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Some chemical properties of white lupin seeds (*Lupinus albus* L.)

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Abstract

Lupin seeds (*Lupinus albus* L.), grown in Turkey, were investigated. Density, thousand grain weight, and hectolitre weight of seeds were 1.16 g/cm^3, 411.4 g, and 68.12 kg/100 l, respectively. The results showed that lupin contained high amounts of protein (32.2%), fibre (16.2%), oil (5.95%), and sugar (5.82%). Oil of seeds was composed of 13.5% saturated, 55.4% monounsaturated, and 31.1% polyunsaturated fatty acids. Sucrose constituted 71% of total sugar content of seeds. Lupin seeds contained 3.9 mg/kg of thiamin, 2.3 mg/kg of riboflavin and 39 mg/kg of niacin. It can be concluded that lupin is an excellent food material with a high nutritional value.

Keywords: White lupin; *Lupinus albus* L; Chemical composition

1. Introduction

Lupin (*Lupinus albus* L.) is a species of the genus *Lupinus* (more than 200 species) in the family *Leguminosae*. The species of the genus *Lupinus* are distributed in two centres of origin. One is the Mediterranean basin and the other extends through South America (Dervas, Doxastakis, Zinoviadi, & Triandatafillakos, 1999; Huyghe, 1997; Swiecicki, Buirchell, & Cowling, 2000). The major cultivated species of lupins are *Lupinus albus* L. (white lupin), *Lupinus angustifolius* L. (blue lupin), *Lupinus luteus* L. (yellow lupin) and *Lupinus mutabulies* (pearl lupin). The first three species originate in the Mediterranean area while *Lupinus mutabulies* belongs to South America (Allen, 1998; Mülayim, Tamkoç, & Babaoglu, 2002). Lupins are cultivated for three main reasons: as a ruminant feed, as a green manure contributing to improved soil structure, and for human nutrition because of their high protein and oil contents (Faluyi et al., 2000; Huyghe, 1997). In addition, lupin plants are grown for use as a cut flower in the flowering period.

Seeds of white lupin have a protein content ranging from 33% to 47%, according to genotype and location. Contrary to cereals, lupin proteins contain a high amount of lysine and a low amount of sulphur-containing amino acids (Dervas et al., 1999). Oil content varies from 6% to 13% with a high concentration of polyunsaturated fatty acid (Huyghe, 1997).

Trypsin inhibitor activity is very low in lupins, ranging from 0.1 to 0.2 mg/g in *L. albus.* Lupins species can not be consumed directly because they contain quinolizidine alkaloids, mainly sparteine and lupanine, giving a bitter taste in white lupin and causing respiration problems and liver damage. The presence of alkaloids proves to be non-toxic at low concentrations. Since most alkaloids of lupin are water-soluble, the alkaloid level of lupin (0.5–4%) can be decreased to 0.04% by soaking in running water, brine or scalding. Also it has been possible to grow sweet genetic varieties with low alkaloid contents ranging from 0.008% to 0.012% (Allen, 1998; Knight, 2000; Tsaliki, Lagaouri, & Doxastakis, 1999; Vasilakis & Doxastakis, 1999).

Lupin flour can be used in production of different fermented products. It can be added to pasta, crisps, bread and emulsified meat products to increase nutritional value and aroma and to modify texture. Also, protein isolate can be produced from lupin seeds. In the Middle East, lupin seeds are consumed as a snack after they are soaked in runnig water, scalded and dehulled.

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In some European counties, pickle is produced from lupin seeds (Akyıldız, 1969; Dervas et al., 1999; Papavergou, Bloukas, & Doxastakıs, 1999; Petterson, 1998; Vasilakis & Doxastakis, 1999).

White lupin, which has been consumed as a food in a narrow area for a long time, was accepted for human consumption by the Australian government in 1987 and by the United Kingdom government in 1996 (Cox, 1998; Swam, 2000).

The average price of lupin seeds is about 185 $/ton (GrainPool, 2003). 1,387,660 tons of lupin were produced in the world in 2001. Australia, which produced 89% of this amount, is the largest lupin-producing country. The other important lupin producers are Poland, France and South America (FAOSTAT, 2001).

The objective of the present investigation was to characterize chemical and nutritional properties of the white lupin (*L. albus* L.) grown in Turkey.

2. Material and methods

2.1. Materials

2.1.1. Raw materials

Lupin seeds (*L. albus* L.) that had been cultivated in the Gazipasa district (36°17′N, 31°25′E) of Antalya, Turkey, in 2002, were obtained from a local seller.

2.1.2. Chemicals

HPLC grade acetonitrile was obtained from Riedel-de Haen (Seelze, Germany). Standards of sugar (Sigma CAR-11), vitamin (Sigma V-1) and *n*-hexane were purchased from Sigma (St. Louis, Missouri, USA). HPLC grade methanol, benzene, 2,2-dimethoxypropane and *n*-heptane were obtained from Merck (Darmstadt, Germany). The other chemicals were of analytical grade.

2.2. Methods

2.2.1. Physical characterization of lupin seeds

Physical properties of lupin seeds were characterized by measuring dimension and density of seeds, thousand-grain weight, and hectolitre weight (Elgün & Ertugay et al., 1999).

2.2.2. Determination of water activity

Water activity was calculated by using the equilibrium relative humidity principle from a sorption isotherm (Palacha & Flink, 1987).

2.2.3. Determination of crude protein, moisture, ash, oil, titratable acidity, pH and crude fibre

Before chemical analysis, lupin seeds were milled into fine powder without hulling. Nitrogen content was determined by using the Kjeldahl method and multiplied by a factor 6.25 to determine the crude protein content (AOAC, 1975; Faluyi et al., 2000). Moisture content was determined by drying the samples at 105 °C to a constant weight. Ash content was determined by ashing the sample at 925 °C to constant weight. The oil was determined by the Soxhlet method, pH values were measured after 4 volumes of water were added to the sample (WTW 537, Weilheim, Germany). Titratable acidity was determined by titrating with 0.1 N NaOH up to pH 8.1 and expressed as sulfuric acid (AOAC, 1984; Nielsen, 1998; Skoog, West, & Holler, 1996). Crude fibre content of the defatted samples was determined by decomposing starches with acids and proteins, with base and then filtering (Nielsen, 1998). All the determinations were expressed on a dry weight basis.

2.2.4. Determination of mono- and disaccharides

Sugar and vitamin analyses were carried out with a Varian HPLC equipped with a model 9010 solvent delivery system and a Marathon autosampler with a 20 μl Loop (Varian, Harbor City, California, USA).

Sugars were determined by modifying a previously described method (Camara, Diez, & Torija, 1996; Karkacier, Erbaş, Uslu, & Aksu, 2003). Lupin flour (10 g) was mixed with 25 ml of HPLC grade water. The mixture was homogenized (Ultraturrax T-25, IKA Labortechnik, Stauten, Germany) at 12,000 rpm and centrifuged at 3250*g* for 30 min at ambient temperature. The supernatant was filtered through a Sep-Pack C_{18} (Alltech, Deerfield, Illionis, USA) cartridge. 2.5 ml of filtrate were blended with 7.5 ml acetonitrile; subsequently, the mixture was filtered through a 0.45 μm membrane (Sigma, Stenheim, Germany); finally, 20 μl of the mixture were injected into an HPLC equipped with a RI detector. The analytical column used was an Alltech amino-bonded carbohydrate column (10 μm, 300×4.6 mm i.d.). The mobile phase was an isocratic solvent system consisting of acetonitrile–water (75:25, v/v), the flow rate was 1.4 ml/min. Standard sugar solutions were prepared in a mobile phase to contain 5–100 μg/ml. Peaks were verified by adding the standard sugars to some samples and each peak area was calculated in relation to standard sugar peak. The results were calculated on a dry weight basis.

2.2.5. Determination of vitamins

For extraction, 2 g of lupin flour were mixed with 4 ml *n*-hexane and 16 ml HPLC grade water. The mixture was homogenized using an Ultraturrax at 12,000 rpm and then centrifuged at 3250*g* for 30 min. The aqueous phase was filtered through a Whatman 42 (Kent, UK) filter paper and 0.45 μm membrane filter sequentially. Then, 20 μl of supernatant were injected in to the HPLC system equipped with a UV–Vis detector, which was set to 254 nm in absorbance mode. An analytical column (Merck, $5C_{18}$, 300×4.6 mm^2) was used with an isocratic

solvent system consisting of 95% of 50 mM KH_2PO_4 and 5% acetonitrile. The flow rate was 1 ml/min (Sancho et al., 1998). The vitamin standards were prepared in mobile phase. Peaks were verified by adding the standard vitamins to some samples and each peak area was calculated in relation to the standard vitamin peak. The results were calculated on a dry weight basis.

2.2.6. Determination of fatty acids

Methyl esters of fatty acids were prepared by using a reaction mixture consisting of methanol, benzene, 2,2-dimethoxypropane (37:20:5:2) and *n*-heptane, as described previously (Garces & Mancha, 1993). Lupin flour (250 mg) was weighed in to a glass tube, then, 3 ml of reaction mixture and 2 ml *n*-heptane were added to the sample. Headspace of the tube was filled with carbon dioxide gas and covered with a teflon lid. The tube was shaken strongly and placed in a water bath at 80 °C for 2 h. Then, the tube was allowed to reach room temperature until two phases formed. The upper phase (*n*-heptane, 1 μl), containing methyl esters of fatty acids, was injected into a gas chromatograph (Fisons HRGC Mega 2, Milan, Italy) equipped with a fused silica capillary column (Macherey-nagel, FS- FFAP-DF, 25 m × 0.25 mm i.d., 0.25 μm film thickness, Düren, Germany). The injector block and flame ionization detector (FID) were maintained at 250 and 260 °C, respectively. The oven temperature was gradually increased from 150 to 200 °C at 5 °C/min. The pressure of carrier gas (helium) was 150 kPa and the pressures of hydrogen and dry air used in FID were 50 and 90 kPa, respectively. Peaks were identified by comparison of retention times with those of standard compounds. The percent fatty acid composition was calculated from the ratio of individual pick area to total definable pick area.

3. Results and discussion

Dimensions of lupin seeds were (5.1 ± 0.3 mm) × (12.2 ± 0.9 mm) × (12.2 ± 0.7 mm). Thousand grain weight, hectolitre weight, and density of seeds were found as 411.4 ± 15.2 g, 68.12 ± 1.28 kg/100 l and 1.16 ± 0.012 g/cm^3, respectively. The water activity of seeds was calculated as 0.61 ± 0.03 and pH of lupin flour was 5.78 ± 0.04. The chemical composition of white lupin is presented in Table 1. Similar results for moisture, crude protein, crude fibre, oil and ash content of lupin have been reported in the previous works (Akyıldız, 1969; Cox, 1998; Dervas et al., 1999; Ergül, 1988; Petterson, 1998). Protein content of lupin (32.2%) was higher than that of a lot of legumes. Favier, Ripert, Toque, and Feinberg (1995) reported that haricot bean, lentil and soy bean contain 28.8%, 26.7% and 40.5% protein, respectively. Because of the high protein content, lupin flour could be used in the human diet. Also, temperature of denaturation of these proteins is higher than animal protein, so they are technologically easier to handle (Chapleau & Lamballerie-Anton, 2003). Lupin flour had a high amount of crude fibre (16.2%). These fibres have many desirable properties, including white colour, high water-holding capacity (7.1 g H_2O/g) and beneficial effects on human health (Huyghe, 1997). Therefore, lupin flour can be incorporated into a wide range of foods to make dietary products.

Table 1
Chemical composition of white lupin (*L. albus*)

Components	Mean value[b] (%)
Moisture	8.32 ± 0.03
Crude protein[a]	32.2 ± 1.10
Crude fibre[a]	16.2 ± 1.51
Oil[a]	5.95 ± 0.09
Ash[a]	2.65 ± 0.18
Acidity[a]	0.13 ± 0.02

[a] Data are reported on a dry mater basis.
[b] Mean value ± standard deviation, $n = 3$.

The levels of mono- and disaccharides determined in the lupin are shown in Table 2. Mono- and disaccharides constituted 5.82% of lupin seeds and sucrose (70.7%) was the most abundant sugar. Galactose, glucose, ribose, maltose, fructose and xylose followed sucrose in that order. Lupin seed contained a higher amount of sugar than wheat and legumes, except for soy bean. It was reported that haricot bean, lentil, soy bean, and wheat contained 2.7%, 1.1%, 7.6% and 2.54% sugar, respectively (Favier et al., 1995).

Niacin, thiamin and riboflavin contents of lupin were determined in the present study and compared with other legumes and wheat (Table 3). Among the legumes listed in Table 3, niacin content was the highest in lupin. However, its thiamin content was lower than both legumes and wheat. Riboflavin content of lupin seeds was higher than wheat and haricot bean but it was lower than lentil and soy bean. Daily requirement of human for niacin, thiamin and riboflavin are 6.6, 0.4 and 0.6 mg/1000 kcal, respectively (Eastwood, 1997). Lupin

Table 2
Mono- and disaccharide composition of lupin (*L. albus*) and ratios of individual sugars to total sugar

Mono and disaccharides[a]	Mean value[b] (mg/kg)	Portion in total (%)
Sucrose	41151 ± 1543	70.7
Galactose	4880 ± 319	8.4
Glucose	3902 ± 269	6.7
Ribose	3352 ± 43	5.8
Maltose	2955 ± 234	5.1
Fructose	1609 ± 39	2.8
Xylose	321 ± 48	0.6
Total	58 170	

[a] Data are reported on a dry mater basis.
[b] Mean value ± standard deviation, $n = 3$.

Table 3
B vitamin contents of lupin (*L. albus*), some legumes and wheat

Vitamins[a]	Lupin[b]	Haricot bean[c]	Lentil[c]	Soy bean[c]	Wheat[c]	Wheat[d]
Thiamin (B_1)	3.9 ± 0.2	5.6	5.6	7.6	4.7	4.5
Riboflavin (B_2)	2.3 ± 0.1	1.8	2.8	3.0	1.3	1.3
Niacin	39.1 ± 1.1	22.5	24.5	32.6	54.3	54

[a] Data are reported on a dry mater basis (mg/kg).
[b] Mean value ± standard deviation, $n = 3$.
[c] Favier et al. (1995).
[d] Pomeranz (1988).

Table 4
Saturated and unsaturated fatty acid composition of lupin oil (*L. albus*), and other vegetable oils

Fatty acids	%						
	Lupin	Soy bean[a]	Sesam[a]	Sunflower[a]	Olive[a]	Wheat[a]	Corn[b]
Saturated	13.5	15.5	14.6	11.0	15.2	21.1	7.5
Monounsaturated	55.4	23.7	39.5	20.1	64.3	15.7	16.5
Polyunsaturated	31.1	60.8	45.8	68.9	10.5	63.2	76.0

[a] Favier et al. (1995).
[b] Nas, Gökalp, and Ünsal (1992).

seeds (100 g) can approximately satisfy 30% of niacin, 50% of thiamin and 20% of riboflavin requirements for a diet of 2000 kcal/day.

Table 4 shows that fatty acids of lupin seed are composed of 13.5% saturated fatty acids and 86.5% unsaturated fatty acid. Saturated fatty acids content of lupin oil was lower than many vegetable oils (Table 4). The high content of oil in lupin seeds (5.95%, Table 1), with a high proportion of unsaturated fatty acids, is desirable for human nutrition (see Table 5).

Oleic acid (55.4%) was the predominant fatty acid in lupin seed oil. Also, among essential fatty acids, the oil contained linoleic and linolenic acids. Similar results were presented in earlier papers (Mülayim et al., 2002; Petterson, 1998). Fatty acid composition of lupin resembles that of peanut and rapeseed, but does not involve any erusic acid. Peanut oil contains 6–9% palmitic acid, 53–71% oleic acid and 13–27% linoleic acid. Rapeseed oil contains 48–55% oleic acid, 27–31% linoleic acid and 10–14% linolenic acid (Nas et al., 1992).

In summary, *L. albus*, which is not as commonly consumed as other legumes, is a very nutritive crop. The high protein, dietary fibre, oil and sugar content, the relatively balanced fatty acids, and the vitamin B levels make it a good source of food material. The whole seed can be consumed as a snack or pickle. Its flour can be incorporated into a wide range of foods, such as bakery and emulsified meat products. It is considered that lupin is an economical and nutritive food for a very rapidly increasing world population.

Table 5
Fatty acid profile of lupin (*L. albus*)

Fatty acid	Mean value[a] (%)
Palmitic acid (16:0)	11.6 ± 0.9
Stearic acid (18:0)	1.9 ± 0.5
Oleic acid (18:1)	55.4 ± 1.2
Linoleic acid (18:2)	22.4 ± 0.9
Linolenic acid (18:3)	8.7 ± 0.6

[a] Mean value ± standard deviation, $n = 3$.

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