time ^c	48 h	2.5±0.47a	40.9±3.51a	998.5±91.96a	32.8±6.18c	86.2±0.85a	−0.87±0.13c	34.4±1.14a
	96 h	2.3±0.30b	40.4±2.91b	596.2±212.85b	59.9±14.32b	85.5±1.33b	−0.62±0.24b	32.7±2.30c
	144 h	2.1±0.25c	39.9±1.23c	425.7±263.76c	71.4±17.74a	84.9±1.80c	−0.54±0.40a	33.0±2.12b

^a Variables were determined by the two-way ANOVA model, means with different superscripts in the same column are significantly different ($p<0.05$). Experiments were conducted at 3 soaking mediums and 3 soaking times according to 3x3 factorial design. Values are the average of triplicate measurements on the duplicate samples.

^b Soaking mediums: distilled water at 25 °C; distilled water at 55 °C and 0.5 % NaHCO₃ solution at 25 °C

^c Soaking time; 48, 96 or 144 h in different soaking mediums (distilled water at 25 °C; distilled water at 55 °C and 0.5 % NaHCO₃ solution at 25 °C)

Table 4 Effect of soaking medium and soaking time on mineral contents of lupin seeds^a ($n=3$)

Soaking properties		Ca	P	Zn	Fe	Mg	Mn
Soaking medium ^b	25 °C	172.5±28.29a	400.4±13.51a	4.1±0.28a	1.36±0.04a	54.4±5.41a	50.1±1.65a
	55 °C	90.7±4.67c	352.1±22.74c	2.8±0.38c	1.23±0.04c	33.8±6.47c	31.5±2.07c
	NaHCO ₃	104.6±25.28b	359.7±40.2b	3.6±0.11b	1.34±0.07b	40.5±2.12b	41.5±0.95b
Soaking time ^c	48 h	134.8±54.09a	394.2±16.62a	3.2±0.63c	1.29±0.11b	42.7±12.34b	40.7±11.15a
	96 h	132.0±45.04b	373.3±31.69b	3.6±0.54b	1.32±0.10a	44.0±5.01a	41.3±7.51a
	144 h	101.0±35.26c	344.7±35.31c	3.7±0.74a	1.33±0.03a	42.0±15.24c	41.1±9.27a

^a Variables were determined by the two- way ANOVA model, means with different superscripts in the same column are significantly different ($p<0.05$). Experiments were conducted at 3 soaking mediums and 3 soaking times according to 3×3 factorial design. Values are the average of triplicate measurements on the duplicate samples.

^b Soaking mediums: distilled water at 25 °C; distilled water at 55 °C and 0.5 % NaHCO₃ solution at 25 °C

^c Soaking time; 48, 96 or 144 h in different soaking mediums (distilled water at 25 °C; distilled water at 55 °C and 0.5 % NaHCO₃ solution at 25 °C)

about by higher temperature (Table 4). Mineral content loss increased with increasing soaking time at all soaking mediums. Variable mineral loss degree with soaking process of legume seeds have been reported by Saharan et al. (2001) for ricebean, fababean and by Duhan et al. (2002) for pigeon pea.

Table 5 lists the effect of soaking medium and soaking time on sensory quality of lupin seeds. Lupin seeds soaked in 0.5 % NaHCO₃ solution got the highest scores for taste, odor, bitterness, chewiness, hardness and overall acceptability. In the study of Erbaş (2010), debittering using water at room temperature and debittering by alkaline at room temperature gave the same statistic results in terms of sensory quality. But descriptively, the panelists preferred debittering by water at room temperature because of golden yellow color, and a good taste and texture of lupin. In the present study, increasing soaking time increased the taste, odor, bitterness, chewiness, hardness and overall acceptability values.

Conclusions

In this study the effect of debittering processes on physical, chemical and sensory properties of lupin seed was researched. Debittering processes containing cooking and soaking caused significant ($p<0.05$) decrease on chemical compositions (ash and minerals) and antinutrient as PA. Generally distilled water at 55 °C and 144 h soaking time had higher decreasing effect on ash, minerals, PA, lightness and yellowness of the lupin seeds. Soaking in 0.5 % NaHCO₃ solution had the superior effect on the elimination of the bitterness. Lupin seeds soaked in 0.5 % NaHCO₃ solution and 144 h soaking time got higher sensory scores compared to other soaking medium/soaking time. As a result, debittering process is necessary for removing toxic substances and antinutrients and also for improving eating quality of lupin. On the other hand some mineral loss occurs during debittering. In order to increase the potential use of

Table 5 Effect of soaking medium and soaking time on sensory properties of debittered lupin seeds^a ($n=3$)

Soaking properties		Color	Taste	Odor	Bitterness	Chewiness	Hardness	Overall acceptability
Soaking medium ^b	25 °C	7.9±0.58a	4.8±2.00b	5.6±0.58b	3.8±2.00b	6.7±1.00ab	6.7±2.00ab	6.3±1.53b
	55 °C	5.3±1.00b	3.8±0.58c	4.2±1.00c	3.1±2.00b	6.5±0.58b	6.5±1.53b	6.0±1.00b
	NaHCO ₃	7.3±1.00a	7.0±1.73a	6.8±1.53a	5.4±2.52a	7.8±1.00a	7.6±1.15a	7.7±1.53a
Soaking time ^c	48 h	5.9±1.53b	3.8±1.15c	4.4±1.15b	2.1±1.00c	6.2±0.58b	5.5±0.58b	5.5±0.58b
	96 h	7.6±1.15a	5.6±2.08b	6.0±1.00a	4.3±1.53b	7.2±0.58a	7.2±0.58a	7.2±0.58a
	144 h	6.9±1.53a	6.3±2.08a	6.1±2.00a	6.0±1.53a	7.6±1.00a	8.1±0.58a	7.3±1.53a

^a Variables were determined by the two- way ANOVA model, means with different superscripts in the same column are significantly different ($p<0.05$). Experiments were conducted at 3 soaking mediums and 3 soaking times according to 3×3 factorial design. Values are the average of triplicate measurements on the duplicate samples. 9 point hedonic scale: 1-Dislike extremely, 2-Dislike very much, 3-Dislike moderately, 4-Dislike slightly, 5-Neither like nor dislike, 6-Like slightly, 7-Like moderately, 8-Like very much, 9-Like extremely

^b Soaking medium: distilled water at 25 °C; distilled water at 55 °C and 0.5 % NaHCO₃ solution at 25 °C

^c Soaking time; 48, 96 or 144 h in different soaking mediums (distilled water at 25 °C; distilled water at 55 °C and 0.5 % NaHCO₃ solution at 25 °C)

lupin seeds as foodstuffs, further investigations should be undertaken and mineral loss during debittering process should be minimized. Otherwise, traditional debittering process takes a long time, which includes cooking and 3–6 days soaking. This process should be shortened by trying of novel technology as ultrasound soaking and microwave cooking.

References

- AACC (1990) Approved methods of the American Association of Cereal Chemists, 8th edn. AACC International, St. Paul
- Afify AMR, El-Beltagi HS, Abd El-Salam SM, Orman AA (2012) Biochemical changes in phenols, flavonoids, tannins, vitamin E, β -carotene and antioxidant activity during soaking of three white sorghum varieties. *Asian Pac J Trop Med* 203–209
- Arvanitoyannis IS, Tserkezou P (2008) Wheat, barley and oat waste: a comparative and critical presentation of methods and potential uses of treated waste. *Int J Food Sci Tech* 434:694–725
- Arvanitoyannis IS, Varzakas TH (2008) Vegetable waste treatment: Comparison and critical presentation of methodologies. *Crit Rev Food Sci* 48:205–247
- Avila IMLB, Silva CLM (1999) Modelling kinetics of thermal degradation of colour in peach puree. *J Food Eng* 39:161–166
- Awada SH, Hady A, Hassan AB, Ali I, Babiker EE (2005) Antinutritional factors content and availability of protein, starch and mineral of maize (*Zeamays linnaus*) and lentil (*Lens culinaris*) as influenced by domestic processing. *Food Technol-Chicago* 3:523–528
- Barreiro JA, Milano M, Sandoval AJ (1997) Kinetics of colour change of double concentrated tomato paste during thermal treatment. *J Food Eng* 33:359–371
- Bayram M, Kaya A, Öner MD (2004) Changes in properties of soaking water during production of soy-bulgur. *J Food Eng* 61:221–230
- Bilgiçli N (2009) Effects of cooking and drying processes on physical, chemical and sensory properties of legume based bulgur. *J Food Process Pres* 3:590–604
- Bilgiçli N, Elgün A, Türker S (2006) Effects of various phytase sources on phytic acid content, mineral extractability and protein digestibility of tarhana. *Food Chem* 98:329–337
- Birk Y (1993) Antinutritional factors ANFs. in lupin and in other legume seeds: pros and cons. In: *Proc 7th Int Lupin Conf Evora Portugal*, pp 424–429
- Błaszczek B, Stobiecki M, Kowalczyk-Bronisz SH, Gulewicz K, Szymaniec S (1994) Immunotropic activity of lupin seeds extracts and fractions from *Lupinus angustifolius* and *Lupinus albus*. *Arch Immunol Ther Exp* 42:147–153
- Delzenne NM, Roberfroid MR (1994) Physiological effects of non-digestible oligosaccharides. *Lebensm Wiss Technol* 27:1–6
- Dervas G, Doxastakis G, Hadjisavva-Zinoviadi S, Triantaafillakos N (1999) Lupin flour addition to wheat flour doughs and effect on rheological properties. *Food Chem* 66:67–73
- 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
- El-Adawy TA (2002) Nutritional composition and antinutritional factors of chickpeas (*Cicer arietinum L.*) undergoing different cooking methods and germination. *Plant Food Hum Nutr* 57:83–97
- Erbaş M (2010) The effects of different debittering methods on the production of lupin bean snack from bitter *Lupinus albus L.* seeds. *J Food Quality* 33:742–757
- Erbaş M, Certel M, Uslu MK (2005) Some chemical properties of white lupin seeds (*Lupinus albus L.*). *Food Chem* 89:341–345
- Ertas N, Türker S (2012) Bulgur processes increase nutrition value: possible role in-vitro protein digestability, phytic acid, trypsin inhibitor activity and mineral bioavailability. *J Food Sci Tech Mys*. doi:10.1007/s13197-012-0638-7
- Evans RI, Bandemer SL (1967) Nutritive value of legume seed proteins. *J Agr Food Chem* 15:439–443
- Fagbemi TN, Oshodi AA, Ipinmoroti KO (2005) Processing effects on some antinutritional factors and in vitro multienzyme protein digestibility (IVPD) of three tropical seeds: Breadnut (*Artocarpus altilis*), Cashewnut (*Anacardium occidentale*) and fluted pumpkin (*Telfairia occidentalis*). *Pak J Nutr* 4:250–256
- Gulewicz P, Szymaniec S, Bubak B, Frias J, Vidal-Valverde C, Trojanowska K, Gulewicz K (2002) Biological activity of α -galactoside preparations from *Lupinus angustifolius L.* and *Pisum sativum L.* seeds. *J Agr Food Chem* 50:384–389
- Güzel D, Sayar S (2012) Effect of cooking methods on selected physicochemical and nutritional properties of barlotto bean, chickpea, faba bean, and white kidney bean. *J Food Sci Tech Mys* 49:89–95
- 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
- Huyghe C (1997) White lupin (*Lupinus albus L.*). *Field Crops Res* 53:147–160
- Ibarz A, Pagan J, Garza S (1999) Kinetic models for colour changes in pear puree during heating at relatively high temperatures. *J Food Eng* 39:415–422
- Igbedioh SO, Shaire S, Aderiye BJI (1995) Effects of processing on total phenols and proximate composition of pigeon pea (*Cajanus cajan*) and climbing bean (*Vigna umbellata*). *J Food Sci Tech Mys* 32:497–500
- Kinghorn AD, Balandrin MF (1984) Quinolizidine alkaloids of the leguminosae: structural types, analysis, chemotaxonomy and biological activities. In: Pelletier SW (ed) *Alkaloids: chemical and biological perspectives*. Wiley, New York, pp 105–148
- Lasztity R, Lasztity L (1990) Phytic acid in cereal technology. In: Pomeranz Y (ed) *Advances in cereal science and technology*. St. Paul
- Lozano JE, Ibarz A (1997) Colour changes in concentrated fruit pulp during heating at high temperatures. *J Food Eng* 31:365–373
- Manez G, Alegria A, Fare R, Frigola A (2002) Effect of traditional, microwave and industrial cooking on inositol phosphate content in beans, chickpeas and lentils. *Int J Food Sci Nutr* 53:503–508
- Morrow B (1991) The rebirth of legumes. *Food Technol* 45:96–121
- Mubarak AE (2005) Nutritional composition and antinutritional factors of mung bean seeds (*Phaseolus aureus*) as affected by some home traditional processes. *Food Chem* 89:489–495
- Rahma EH, Narasinga RMS (1984) Effect of debittering treatment on the composition and protein components of lupin seeds (*Lupinus termis*). *J Agr Food Chem* 1026–1030
- Reddy NR, Sathe SK, Salunkhe DK (1982) Phytates in legumes and cereals. *Adv Food Res* 28:1–92
- Rhim JW, Nunes RV, Jones VA, Swartzel KR (1989) Kinetics of colour change of grape juice generated using linearly increasing temperature. *J Food Sci* 54:776–777

- Rickard ES, Thompson LU (1997) Interactions and effects of phytic acid. In: Shahidi F (ed) Antinutrients and phytochemicals in foods. American Chemical Society, Washington, pp 294–312
- Saharan K, Khetarpaul N, Bishnoi S (2001) HCl-extractibility of minerals from ricebean and fababean: influence of domestic processing methods. *Innov Food Sci Emerg* 2:323–325
- Skujins S (1998) Handbook for ICP—AES (Vartian-Vista). A Short Guide to Vista Series ICP—AES Operation. Variant Int. AG. Zug, version 1.0. Switzerland
- Torre M, Rodriguez AR, Saura-Calixto F (1991) Effects of dietary fiber and phytic acid on mineral availability. *Crit Rev Food Sci* 30:1–22
- Wang N, Hatcher DW, Gawalko EJ (2008) Effect of variety and processing on nutrients and certain antinutrients in field peas (*Pisum sativum*). *Food Chem* 111:132–138
- 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
- Yorgancılar M, Bilgiçli N (2010) Utilization of lupin seed in bulgur production. *J Food Agric Environ* 8:167–169
- Yorgancılar M, Bilgiçli N (2012) Chemical and nutritional changes in bitter and sweet lupin seeds (*Lupinus albus* L.) during bulgur production. *J Food Sci Technol*. doi:[10.1007/s13197-012-0640-0](https://doi.org/10.1007/s13197-012-0640-0)