High protein and low-fat chips (snack) made out of a legume mixture

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ABSTRACT
Snacks tend to be unhealthy products, so it is important to develop more nutritious alternatives. For this reason, the aim of this research was to develop legume chips for use as a snack food and evaluate their nutritional properties and sensory characteristics. Common bean, broad bean, and textured soy bean flour mixtures at different ratios were used as ingredients in the chips. The formulation most accepted by the consumers was made of 65% of broad bean and 35% of soy bean. This formulation had the highest level of protein 34.17 g/100g, with 11.53 g/100 g of fiber, and 3.52 g/100 g of lipids. 65/35 BB/S (broad bean/soy bean) was the product with greater protein digestibility 72 g/100 g. The results show that it is feasible to develop a legume snack without the use of cereals that is pleasant to the senses, offering nutritional alternatives and natural potential functional food.

1. Introduction
A snack is anything consumed between main meals and tends to be energy-dense but nutrient-poor (Hartmann, Siegrist, & Van der Horst, 2013; Piernas & Popkin, 2010). The main reasons for unhealthy snacking include enjoying a special occasion, opportunity-induced energy balance. The consumption of unhealthy snacks (chips, cakes, cookies, sweets, soft drinks, and other high-calorie products) is on the rise. These unhealthy products contain high concentrations of sugar, fats, and refined grains, and are directly related to overweight and obesity (Piernas & Popkin, 2010).

The World Health Organization (WHO) catalogued obesity as a global health epidemic in 2003, and in 2014, the statistics for this organization indicated that 13% of adults 18 years old or older worldwide are obese with 39% being overweight, also 41 million children under the age of five are obese or overweight. Therefore, an epidemic of obesity is a large-scale health problem (Madhusoodanan, 2017). Obesity is associated with health problems, including diabetes, heart disease, disorders of the locomotor system, and some cancers. However, not all snacks are unhealthy; snacking on whole fruit, vegetables, and crackers has been found to contribute to better overall diet quality (Hartmann et al., 2013).

Nutritious snacks can increase access to healthy, low-energy food choices. In order to avoid obesity and all diseases related to this epidemic, it can help to establish healthy snacking habits and assess the nutritional quality of products (De Vlieger, Collins, & Bucher, 2017). A healthy snack can be obtained by supplementing with legumes, which have a high protein content compared with cereals and provide soluble and insoluble dietary fibers, vitamins, and minerals (Qayyum, Butt, Anjum, & Nawaz, 2012).

For example, beans contain 21 to 24 g/100 g of protein and also contain significant quantities of minerals and multiple vitamins, while being low in fat (Mitchell, Lawrence, & Hartman, 2009). Studies report that pinto beans, in a reasonable quantity, provide health benefits that include lowering serum lipoproteins and reducing risks of coronary heart disease (Winham, Hutchins, & Johnston, 2007).

Broad beans are widely available and used as a source of protein and add complex carbohydrates, soluble fiber, and essential vitamins and minerals to the diet, yet are low in fat,
sodium and are cholesterol free (Akabor, 2003). They are a source of 3,4-dihydroxyphenylalanine, a major ingredient in medicines used to treat Parkinson disease patients (Apaydın, Ertan, & Ozekmekçi, 2000). Soybeans are an economical source of protein (40 g/100 g) and essential amino acids. They have high polyunsaturated fat content and absence of cholesterol and lactose. Soybeans are also a good source of minerals and isoflavones, phytoestrogens, protease inhibitors, inositol hexaphosphate, and saponins (Hertrampf & Piedad-Pascual, 2000). Soy is associated with appetite and obesity control and prevention of cancer (Hawrylywicz, Zapata, & Blair, 1995).

Moreover, legumes are consumed in lower quantities than is recommended by nutrition institutions. For this reason, some researchers have developed snacks or other products that are supplemented with legumes. Ochoa-Martínez, Castillo-Vázquez, Figueroa-Cárdenas, Morales-Castro, and Gallegos-Infante (2016) added bean flour to corn flour at different concentrations when manufacturing corn chips to produce superior nutritional properties and similar texture attributes to those of corn snacks that are currently found on the market. Man and Páuecan (2013) reported that supplementation of wheat flours with legume flours that have a high protein content provides an improvement in the nutritional quality of baked goods. Legume consumption in various forms that is different from traditional consumption may be a way to contribute to a healthier diet; however, it is important to ensure the stability of the nutrients throughout the production process and during the shelf life of the product (Gulia, Dhaka, & Khatkar, 2014). In addition to the nutritive value, sensory characteristics should be taken into account to develop products that are attractive to people. In this context, the aim of this investigation was to develop a chips snack based on legumes and evaluate its nutritional properties and sensory characteristics.

2. Materials and methods

2.1. Preparation of legume chips

A common bean (Phaseolus vulgaris L.) of the pinto variety, broad bean (Vicia faba) and textured soy bean (Glycine max L.) were purchased at a store in S.L.P., México. Beans and broad beans were dried in a drying oven (Binder, Germany) at 55°C for 6 h. The dried seeds were ground by passing them through a mill (Corona, China) adapted with a 400 rpm motor at ambient temperature (23 ± 2°C). The openings of the sieves that the flour passed through were 0.5 mm in diameter. Isolated soy beans were ground directly in the mill. Once the flours were obtained, they were mixed in combinations (w/w) as shown in Table 1.

The formulation to prepare the dough for the chips included 47.5 g/100 g flour, 47 g/100 g water, 5 g/100 g vegetable oil and 0.5 g/100 g salt. The flour mixtures were manually combined with water, salt, and oil to produce the dough, which was in turn passed through a manual tortilla-rolling machine (TM-G, México) to obtain 1 mm-thick chips. These were then shaped using a 3 x 4 cm triangular cutter. Afterwards, they were baked in an oven (San-Son, México) at 100°C for 100 min and allowed to cool for 2 h before final storage in cellophane bags. The chips were stored at room temperature for 24 h before being analyzed.

| Table 1. Formulations used for sensory analysis and for experimental design. |
|---------------------------------------------------------------|
| **Formulation** | **B** (g/100 g) | **S** (g/100 g) | **BB** (g/100 g) | **Acceptation of hedonic test** |
|-----------------|----------------|----------------|----------------|-------------------------------|
| 1               | 25             | 0              | 75             | 6.38 ± 0.21                   |
| 2               | 0              | 75             | 25             | 5.68 ± 0.24                   |
| 3               | 25             | 75             | 0              | 5.65 ± 0.44                   |
| 4               | 75             | 0              | 25             | 5.7 ± 0.39                    |
| 5               | 0              | 25             | 75             | 5.7 ± 0.11                    |
| 6               | 75             | 25             | 0              | 5.73 ± 0.02                   |
| 7               | 35             | 0              | 65             | 5.71 ± 0.3                    |
| 8               | 0              | 65             | 35             | 5.17 ± 0.09                   |
| 9               | 35             | 65             | 0              | 6.35 ± 0.18                   |
| 10              | 65             | 0              | 35             | 6.46 ± 0.24                   |
| 11              | 0              | 35             | 65             | 7.26 ± 0.58                   |
| 12              | 65             | 35             | 0              | 5.58 ± 0.36                   |
| 13              | 50             | 50             | 0              | 6.66 ± 0.2                    |
| 14              | 0              | 50             | 50             | 5.69 ± 0.5                    |
| 15              | 50             | 0              | 50             | 5.56 ± 0.04                   |

* B – bean, S – soy bean, BB – broad bean

The shaded rows correspond to selected formulation for the experimental design

2.2. Sensory analysis of the chips

The chips were evaluated by an untrained panel of 100 judges between 18 and 80 years old who consume chips at least once per month. These consumers evaluated the degree of acceptance using a 9-point hedonic scale (Since 1 = “I dislike them extremely” from to 9 = “I like them extremely”). The evaluation was applied on 3 different days (5 samples per day). The mean ± std. deviation of the hedonic scale was obtained (from 1 to 9) for each of the analyzed samples. The top 5 formulations according to the sensory analysis underwent moisture content, protein, fat, total carbohydrate, dietary fiber, amino acid profile and protein digestibility analysis.

2.3. Proximate composition

The proximate composition of the raw materials and chips was determined by following the American Oil Chemists’ Society recommended official methods (AOAC, 1990). The crude protein content was estimated following the method 954.01 to determine the nitrogen content (N). The factor used to convert N to the estimated protein content for soy bean was 5.65 and 5.4 for broad bean and bean (De Almeida Costa, Queiroz-Monici, Machado Reis, & Costa de Oliveira, 2006; Moss, 1990). Total carbohydrates were obtained according to the Official Mexican Standard (NMX-F-089–1978) technique. The total fat proportion was determined following the Official Mexican Standard (NMX-F-312–1978). The moisture content was determined in a drying oven (APSA, México) at 105°C using the AOAC 930.15 method, the samples were previously defatted. All samples were made in triplicate, and the means were reported with their standard deviations.

As a control, the proximate composition, total dietary fiber and protein digestibility of two commercial tortilla chips were provided. The first two were given by the supplier and the digestibility was determined under the same conditions as those of the legume chips.
2.4. Total dietary fiber (TDF)

TDF was determined using the gravimetric-enzymatic method (985.29 of the AOAC), consisting of the simulation of the digestion of the pre-treated sample with the use of enzymes (Megazyme International, Wicklow, Ireland). 1 g of ground, defatted sample was used. Samples were gelatinized with α-amylase (95°C, pH 6, 15 min) and then enzymatically digested with protease (60°C, pH 7.5, 30 min), after which they were incubated with amyloglucosidase (60°C, pH 4.5, 30 min). Then the samples were filtered and simultaneously washed with 95% ethanol and acetone. The recovered filtrate was dried, and protein and ash content were determined to calculate the TDF content. TDF was determined in quadruplicate.

2.5. Amino acid determination

The snack’s nutritional value was calculated by amino acid profile using UPLC-UV. Between 2.6 to 3.1 mg, previously crushed, dried and defatted samples were hydrolyzed and derivatized and after this a UPLC-UV analysis were determined on an Acquity UPLC system (Waters, Milford, CT, USA). The system consisted of a binary solvent manager, a sample manager and a photodiode array detector. The output signal was monitored and processed using the Waters Empower 2 software. The column was a Waters Acquity UPLC HSS C18, which was held at 30°C at a flow rate of 0.18 mL/min; the injection volume was 10 µL. UV detection was set to 210 nm. The mobile phase consisted of eluents (A and B) purchased from Waters (composition proprietary) used according to the manufacturer’s specifications. The gradient elution was as follows: 0 min, 60% B; 4 min, 80% B; 9 min, 100% B; 11 min, 100% B; 11.1 min, 60% B; and 15 min, 60% B.

2.6. Protein digestibility of the chips (in vitro)

Protein was digested using the method proposed by Yang et al. (2014) with some modifications. Briefly, 4 g of the ground (approx. 0.5 mm) oily sample was mixed with 50 mL of distilled water, and the pH was adjusted to 2 with 6 N HCl. Then, 2 mL of pepsin (10% w/v, SIGMA, USA) was added, and the mixture was incubated at 37°C over the course of 2 h. Then, the pH was adjusted to 5.3 with 0.9 NaHCO₃ and to 7.5 with 1 M NaOH. Then, 5 mL of pancreatin was added to 5% w/v (SIGMA, USA), mixed and incubated at 37°C for 2 h. The enzymes were inactivated by submerging the tubes in boiling water for 10 min. The samples were cooled to room temperature and centrifuged at 4500 rpm for 20 min at 15°C. A blank that only included the enzymes was simultaneously run. The g/100 g of in vitro protein digestibility was calculated as ((total protein-residue protein))/total protein) * 100.

2.7. Statistical analysis

Sensory evaluation was statistically analyzed using the Kruskal-Wallis non-parametric statistics test for independent samples. For the statistical analysis of the proximal data and dietary fiber, the five best formulations selected in the sensory study and the raw materials were used. The experiment design used was a ternary mixture of Taguchi (Table 1, shaded rows). ANOVA was performed with a confidence level of 95% (p < .05) using Design-Expert software package, version 7.1.5 (Stat-Ease, Inc., Minneapolis, Minn, USA). Multiple regression analysis was used to fit a full polynomial equation (Eq. 1) to each of the evaluated dependent variables:

\[ y = \beta_0 + \beta_1 B + \beta_2 S + \beta_3 BB + \beta_4 AS + \beta_5 SBB + \beta_6 BBB \]  

(1)

where y is the studied variable, β0 to β6 are the regression coefficients of the model and B, S and BB are the bean, soy bean, and broad bean flours, respectively.

The difference between the five chips selected in the different analyses was compared using a least square means test (orthogonal contrasts) that was performed to detect significant differences at p < .05 (for the proximate compositions of the legume chips that had different formulations). Statistical analysis was applied using STATISTICA software version 7.0 (Stat Soft, Tulsa, Oklahoma, USA), considering a significance level of α = 0.05.

3. Results and discussion

3.1. Sensory evaluation of the chips

The fifteen chip formulations with different concentrations of legume flour (Table 1) were prepared and evaluated by the consumer judges. Nonparametric tests showed that with a p ≤ .001, the null hypothesis of the test should be rejected. Therefore, the difference in the results of the sensory analyses is due to the formulation of the samples. Consumers’ product acceptance (hedonic test) is shown in Table 1. In general, the legume chips were accepted by the consumers in all formulations, with a mean above 5, indicating on the hedonic scale that the consumers liked the product. The chips that were evaluated best were made of 65 g/100 g broad bean: 35 g/100 g soy bean (65/35 BB/S), 35 g/100 g bean: 65 g/100 g soy bean (35/65 B/S), 50 g/100 g broad bean: 50 g/100 g soy bean (50/50 BB/S), 75 g/100 g broad bean: 25 g/100 g bean (75/25 BB/B) and 35 g/100 g broad bean: 65 g/100 g bean (35/65 BB/B). The 65/35 BB/S formulation was the best evaluated and was between 7 and 8 on the hedonic scale, suggesting that this formulation was liked much by the consumers. The other 4 best formulations did not exhibit a significant difference in the sensorial analysis. The five best formulations were analyzed for moisture content, protein, fat, total carbohydrate, dietary fiber, amino acid profile, and digestibility.

3.2. Proximate composition

Proximate composition was determined for the raw materials and the samples that obtained the best results in the sensory evaluation; the controls were the values of 2 commercial brands of tortilla chips. According to the analysis of variance (Table 2), it was observed that soy bean was the most important factor that affected the protein content in the different formulations produced with mixtures of legumes flour, as well as the interactions when it was included (p < .0001). With respect to carbohydrate content, bean and soy bean were the most important factors that affected these biomolecules (p < .0001) as were soy bean and broad bean for the fiber content (p < .0001). However, the lipids and moisture content were not significantly affected by these factors (p = .393 and p = .55, respectively).
Los resultados de la composición proximada se muestran en el cuadro 3; los valores de proteína de los chips de legumbres varían entre 21.39 y 34.17 g/100 g, y la diferencia fue significativa ($p < .05$) para todas las formulaciones y los controles. Los chips de legumbres con la proteína más alta contenían 27.84 g/100 g de proteína más que el control. Los resultados de la composición de proteínas se esperaron porque la alta proteína de las legumbres está en acuerdo con los informes previos donde la harina de legumbres se adicionó a sus formulaciones (Man & Páucean, 2013). Este alto contenido de proteínas es importante, porque en los últimos años, las personas han comenzado a enfocarse en aumentar la proteína en la dieta, además, muchas personas están tratando fuentes de proteína no de origen animal.

Los valores de carbohidratos de los chips de legumbres fueron entre 35.03 y 55.98 g/100 g, que es más bajo que los controles que tenían 72.22 y 78.56 g/100 g ($p < .05$). Todos los legumes, las harinas con un contenido de proteínas, carbohidratos, lipídeos, humedad y fibra en función de la interacción de las harinas de frijol, soja y haba.

El contenido de proteínas, carbohidratos, lipídeos, humedad y fibra se evaluaron con el modelo polinomial (Matos-Chamorro & Chambilla-Mamani, 2015). En la tabla 3 se muestran los coeficientes de regresión y análisis de varianza del modelo polinomial, para evaluar la variación del contenido de proteínas, carbohidratos, lipídeos, humedad y fibra en función de la interacción de las harinas de frijol, soja y haba.

La humedad se encontró entre 3.52 g/100 g y 5.31 g/100 g, con una humedad más alta en los chips de soja que en los chips de frijol y haba. El contenido de fibra se encontró entre 3.23 g/100 g y 19.21 g/100 g, con un mayor contenido de fibra en los chips de frijol que en los chips de soja y haba. Los chips de soja tuvieron un mayor contenido de fibra que el control, y la fibra reduce el riesgo de enfermedades cardiovasculares, diabetes, obesidad, colon cancer, y una variedad de otras enfermedades (Matos-Chamorro & Chambilla-Mamani, 2010). Un consumo adecuado de fibra en la dieta puede reducir el riesgo de enfermedades cardiovasculares, diabetes, obesidad, colon cancer, y una variedad de otras enfermedades (Matos-Chamorro & Chambilla-Mamani, 2010). En la tabla 4 se muestra el contenido de proteínas, carbohidratos, lipídeos, humedad y fibra en función de la interacción de las harinas de frijol, soja y haba.

En la tabla 5 se muestra el contenido de proteínas, carbohidratos, lipídeos, humedad y fibra en función de la interacción de las harinas de frijol, soja y haba. Los chips de soja y haba tuvieron un mayor contenido de proteínas que los chips de frijol. En la tabla 6 se muestra el contenido de proteínas, carbohidratos, lipídeos, humedad y fibra en función de la interacción de las harinas de frijol, soja y haba. Los chips de soja y haba tuvieron un mayor contenido de proteínas que los chips de frijol. En la tabla 7 se muestra el contenido de proteínas, carbohidratos, lipídeos, humedad y fibra en función de la interacción de las harinas de frijol, soja y haba. Los chips de soja y haba tuvieron un mayor contenido de proteínas que los chips de frijol. En la tabla 8 se muestra el contenido de proteínas, carbohidratos, lipídeos, humedad y fibra en función de la interacción de las harinas de frijol, soja y haba. Los chips de soja y haba tuvieron un mayor contenido de proteínas que los chips de frijol.
content (35/65 B/S) provides an intake of 5.4 g of fiber, and with the formulation with less fiber (65/35 BB/S), it provides 3.3 g; this is a considerable amount of the daily requirements recommended (United States Department of Agriculture, 2007). Importantly, high-fiber and high-protein foods, such as legume chips, have the potential to promote satiety (Gupta & Premavalli, 2012). The chips’ proximal content is attributed mostly to the compositions of the raw materials, as is shown in Table 3.

Based on the percentages in the formulations, we calculated the theoretical protein content of the raw materials of each formulation and compared them with the protein percentages in the final legume chips, and we observed a 3 to 5 g/100 g protein loss in these products. This reduction is perhaps because of cross-link and Maillard reactions; the Maillard reaction is a nonenzymatic browning reaction that mainly occurs between reducing sugars and free amino groups with lysine being the most susceptible. This is similar to the results of Cruz-Solorio, Villanueva-Arce, Garín-Aguilar, Leal-Lara, and Valencia Del Toro (2018). The protein content was reduced after the drying and baking process. Some investigations report similar protein reductions in their products during these processes (Gutiérrez-Dorado et al., 2008).

To establish the effect of baking on the protein quality in the legume chips prepared from blended flours from pinto beans, broad bean and soy bean, the amino acid profile was determined by UPLC-UV.

### 3.3. Amino acid contents

The amounts of almost all amino acids in the legume chips were lower compared with the amounts in the raw materials, indicating that processing reduced them in the final products (Table 4). The amino acid contents of the raw materials were similar to those reported by Nosworthy et al. (2017).

The amino acids that decreased most through processing were Thr, Ala, Pro, Lys and Tyr (between 7 and 20 g/100 g). Between 8 and 14 g/100 g of Thr and between 13 and 20 g/100 g of Lys were lost in the different formulations. Lys is known to be sensitive to heat and is lost during some processes (Cruz-Solorio et al., 2018).

The remaining amino acids suffered minor losses of between 0 and 8 g/100 g. The amino acids that were less affected included lle with a maximum loss of 3 g/100 g in one of the formulations and Met with a loss of 4 g/100 g. This finding is important because these are essential amino acids (EA); additionally, sulfur amino acid is limited in this kind of product. People must have an adequate balance of amino acids in their diets since they act as agents against chronic human diseases and are conducive to maintaining general well-being; for example, the consumption of Arg is beneficial for promoting skeletal muscle gain and reducing whole body fat accretion, may have a cholesterol-lowering effect, inhibits platelet aggregation, may reduce atherosclerosis, and improves peripheral endothelium dependent dilatation (Aji et al., 1997). Additionally, Arg, Gly, Ala, Ser, Cys and Thr provide protective effects against cardiovascular diseases and cancer (Krajcovicova-Kudlackova, Babinska, & Valachovicova, 2005). Residues of His have been associated with proliferation of hepatocytes during regeneration of the liver following mechanical damage, and it has been identified as crucial for rapid fibrillation to prevent some diseases, such as type 2 diabetes, Alzheimer’s and Parkinson’s (Besant & Paul, 2012). Sulfur amino acids are involved in DNA transcription and RNA translation and may play a role in reducing the risk of CVD, dementia, cirrhosis, and immunomodulation (Townsend, Tew, & Tapiero, 2004). Leu has many roles, such as in the synthesis of new proteins, as a modulator of insulin and as a donor to produce alanine and glutamine in skeletal muscle (Baum et al., 2005).

It has been documented that cereal proteins, which are a common raw material in chips (corn), are deficient in certain essential amino acids, particularly in Lys (Anjum, Ahmad, Butt, Sheikh, & Pasha, 2005) and that legumes contain sufficient amounts of this amino acid (Sai-Ut, Ketnawa, Chaiwut, & Pasha, 2017) and that legumes contain sufficient amounts of this amino acid (Sai-Ut, Ketnawa, Chaiwut, & Pasha, 2017). Therefore, it is important to include these legumes to improve the protein and amino acid contents.

Millward, Layman, Tomé, and Schaffer (2008) mentioned that in addition to identifying the optimal dietary amino acid pattern in terms of specific amino acids, for the determination of protein quality, it is important to evaluate the digestibility of a protein or the capacity to provide metabolically available nitrogen and amino acid to tissues and organs; for this reason, we evaluated the protein digestibility of these chips.

### 3.4. Protein digestibility

The protein digestibility values of the chips are shown in Table 5. The highest value of protein digestibility was observed for chips prepared with broad bean and soybeans.

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**Table 3. Proximate composition of the legume chips (g/100 g) wet base.**

| Sample     | Protein (g/100 g) | Carbohydrates (g/100 g) | Dietary Fiber (g/100 g) | Lipid (g/100 g) | Moisture (g/100 g) |
|------------|------------------|-------------------------|-------------------------|----------------|-------------------|
| B*         | 22.81 ± 0.02     | 63.00 ± 0.11            | 15.04*                  | 2.12 ± 0.00    | 6.06 ± 0.09       |
| S          | 48.16 ± 0.13     | 25.23 ± 0.06            | 22.12                   | 1.35 ± 0.03    | 5.41 ± 0.32       |
| BB         | 20.81 ± 0.25     | 50.22 ± 0.83            | 9.5*                    | 2.71 ± 0.02    | 8.52 ± 0.01       |
| 65/35 BB/S | 34.17 ± 0.12a    | 41.99 ± 0.11a           | 11.53 ± 0.45a           | 3.42 ± 0.01a   | 3.52 ± 0.15a      |
| 50/50 BB/S | 32.93 ± 0.02b    | 35.03 ± 0.45b           | 19.21 ± 0.01b           | 2.16 ± 0.02b   | 4.53 ± 0.05b      |
| 35/65 BB/B | 22.13 ± 0.06c    | 55.79 ± 1.12c           | 14.00 ± 1.01c           | 2.51 ± 0.29c   | 5.29 ± 0.26c      |
| 75/25 BB/B | 23.64 ± 0.21d    | 59.96 ± 0.63d           | 11.71 ± 0.29d           | 3.21 ± 0.45d   | 4.02 ± 0.10d      |
| 35/65 BS   | 21.39 ± 0.16e    | 50.99 ± 0.33e           | 11.48 ± 0.33e           | 3.41 ± 0.33e   | 5.31 ± 0.09e      |
| Control 1  | 5.55f            | 78.56f                  | 2.02f                   | 5.55f          | 3.44f             |
| Control 2  | 6.33f            | 72.22f                  | 8.30f                   | 2.15f          | 3.56f             |

**Mean ± Std. deviation; n = 3 *** n = 4. Means within a column followed by different letters are significantly different (p < 0.05). *The data was given by the provider.**

** Media ± desviación estándar; n = 3 *** n = 4. Los promedios dentro de una columna seguidos por letras diferentes son significativamente diferentes (p < 0.05).” Los datos fueron proporcionados por el proveedor g/100 g base húmeda.”
Table 5. Digestibility in vitro of proteins of the totopos.

| Sample           | Digested protein (g/100 g) |
|------------------|----------------------------|
| 65/35 BB/S       | 71.91 ± 2.2*               |
| 50/50 BB/S       | 59.11 ± 0.4*               |
| 35/65 BB/B       | 61.17 ± 0.6*               |
| 50/50 BB/B       | 66.11 ± 1.2p               |
| 35/65 B/S        | 49.81 ± 3.15               |
| Control 1        | 72.21 ± 2.5*               |
| Control 2        | 70.05 ± 1.12               |

** Mean ± Std. deviation; n = 3 (p < 0.05). Means within a column followed by different letters are significantly different (p < 0.05). **

(65/35), and the lowest was for chips made with bean and soybeans (35/65). In general, when broad bean was included in the formulation, a higher digestibility was obtained. Our results are in agreement with those reported by Tazrart, Lamacchia, Zaidic, and Haros (2016), who described that the inclusion of broad bean in fresh pasta improved protein digestibility. This improvement is probably because the inclusion of broad-bean flour increased the content of more digestible proteins (globulins). It’s important to notice that chips prepared with broad bean and soybeans (65/35), had the same values of digestibility as those of the control. The low digestibility observed in the sample with bean and soybeans (35/65) is possibly because of protein aggregation during heat processing (Carbonaro, Cappelloni, Nicoli, Lucarini, & Carnovale, 1997). Low digestibility of protein legumes is due to the presence of antinutritional factors (Alonso, Aguirre, & Marzo, 2000). In these chips these anti-nutritional compounds were probably not completely removed following the baking process. However, according to De Vlieger et al. (2017), these legume snacks could be categorized as a nutritious food because they provide a higher proportion of essential nutrients (approx. 50 g/100 g of the EA of the total amino acids) relative to the energy content or portion size, high fiber content (between 11 and 19 g/100 g) and low fat content (between 2.26 and 3.49 g/100 g). They will also have a long shelf life due to their low moisture content. The demand for nutritional food is high, and this is one alternative. Other advantages include the increased nutritional value of the snack without an increase in cost because the process only involves raw material sources that are already available. Thus, there is no need to invest in expensive processes, such as genetic modifications. This product also supports farmers because it uses their products. Additionally, legume chips have a potential use as a natural functional food due to their chemical composition.

4. Conclusion

The elaboration of a legume snack without the use of cereals was accepted by consumers, which offers a nutritious alternative to fried or baked corn flour goods high in calories and low in protein content. In this investigation, the formulation most accepted by the consumers was elaborated with 65% of broad bean and 35% of soy bean flour. This formulation had 34.17 g/100g of protein (approx. 50% are essential amino acids), 11.53 g/100 g of fiber and 3.52 g/100 g of
lipids. The legume chips developed via baking resulted in a depletion of protein between 3 and 5 g/100 g, which does not represent a major loss due to the high protein content. 65/35 BB/S (broad bean/soy bean) was the product with greater digestibility 72 g/100 g, like commercial tortilla chips. In general, when broad bean was included in the formulation, a higher digestibility was obtained. In future investigations the legumes could be pre-cooked to improve the digestibility in this kind of products or add small quantities of cereals to increase the content of some essential amino acids such as Met.

Disclosure statement
No potential conflict of interest was reported by the authors.

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