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/100g in dry basis and of oil of 8-12g/100g 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 sample, in according to standard methods of AOAC [15].

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/100g of sample in L. mexicanus to 43.93 g/100g 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/100g and Lagunes-Espinoza et al., [16] of 38.7g/100g in this same species, whereas the values in L. elegans (43.66g/100g ) and L. rotundiflorus (41.96g/100g ) 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/100g ), L. splendens (37.2), L. campestris (39.7) and L. barkeri (37.07g/100g ) [2, 14, 17] and from Spain, such

<table>
<thead>
<tr>
<th>TABLE 1</th>
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<tbody>
<tr>
<td>Chemical composition of raw and cooked L.exaltatus, L.elegans, L.mexicanus, L.montanus and L.rotundiflorus seeds (g/100 g in dry basis)</td>
</tr>
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<table>
<thead>
<tr>
<th>SPECIES</th>
<th>PROTEIN (N x 6.25)</th>
<th>FAT</th>
<th>ASH</th>
<th>DF</th>
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<tbody>
<tr>
<td>L. exaltatus</td>
<td></td>
<td></td>
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<tr>
<td>Raw</td>
<td>43,93 ±0.4</td>
<td>8,76±0.2*</td>
<td>3,47±0.1*</td>
<td>17,72±0.1*</td>
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<tr>
<td>Cooked</td>
<td>43,46 ±0.5</td>
<td>8,21±0.1</td>
<td>2,88±0.2</td>
<td>33,06±0.1</td>
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<tr>
<td>L. elegans</td>
<td></td>
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<tr>
<td>Raw</td>
<td>43,66 ±0.2</td>
<td>7,31±0.1*</td>
<td>4,27±0.0</td>
<td>21,07±0.0</td>
</tr>
<tr>
<td>Cooked</td>
<td>43,33 ±0.2</td>
<td>6,42±0.1</td>
<td>4,05±0.1</td>
<td>21,45±0.1</td>
</tr>
<tr>
<td>L. mexicanus</td>
<td></td>
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<tr>
<td>Raw</td>
<td>34,76 ±0.3*</td>
<td>6,10±0.2*</td>
<td>3,84±0.5*</td>
<td>20,90±0.5*</td>
</tr>
<tr>
<td>Cooked</td>
<td>33,11 ±0.9</td>
<td>5,41±0.1</td>
<td>4,53±0.0</td>
<td>28,48±0.0</td>
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<tr>
<td>L. montanus</td>
<td></td>
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<tr>
<td>Raw</td>
<td>42,42 ±0.3</td>
<td>7,57±0.2</td>
<td>3,64±0.1*</td>
<td>24,63±0.1*</td>
</tr>
<tr>
<td>Cooked</td>
<td>42,20 ±0.1</td>
<td>7,32±0.1</td>
<td>3,25±1.1</td>
<td>26,10±0.1</td>
</tr>
<tr>
<td>L. rotundiflorus</td>
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</tr>
<tr>
<td>Raw</td>
<td>41,96 ±0.1*</td>
<td>6,45±0.1</td>
<td>3,10±0.1</td>
<td>27,93±0.1</td>
</tr>
<tr>
<td>Cooked</td>
<td>37,52 ±0.3</td>
<td>6,26±0.1</td>
<td>3,04±0.0</td>
<td>27,41±0.0</td>
</tr>
</tbody>
</table>

*Means ± 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/100g), L. mariaejosephi (32.9) and L. luteus (33.6g/100g) [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. campesstris (10.8g/100 g) by Jiménez et al., [2]. Cooking had an effect on fat to reducing the content in all the analyzed species [29]. 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. campesstris (10.8g/100 g) by Jiménez et al., [2]. Cooking had an effect on fat to reducing the content in all the analyzed species [29].

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. 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].

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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 2664.6 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) a 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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