

THE USE OF LUPINS IN HUMAN NUTRITION

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ABSTRACT

The rising demand for food for human consumption will necessarily result in the increased cultivation of products with high metabolizable energy and nutritional values. Among the legumes, the seeds of the sweet lupin as well as low alkaloid fractions of the bitter lupin are suitable food components for human nutrition. Composition data, nutritional value and safety of lupin seeds and fractions have been checked by chemical determination and in experiments both with animals and in human studies. Lupin seeds as a new food or part of a food will help to cover the essential nutrient requirements, in particular amino acids, of the population in the developing countries. Furthermore, in developed countries, advice of nutritionists to consume more products of vegetable origin with a lower calorie content and less of animal-based foodstuffs has enlarged the market for such "alternative green" products, including fermented lupin products. Small amounts of lupin seed flour improve quality parameters of bakery products, utilizing the functional (technological) properties such as water-binding to increase freshness and prolong shelf-life. Many of the so-called antinutritive factors (except the toxic alkaloids) are now seen as important factors of a functional food. In this respect, the potential importance of Lupin seeds is as yet undiscovered.

KEYWORDS

human nutrition, nutritive value, lupin food, functional properties

INTRODUCTION

With continued population growth and income increase, global demand for food is expected to increase substantially during the coming decades. The world's population today numbering 5.5 billion people will most likely increase by nearly 100 million a year. Over 93% of this growth will take place in the developing countries, especially in Asia and Latin America. In a series of papers: "A 2020 Vision for Food, Agriculture and the Environment" the International Food Policy Research Institute, Washington, DC, deals with the main problems on various aspects for action on how to meet future world food needs.

Concerning these three topics: food, agriculture and environment, lupins may contribute positively as a traditional food of high nutritional value, as investigated and tested scientifically with modern methods during the last three decades. Lupins grow on poor sandy soil under

unfavorable conditions and are improving the quality of the soil via nitrogen collecting root microorganisms. Crop rotation with lupins also enables a reduction in the amount of fertilizer used, which is a favorable ecological aspect.

NUTRITIONAL VALUE OF LUPINS

There are more than 200 varieties of lupins worldwide. These can be differentiated by various parameters: the appearance of the plant, the color of the blossoms, the appearance and the size of the seeds, and other characteristics. The following is the well-known classification of the main varieties of lupins: *L. albus* = white lupin, *L. luteus* = yellow lupin, *L. angustifolius* = narrow leaf (blue lupin), *L. mutabilis* = lupin from the Andes and *L. polyphyllus* = perennial lupin. Nutritional values relevant to human nutrition are mean values, which vary considerably from variety to variety. For example, in most types the oil content is between 8 and 15%, whereas *L. mutabilis* can contain up to 24% oil.

PROTEIN QUALITY AND DIGESTIBILITY

Adult humans require eight essential amino acids in their diet to maintain normal body functions. The remaining non-essential amino acids can be used directly or to synthesize other non-essential amino acids. The protein content of the seeds is very high in all varieties and can constitute more than half the total weight. As a mean value for the seeds plus hull, this is approximately 35-40 g 100 g⁻¹; for the dehulled seed 45-50 g 100 g⁻¹ (Schoeneberger *et al.* 1982). The protein bodies mainly belong to globulins, which themselves are divided into 5 fractions (Hill 1977). The digestibility and bioavailability of the protein are comparable to soy protein. In both legumes sulphur-containing amino acids are the limiting amino acids. The amino acid lysine is present in relatively large quantities. It is well known from ancient cultures that a combination of legumes such as lupin, soy or beans with cereals e.g. barley, maize or rice results in a high supplemental effect, which increases the nutritional value of the mixture and brings it almost in line with animal protein. The reason is an improved supply of methionine + cysteine and lysine provided by the combination. In practice, the amount of protein required to cover the needs is decreasing, if a combination of proteins with supplemental effect is consumed. The cholesterol-lowering effect of some plant proteins in comparison to casein, for example soy protein, was not seen with lupin seeds as a protein source in experiments with rats (Chango *et al.* 1998). The potential

allergenicity of various plant foodstuffs was determined in tests with school children. It was proved that soybean protein has a greater potential allergenicity than lupin seed protein (Feldheim *et al.* 1989).

LIPIDS

The triglycerides of lupins feature a high proportion of oleic acid (44%), linoleic acid (36%), as well as linolenic acid (2%) (Feldheim 1991). This pattern of fatty acids with a high concentration of unsaturated fatty acids is in agreement with modern nutritional concepts. Increasing fat content in seeds of a variety leads to a rise in oleic acid concentration. The most important saturated fatty acid is palmitic acid (12%). The lecithin content of the oil is approximately 2%. The steroids present in the non-saponifiable fraction of the oil contain β -sitosterol and campesterol as the main components, and stigmaterol and avenasterol in lower concentrations (Feldheim and Eckhardt 1982). Vitamin E is present in the seeds mainly in the form of gamma-tocopherol, which is highly effective as an antioxidant, and protects the unsaturated fatty acids. During germination, the oil content of the seeds as well as the concentration of gamma-tocopherol decreases, whereas in the same time the fraction of alpha-tocopherol is increasing (Feldheim *et al.* 1986). Carotenoids are also present in the seed as additional protective substances.

CARBOHYDRATES AND DIETARY FIBER

Values reported in the literature for seed carbohydrate content are too high. There are two reasons for this over estimation: (I) they were determined as N-free substances or (II) estimation as residue differences during extraction carbohydrates by difference. Starch is not present in lupin seeds. The oligosaccharide fraction (8.5-10%) contains stachiose, verbascose and ajugose. Saccharose was established as a disaccharide. 100 g of the hull of lupin seeds contain 95 g fiber determined by the Theander and Westerlund method (1986). The fiber content can be split into 77 g insoluble and 15 g soluble fiber (Feldheim and Wisker 1986). The hull mainly consists of cellulose, xylose, and uronic acid, which are present as other constituents. Thus the composition of the lupin hull much resembles that of the soy hull. The fiber content of the dehulled seed is 14-20%, the main structure components are galactose and arabinose as well as uronic acid and glucose. As with soy, arabino-galactanes are important components of the cell wall material of the cotyledon. In fermentation tests with microorganisms of the human large bowel, it was shown that extensive biodegradation and formation of short chain fatty acids occurs (Feldheim 1994).

WATER SOLUBLE VITAMINS

There are a few data dealing only with the vitamin content of lupin seeds. The amounts are similar to that of other legume species. For *L. angustifolius*, the contents of vitamins of the B-group are (in mg 100g⁻¹ seed) thiamin

0.33, riboflavin 0.24, biotin 0.004, folic acid 0.04, niacin 3.6 and pantothenic acid 0.16 (Hill 1977).

MINERALS AND TRACE ELEMENTS

The mineral (ash) content of different lupin varieties fluctuates between 3.2 and 4.6g 100g⁻¹ dry matter. Determination of mineral and trace element constituents gave the following results (in mg 100g⁻¹): calcium between 128 and 260, Magnesium 121-234, Sodium 11-44, potassium 525-1340; iron 3.6-6.5, zinc 4.4-6.4, manganese 2.6-10.7 and copper 0.5-1.1. Legumes are considered to be a good source of minerals and trace elements, and lupins feature a higher calcium and phosphorus content than cereals. The content of trace elements can vary considerably depending on the variety of lupin and the mineral content of the soil (Hill 1977).

SWEET LUPIN VS BITTER LUPIN

Sweet lupin flour, obtained by a simple grinding process, features promising characteristics for becoming an element of the diet, mainly due to a high content in proteins mainly and a very low concentration of alkaloids (Hackbarth and Husfeld 1939). The protein content is comparable to that of soybeans and can be as high as 50%. The nutritional value of lupin seed is well analyzed and documented in extended animal and human studies.

The presence of alkaloids with a bitter taste is undoubtedly a factor that could limit the acceptance of bitter lupin seed for human consumption. Concerning bitter lupin seeds, primitive extraction procedures have been used for centuries in South America. Rinsed in running water, most of the alkaloids of the cooked seeds and also parts of other water-soluble nutrients are extracted. As a result of modern processing technology, lupin protein concentrates or isolates, and fractions of bitter lupin seeds rich in dietary fiber are available after the removal of the alkaloids. For example, after extraction and drying, a protein isolate with 96g protein 100g⁻¹ dry matter and an alkaloid content of less than 0.02-0.01% was obtained.

APPLICATIONS OF LUPINS OR LUPIN FRACTIONS IN HUMAN NUTRITION

The range of possible applications for lupins as a constituent in human nutrition is basically the same as for soybeans. Areas of use are to improve the supply of nutrients, mainly proteins, but also other essential nutrients for the consumer in the developing countries. Well known examples were reported as long as 20 years ago at the First International Lupine Workshop at Lima: the traditional use of soaked seeds of bitter lupins in Peru as soups, legumes or salads and the addition of lupin flour in the range of 10-15% to composite flour in baking (Martins *et al.* 1991). The acceptance of the light yellow protein enriched breads, rolls, cakes, cookies and other bakery products is very high. The carotinoid content of the flour gives the products an attractive slightly yellow tone, the taste and aroma can be described as slightly nut-like. At the same time, reports

from Temuco, Chile were presented on the use of sweet lupin flour in infant formulas and in the meals of school children. A plant-milk, made from lupin seeds by extraction, was recommended.

The extended interest and growing cultivation of lupins in Australia and New Zealand and the introduction of lupins as raw material from there into the East Asian markets, particularly in South Korea, opened a new use for lupin seeds in human nutrition in this area. Instead of soybeans as the basic ingredient for processing, lupin seeds were used for plant-milk or different fermented products such as sauces or lactic acid beverages and yoghurts.

The increase of overnutrition and the rise of nutrition related diseases are of growing concern in many developed countries. As an alternative, diets with a higher portion of plant derived foodstuffs are recommended to lower the fat and energy intake. In industrialized western countries, there is a small but growing market for such alternative products as replacements for foods of animal origin. Many of the products are soybean analogs like tempeh, tofu, miso or other fermented items. As an advantage of the new products, the often bean-like taste of soy products is absent. For example, the processing of lupin protein concentrates for a plant spread and a cheese like product (Harzer Käse, Handkäse) from lupin curds is presented in detail. For all these products, lupin flours or lupin fractions are the main raw ingredients.

Another important application is the use of lupin flour in smaller amounts to improve the functional (technical) properties of foods. Flours are available as a full-fat (not quite as rich as soy flour) or de-fatted flour. For example, full-fat toasted lupin flour is already in widespread use in the bakery industry in such products as sponge cakes, Stollen, waffles, biscuits, fruit cake bases, frozen pastries, snack products etc., as well as in fine bakery products and in confectionery. For declaration purposes, the terms sweet lupin flour, pulse or legume flour are accepted. Such products are already for sale in Belgium, Holland and Germany (and a selection will be offered during the next coffee break). The protein content of the seed flour used is approximately 38-40% and can be regarded as a satisfactory alternative to full-fat soy flour. At the same time, a fat content of 8-10 % means that it is likewise an alternative to de-fatted soy flour. If necessary, this fat content, which is slightly lower than in soy flour, can be supplemented with lecithin.

Noodles containing 10% lupin flour are better than a reference product without lupin flour with regard to appearance, acceptability and cooking performance. In general, some of the quality parameters of food are improved by adding small amounts of lupin seed flour during processing.

LUPIN SEED AS FUNCTIONAL FOOD?

A new concept of functional food is created in nutritional sciences. It is based on the fact that many foods for

humans, especially of plant origin, show more components than the well-known calorie-rich macronutrients and essential nutrients like amino acids, vitamins and minerals. In plants these so-called non-nutrient (for humans) but bioactive substances are used to defend the plant system against environmental enemies or stress. It is speculated that these plant components are of a certain importance for humans, too, in reducing the risk of chronic diseases like cardiovascular disease, some cancers and obesity and so improving human health and wellbeing.

In this respect of the legume sector, a lot of investigations have been performed with only soybeans and the results published (Messina 1995). Most of the antinutritional factors of the soybeans were declared to be functional because of their estrogenic, antiestrogenic, anticarcinogenic, antiviral, antifungal or antioxidant activities (Mazur *et al.* 1998). As far as lupin seeds are concerned, only a few investigations have been carried out so far. With soybeans, the potential functional factors could be dietary fiber and oligosaccharides as selected substrates of the microflora of the colon showing prebiotic properties and perhaps with a cholesterol lowering effect. Phytoestrogens (isoflavonols and lignans) may be involved in hormone related carcinogenesis like mammalian or prostate cancer. In the seeds of *L. mutabilis*, formononetin, genistein, and total secoisolariciresinol were detected in concentrations of 23.1, 2.42 and 3.1 $\mu\text{g } 100\text{g}^{-1}$, respectively. Compared with soybeans, these amounts are small. For phytate (inositol hexaphosphate) an anticancer function is implied. Saponins as anticarcinogens show a dose dependent inhibitory effect on human carcinoma cells HCT-15. The protease inhibitor and the Bowman-Birk inhibitor suppress carcinogenesis *in vitro*. There is much evidence to suggest that diets containing large amounts of these functional (antinutritional) factors are associated with overall low cancer mortality rates, particularly for cancers of the colon, breast and prostate. All these components are detectable in soybeans and lupin seeds as well - their role must be looked at more closely in future.

LITERATURE CITED

- Ballester, D., P. Carreno, X. Urrutia, and E. Yanez. 1986. Chemical composition and nutritional quality of sugar cookies containing full-fat sweet lupine flour. *J. Food Sci.* 51:645-646.
- Chango, A., C. Villaume, H. Ming Bau, A. Schwertz, J.P. Nicolas, and L. Mejean. 1998. Effects of casein, sweet white lupin and sweet yellow lupin diet on cholesterol metabolism in rats. *J. Food Sci. Agric.* 76:303-309.
- Feldheim, W. 1991. Use of lupins as source of lipids and dietary fibre in human nutrition. p.124 -131. *IN* D. von Baer (Ed.) Proc. VIth Int. Lupin Conf., Temuco-Pucon, Chile. 25-30 Nov. 1990.
- Feldheim, W. 1994. Fermentation of lupin fibre. p. 445 - 451. *IN* J.M. Neves-Martins and M.L. Beirao da Costa (Eds.) Proc. VII. Int. Lupin Conf. Evora, Portugal. 18-23 Apr 1993.

- Feldheim, W. 1996. Sweet lupin flour - a very healthy asset. *J. Food Ingrid.* 5/98:25-26.
- Feldheim, W., and W.R. Eckardt. 1982. Unsaponifiable lipids from lupin oil. p. 499 - 502. *IN* R. Gross and E.S. Bunting (Eds.) *Proc. 1st Int. Lupin Workshop*. Lima-Cuzco, Peru 12-21 Apr. 1980.
- Feldheim, W., and E. Wisker. 1986. Use of lupin seed hull for enrichment with dietary fibre. p. 298. *In* Anon., *Proc. IV. Int. Lupin Conf.* Geraldton, Western Australia. 15-22. Aug. 1986.
- Feldheim, W., G. Feldheim, U. Gross, and R. Gross. 1989. Lupins and allergic reactions. *Lupin Newsletter* 13:41-45.
- Feldheim, W., G. Lausch, H. Schulz, and P.H. Cummings. 1986. Effect of germination on tocopherol pattern of seeds of wheat, lupin, soya and sunflower. *Nutrition* 10:21-24.
- Hackbarth, J., and B. Husfeld. 1939. *Die Süßlupine*. Verlag Paul Parey, Berlin.
- Hill, H.D. 1977. The composition and nutritive value of lupin seed. *Nutr. Abstr. & Rev.* 47 B:511-529.
- Martins, M., G. Sena, and M.L. Beirao da Costa. 1991. Lupin breakfast cereal production by extrusion cooking. p. 35. *IN* D. von Baer (Ed.) *Proc. VII. Int. Lupin Conf.* Temico-Pucon, Chile. 25-30 Nov 1990
- Mazur, W.M., J.A. Duke, K. Wähälä, S. Rasku, and H. Adlerkreutz. 1998. Isoflavonoids and lignans in legumes: nutritional and health aspects in humans, *Nutr. Biochem.* 9:193-200.
- Messina, M. 1995. Modern applications for an ancient bean: soybeans and the prevention and treatment of chronic disease. *J. Nutr.* 125:567S-569S.
- Pfeiffer, G., M. Gutman, and B. Müller, 1997. *Lebensmittel aus Lupinen*. *Lebensm. Techn.* 3/97:44-48.
- Schoeneberger, H. R. Gross, H.D. Cremer, and I. Elmadfa. 1982. Composition and protein quality of *Lupinus mutabilis*. *J. Nutr.* 112:70-76.
- Theander, O., and E.A. Westerlund. 1986. Studies on dietary fiber. 3. Improved procedure for analysis of dietary fiber. *J. Agric.Food Chem.* 34:330-336.