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Efecto del tratamiento térmico sobre la composición química y minerales en semillas de lupinos silvestres

Effect of thermal treatment on the chemical composition and minerals of wild lupin seeds

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ABSTRACT

Wild lupine consumption has restrictions due to the presence of alkaloids; however, these components can be reduced with a suitable thermal treatment. The aim of this research was to determine the thermal effect on chemical composition and minerals of wild lupine. *Lupinus mexicanus* had a reduction in protein and fat contents of 34.76 to 33.11 and 6.10 to 5.41 g/100 g of sample respectively, and an increase in ash and dietary fiber of 3.84 to 4.53 g/100g and 20.9 to 28.48 g/100 g respectively. *L. mexicanus* raw seeds revealed the highest Ca content (3,252 mg/kg), *L. elegans* was the highest in Mg with 2,656 mg/kg. Highest Fe content was found in *Lupinus rotundiflorus* (82.8 mg/kg), and *Lupinus exaltatus* in Cu (184.4 mg/kg). All species showed similar Zn content of 73.3 mg/kg (*Lupinus montanus*) to 89.6 mg/kg (*L. exaltatus*). In all species the Cu content decreased, mainly in *Lupinus elegans* with a loss of 76,71 %.

Key words: *Lupinus*, legumes, minerals, thermal effect, dietary fiber.

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INTRODUCTION

Legumes are the most important vegetable source of protein and represent approximately 20% of human diets. Throughout history they have been a very important food resource, also they are an inexpensive source of dietary fiber (DF) and minerals [1].

The legume consumption presents inconveniences because of presence of antinutritional and toxic factors, nevertheless these components can be eliminated or decreased with an adequate thermal treatment [2, 3], but this treatment also affects the nutrients so it is necessary to know its effect on them.

Dietary fiber (DF) is one of the most important nutritional ingredients used in functional foods and in 1980's decade it was one of the first ingredients associated with health [4], given that epidemiologic studies have suggested there is a relation between a decrease in DF consumption and an increase

in gastrointestinal illnesses [5], hypercholesterolemia and colorectal cancer [6]. The DF is non-digestible carbohydrates and lignin which are inherent on the plant's cell wall and for their non-digestible characteristics some DF are considered prebiotic, a growth stimulant of beneficial intestinal bacteria, which improves the health of host [7].

Even though legumes are an important source of DF there are few studies on their modification after being treated thermally [2, 8].

Lupin kernel flour (LKF) is a novel food ingredient that is high in protein and fiber, and to show that partial substitution of refined wheat-derived carbohydrate in bread with protein and fibre from LKF can reduce appetite and energy intake acutely. In addition, several studies have suggested that lupin may reduce cholesterol concentrations and benefit glucose and insulin metabolism [9].

In this respect, species of the *Lupinus* genus (legumes)

are currently receiving great interest as a promising source of nutritional ingredients, and in countries such as Australia, Poland, Germany, Chile, and Ecuador, different species are being cultivated such as *L. albus*, *L. angustifolius*, *L. luteus* and *L. mutabilis* [10] and incorporating their seeds into different foods for human and animal consumption [11].

Lupin cultivation represents 10% of the world's grain production, currently the largest production is in Australia (779,242 tons per year on average in the last five years) where in 2009, the FAOSTAT reported a cultivated surface area of 662,712 Ha of this legume, which represents 85% of the lupine cultivation in the world.

In the other hand, in Mexico there are close to 100 native species of *Lupinus* widely distributed, representing a great potential due to high protein content which varies from 30-40g/100 g in dry basis and of oil of 8-12g/100 g depending on the species, variety, and environmental conditions [12, 13]. However, their use is limited by quinolizidine alkaloid content which makes the seed bitter and toxic, nevertheless these compounds may be removed up to a 95% through an extraction with boiling water [2, 14].

Due to the aforementioned, this investigation analyzed the thermal effect (cooking) on chemical composition, total dietary fiber and minerals content in seeds of five species of wild *Lupinus* from Jalisco state, Mexico.

MATERIALS AND METHOD

Lupin samples: Mature seeds from *L. rotundiflorus*, *L. exaltatus*, *L. elegans*, *L. montanus* and *L. mexicanus* were collected in various regions in Jalisco state of Mexico during the spring-fall seasons of 2010. All species were botanically classified and deposited in Herbarium of Botany Institute of the University of Guadalajara (IBUG) Mexico.

Chemical analysis: From the collected seeds, 500g of each species were boiled in bidistilled water (1:5 w/v) at atmospheric pressure for 3 hours, with water replacements, the raw and boiled seeds were dehydrated at 55°C for 48

hours on a forced air furnace and ground to a size of 0,5mm of diameter to carry out a chemical analysis in triplicate for each samples, in according to standard methods of AOAC [15] fat (930.09), ash (940.26), protein (950.48), and dietary fiber were analyzed by means of the enzymatic-gravimetric method.

Mineral analysis: The content of minerals (Ca, Mg, Fe, Zn, Cu) was carried out in triplicate by means of flame atomic absorption (GBC- AVANTA), the ashes from the samples were diluted in an acid solution and filtered (AOAC [15] method 968.08). Phosphorus was analyzed through the colorimetric method using ammonium molybdenum (AOAC [15] method 965.17).

Statistical analysis: The data was analyzed using t test, with a confidence interval of 95% using the statistical software JMP®.

RESULTS AND DISCUSSION

The results on the chemical composition and the cooking effect on the five *Lupinus* species analyzed are shown in table 1.

Protein value in raw seeds varied depending of species, from 34.76 g/100 g of sample in *L. mexicanus* to 43.93 g/100 g in *L. exaltatus*, the value in this species was greater to that reported early in wild lupins [13, 14, 16]. Also, in *L. montanus* a higher protein content was found (42.42 g/100 g) than those observed by Guemes-Vera et al., [17] of 35.27g/100 g and Lagunes-Espinoza et al., [16] of 38.7g/100 g in this same specie, whereas the values in *L. elegans* (43.66g/100 g) and *L. rotundiflorus* (41.96g/100 g) were slightly lower than those reported by Ruiz and Sotelo [14] of 45.41 and 42.82 respectively. These divergences in chemical composition of the same species is due, according to Wolko et al. [18], to differences in the locality, time of the year or climate conditions of the collected seeds.

Overall, protein content in researched lupines was greater than those found in other Mexico wild species as *L. reflexus* (37.31g/100 g), *L. splendens* (37.2), *L. campestris* (39.7) and *L. barkeri* (37.07 g/100 g) [2, 14, 17] and from Spain, such

TABLE 1

Chemical composition of raw and cooked *L. exaltatus*, *L. elegans*, *L. mexicanus*, *L. montanus* and *L. rotundiflorus* seeds (g/100 g in dry basis)^a

SPECIES		PROTEIN (N x 6.25)	FAT	ASH	DF
<i>L. exaltatus</i>	Raw	43,93 ±0.4	8,76±0.2*	3,47±0.1*	17,72±0.1*
	Cooked	43,46 ±0.5	8,21± 0.1	2,88±0.2	33,06±0.1
<i>L. elegans</i>	Raw	43,66 ±0.2	7,31±0.1*	4,27±0.0	21,07±0.0
	Cooked	43,33 ±0.2	6,42±0.1	4,05±0.1	21,45±0.1
<i>L. mexicanus</i>	Raw	34,76 ±0.3*	6,10±0.2*	3,84±0.5*	20,90±0.5*
	Cooked	33,11 ±0.9	5,41±0.1	4,53±0.0	28,48±0.0
<i>L. montanus</i>	Raw	42,42 ±0.3	7,57±0.2	3,64±0.1*	24,63±0.1*
	Cooked	42,20 ±0.1	7,32±0.1	3,25±1.1	26,10±0.1
<i>L. rotundiflorus</i>	Raw	41,96 ±0.1*	6,45±0.1	3,10±0.1	27,93±0.1
	Cooked	37,52 ±0.3	6,26±0.1	3,04±0.0	27,41±0.0

^aMeans ± standard deviation of three determinations.

*indicate significant difference (p< 0.05) for the same species in raw and cooked seeds.

as *L. gredensis* (23.8g/100 g), *L. mariaejosephi* (32.9) and *L. luteus* (33.6g/100 g) [19, 20] and similar to the domesticated varieties of *L. albus*, *L. luteus* and *L. angustifolius* (30 to 40 g/100 g) [21].

All of the seeds had a slight reduction in protein due to the thermal treatment but not significant, with exception of *L. rotundiflorus* with a significant reduction ($p < 0.05$) of 41.96 to 37.52 g/100 g. These results do not coincide with those reported by Jiménez et al., [2] whom observed an increase of this nutrient in *Lupinus campestris* seeds of 39.7g/100 g to 49.7g/100 g after being submitted to a six hour thermal treatment. This difference may be possible due to different cooking times. However, our results were similar to those reported in other legumes where cooking of the *Canavalia cathartica* seeds did not show any significant statistical difference in relation to the raw seeds [22]. Additionally, other authors observed a 50% or more reduction in the protein content in traditional legume consumption, such as *Phaseolus vulgaris*, *Cicer arietinum*, *Pisum sativum* and *Lens culinaris* with less or equal cooking times [23], this is because these legumes have a softer coat more than the lupins, which made it easier to solubilize the proteins while cooking.

The fat value was 6.1 g/100 g in *L. mexicanus* at 8.76 g/100 g in *L. exaltatus* in raw seeds it was similar to what was found by Ruiz and Sotelo [14] whom reported percentages in wild lupines of 5.79 to 8.89 and less to what was reported in *L. campestris* (10.8g/100 g) by Jiménez et al., [2]. Cooking had an effect on fat to reducing the content in all the analyzed seeds, this does not correspond with what Jiménez et al., [2] who reported an increase in fat was assessed in the *L. campestris* of 10.8g/100 g to 13.2g/100 g with an aqueous thermal treatment. On their behalf, Alajaji and El-Adawy [24] reported that when boiling in water, fat was reduced in chickpea seeds (6.48 to 6.22g/100 g).

Ash content of 3.10g/100 g in *L. rotundiflorus* to 4.27 g/100 g in *L. elegans* was within the reported range by other authors. Ashes presented a statistically significant reduction ($p < 0.05$) by the thermal treatment except for *L. elegans* and

an increase in *L. mexicanus* of 3.84 to 4.53g/100 g.

The loss of total minerals varies with treatment in regards to the element and species. The contact with the water, especially during cooking and blanching, causes considerable mineral loss depending on the solubility of the mineral.

Meanwhile, dietary fiber (DF) in raw seeds showed a greater variation with values of 17.72 g/100 g (*L. exaltatus*) to 27.93 g/100 g (*L. rotundiflorus*). There are no reports on the DF in wild lupines, only in domestic species, such as *L. albus* with 35.3 to 50.4 g/100 g [25] and *L. angustifolius* with 31.6g/100 g [26], these values are greater than those found in the analyzed species in this investigation. The values of wild lupin studied are highest to others legumes reported as soybean, black soybean, azuki bean and mung bean [27].

An increase in DF content was observed by the thermal treatment in all of the analyzed species and statistically significant ($p < 0.05$) in *L. exaltatus*, *L. mexicanus* and *L. montanus* of 17.72 to 33.06 g/100 g, 20.90 to 28.48 g/100 g and 24.63 to 26.1 g/100 g, respectively, similar data was found by Alajaji and El-Adawy [24] where they report a statistically significant ($p < 0.05$) increase in chickpea fiber content when subjected to cooking in water. Lintas et al. [28] recount that thermal treatment may have different effects in the content of DF in food, since cooking promotes the breakdown of components of the DF with proteins and lipids creating essential qualitative and/or quantitative changes.

There is a contradiction between authors when reporting a rise or reduction in the DF as a consequence of cooking. These differences are due to the soluble or insoluble components of the DF which react during the soaking and cooking of the seeds [29].

Minerals concentration in raw seeds varied among species (table 2), in *L. mexicanus* have greatest value of calcium (3252 mg/kg) followed by *L. montanus* (2074 mg/kg) and *L. exaltatus* (2052 mg/kg). These values are higher to the ones reported in *L. montanus* (800 mg/kg) and *L. exaltatus* (1600 mg/kg) from Puebla, Mexico [30]. As well *L. angustifolius* (2200 mg/kg), *L. albus* (2000 mg/kg), *L. mutabilis* (1800 mg/kg) and *L.*

TABLE 2

Mineral content in raw and cooked *L.exaltatus*, *L.elegans*, *L.mexicanus*, *L. montanus* and *L. rotundiflorus* seeds (mg/kg in dry basis)^a

SPECIES		Ca	P	Mg	Fe	Zn	Cu
<i>L. exaltatus</i>	Raw	2052±305	584±321	2330±212*	61,8±7,5	89,6±1,6*	184±3,1*
	Cooked	1700±404	458±43,6	1690±113	49,3±10,0	76,5±5,5	68,5±14,1
<i>L. elegans</i>	Raw	1777±702*	6441±702*	2656±423	70,9±11,3*	73,6±4,4	64,8±4,2*
	Cooked	680± 200	2876±435	2488±121	52,4±5,6	74,8±4,4	15,1±1,2
<i>L. mexicanus</i>	Raw	3252±378	5865±115	2651±618	63,1±11,0	73,7±3,4	70,8±21,4*
	Cooked	3080±435	5425±351	2266±311	8,5±6,6	77,4±4,8	18,8±0,4
<i>L. montanus</i>	Raw	2074±750	7690±458*	2443±802*	77,7±4,2	73,3±5,9*	56,2±8,8*
	Cooked	1278±423	6332±152	1402±70,2	73,7±8,5	59,9±4,1	18,1±0,5
<i>L. rotundiflorus</i>	Raw	1887±503	6166±115*	2213±471	82,8±9,2*	79,0±6,3*	64,9±14,2*
	Cooked	1316±472	3771±556	1652±638	61,2±4,2	62,9±1,2	18,0±0,7

^aMeans ± standard deviation of three determinations.

*Indicate significant differences ($p < 0.05$) for the same species in raw and cooked seeds.

luteus (1500 mg/kg) [32], while the lowest value was found in *L. elegans* (1777 mg/kg).

The P contents had the highest variation from 584 mg/kg in *L. exaltatus* to 7690 mg/kg in *L. montanus*, superior to reported by Pablo-Pérez et al., [30] and with the exception of *L. exaltatus*, the rest of the analyzed species registered higher values of P than *L. luteus* (5100 mg/kg), *L. albus* (3600 mg/kg) and *L. angustifolius* (3000 mg/kg) [31]. In the remainder of the minerals contents were similar between species; *L. elegans* had the highest Mg register with 2656 mg/kg, while *L. rotundiflorus* was the lowest with 2213 mg/kg. These values are greater than those reported in domesticated species of 1400 mg/kg in *L. albus* at 2100 mg/kg in *L. luteus*. The range of Fe was of 61.8 to 82.8 mg/kg, for *L. exaltatus* and *L. rotundiflorus* respectively, whereas the *L. exaltatus* seeds registered the highest values in Zn and Cu with 89.6 and 184 mg/kg respectively, while in *L. montanus* the lowest levels of these elements were obtained with 73.3 and 56.2 mg/kg respectively. These contents were similar to those reported in domesticated lupines [31].

Overall, there was a loss in minerals by the thermal effect (table 2). The most affected was Cu which decreased ($p < 0.05$) in all species, mainly in *L. elegans* from 64.8 to 15.1 mg/kg (loss of 76.7 %), and the lowest was in *L. exaltatus* from 184 to 68.5 mg/kg (loss of 62.85 %).

In P had a significant loss in three species; the highest was *L. elegans* (6441 to 2876 mg/kg, with a 55.34 % of loss), *L. rotundiflorus* (from 6166 to 3771 mg/kg, 38.8% less) and lastly *L. montanus* (from 7690 to 6332 mg/kg, with a loss of 17.66 %). Likewise, the Zn decreased significantly in three species, *L. rotundiflorus*, *L. montanus* and *L. exaltatus*, with losses of 20.38 % (79 to 62.9 mg/kg), 18.28 % (73.3 to 59.9 mg/kg) and 14.62 % (89.6 to 76.5 mg/kg), respectively.

The Fe (in *L. elegans* and *L. rotundiflorus* with a loss of 26.1 %) and Mg (in *L. montanus* and *L. exaltatus* with a loss of 42.6 y 27.43 % respectively) only decreased statistically in two species. The mineral least affected was the Ca since statistically it only decreased in *L. elegans* from 1777 to 680 mg/kg, with 61.56 % loss, even though in the rest of the species there was also a reduction of this element, but it was not statistically significant ($p > 0.05$).

The most affected species was *L. elegans* since all their minerals were lost by cooking, for the reason that this species has the thinnest coat and when it was cooked it eliminated it faster, because according to Hung et al., [32] the minerals primarily concentrate on the endosperm of the seeds which caused a removal or leachate of minerals in the endosperm.

This occurs with legumes of popular consumption, with traditional cooking the minerals are lost, in beans the highest loss is of P (28.3 %), in chickpeas is calcium with loss of 22.2% and in lentils the Mg (with 26%) [33].

Additionally, Alajaji and El-Adawy [24], found that boiling in water causes losses in the content of Ca, Mg, P, Zn, Cu and Fe, in chickpeas Seena et al., [22] reported that pressure cooking decreased the mineral content (P, Mg, Fe) in a significant way in *Canavalia cathartica* seeds. On the contrary, Lazzari and Beleia, [34] reported that cooking does not affect the contents of calcium, zinc, and iron, in some varieties in soy seed.

CONCLUSIÓN

The results obtained allow to conclude that the thermal treatment used affects the content of nutrients in a different way depending on the lupin species. The rise in content of dietary fiber after cooking, suggests a potential consumption

in these species without apparent toxicity risk with the favorable physiological advantages that provide this component.

The mineral content in raw seeds vary among species, *L. elegans* showed higher values of P and Mg, in *L. exaltatus* the highest levels of Zn and Cu were quantified while *L. mexicanus* and *L. rotundiflorus* had the highest Ca and Fe contents, respectively. The analyzed lupins presented a higher level of Ca and Mg than the domesticated species of lupins. Overall, there was a reduction in minerals as a result of cooking; the most affected was the Cu which decreased in all of the species this may be due to lixiviation during the cooking process.

RESUMEN

El consumo de lupinos silvestres se limita por la presencia de alcaloides, sin embargo se pueden reducir con un tratamiento térmico adecuado. El objetivo de esta investigación fue determinar el efecto térmico sobre la composición química y de minerales de lupinos. En *Lupinus mexicanus* se observó una reducción en proteínas y grasas de 34,76 a 33,11 g/100 g y de 6,10 a 5,41 g/100 g respectivamente, un incremento de cenizas y fibra dietaria de 3,84 a 4,53 y de 20,9 a 28,48 g/100 g. La semilla cruda de *L. mexicanus* reveló el más alto contenido de Ca (3252,6 mg/kg), *Lupinus elegans* en Mg con 2656,4 mg/kg, mientras que *Lupinus rotundiflorus* fue de Fe (82,8 mg/kg) y *Lupinus exaltatus* en Cu (184,4 mg/kg). Todas las especies mostraron similar contenido de Zn de 73,3 (*L. montanus*) to 89,6 mg/kg (*L. exaltatus*). En todas las especies disminuyó el Cu, principalmente en *L. elegans* con una pérdida del 76,71 %.

Palabras clave: *Lupinus*, leguminosas, minerales, efecto térmico, fibra dietaria.

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