Formulation of a functional cookie to take advantage of the nutritional properties of lupin flour (Lupinus mutabilis)

Formulación de una galleta funcional para el aprovechamiento de las propiedades nutricionales de la harina de chocho (Lupinus mutabilis)

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ABSTRACT

The perspective on health and nutrition has changed radically due to the growing awareness of diseases resulting from poor nutrition. In this sense, lupin flour (Lupinus mutabilis) emerges as an interesting alternative as an ingredient for the development of functional foods thanks to its high protein and fibre content. This study formulated a functional cookie with lupin flour, analysing its physicochemical, rheological and textural properties, as well as its acceptability through sensory analysis. The flour revealed a high protein (49.58%) and total dietary fibre (24.40%) content compared to wheat flour. The lupin flour cookie had a protein percentage (26.31%) five times higher than commercial wheat flour cookie. Texture analysis indicated higher hardness and fracturability. Finally, rheological analysis at Mixolab indicated that lupin flour has a dough development (120 Nm) and swelling power (0.50 Nm) comparable to wheat flour. The study suggests that the developed lupin flour cookie could be a possible snack alternative for coeliacs with high protein content and a pleasant level of acceptability for all types of consumers.

Keywords: Flours, lupin, wheat, cookies, gluten free, mixolab, texturometer.

RESUMEN

La perspectiva sobre la salud y nutrición ha cambiado radicalmente debido a la creciente conciencia de las enfermedades derivadas de una mala alimentación. En este sentido, la harina de chocho (Lupinus mutabilis) emerge como una interesante alternativa como ingrediente para el desarrollo de alimentos funcionales gracias a su elevado contenido de proteínas y fibra. Este estudio formuló una galleta funcional con harina de chocho, analizando sus propiedades fisicoquímicas, reológicas y de textura, además de su aceptabilidad mediante análisis sensoriales. La harina reveló un elevado contenido proteico (49.58%) y de fibra dietética total (24.40%) comparado con la harina de trigo. La galleta de harina de chocho presentó un porcentaje de proteína (26.31%) cinco veces más alto que las galletas de harina de trigo comerciales. El análisis de textura indicó mayor dureza y fracturabilidad. Finalmente, el análisis reológico realizado en Mixolab, indicó que la harina de chocho posee un desarrollo de masa (120 Nm) y poder de hinchamiento (0.50 Nm) comparables a la harina de trigo. El estudio sugiere que la galleta de harina de chocho desarrollada podría resultar como una posible alternativa de snack para celiacos con alto contenido proteico y un nivel de aceptabilidad agradable para todo tipo de consumidor.

Palabras clave: Harinas, chocho, trigo, galletas, libre de gluten, mixolab, texturómetro.

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1. INTRODUCTION

The perspective of health and healthy nutrition has changed drastically in recent years due to the awareness of the population and governments about the diseases resulting from a poor diet full of carbohydrates. Currently, different ways have been sought to promote the consumption of functional foods, which are packed with bioactive compounds such as antioxidants, vitamins, minerals, probiotics, prebiotics, and more (Berru et al., 2021). Legumes with their high protein content are considered as functional food and can be used even for reclamation of land considered poor. The lupin (Lupinus mutabilis) is considered one of the most promising legumes due to its high-quality protein content and its possible positive impacts on health (Gulisano, Alves, Martins, & Trindade, 2019).

In this sense, lupin flour, derived from the legume (lupin or tarwi) has been recognized for its exceptional content of protein, dietary fiber, and a wide range of essential nutrients such as calcium, iron and zinc (Curti, Alcócer, Rivas, Vinderola, & Ramón, 2022). As for the formulation of cookies, the enrichment with lupin flour at different percentages is proposed in order to take advantage of its nutritional properties and improve the added value of baked products.

The development of products enriched with functional ingredients such as lupin flour has gained widespread popularity in the food industry, specifically in the context of the growing awareness of the importance of maintaining a balanced and nutritious diet. Currently, lupin flour products have been developed as snacks through extrusion processes. In the context of baked goods, there are products such as breads and cookies that use lupin flour to enrich them and increase their protein content. However, the varieties used for these products are mostly Lupinus albus, Lupinus luteus and Lupinus angustifolius, and there are very few studies using Lupinus mutabilis (Aranda Tarazona et al., 2021; Mostafa, El-Desouky, Sharoba, Mohamed, & Morsy, 2022). However, a small part of the population due to their genetic predisposition suffers from intolerance to a set of prolamin and glutelin type proteins that is commonly known as gluten, so that, being unable to assimilate foods with this protein, they suffer damage at the intestinal level and potential health problems (Villanueva Flores, 2017). Under this context, the objective of the present research is to develop a formulation that allows the production of a gluten-free food taking advantage of the nutritional properties of lupin flour, in order to avoid the aforementioned problems.

Currently, Ecuador maintains 61 companies belonging to the processing industry of dry bakery products such as cookies, biscuits, muffins and among others (Ríos Albuja, 2013). Composition analysis of lupin flour shows that evidently lupin protein is at the level of grains such as soybean that have protein levels between 35 and 50% (Bracamonte Herrera, 2023). In particular, lupin has a protein content of 49.6 g per 100 g of flour. However, for the production of cookies, a large part of the protein content initially present in the flour is lost due to the thermal treatment that they undergo (Asalde Montero & Iparraguirre Lozano, 2023). From the above, it is hypothesized that if it is possible to improve the combination of lupin flour and other healthy components when making cookies, it is possible to obtain a significant increase in the level of protein and fiber, which can contribute to enrich the nutritional quality of the finished product.

The present study proposes a possible alternative snack for celiacs, not only with a high protein content but also with a pleasant taste acceptable to all types of consumers. In addition, the study seeks a better

understanding of functional food by providing a deeper understanding of the potential benefits of lupin flour in the production of cookies. Finally, by improving the nutritional quality of the cookies and generating a higher level of awareness of the value of local food ingredients such as lupin, the pre-sent study could lay the foundation for the production of healthier foods with a better level of sustainability, thus contributing significantly to the general welfare of the population and to the development of the food industry as a whole.

2. MATERIALS AND METHODS

This research studies the use of the nutritional properties of lupin flour in the formulation of a cookie, for which physicochemical, sensory, rheological and texture analyses were carried out. The physicochemical and rheological analyses were carried out in triplicate except for the texture analysis where ten replicates were performed to obtain more reliable results.

Raw Materials

The wheat flour, peeled walnuts, butter, egg yolks and powdered sugar were obtained from markets and supermarkets in Ambato city. The lupin flour was provided by ALIMENTARTE S.A. BIC.

Cookie Making

Stainless steel utensils and equipment were used to make the cookies. To start mixing the ingredients, we used the creaming-method. The first step was to melt the unsalted butter and then mix it with the powdered sugar, using a mixer at its lowest speed for a period of 5 minutes, then the egg yolk was added and beaten until a homogeneous mixture without lumps was obtained. Afterwards, the lupin and wheat flour were added according to the different proportions described in Table 1, the nuts were added and mixed and kneaded again for 3 more minutes. The proportions of the other ingredients used are described in Table 2.

The dough was left to rest for 15 minutes at a temperature between 15 and 18 °C. Then, small portions of 50 grams of the mixture were taken to be rolled with a rolling pin to a thickness of approximately 5 mm. With a 2.5 cm diameter circular cookie cutter, the dough was cut out and the circles of dough were placed on a baking sheet. Finally, the cookies were baked at a temperature of 180°C and after 15 minutes were re-moved from the oven (Cabrera Mera, Benavides Panchana, Cortez Espinoza, Aldas Morejon, & Revilla Escobar, 2023).

Table 1. Flour proportions for each cookie formulation.

Formulations	Description
LMS	0% Lupin flour + 100% Wheat flour
LMC	50% Lupin flour + 50% Wheat flour
LMP	100% Lupin flour + 0% Wheat flour

Table 2. Proportion of ingredients in each cookie formulation

*Ingredients	LMS %	LMC %	LMP %
Wheat Flour	32.18	16.09	-
Lupin Flour	-	16.09	32.18
Nuts	18.39	18.39	18.39
Butter	27.59	27.59	27.59
Sugar	9.20	9.20	9.20
Eggs	12.64	12.64	12.64

* The proportions of the ingredients are expressed as a percentage.

Sensory Analysis

Produced cookies, were used to sensory analysis, to determine the acceptability of the best cookie formulation, a panel of 15 trained judges participated on the different characteristics of the product. Parameters such as color, odor, taste, flavor, texture, and acceptability of the cookies were evaluated along with a five-point hedonic scale with 1 = do not like at all, 2 = do not like moderately, 3 = neither like nor dislike, 4 = like moderately, and 5 = like very much (Lin et al., 2017). Each panelist was given a tasting card along with instructions to mark their response according to their perception. They were also asked to indicate any novelties in the comments section of the tasting card.

Triangular Discriminative Test

For the second part of the sensory evaluation, two triangular tests were performed to know if a significant difference is found between cookies due to the partial substitution of flours, first a test was performed with the LMS and LMC formulations, and then another one with the LMC and LMP formulations described in Table 1. In the first case, two cookies were taken from the LMS formulation and one cookie from the LMC formulation. And in the second case, two cookies of the LMC formulation and one cookie of the LMP formulation were taken (Garrido et al., 2009). Similarly, a tasting card was given to each panelist and the instructions of the test were explained to them so that they could adequately mark their answer.

Rheological Analysis of Lupin Flour

The lupin flour was evaluated in the Mixolab equipment (CHOPIN Technologies) where different farinographic parameters such as water absorption rate, stability and weakening, development time, dough development, gelatinization and starch power, retrogradation and amylase activity were determined. The method applied was the one described in the manual standardized by AACC 54-60.01 (Acurio, Villacrés, & Paredes, 2018).

Texture Analysis of Cookies

The Brookfield texturometer was used to determine the hardness and fracturability properties of the cookie with the guidance of the manual. A cylindrical probe (TA39) and a luminaire base (TA-BT-KIT) were used, and the texturometer was configured with a speed of 2 mm/s and a penetration distance of 5 mm (Aponte, Franco-Crespo, & Jacome, 2023).

Physicochemical analysis of the lupin flour and the cookie

For the determination of the nutritional properties of the flour and cookie with the best formulation, protein determination analysis were performed following the methodology AOAC 992.23, (2023), fat according to AOAC 2003.06, (2023), ash by the method of AOAC 923.03, (2023), moisture according to AOAC 925.10, (2023), dietary fiber by the methodology of AOAC 985.29, (2023), carbohydrates according to the guidelines of the Food and Agriculture Organization of the United Nations, (2002) and energy using the method used by Deng, Wang, Zhong, & Yu, (2018).

3. RESULTS

The sensory analysis for the determination of the cookie with the best acceptability was carried out using a five-point hedonic scale where three cookies substituted with different percentages of lupin flour (0%, 50% and 100%) were compared. Table 3 shows the different scores obtained in the sensory evaluation. The results obtained reflected that there is no significant difference ($p > 0.05$) between the white (LMS) and the other cookie formulations substituted with lupin flour in the sensory parameters analysed (color, odor, flavor and texture). However, in acceptability, there is a significant difference between the control with a score of 3.33 (± 0.90) and the LMP formulation with 4.60 (± 0.51), which indicates that the most acceptable formulation was the one composed of 100% lupin flour (Figure 1). On the other hand, in previous studies where cookies were made by substituting lupin flour at different percentages, it was found that the formulation with 8% substitution showed better sensory properties (Mostafa et al., 2022). However, within the formulation of the cookies produced in the present study, there were pieces of nuts that contributed a slight bitterness to the cookies, and this was balanced with the bitterness of the lupin flour. In this way, a balance between the three formulations was achieved, making the panelists' perception of the flavor of the cookies fairer.

Table 3. Mean sensory scores of different cookies with lupin flour substitutions.

Formulations	Color	Odor	Taste	Texture	Acceptability
LMS	3.93 ± 0.80a	3.60 ± 1.18a	3.87 ± 1.19a	3.47 ± 0.92a	3.33 ± 0.90b
LMC	3.80 ± 0.68a	3.07 ± 0.70a	3.27 ± 0.88a	3.00 ± 0.85a	2.73 ± 0.96b
LMP	3.80 ± 0.77a	3.53 ± 1.06a	3.67 ± 1.18a	3.53 ± 1.13a	4.60 ± 0.51a

LMS: formulation composed of 100% wheat flour, LMC: formulation composed of 50% wheat flour and 50% lupin flour, LMP: formulation composed of 100% lupin flour. Results are reported as means ± standard deviation (SD) of three cookie formulations, data marked with a different letter in the same column are significantly different ($p > 0.05$).

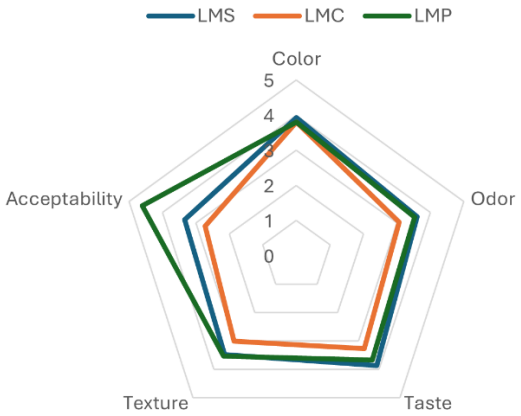

Figure 1. Sensory analysis of different cookies with lupin flour substitutions.

In the second sensory evaluation, a triangular discriminative test was applied, which consisted of comparing the formulations LMS with LMC (Part 1) and LMC with LMP (Part 2) to find out if there are significant differences in the flavor of the cookies. For this purpose, the chi-square test was used, where a null hypothesis (H0) indicating that no significant sensory difference was perceived between the cookies and an alternative hypothesis (H1) indicating that a significant sensory difference was perceived between the cookies. In Table 4, the calculated chi-square values of the two evaluated pairs can be observed. The first part of the evaluation where the LMS and LMC formulations are related presented a chi-square value of 1.20 which is lower than the chi of tables accepting the H0, therefore, no significant differences have been found in the taste of the cookies. In the second part of the evaluation, the LMC and LMP formulations were related, where a chi-square value of 0.30 was obtained, which is also lower than the chi of the tables, accepting the H0 and, therefore, it is concluded that no significant differences were found in the flavour of these cookies. However, the chi value of the second part of the evaluation was significantly lower than that of the first part, indicating that there was a percentage of panelists who did find a difference in the taste of the cookies. Therefore, it can be understood that, thanks to the presence of nuts in the cookie formulation, the bitterness of the lupin flour was attenuated, avoiding the perception of significant differences in its flavour (Garrido et al., 2009).

Table 4. Chi-square results of triangular discriminative test.

Tests	Calculated Chi	Chi of tables
Part 1	1.20	3.85
Part 2	0.30	3.85

Part 1: Triangular test between LMS and LMC formulation, Part 2: Triangular test between LMC and LMP formulations.

The nutritional composition of lupin flour is shown in Table 5 together with the composition of enriched and bleached wheat flour. This type of flour was used because it is considered a multipurpose flour. The wheat flour composition data were obtained from the U.S. Department of Agriculture, (2020). First of all, as it can be observed, compared to wheat flour which only has 10.90% of protein, lupin flour represents 49.58% of its entire composition, being almost 5 times higher than wheat flour. In previous studies, lupin flour presented very similar protein values that ranged from 39.40% to

53.60% due to the different debittering treatments used and the nutrients present in the environment in which it is surrounded (Curti et al., 2022; Mostafa et al., 2022). Therefore, it can be intuited that due to the high protein content of lupin flour com-pared to wheat flour, it could be considered as an ingredient with high commercial value and as an attractive alternative for the development of gluten-free products.

The fat content of the lupin flour obtained was 14.10%, within which approximately 80% contains monounsaturated and polyunsaturated fatty acids such as oleic (46.40%) and linoleic (33.10%) acid, associated with the reduction of cardiovascular diseases and great health benefits (Carvajal-Larenas, Linnemann, Nout, Koziol, & van Boekel, 2016; Visioli & Poli, 2020). Under the same context, wheat flour has only 1.48% fat of its total composition, where 78.62% contains unsaturated fatty acids consisting mainly of oleic acid (20.28%) and linoleic acid (57.67%) (Nikolić et al., 2008).

The values obtained in the determination of ash and moisture of lupin flour were 0.07% and 7.43%, respectively, comparable to those of wheat flour with an ash content of 0.42% and moisture of 9.83%. The low ash levels in the lupin flour could be at-tributed to the debittering treatments performed, which include soaking and cooking. As a consequence of these processes, several soluble minerals may be lost from the lupin, reducing the total ash content. On the other hand, the moisture content of lupin flour is within acceptable ranges and is similar to values reported in previous studies (Mostafa et al., 2022).

The total dietary fiber content of the lupin flour obtained was 24.40% in contrast to wheat flour, which only has 0.07%. Although the fiber content of lupin flour is apparently high, it was possibly reduced due to the debittering process, and the insoluble fraction of the fiber could also be affected by the detachment of the lupin husk in the soaking and cooking processes. In this way, the difference in the total dietary fiber values obtained and those presented by Curti et al., (2022), where a total dietary fiber content of 35.2% is obtained. In the same context, within the dietary fiber of lupin flour there are soluble and insoluble dietary fibers, where the in-soluble ones have an effect on the volume of fecal material and are not used by intestinal bacteria. While the soluble ones, can be metabolized into beneficial compounds and positively regulate the intestinal microbiota (Guan, Yu, & Feng, 2021).

The carbohydrate value obtained from lupin flour, as opposed to its other components, was 4.41%. This value is low in comparison with wheat flour where its carbohydrate content represents 77.30% of its total composition. According to the proximate analysis of lupin flour by Curti et al., (2022) no carbohydrates were found in the composition of the flour, however, this result may differ due to the debittering of lupin. In addition, the result obtained can be considered favourable due to the fact that nowadays the market is looking for alternatives with less carbohydrates and more proteins.

Even when the amount of energy of the flours (kcal) appears to be similar, it can be understood that in lupin flour most of the energy comes from protein, while in wheat flour it comes from carbohydrates. Specifically, lupin flour provides 344.07 kcal, whereas wheat flour provides 366 kcal, as the protein, fat and carbohydrate content of the flours were taken into account for the energy calculation.

Table 5. Nutritional composition of lupin flour vs wheat flour.

Features	Lupin flour	*Wheat Flour
Protein (%)	49.58 ± 0.98	10.90
Fat (%)	14.10 ± 0.00	1.48
Ash (%)	0.07 ± 0.03	0.42
Humidity (%)	7.43 ± 0.03	9.83
Total dietary fiber (%)	24.40 ± 0.00	0.07
Carbohydrates (%)	4.41 ± 0.99	77.30
Energy (kcal)	344.07 ± 0.03	366.00

Results are reported as means ± standard deviation (SD).

* Values obtained from the U.S. Department of Agriculture, (2020).

The nutritional composition of the lupin flour cookie (LFC) is detailed in Table 6 together with the composition of the wheat flour cookie with pecans (WFC). This cookie was used since its composition and ingredients are similar to formulated lupin flour cookie. The wheat flour cookie composition data were obtained from the U.S. Department of Agriculture, (2019). The protein content obtained in LFC was 26.31% as opposed to WFC which has only 4.90%%. Evidently this large difference is due to the lupin flour, which has a high protein content. In addition, the protein values comply with NTE INEN 2085:2005, which establishes that the cookie must exceed 3% protein (INEN, 2005). Being a cookie composed entirely of lupin flour, it is completely free of gluten, avoiding the annoying digestive problems suffered by a small part of the population due to gluten intolerance.

The fat content of the LFC was 43.30% which is a little high due to the fact that the cookie has nuts and butter in its formulation. However, there is not an abysmal difference with WFC which has 32.50% fat. The absence of gluten in the lupin flour requires the use of fats, such as butter, to maintain an adequate texture. However, cookies composed of 10% lupin flour had a fat percentage of approximately 20%. This is due to the fact that the rest of their composition is wheat flour, reducing the amount of butter required (Mostafa et al., 2022).

The ash value of the LFC that was determined was 0.08%, which is extremely low compared to studies that reported ash values of approximately 0.80%. However, this difference is attributed to the substitution of only 10% lupin flour in this formulation (Mostafa et al., 2022). In addition, it also differs with the ash content of WFC (1%).

The moisture value obtained for the LFC was 5.48%, being within the maximum allowed moisture range for cookies of 10% as established by NTE INEN 2085:2005, as well as the WFC complies with the standard, maintaining a moisture content of 3.30% (INEN, 2005).

The total dietary fiber content of the LFC obtained was 17.80%. This value is at-tributed to the fiber content of the lupin flour, surpassing the WFC, which has only 1.80% of total dietary fiber. In addition, the low fiber content of WFC is due to the presence of nuts in its formulation, and not to the wheat flour. However, in studies where 10% substitutions of lupin flour are made for cookies, fiber values of approximately 0.70% are presented. Possibly, due to the low amount of lupin flour used (Mostafa et al., 2022).

The carbohydrate value obtained by difference of the other components was 7.03% for LFC and 58.30% for WFC. The low percentage of carbohydrates in LFC can be very attractive to the market by providing healthier and more nutritious properties, since there is currently a tendency for the population to consume healthier foods (Aranda Tarazona et al., 2021).

The energy intake of LFC (518.36 kcal) was relatively lower than that of wheat (542 kcal). However, most of the energy provided by LFC is from protein and fat, while WFC is mostly from fat and carbohydrates.

Table 6. Nutritional composition of lupin flour cookie vs wheat flour cookie.

Features	**Lupin flour Cookie**			***Wheat Flour Cookie**
Protein (%)	26.31	±	0.88	4.90
Fat (%)	43.30	±	0.00	32.50
Ash (%)	0.08	±	0.01	1.00
Humidity (%)	5.48	±	0.16	3.30
Total dietary fiber (%)	17.80	±	0.00	1.80
Carbohydrates (%)	7.03	±	0.85	58.30
Energy (kcal)	518.36	±	0.65	542.00

Results are reported as means ± standard deviation (SD).

*Values obtained from the U.S. Department of Agriculture, (2019).

A comparison between the nutritional composition of cookies and flours is shown in the Figure 2, where is clearly visible the difference related to the amount of carbohydrates contained in the wheat compared to lupin, also the protein present in lupin is considerably superior, about the fat, the quantity of fat is clearly changed due to the ingredients used in the cookie formulation but is lightly superior in lupin due to its nature.

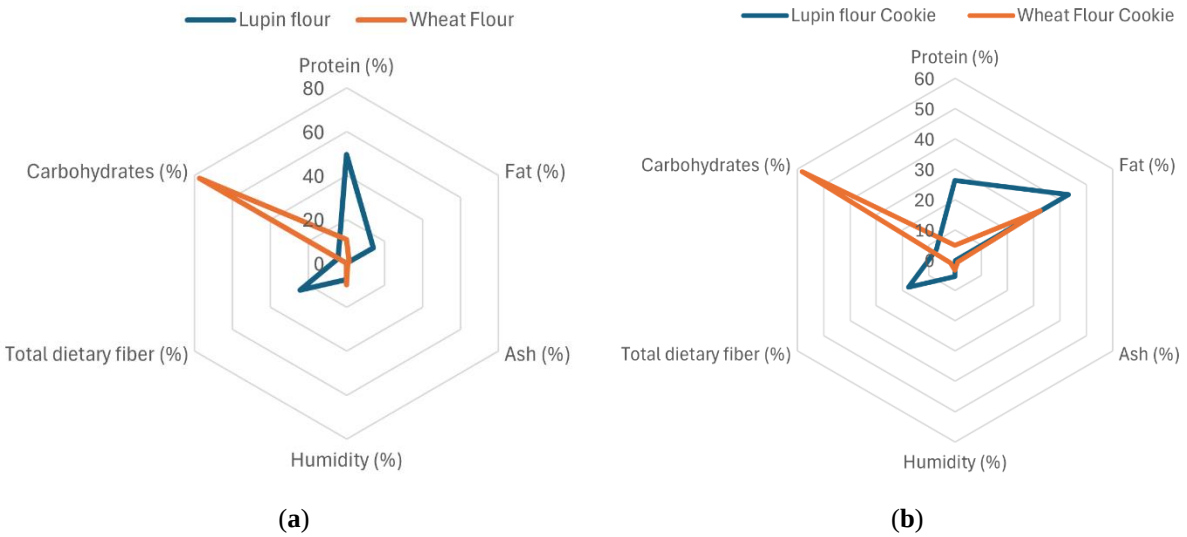

Figure 2. Comparison of nutritional composition of cookies and flours used in the study: (a) lupin flour vs wheat flour, (b) lupin flour cookie vs wheat flour cookie.

Additionally, a texture analysis of the cookies was performed to determine their hardness and fracturability as shown in Table 7. These parameters were determined with the help of the Brookfield Texturometer. For the analysis a TA39 cylindrical probe was used together with the TA-BT-KIT fixture base which compressed the cookies at a penetration distance of 5 mm and a speed of 2 mm/s simulating the bite force of a human. By performing this procedure, the cookie can be broken by measuring the parameters of hardness, as the cookie penetrates, and fracturability, as it retracts.

It should be noted that the values for both hardness and fracturability were identical, which is in line with previous research. However, a high deviation was observed in the results obtained. This is attributed to the presence of nut pieces scattered inside the cookie, which could have caused this variability. Hardness and fracturability are directly related between the water content of the cookie, its different individual ingredients and the chemical bonds between complex molecules such as starch, proteins and their ability to both bind and retain water. In addition, a significant difference was found in the hardness and fracturability parameters ($p > 0.05$) between the LMS formulation and the LMC and LMP formulations. This may be due to the proportion of ingredients used in the three formulations, since the same amount of butter was used for all of them, which may have influenced the result of the analysis of the parameters, causing the cookies with the presence of lupin flour in their formulation to present higher hardness and fracturability. The higher hardness in the cookies with lupin flour could be explained by the relation between starch and protein, because the protein in the cookies with lupin flour is higher, which would lead to a harder structure, and the high presence of fibre could also contribute even more to their hardness (Aponte et al., 2023; Kukurová et al., 2023).

Table 7. Textural properties of cookies.

Formulations	Hardness			Fracturability		
LMS	179.30	±	46.26b	179.30	±	46.26b
LMC	287.40	±	75.85a	287.40	±	75.85a
LMP	287.90	±	77.98a	287.90	±	77.98a

LMS: formulation composed of 100% wheat flour, LMC: formulation composed of 50% wheat flour and 50% lupin flour, LMP: formulation composed of 100% lupin flour. Results are reported as means ± standard deviation (SD) of three cookie formulations, data marked with a different letter in the same column are significantly different ($p > 0.05$).

Table 8 presents the analysis of the rheological properties performed by Mixolab, where it was observed that the dough development (C1) of the lupin flour sample was 1.20 (± 0.04) Nm which represents the maximum torque during mixing, similar to values presented by different wheat flours from other studies with 1.11(± 0.04) Nm.

In the zone of thermal weakening of the proteins, a mass weakening (C1-C2) occurs due to the unfolding of hydrophobic proteins. Here a torque decrease was observed at a weakening rate (α) of -0.05 (± 0.00) Nm/min until reaching a swelling pow-er (C2) of 0.50 (± 0.01) Nm which is equivalent to that presented by wheat flours with 0.47 (± 0.03) Nm.

In the second heating phase, the starch gelatinization rate (β) between C2 and C3 was 0.02 (± 0.03) Nm/min. Here the dough was heated with the water released by the denatured proteins causing starch gelatinization. The consistency of the dough in-creases due to swelling and hydration of the starch granules. Finally, when mechanical shear forces and temperature split the granules, the process stops.

In the lupin flour sample, the starch gelatinization (C3) was 0.88 (± 0.35) Nm as opposed to the wheat flour which presents a torque of 2.21 (± 0.18) Nm. This indicates that the dough of lupin flour is possibly not very viscous, which is why it is ideal for cookies.
After reaching 90°C in the analysis, at an enzymatic hydrolysis rate (γ) of -0.05 (± 0.03) Nm/min produced between C3 and C4, a strength for amylasic activity (C4) in lupin flour of 0.83 (± 0.35) Nm was obtained. On the other hand, wheat flour presented force values of 1.84 (± 0.17) Nm, which indicates that the starch degrading capacity of lupin flour is lower.

Finally, there was a cooling of the starch gel where there was an increase in the consistency of the dough up to C5, corresponding to the end of the starch retrogradation period, and strength values of 1.58 (± 0.12) Nm were obtained compared to the wheat flour where values of 3.12 (± 0.31) Nm were obtained. This indicates that the retrogradation in the lupin flour sample is rather slow (Acurio et al., 2018; Banu, Stoenescu, Ionescu, & Aprodu, 2011).

Table 8. Mixolab's characteristics of lupin flour.

Replicas	C1	C2	C3	C4	C5	α	β	γ	Amplitude	Stability
			(Nm)				(Nm/min)		(Nm)	(min)
1	1.250	0.498	0.682	0.632	1.717	-0.046	-0.002	-0.062	0.110	7.6
2	1.178	0.513	0.668	0.613	1.486	-0.046	0.012	-0.072	0.126	8.7
3	1.177	0.490	1.289	1.236	1.546	-0.052	0.052	-0.012	0.083	8.6
Media ± DE	1.20 ± 0.04	0.50 ± 0.01	0.88 ± 0.35	0.83 ± 0.35	1.58 ± 0.12	-0.05 ± 0.00	0.02 ± 0.03	-0.05 ± 0.03	0.11 ± 0.02	8.30 ± 0.61

4. CONCLUSIONS

Sensory evaluations showed that there were only significant differences in the acceptability of the cookies. The most accepted cookie formulation was the one containing 100% lupin flour (LMP), maybe due to a sensory panel who was looking for the product with more nutritional benefits. On the other hand, in the second sensory evaluation, it was observed that there were no significant differences between the two pairs evaluated because the chi-square values calculated were lower than those of the tables.

The physicochemical analysis of lupin flour showed that it is evidently far superior to wheat flour in terms of protein, fat and fiber content. It should be noted that its caloric contribution does not come mainly from carbohydrates as in the case of wheat flour. Thanks to the properties of lupin flour, it was possible to develop a cookie that significantly surpasses wheat flour cookies with a similar composition, highlighting mainly its protein and fiber levels, as well as its low percentage of carbohydrates.

Finally, the rheological and textural properties of both the lupin flour and the cookie with the best acceptability were defined. The texture analysis performed in the Brookfield Texturometer revealed that the cookie composed of 100% lupin flour presented the highest values of hardness and fracturability. In the rheological analysis of lupin flour, a dough development and starch swelling

power similar to wheat flour were observed; however, in the properties of starch gelatinization, amylasic activity and retrogradation, values far below those of wheat flour were obtained.

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