Lupin Composition and Possible Use in Bakery– A Review

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Abstract

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Legume seeds are an abundant source of proteins and, among them, lupin is one of the richest. Lupin seed deserves great interest due to its chemical composition and augmented availability in many countries in recent years. The review reports on the current knowledge about nutritional characteristics (proteins, amino acids, starch, sugars, fiber, lipids, fatty acids, vitamins, antinutritional compounds) and potential use of different lupin seed products (flour, kernel fiber, protein isolates and concentrates) for baking applications. The influence of lupin addition on the rheological properties of dough and quality of final products are also described. A separate part of the article is focused on the foaming and emulsifying properties of lupin proteins.

Keywords: lupin; nutrition value;, baking applications

Legumes represent, together with cereals, the main plant source of proteins in human diet. They are also generally rich in dietary fibre and carbohydrates (Rochfort & Panozzo 2007). Minor compounds of legumes are lipids, polyphenols, and bioactive peptides (Pastor-Cavada *et al.* 2009).

Lupin is an economically and agriculturally valuable plant (Sujak *et al*. 2006; Gulewicz *et al.* 2008). Its seeds are employed as a protein source for animal and human nutrition in various parts of the world, not only for their nutritional value, but also for their adaptability to marginal soils and climates. Human consumption of lupins has increased in recent years (De Cortes Sánchez *et al.* 2005).

Lupins (*Lupinus* spp.) belong to the *Genisteae* family, *Fabaceae or Leguminosae* (Uzun *et al.* 2007; Pastor-Cavada *et al.* 2009). From the genus *Lupinus* more than 400 species are known, from which only four are of agronomic interest (Reinhard *et al.* 2006): (*L. albus* L.: white lupin, *L. angustifolius* L.: blue or narrow-leafed lupin, *L. luteus* L.: yellow lupin and *L. mutabilis* L.: pearl or Tarrwi lupin) (Reinhard *et al.* 2006; Mülayim *et al.* 2002; Uzun *et al.* 2007). The first three species originate from the Mediterranean area, including Turkey, while *L. mutabilis* belongs to South America (Mülayim *et al.* 2002). These species are known as sweet lupins due to their low levels (0.003%) of bitter-tasting and potentially toxic alkaloids (Wäsche *et al.* 2001) and, therefore, there is no risk of toxicity for animals and humans (Martinez-Villalluenga *et al.* 2006a).

In Australia, 1.6 milion tonnes of lupin seed is produced annually, representing 80% of the total world production (Pollard *et al.* 2002). Other main lupin producing countries are Russia (*L. lu-*

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teus) and Poland (*L. luteus*) (Reinhard *et al.* 2006). The improvement on lupin cultivation (mainly *L. albus*) had been very slow until breeders discovered sweet (low alkaloid) genotypes before the Second World War, which later stimulated lupin cultivation mainly in Germany, France, Spain, Poland, and the former USSR (Mülayim *et al.* 2002).

Lupins are used for many purposes, such as pasture improvement and rnamentation, erosion control or soil stabilisation (Uzun *et al.* 2007). They are also used as green forage, as manure, and for fixing atmospheric nitrogen to soil (Sujak *et al.* 2006; Uzun *et al.* 2007; Gulewicz *et al.* 2008).

Chemical composition of lupin seeds

Lupin is a good source of nutrients, not only proteins but also lipids, dietary fibre, minerals, and vitamins (Martínez-Villaluenga *et al.* 2006a, 2009; Zielinska *et al.* 2008) (Table 1). Lupin generally contains about twice the amount of proteins found in those legumes that are commonly consumed by humans. There are variations in the protein content between species and cultivars as a result of the characteristics of the growing conditions and soil types (Martínez-Villaluenga *et al.* 2006a) from 28% in to 48% (Sousa *et al.* 1996; Ögüt 1998; Papavergou *et al.* 1999; Linnemann & Dijkstra 2002; Mülayim *et al.* 2002; Sironi *et al.* 2005; Capraroa *et al.* 2008). Globulins (α-conglutin or 11S-like protein, β-conglutin or 7S-like protein, and γ-conglutin) are the main storage proteins (80–90%) in lupins (Rodríguez-Ambriz *et al.* 2005) while prolamines and glutelins are detected in small amounts similar to those reported in most legume seeds (Gulewicz *et al.* 2008).

Lupin seeds represent a good balance of essential amino acids (Drakos *et al.* 2007). They

Table 1. Nutritional value of white lupin (*Lupinus albus*) seeds (Martínez-Villaluenga *et al.* 2006a)

Nutritional components	White lupin		Yellow lupin	
	cv. Multolupa	cv. Marta	cv. 4486	cv. 4492
Protein (g/100 g d.m.)	30.6 ± 0.26	37.4 ± 3.12	37.9 ± 2.44	36.8 ± 0.77
Fat (g/100 g d.m.)	14.64 ± 1.11	11.34 ± 0.73	8.79 ± 0.42	8.54 ± 0.02
Ash (g/100 g d.m.)	3.65 ± 0.29	3.79 ± 0.06	4.95 ± 0.12	3.14 ± 0.07
Soluble carbohydrates (g/100 g d.m.)				
Sucrose	2.58 ± 0.06	3.09 ± 0.08	1.38 ± 0.13	1.21 ± 0.04
Dietary fibre				
Soluble	5.21 ± 0.18	3.64 ± 0.12	4.90 ± 0.03	3.21 ± 0.05
Insoluble	34.22 ± 0.08	30.80 ± 0.11	28.78 ± 0.01	31.13 ± 0.28
Total fibre	39.42 ± 0.26	34.44 ± 0.23	33.68 ± 0.04	34.33 ± 0.34
Starch				
Total	3.27 ± 0.23	2.81 ± 0.08	4.53 ± 0.41	4.00 ± 0.09
Available	1.78 ± 0.11	1.84 ± 0.13	1.84 ± 0.13	2.20 ± 0.24
Vitamins (mg/100 g d.m.)				
α-Tocopherol	0.19 ± 0.01	0.47 ± 0.02	0.48 ± 0.01	0.27 ± 0.02
γ-Tocopherol	20.1 ± 0.86	51.6 ± 0.5	11.19 ± 0.63	9.41 ± 0.16
δ-Tocopherol	0.25 ± 0.02	0.41 ± 0.02	0.38 ± 0.01	0.24 ± 0.01
Thiamin	0.36 ± 0.01	0.34 ± 0.01	1.49 ± 1.12	1.16 ± 0.07
Riboflavin	0.61 ± 0.04	0.65 ± 0.05	0.85 ± 0.04	0.37 ± 0.02
Vitamin C	6.48 ± 0.09	ND	2.56 ± 0.13	ND

ND – non detectable, d.m. – dry matter

are considered to be a good source of lysine, and are generally poor in the sulfur-containing amino acids (methionine and cysteín) (Martinéz-Villaluenga *et al.* 2006b; Gulewicz *et al.* 2008) and threonine (Pisariková *et al.* 2008).

Dietary fiber represents 40% of the kernel weight of sweet lupin, which is a higher level than in most other legumes (Clark & Johnson 2002; Hall *et al.* 2005; Smith *et al.* 2006). The seed cover of *Lupinus albus* (white lupin) contains after the debittering process 89% of insoluble dietary fiber. The main component of the insoluble dietary fiber is cellulose (79%). Other ones, i.e. hemicellulose and lignin, remain at the levels of 14% and 7%, respectively (Ciesolska *et al.* 2005).

Although lupin belongs to the legumes and is not described as an oilseed crop, it has a considerable amount of oil in its seeds (Uzun *et al.* 2007). It is a legume that contains approximately 5–20% of crude oil in the whole seed (Mohamed & Rayas-Duarte 1995). In general, lupin oil is characterised by a balanced fatty acid composition with total saturated fatty acids of 10% and total unsaturated fatty acids of 90%, of which 32% to 50% is oleic (18:1) acid, 17% to 47% is linoleic (18:2) acid, and 3% to 11% is linolenic (18:3) acid (Bhardwaj *et al.* 1998; Hamama & Bhardwaj 2004).

Lupin seed contains higher amounts of available soluble sugars than wheat and others legumes, except for soybean (Martínez-Villaluenga *et al.* 2006a). The seed contains minute amounts of starch (5% to 12%) and higher levels of soluble non-starch polysaccharides (30–40%) (Erbas *et al.* 2005).

Furthermore, lupin contains phytochemicals with antioxidant capacity such as polyphenols, mainly tannins and flavonoids (Tsaliki *et al*. 1999; Oomah *et al.* 2006; Zielinska *et al*. 2008; Martinez-Villalunga *et al.* 2009).

It has been reported that lupin has lower levels of undesirable constituents, such as phytic acid, oligosaccharides, trypsin inhibitors, and lectins and saponins in comparison with other legumes (Martínez-Villaluenga *et al.* 2006a; Fernandez-Orozco *et al.* 2008; Pastor-Cavada *et al.* 2009). The main anti-nutritional substances found in lupin seeds are various alkaloids of the quinolizidine group (El-Adawy *et al.* 2001; Jiménez-Martínez *et al.* 2001; Sujak *et al.* 2006) such as lupinine, lupanine, sparteine, lupinidine, hydroxylupanine, anagirine, monolupine, termophsine, puziline, angustifoline, and others (Maknickienė & Ražukas 2007). The presence of these compounds is a limiting factor for lupin consumption (De Cortes Sánches *et al.* 2005).

Significance of lupin for bakery industry

Lupin appears to be a widely utilised commodity in food applications (Xu & Mohamed 2003; Xu *et al.* 2006, 2008). Various researchers have investigated the use of lupin in a substitutional role in a variety of cereal-based products (Dervas *et al.* 1999).

Lupin flour is widely considered an excellent raw material for supplementing different food products owing to its high protein content (Pollard *et al.* 2002; De Cortes Sánchez *et al.* 2005; Sironi *et al*. 2005) and is largely used as eggs substitute, for example in cakes, pancakes, biscuits, or brioche (Tronc 1999), and has been added to spaghetti (Rayas-Duarte *et al.* 1996), pasta, crisps (Lampart-Szczapa *et al*. 1997), and bread (Dervas *et al*. 1999; Papavergou *et al.* 1999). It has been also used as a butter substitute in cake, brioche, and croissant (Tronc 1999). Lupin does not contain gluten, thus it is sometimes used as a functional ingredient in gluten-free foods (Scarafoni *et al.* 2009). However, allergic reactions to lupin have been reported in peanut-allergic individuals, with a cross-reactivity (Moneret *et al.* 1999) rate to lupin flour in the peanut-allergic individuals of around 30% (Magni *et al.* 2005). Cross-reactivity is generally the result of homologous epitopes in proteins with conserved amino acid sequences or steric domains (Dooper *et al.* 2009). It has been suggested that lupin allergens may cross-react with the peanut allergens Ara h 1 and Ara h 8, which has been confirmed by studies showing that IgE-binding lupin proteins indicate a high similarity to Ara h 1 as well as soybean β-conglycinins (Galan *et al*. 2010).

For this reason, lupin seeds and the products thereof were recently included in the Annex IIIa of Directive 2000/13/ EC (Directive 2006/142/EC), which lists the ingredients which must appear under all circumstances on the labelling of foodstuffs (Scarafoni *et al.* 2009).

Lupin chips have been proposed in the Food Ingredients Europe, as a new product. These chips can be added as a nutritional ingredient to salads, soups, with the addition of a yellow colour researched by industrial (Tronc 1999).

Lupin kernel fiber has also a potential as a human food ingredient as it has been used in the production of palatable fiber-enriched baked goods and pasta (Clark & Johnson 2002; Hall *et al.* 2005; Smith *et al.* 2006).

Influence of lupin addition on dough and quality of final products

Lupin flour can be incorporated into wheat flour to improve the nutritional value of the final products without detrimental effects on the quality (Pollard *et al.* 2002). In general, the addition of up to 10% lupin flour improves water binding, texture, shelf-life, and aroma (Fudiyansyah *et al.* 1995; Martinéz-Villaluenga *et al.* 2006b).

The presence of lupin flour in the products increased the amount of water required for the optimum breadmaking absorption. It was also concluded that lupin flour, at 5% substitution level, increased the stability and tolerance index of the dough (Dervas *et al.* 1999), however, the mixing time and dough stability decreased as the substitution level increased (Doxastakis *et al.* 2002).

The unique bread-making properties of wheat flour can be attributed mainly to the ability of its gluten proteins to form a viscoelastic network when mixed with water. The worsening of the viscoelastic properties of wheat flour dough, after substitution with lupin, reduces the bread-making potential. It was suggested that the weakening effect of foreign proteins (lupin) on wheat flour doughs is the result of the dilution of the gluten structure by the protein added. This results in a smaller loaf volume and has subsequently a negative affect on other quality attributes, such as crumb grain and tenderness (Dervas *et al.* 1999; Doxastakis *et al.* 2002). Lucisano and Pompei (1981) stated that the reason for the gradual decrease in the loaf volume is due to the loaf cell structure being unable to retain gas during proofing and baking. Sosulski and Dabrowski (1983) commented that the gluten matrix was subjected to a greater stress in the sections that covered the starch granules, permitting gas to escape which resulted in a low loaf volume (Pollard *et al*. 2002).

The substitution of wheat flour by lupin flour decreased the darkness of the crust, and the crumb colour (Pollard *et al.* 2002) became more yellow while the crumb texture showed evidence for thickened cells (Dervas *et al.* 1999; Doxastakis *et al.* 2002). The yellow coloration of lupin flours and protein concentrates can be reduced by the use of citric acid (1%) (Guémes-Vera *et al.* 2008).

The yellow colours of lupin flours have a considerable appeal and would be of value in many goods and in pasta and noodle dishes (Dervas *et al.* 1999; Doxastakis *et al.* 2002). The fortification of spaghetti with up to 5% lupin protein isolate permits to obtain a functional food product endowed by an acceptable colour, satisfactory standard parameters defining the cooking quality, and good nutritional characteristics. In the countries where pasta is a staple food, the daily consumption of a normal serving of these spaghetti (dry weight from 80 g to 100 g) would correspond to a lupin protein intake of 4–5 g, about one fifth of the dose that each hypercholesterolemic patient should consume for reducing the cardiovascular risk (Doxastakis *et al.* 2007). It was found that phytochemicals from legumes may be responsible for the beneficial cardiovascular effects (Campos-Vega *et al.* 2010). The phenolic content and composition of *L. angustifolius,* despite its weak antioxidant capacity, may have positive implications for reducing the risk of cardiovascular disease due to its protective effects on blood vessel health (Oomah *et al.* 2006).

The assessment of the suitability of high dietary fiber lupin product and its utilisation as a valuable source of dietary fiber was carried out in experimental baking, where 10%, 15%, and 20% additions of high dietary fiber lupin product to wheat dough were used. It was found that the contribution of high dietary fiber lupin product in the mixture with wheat flour affects the increase the water absorption capability (of water absorbability) in comparison with the control dough. Also, advantageous effects were observed of high dietary fiber lupin product on the rheological properties of dough such as its development, timestability, and index tolerance to kneading. The best organoleptic effect was obtained when a 10% addition of high dietary fiber lupin product was used. Furthermore, a delicate structure of crumb was also observed (Ciesolska *et al.* 2005).

Foaming and emulsifying properties of lupin

Lupin seed proteins are highly soluble at pH > 5.5, and show good water- and fat-binding capacities, foaming capacity, and emulsifying ability (Alamanou & Doxastakis 1997; Dervas *et al.* 1999; Chapleau & de Lamballerie-Anton

2003; Hojilla-Evangelista *et al.* 2004). Due to their good nutritional quality and satisfactory functional properties, lupin seed protein fractions (flour, concentrates, isolates) have been used in the production of various foods (Fudiyansyah *et al.* 1995). Lupin proteins have some additional advantages, among them that they are technologically easier to handle and that the temperature of denaturation is higher than that of animal proteins (Chapleau & de Lamballerie-Anton 2003).

Lupin flour has a potential to be used as a suitable substitute for egg albumin as a foaming agent in food (Pollard *et al.* 2002). It was found that the lupin foam became very similar in texture and microstructure to the uncooked egg-white foams when boiled in water for 5 min (Raymundo *et al.* 1998a), and that the foaming stability of lupin proteins concentrate and flour was strong even after 36 h (Pollard *et al.* 2002).

Lipids in lupin impair the foaming properties of flours. The reason for the low foaming potential of non defatted flour resides in that different lipids have different effects on the foam structure. In general, the more polar lipids (glycolipids, phospholipids) act as foam stabilisers. They act by absorbing at the air-aquinous interface and forming stable films. The less polar lipids (triglycerides) are weakly surface active and tend to give condensed monolayers (low compressibility) which can be desorbed more easily (Pollard *et al.* 2002). It was implied that the procedure of defatting the lupin products does not damage the lupin protein or other ingredients (Xu & Mohamed 2003), and increases the foaming capacity of the lupin products, although these foams are less stable than the undefatted protein concentrate and flours (Pollard *et al.* 2002). The method of fat extraction used can have a marked effect on the lupin properties. The solvent, *n*-hexane, markedly affects the functionality by removing apolar lipids such as triglycerides and excluding polar lipids such as fatty acids and phospholipids (Dervas *et al.* 1999). This extraction agent can be used at a ratio of 1:3 (Xu & Mohamed 2003) or 1:4 (Dervas *et al.* 1999) (lupin product/hexan, w/v). The solvent, methanol, used for fat extraction of concentrated lupin flour, also markedly affects the functionality by excluding apolar lipids. Triglycerides solubility in alcoholic solvents increases with the chain length of the hydrocarbon moiety of the alcohol, accordingly they are generally more soluble in ethanol and completely insoluble in *n*-butanol (Dervas *et al.* 1999).

Lupin proteins possess important emulsifying properties (Pozani *et al.* 2002) and are expected to contribute to the stabilisation of fat particles. Additionally, their gel-forming ability allows them to strengthen the structure of a processed/cooked product (Drakos *et al.* 2007). It was stated that lupin protein concentrates have a better emulsifying capacity and a poorer emulsion stability than whole flour (Pollard *et al.* 2002). Raymondo *et al.* (1998b) increased the emulsion stability of lupin proteins by thermal treatments, which favoured protein binding, yielding the development of an entanglement network. The emulsifying properties are thus a promising functional characteristic for further development of lupins utilisation (Pollard *et al.* 2002).

Lupin protein isolates and concentrates

Protein concentrates (containing 60–70% of crude protein) (Wasche *et al.* 2001; Chapleau & de Lamballerie-Anton 2003; Sujak *et al.* 2006) and isolates (90% protein minimum dry weight basis) obtained from lupins have a potential as an additional source of protein for human nutrition (El-Adawy *et al.* 2001) with good functional and nutritional properties (Raymundo *et al.* 1998; Lqari *et al.* 2002; Martínez-Villaluenga 2009; Pastor-Cavada *et al.* 2009), improving the technological properties and giving thus higher quality foods (Torres *et al.* 2007; Gulewicz *et al.* 2008).

To prepare protein concentrates of higher protein contents from lupin flour, it is necessary further to process flours to remove some of the low-molecular-weight components (water-soluble sugars, ash, and other minor constituents of flours). In the process used, the non protein constituents are extracted with aqueous alcohol, leaving the proteins and polysaccharides which are subsequently desolventised and freeze-dried to yield the concentrate (Dervas *et al.* 1999).

Two semi-industrial preparations of lupin proteins type E and type F are the most characterised protein isolates so far and have been shown to possess specific functionalities (Wäsche *et al.* 2001). Specifically speaking, Type E, which contains α-, β-, and δ-conglutins shows an extremely good emulsifying capacity and emulsion stability, as compared to similar fractions from other legume seeds, while Type F, which contains γ-coglutins, has a great solubility over a wide range of pH values and a very good foaming activity and foam stability properties. It has also been observed that high pressure treatment reveals positive effects in decreasing the size of droplets, flocculation, and creaming index (Chapleau & de Lamballerie-Anton 2003; Duranti *et al.* 2008).

Separate lupin protein fractions, by allowing the tailoring of functionalities, are also excellent candidates for the development of a variety of food products, including pasta, crisps, bread, biscuits, and cakes, as well as of fine bakery and confectionery products (Martinéz-Villaluenga *et al.* 2006b). In particular, lupin protein isolates were successfully tested as ingredients in the production of muffins in which egg and milk proteins had been totally replaced, and in diet biscuits with high protein contents. More recently, lupin flour and different protein fractions have been included in pasta and bakery products. Furthermore, a patent has been deposited on the preparation of pasta enriched with lupin protein isolates and concentrates (Duranti *et al.* 2008).

Lupin-derived protein ingredients have to provide both adequate nutritional and useful technological functionality to the foods in which they are incorporated in order to meet the needs of consumers and the food industry (Zralý *et al*. 2008).

CONCLUSION

The need for plant-derived nutrients is expected to grow due to the economic and environmental factors as well as the support of the development of new, safe, and healthy foods which may respond to the consumers' increasing awareness of the impact of dietary habits on human well-being (Duranti *et al.* 2008). Leguminous seeds present one of the most promising alternative protein sources for the nutritional supplementation and technological improvement of traditional foods (Martínez-Villaluenga *et al*. 2009).

Lupin has attracted interest worldwide as a potential food ingredient suitable for human consumption (Fudiyansyah *et al.* 1995; Martinéz *et al.* 2006b). Its special composition, mostly consisting of protein, fibre, and limited amounts of oil, means that this seed can play a valuable role as a rich source of a variety of specific ingredients. Various food industries are becoming aware of the potential of lupin seed and a growing number are available of products including lupin flour and protein or fibre fractions (Duranti *et al*. 2008).

In the bakery industry, lupin derived raw materials can be used for the manufacture of different bakery products (Erbas *et al.* 2005; Scarafoni *et al.* 2009). Generally, they can be added to pasta, crisps, and bread (Erbas *et al.* 2005). Besides, lupin flour has been shown to improve the microdistribution of water in doughs and mixtures: the products can then better resist freezing and thawing, the preparation of bread dough can be easier, shrinking can be limited; to have a good emulsifying power; to give the products a yellow colour; and to change some rheological parameters, like cripness and smootness (Tronc 1999).

For more complex implementation of lupin products to bakery and other food products, the further research activities and reciprocal cooperation among lupine cultivators, processors, and food manufacturers is necessary.

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