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Phytic acid and selected mineral composition of seed from wild species and cultivated varieties of lupin

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Seeds of wild lupin species and several cultivars were analyzed for phytate, calcium, zinc, iron, copper and manganese composition. Mineral content showed high variability within varieties, particularly Mn, with 61–327 mg/100 g dry matter for *L. albus* and 1·5–38 mg/100 g dry matter between other species. The ranges (mg/100 g dry matter) of other minerals were: Ca, 134–350; Fe, 2·4–10·8; Zn, 2·9–17·6; Cu, 0·4–1·4. Phytate varied from 0·4 to 1·2 g/100 g dry matter with cultivars of *L. albus* and *L. cosentinii* presenting the lowest values. Very low phytate:Zn and (phytate × Ca):Zn molar ratios were observed in wild *L. digitatus* (4·4 and 0·3) and *L. pilosis* P23030 (5·3 and 0·3), indicating excellent Zn bioavailability. Phytate:Ca molar ratios of all samples indicate similar or better bioavailability of Ca as compared to other legume seeds.

INTRODUCTION

Lupin seeds have been used as a source of protein and oil from ancient times. Interest in a wider utilization of this legume seed is mainly due to its similarity to soybeans as a high source of protein and to the fact that it can be grown in more temperate climates and is tolerant to poor soils (Hill, 1977).

Lupins, as other legume seeds, are also good dietary sources of minerals and some remarkable differences have been described in mineral contents either between lupin species or in comparison to other legumes. Lupin seeds have low levels of calcium and phosphorus but are similar or even better sources of trace minerals such as iron, zinc and copper when compared to other legumes (Hill, 1977; Sathe *et al.*, 1984; Donangelo *et al.*, 1986). Another striking observation is the very high level of manganese found in some varieties of *L. albus* (up to 350 mg/100 g) in comparison to other species (less than 4 mg/100 g) (Gladstones & Driver, 1962; Burbano *et al.*, 182; Savage *et al.*, 1988). Mineral compositions of lupin seeds have been measured mainly in cultivars (Hill, 1977; Burbano *et al.*, 1982; Savage *et al.*, 1988) but little is known about mineral composition of wild lupin species.

The biological utilization of dietary minerals is dependent upon several factors including antinutritional components such as phytate which may adversely affect mineral absorption (Santström, 1988). Therefore, the mineral content of a food product or diet should be determined together with its phytate content, in order to have a better evaluation of its potential as a mineral source.

Phytate is an abundant plant constituent usually found in high levels in cereals and legumes (Harland & Oberleas, 1987). It may be anticipated, therefore, that lupin seeds may contain substantial amounts of this compound since data on phytate composition of lupin seeds are scarce.

In this work, the seed compositions of several cultivars and wild lupin species were studied in terms of phytic acid, calcium, zinc, iron, copper and manganese. Phytate:mineral molar ratios were calculated for comparison of the potential mineral bioavailability of the seeds.

MATERIALS AND METHODS

Seed samples of four cultivars and eight wild lupin species, including several varieties each, were analyzed. *L. albus* samples were provided by the Instituto Agronômico do Paraná, Brasil, and *L. microcarpus* by the University of Concepción, Chile. Other samples were provided by the University of Western Australia. All samples were carefully brushed to remove superficial loose particles and milled in stainless-steel equipment to pass a 0·75-mm sieve before analysis.

Zn, Fe, Cu and Mn were measured by flame absorp-

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tion spectrophotometry (Varian, New Jersey, USA, model AA 1475), after dry ashing of samples at 470°C and solubilization of ash with HCl (6N) (final concentration 1·2 N). Conditions were carefully controlled to avoid contamination or loss of minerals. Intra-assay ($n = 10$) coefficients of variation (CV) were 3·4, 3·9, 4·0 and 2·0% for Zn, Fe, Cu and Mn, respectively. Recovery of added known amounts of standards to samples gave 98–105% of expected values for all minerals.

Ca was analyzed in the ash solution of samples by the methyl–thymol blue reaction (Gindler & King, 1972) using a commercial kit (Biolab, Rio de Janeiro, Brazil). Intra-assay ($n = 6$) CV was 2·7% and recovery of known amounts added to samples was 95%.

Phytic acid was determined by the method described by Harland and Oberleas (1977). The phytic acid content was calculated based on phosphorus determination (Bartlett, 1959) and assuming six phosphorus atoms per phytic acid molecule. Coefficient of variation of the overall method was 7·7%.

Results are the mean of triplicate determinations and expressed as g/100 g dry matter.

RESULTS AND DISCUSSION

The mineral levels of the cultivars and wild lupin species studied (Table 1) are within the range reported for cultivars of lupin seeds (Hill, 1977; Burbano *et al.*, 1982; Savage *et al.*, 1988). There was some variability in mineral content that in general appeared higher between species than for different varieties within the same species. Considering each individual mineral, calcium and copper contents showed little variation, while manganese was the most variable in the lupin seeds. Varieties of *L. albus* had Mn levels about 10–100 times higher than other species as previously observed (Gladstones & Drover, 1962; Burbano *et al.*, 1982; Savage *et al.*, 1988). These levels may be of concern in terms of toxicity. The upper limit of safe intake of Mn for humans is 5 mg/day (National Research Council, 1989). Signs of toxicity in animals have been observed with intakes of 10 mg/100 g of diet or more (Hurley & Keen, 1987). Therefore, seeds with such high Mn levels should be used with caution both for human and animal consumption. Regarding the other species, most of the varieties studied had Mn levels of *c.* 4–5 mg/100 g dry matter; a few varieties had higher levels, particularly *L. micranthus* (38 mg/100 g dry matter), and *L. hispanicus* had relatively low Mn levels (1·5 mg/100 g dry matter).

Based on our data, it is possible to identify wild lupin varieties with desirable mineral profiles. For example. *L. micranthus* had higher Ca levels compared to other lupin seeds, while *L. microcarpus* has higher Fe levels; *L. digitatus* and one variety of *L. pilosus* were substantially higher in Zn and *L. hispanicus* had very low Mn levels, similar to Mn levels found in other legumes such as *Phaseolus* beans (1–2 mg/100 g) (Sathe *et al.*, 1984).

Table 1. Mineral levels in cultivars and wild lupin seeds (mg/100 g, dry basis)

Type	Ca	Fe	Zn	Cu	Mn
Cultivars					
L. albus					
Halbitter	134	7·7	4·7	1·1	327
VegaT85	147	7·3	4·8	1·0	61·0
Kalina	198	3·5	4·5	0·8	139
L. angustifolius					
Marry	180	4·9	5·0	0·6	4·0
Yandee	225	5·3	4·9	0·5	4·5
Illyarrie	191	4·8	4·8	0·4	4·0
Chittick	212	4·4	4·8	0·6	4·7
Wandoo	217	3·2	4·8	0·5	4·0
Danja	168	4·8	5·5	0·5	3·6
L. cosentinii					
Chapman	192	6·1	5·9	1·4	10·3
Erregulla	168	5·5	5·9	1·1	5·4
L. atlanticus					
AM 318	193	4·3	7·3	1·0	4·9
Wild seeds					
L. pilosus					
GRC 5020p	220	7·8	6·2	0·8	5·7
P 23339	215	6·7	6·3	1·0	3·9
P 23030	245	7·0	14·7	0·6	5·5
L. atlanticus					
P 22926	197	5·1	7·2	0·8	4·2
L. palestinus					
P 229432	203	3·6	6·7	1·0	4·4
L. poliphilus	166	4·7	2·9	0·9	7·7
L. micranthus					
GRC 5044u	350	9·7	4·6	1·1	38
L. digitatus					
EGY 5251	233	7·5	17·6	1·1	4·4
L. hispanicus					
P 23015	235	2·4	6·0	0·6	1·5
L. microcarpus	284	10·8	8·0	1·4	7·7

Phytic acid content of the lupin seeds ranged from 0·4 to 1·2 g/100 g dry matter (Table 2), with little variation within each species. The levels observed in the lupin seeds were in the same range reported for common beans, lentils and peas (Donangelo, *et al.*, 1986; Harland & Oberleas, 1987) and in the same range (Davies & Reid, 1979) or lower (Harland & Oberleas, 1987) than reported for soybeans. Particularly low levels (less than 0·7 g/100 g dry matter) were found in *L. albus, L. cosentinii* cultivars Chapman and Erregulla and *L. poliphilus*. These species and varieties may be the choice when considering lupin seeds with low phytic acid content.

Phytate may reduce the intestinal absorption of several minerals such as Mg, Ca, Fe, and Zn by forming insoluble compounds in the conditions of the intestinal tract. Zn is the most affected as demonstrated by several studies both in animals and humans (Sandström, 1988). It has been shown that calcium potentiates the negative effect of phytate on Zn absorption (Forbes *et al.*, 1984). Phytate: mineral molar ratios rather than absolute phytate levels are limiting in terms of mineral bioavailability. Phytate: Zn molar ratios higher than 10 and (phytate × Ca): Zn molar ratios higher than 0·5 are considered potentially inadequate in

Table 2. Phytate levels and phytate: Mineral molar ratios in cultivars and wild lupin seeds

Type	Phytate (g/100 g)[a]	Molar ratios		
		Phytate:Ca	Phytate:Zn	(Phytate × Ca):Zn
Cultivars				
L. albus				
Halbitter	0·5	0·2	10·9	0·4
VegaT85	0·6	0·3	11·8	0·4
L. angustifolius				
Marry	0·8	0·3	15·2	0·7
Yandee	0·8	0·2	14·7	0·8
Illyarrie	1·1	0·4	23·2	1·1
Chittick	0·8	0·2	16·8	0·8
Wandoo	0·7	0·2	15·0	0·8
Danja	0·8	0·3	15·1	0·6
L. cosentinii				
Chapman	0·4	0·1	7·2	0·4
Erregulla	0·6	0·2	10·9	0·5
L. atlanticus				
AM 318	1·1	0·3	14·4	0·6
Wild seeds				
L. pilosus				
GRC 5020p	0·9	0·2	14·2	0·8
P 23339	0·9	0·2	13·3	0·7
P 23030	0·8	0·2	5·3	0·3
L. atlanticus				
P 229256	1·2	0·4	15·9	0·8
L. palestinus				
P 229432	1·2	0·4	17·2	0·9
L. poliphilus	0·7	0·3	23·3	1·0
L. micranthus				
GRC 5044u	0·9	0·2	19·7	1·7
L. digitatus				
EGY 5251	0·8	0·2	4·4	0·3
L. hispanicus				
P 23015	1·2	0·3	19·1	1·1

[a] Dry basis.

terms of Zn bioavailability (Ellis *et al.*, 1987). These ratios were calculated for the lupin seeds studied (Table 2). Values obtained were quite variable and in most cases compatible with low Zn availability as observed in other legume seeds (Erdman, 1981). However, very low molar ratios were observed in some of the wild species such as *L. digitatus* and *L. pilosus* P23030, so that these varieties may be of interest if Zn bioavailability needs to be optimized.

Petterson *et al.* (1990) reported better Zn absorption, measured in human volunteers, from a meal based on *L. angustifolius* flour (28%) as compared to a similar meal based on soy flour (14%). The lupin meal had a phytate:Zn ratio of 17 and the soy flour meal a ratio of 24·6. It is possible that other Lupin varieties with more favourable molar ratios and higher Zn contents such as *L. digitatus*, may have even higher Zn absorptions as compared to soybean.

Phytate:Ca molar ratios greater than 0·2 have been considered to create a risk of calcium deficiency (Morris & Ellis, 1985), although the negative effect of phytate on calcium absorption remains controversial (Greger, 1989). According to the phytate:Ca molar ratio calculated for the lupin seeds studied (Table 2), nearly half of the samples showed ratios above 0·2 both in cultivars and wild seeds.

The data obtained in this work are relevant for selection of higher-mineral nutritive-value lupin species and varieties. In addition, breeding programmes based on these data may be directed to produce low phytate seeds and, consequently to improve mineral bioavailability in the grains.

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