Franco-Sarmiento, Ruz-Echavarría, Torregroza-Espinosa, Martínez-Mera & Torregroza-Espinoza / INGE CUC, vol. 17 no. 2, pp. 102–114. July - December, 2021

Physicochemical and functional characterization of trupillo flour (*Prosopis juliflora* (Sw.) DC) and its inclusion in a food matrix

Caracterización fisicoquímica y funcional de la harina de trupillo (Prosopis juliflora (Sw.) DC) y su inclusión en una matriz alimentaria

DOI: http://doi.org/10.17981/ingecuc.17.2.2021.010

Artículo de Investigación Científica. Fecha de Recepción: 13/01/2021. Fecha de Aceptación: 08/02/2021.

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To cite this paper:
A. Franco-Sarmiento, W. Ruz-Echavarría, A. Torregroza-Espinosa, E. Martínez-Mera & A. Torregroza-Espinoza, "Physicochemical and functional characterization of trupillo flour (Prosopis juliflora (Sw.) DC) and its inclusion in a food matrix", *INGE CUC*, vol. 17, no. 2, pp. 102–114, 2021. DOI: http://doi.org/10.17981/ingecuc.17.2.2021.10

Abstract

Introduction— The high protein content has made legumes a raw material of interest in the formulation of different agro-industrial products; the trupillo (*Prosopis juliflora*) tree is an easily accessible, multipurpose, wild legume that can be used in all its composition, has a high protein value and little commercial level, which is currently being wasted as it is mistakenly considered a weed and that It could be seen as a new alternative that helps in the potentialization of the food sector.

Objective— This research aims to functionally characterize trupillo flour (*Prosopis juliflora*), obtained from leaves and seeds, to include it in a food matrix as a protein extender.

Methodology— The experimental design for this research required three phases, i) obtaining, bromatological and functional characterization of leaf flour and trupillo seeds, ii) standardization of formulations for artisan sausages using trupillo flour as a protein source, and iii) bromatological and sensory characterization of the processed sausages.

Results— It was found that the flours obtained preserved the characteristic odor and color of each raw material. Particularly, the seed flour presented bromatologically and functionally better protein contents (27.7%), ash (8.04%), swelling capacity (16.7 ml water / g sample), water absorption (7.89 g water / g sample) and water retention capacity (27.9 g water/g sample), for which it was selected to be included in the sausages. In the three formulations made (C, CT and T), there were variations in the color and texture of the sausages, with Formulation T standing out for presenting higher protein content (13.7%). However, consumers preferred Formulation C.

Conclusions— These results allow to propose the inclusion of sausage with trupillo flour in the human diet as an alternative to traditional products.

Keywords— Protein extender; water retention capacity; swelling capacity; functional characterization; bromatological analysis

Resumen

Introducción— El alto contenido de proteína ha hecho de las leguminosas una materia prima de interés en la formulación de diferentes productos agroindustriales; el árbol de trupillo (*Prosopis juliflora*) es una leguminosa silvestre de fácil acceso, polivalente, aprovechable en toda su composición, de alto valor proteico y poco nivel comercial, que en la actualidad está siendo desaprovechada por ser considerada erróneamente como una maleza y que podría ser vista como una nueva alternativa que ayude a la potencialización del sector alimentario.

Objetivo— Esta investigación tiene como objetivo caracterizar funcionalmente la harina de trupillo (*Prosopis juliflora*), obtenida a partir de hojas y semillas, para incluirla en una matriz alimentaria como extensor proteico.

Metodología— El diseño experimental de esta investigación requirió de tres fases, i) obtención, caracterización bromatológica y funcional de la harina de hojas y semillas de trupillo, ii) estandarización de formulaciones de embutidos artesanales utilizando la harina de trupillo como fuente proteica, y iii) caracterización bromatológica y sensorial de los embutidos procesados.

Resultados— Se comprobó que las harinas obtenidas conservaron el olor y color característicos de cada materia prima. En particular, la harina de semillas presentó bromatológicamente y funcionalmente mejores contenidos de proteínas (27,7%), cenizas (8,04%), capacidad de hinchamiento (16,7 ml de agua/g de muestra), absorción de agua (7,89 g de agua/g de muestra) y capacidad de retención de agua (27,9 g de agua/g de muestra), por lo que fue seleccionada para ser incluida en los embutidos. En las tres formulaciones realizadas (C, CT y T), hubo variaciones en el color y la textura de las salchichas, destacando la Formulación T por presentar mayor contenido en proteínas (13,7%). Sin embargo, los consumidores prefirieron la Formulación C.

Conclusiones— Estos resultados permiten proponer la inclusión de embutidos con harina de trupillo en la dieta humana como alternativa a los productos tradicionales.

Palabras clave— Extensor proteico; capacidad de retención de agua; capacidad de hinchamiento; caracterización funcional; análisis bromatológico

I. Introduction

In Colombia, protein intake is low in a large sector of the population, which indicates that the recommended daily amount (0.91 g/kg of body weight) cannot be supplied [1]. This fact is predominant in low-income groups due to the high cost and limited availability of protein-rich products [2]. Likewise, the country has great variety of legumes and grasses, including soy, bean, lentils, wheat, corn, among others; which are used in the food industry in multiple transformations and as inputs for the production of sausage-type meat products, called "extenders" [2]. Extenders are used as a key strategy to reduce production costs, increase yield and profits, and improve organoleptic and nutritional characteristics, by replacing part of the animal protein with vegetable protein. Examples of these most common agricultural raw materials are corn, wheat, soy, lentils, beans, or quinoa. However, there are other raw materials that are abundant in some regions but that are underutilized due to limited information, among which it is possible mention: chachafruto (*Erythrina edulis*), quinoa (*Chenopodium quinoa*) [12] and trupillo (*Prosopis julifora*) [1].

The importance of studying the elaboration of food products with this raw material lies in the fact that the trupillo tree is a wild legume with easy access, multipurpose, usable in all its composition, possessing a high protein value and little commercial level, which is being currently wasted by being mistakenly considered as undergrowth and that could be seen as a new alternative that helps in the potentialization of the food sector [3].

Although investigations have been carried out in order to evaluate the effects of the inclusion of new vegetable raw materials or extenders in products such as sausages and some focus their attention specifically on trupillo seed flour. The present work broadens the panorama by evaluating not only the flour obtained from trupillo seeds but also analyzes and characterizes bromatologically and functionally. Additionally, the inclusion of the flour in a food matrix will be validated.

II. Literary Review

From its origins, food has played a fundamental role for man. This not only determined his lifestyle, his place of settlement or represented power, but also allowed his survival. However, since the 1970s, concerns began to arise about global food production and availability under the concept of food security. The Food and Agriculture Organization of the United Nations (FAO) [4] refers to food security as the capacity of all people, at all times, to have physical, social and economic access to sufficient food, safe and nutritious, that satisfies their needs and preferences to lead an active and healthy life.

As a consequence of the above, the food sector has been evolving and transforming its perspectives in order to face the demands of the market and the challenges imposed by the current globalized world. Therefore, investigations of the sector have begun to turn around formulating healthy products, innovation in food and the study and development of new raw materials [5].

Specifically in the meat industry, due to the continuous changes it experiences either by technological innovations or consumer demand for products increasingly protein-rich products, the number of investigations for the inclusion of various raw materials and the search for technologies that allow greater use of existing ones have been gaining place and are relevant for the potentialization of the sector [1], [6], [7]. As a specific example is the use of protein concentrates also called extenders, which are substances that fulfill the purpose of replacing part of the meat that is used, offering protein and functional contribution to the products, increasing yield, maximizing profits and reduce production costs [8], [9], [10], [11].

Some studies documented in the literature and carried out on this subject have been developed for the production of commercial sausages, in which agricultural by-products have been used that due to their properties are capable of replacing conventional wheat or soy flour among which are rice [8], quinoa [12], corn and other vegatables [11], [13], [14], [15], [16]. Researchers from the UNAL (Colombia) [17] used common bean flour (*Phaseolus spp.*) variety sabanera as an extender in the elaboration of a Frankfurt-type sausage, obtaining good results in terms of increased luminosity and increased cutting force and effort as greater proportion is added. Likewise, UniCartagena investigators (Colombia) [2] evaluated the effect of *Lens culinaris* verdina variety flour on the physical characteristics and acceptability of a sausage, achieving positive effects on the texture parameters and interesting protein values.

Studies at the Unicauca (Colombia) [18] produced enriched pasta from quinoa and carrot flour, resulting in products of higher nutritional quality and easy adaptation to the consumer. Research conducted by UTA (Ecuador) [19] analyzed the effect of the substitution of wheat flour for quinoa flour for the formulation and elaboration of Viennese sausages with functional characteristics, of which the formulations, in addition to being accepted by consumers, showed improvements in the nutritional content and functional. Scientists from UNAL (Colombia) [20] evaluated physicochemical and sensory sausages including quinoa flour concluding that quinoa flour could be used as a substitute for wheat flour because it improves the composition of the products and positively affects their acceptance.

On the other hand, Unicartagena [21] based their research on the preliminary study of the technological development of a sausage using trupillo seed flour (*Prosopis juliflora*) obtained in the city of Cartagena (Colombia). The results indicated that the trupillo seed flour contained 33.8% protein and 37.4% carbohydrates. These factors are key for the subsequent incorporation as an input in new products and that open the range of possibilities for the trupillo to be considered an ingredient that responds to the deficit of protein foods in the country and specially in the Colombian Caribbean region. Subsequently, In addition, Unicartagena [1] evaluated the physicochemical, microbiological and sensory quality of a sausage made with trupillo seed flour, concluding that trupillo flour is a non-meat alternative with good functional characteristics that can help reduce production costs in the meat industry and provide protein intake without affecting the sensory characteristics of the final product. However, the trupillo seed is not available throughout the year and it is possible to access it only in the dry season due to the phenology of the tree, which limits the sustainability of flour production, making relevant new studies with other organs of the tree, for example, the leaves.

Studies in reference to the trupillo date from the 20th century in which it is presented as a tree widely used by American indigenous communities for human consumption, for making structures and as fuel [22]. In addition, they show its potential by presenting it as a legume with high protein value, easy access and low commercial level commonly used as a supplement for ruminants [23]. Mexican analyses [24] state that the loss of the fruit as organic matter exceeds 50%, approximately 15% is used for livestock feed and the remaining 35% is sold for various uses. Finally, Colombian studies [3] in his research emphasizes that the industrial analysis of the trupillo fruit has only taken place in countries such as Peru, Mexico and Brazil, however, the creation of companies dedicated to the commercialization of food with this raw material is viable in Colombia.

III. Methodology

For this research the following methodology was used:

A. *Selection of raw material*

Samples of 1 000g of physiologically active leaves, without stains, without fungal contamination and without damage by insects, and 1 000 g of pods from which the seeds were removed, healthy, whole and without insect or fungal damaged.

B. *Preparation of flour leaves and seeds:*

The leaves and seeds were independently dried in an oven at 60ºC for 24 h, they were ground four times in a traditional mill and between each ground they were passed through a No. 20 mesh sieve until a fine flour was obtained. The flour obtained was stored at 30°C ± 2°C, for later analysis. All evaluations were carried out in triplicate and the results were expressed in terms of mean and standard deviation.

C. *Physicochemical characterization of flours*

For the physicochemical characterization, the following analyzes were made:

1) *Protein determination*

The analysis was performed by the accredited laboratory Biotrends Laboratorios S.A.S., which used the method proposed by the ISO 1871:2009 and interpreted the results of the parameters evaluated by the NTC 1325 standard [25].

2) *Humidity determination*

It was carried out in a hot air flow chamber. 3 g of homogenized sample were weighed into a lidded filter scale (previously weighed after drying for 1 h at 105°C). Subsequently, the sample was dried in the oven for 2 h at 100°C-110°C. It was removed from the oven and allowed to cool in the desiccator. When the temperature of the sample was equilibrated with the ambient temperature, the weighing was carried out. This procedure was repeated until a constant weight was obtained. The percentage of humidity was calculated with (1).

$$\% \, humidity = \frac{P\,m\,(g) - (Pmc(g) - Pc(g))}{Pm\,(g)} * 100 \tag{1}$$

Where:

P m	: Grams of sample used initial.
P mc	: Grams of sample and capsule after drying.
P c	: Grams of the dry capsule without sample.

3) *Ash determination*

It was carried out by calcination in a muffle. 2 g of homogenized sample were weighed into a previously weighed crucible for 2 h at 150°C. The sample was calcined in a muffle for 2 h at 550°C. It was cooled in a desiccator and weighed. The ash percentage was calculated with (2) [26].

$$\% \, Ash = \frac{(Pm\ calcined(g) - P\ capsule\ (g))}{P\ sample} * 100 \tag{2}$$

4) *Determination of pH and Acidity*

10 g of homogenized sample were weighed into a 250 ml Erlenmeyer flask, stirred for 10 min and the pH was determined with a food pH meter. Then, the sample was filtered and 20 ml were taken for evaluation by titration with sodium hydroxide (NaOH) to 0.1 N and phenolphthalein indicator (3 drops) to present a turn or change pink in the sample. The percentage of acidity was determined by (3) [27].

$$Acidity = \frac{GB * N * Peq * 100}{A} \tag{3}$$

Where:

GB	: buret flow (ml).
N	: Normality of the titrant agent.
Peq	: u.m.a sample acid.
A	: ml dof titrated sample.

D. *Functional characterization of the flour*

For the functional characterization of the flour, the following analyzes were carried out:

1) *Swelling capacity (SC)*

2.5 g of sample were weighed into a graduated cylinder, an excess of water (30 ml) was added and it was stirred manually. It was left to rest for 24 h at room temperature (27°C ± 0.5°C) and then the final volume (*vf*) of the sample was measured in ml. The SC was calculated with (4):

$$SC = \frac{vf\ (ml)}{Sample\ weight\ (g)} \tag{4}$$

2) *Water retention capacity (WRC)*

1 g of sample was weighed into a test tube, 30 ml of water was added, stirred and allowed to hydrate for 18 h. Then it was centrifuged at 2000 rpm for 30 min, the supernatant was separated and the residue was transferred into a crucible. Then, it was weighed to obtain the wet residue value (wr). Subsequently, the residue was dried at 105°C ± 1°C for 24 h and weighed again obtaining the value of the dry residue (dr). The WRT was calculated with (5):

$$WRC=\frac{wr\ (g)-dr\ (g)}{dr\ (g)} \tag{5}$$

The percentage of soluble material was calculated indirectly from the WRC with (6).

$$\%\ solu=\frac{Sample\ weight\ (g)-dr\ (g)}{Sample\ weight\ (g)}*100 \tag{6}$$

3) *Water absorption capacity (WAC)*

0.5 g of sample was weighed into a test tube, excess water (10 ml) was added and stirred for 30 min. Then it was centrifuged for 10 min at 3000 rpm. The supernatant was removed and the pellet was weighed. The result was expressed in grams of water per grams of sample. The WAC was calculated with (7).

$$WAC=\frac{Sediment\ weight\ (g)-Sample\ weight\ (g)}{Sample\ weight\ (g)} \tag{7}$$

E. *Inclusion of flour in a food matrix*

The food matrix chosen to include trupillo flour was artisan sausages.

1) *Preparation of sausages*

Previous experimental tests were carried out for the selection of the general formulation, and 3 sausage formulations were approved, where only the percentages of the protein extenders (wheat flour and trupillo flour) were varied (Table 1).

Table 1. Formulations for the elaboration of artisan sausage

Input	Formulation C(%)	Formulation CT(%)	Formulation T(%)
Beef	25	25	25
Pork Meat	8	8	8
Grease	6	6	6
Ice	33	33	33
Isolated soy protein	3	3	3
Water	11	11	11
Salt	2	2	2
Nitrites	0.02	0.02	0.02
Polyphosphates	0.3	0.3	0.3
Seasoning type Frank	1	1	1
Ascorbate	0.2	0.2	0.2
*Wheat flour	10	5	0
*Trupillo flour	0	5	10

* Formulation C (100% wheat flour). Formulation CT (50 % wheat flour and 50 % trupillo flour). Formulation T (100% trupillo flour). Source: The authors.

The sausages were made in the Bioprocesses laboratory of the Universidad de la Costa (Colombia). The raw materials were weighed according to the predetermined formulations. All the ingredients were placed for 1 min in the cutter (Kramer KUT09) to homogenize. During this stage, half of the ice to be processed, the seasoning, nitrites (diluted in water), polyphosphates, ascorbate, isolated soy protein and salt were added, taking as reference the percentages established by NTC 1325: 2008 [25].

Then the grease, remaining ice, and extender were added. All raw materials were mixed for 6 min taking care that the process temperature did not exceed 12°C, to avoid denaturation of proteins and loss of water retention capacity. The emulsion was removed from the cutter when its consistency was observed homogeneous.

After obtaining the emulsion, the stuffing was carried out by means of a hydraulic stuffer (Tunder 110 V) using 19-gauge synthetic sausage casing. The sausages were tied manually and it was guaranteed that their weight was homogeneous and consistent with that of commercial sausages. Subsequently, they were subjected to blanching until reaching an internal temperature of 65°C-67°C. This was aimed at the coagulation of the proteins, and which was completed by means of a heat shock with a mixture of water and ice at a temperature of 10°C for 10 min. Finally, the sausages were packed using a vacuum sealing machine (SAVSM260X8. CAZATI) and stored in the refrigerator at 4°C.

F. *Cooking losses*

The weight loss of the products, which were obtained before and after each cooking process or reduction of the cooked portion, was evaluated and calculated using (8).

$$CL = \frac{W\ of\ raw\ sausage - W\ of\ cooked\ sausage}{W\ of\ raw\ sausage} * 100 \qquad (8)$$

G. *Physicochemical characterization of sausages*

For the physicochemical characterization, the determination of proteins, humidity, ash, pH and acidity was carried out, using the procedures described above and required by the NTC 1325: 2008 [25].

H. *Sensorial characterization of sausages:*

An affective sensory evaluation was carried out on 50 untrained panelists with samples of sausages of the different formulations (formulation C, CT and T). A structured hedonic scale was used with the options: "I like it a lot", "I like it", "I'm indifferent", "I dislike it", "I dislike it a lot", evaluating the characteristics of smell, color, taste, texture and general acceptability [29]. For this, the evaluators were provided with a digital form which they accessed through a QR code in which instructions for the test were provided, consent was requested for both the application and data processing, and information was also requested on the age, gender, and stratum.

IV. Results and Disussion

The results obtained from the investigation are shown below:

A. *Obtaining the flours*

The flours obtained showed typical characteristics of each material, maintaining their particular color and smell. From the seed sample, 254.5 g of flour were obtained with a yield of 51%, and from the leaf sample, 192.6 g of flour were obtained with a yield of 39%. Both with solid, smooth, and fluid texture, without agglomerates, with adequate properties of particle size, moisture content and conservation.

The yields obtained in the elaboration of trupillo flour from both the seed and the leaf were low compared with the process of obtaining other flours, for trupillo flour it has been reported

80% [30], for bean concentrate 78% [31] and for quinoa flour 95.72% [32]. The results of the bromatological analysis allowed evaluating the differences between the leaf and seed flour samples with reports from the literature.

B. *Physicochemical characterization of flours*

The physicochemical analysis for trupillo seed and leaf meal showed differences (Table 2). Seed meal obtained higher protein contents (27.7%) and ash (8.04%) compared to leaf meal (20.4 and 2.12%, respectively). Similarly, the percentage of moisture was higher in seed flour (8.7%) than in leaf flour (3.4%). Regarding acidity, leaf flour had higher values (0.0138%) than seed flour (0.0036%). Finally, the pH of the flours was slightly acidic (4.96 and 5.93 leaf and seed flour, respectively).

Table 2. Physicochemical characterization of trupillo flour.

content	Leaf flour	Seed flour
Protein (%)	20.40	27.70
Humidity (%)	3.4 ± 0.002	8.7 ± 0.002
Ashes (%)	2.12 ± 0.004	8.04 ± 0.003
Acidity (%)	0.0138 ± 2.034E-5	0.0036 ± 4,826E-6
pH	0.025	1.93± 0.006

Source: The authors.

Seed meal obtained higher protein contents (27.7%) and ash (8.04%) compared to leaf meal (20.4 and 2.12%, respectively). However, leaf flour presented higher protein and ash values than other flours, for example, wheat flour (12.2% and 3.62%, respectively) [33] and quinoa flour (11.8% and 1.74%, respectively) [34]. Legume seeds are two to three times richer in protein than cereals and the high percentage of ash in flours is directly proportional to the high content of nutrients [5]. On the other hand, the protein content of leaf meal is related to the proximal analyzes of Prosopis juliflora and Prosopis pallida species, which report between 14%-26% [22].

Similarly, the % moisture was higher in seed flour (8.7%) than in leaf flour (3.4%), the first coinciding with values reported for banana (8.28%), lentil (8.53%) and mushroom (9.26%) [5]. Regarding acidity, leaf flour had higher values (0.0138%) than seed flour (0.0036%), while for pH they were 4.96 for leaf flour and 5.93 for seed. In general, both samples were kept within adequate ranges, acidity values higher than 0.25% in flours can modify physical, chemical, and rheological properties of the doughs, and pH lower than 3.4 can cause alterations caused by acetic and butyric microorganisms [5].

C. *Functional characterization of the flours:*

The comparison of the flours obtained from the seeds and leaves of trupillo showed differences in functional properties (Table 3). In the SW and WAC, the seed meal presented a higher value (16.7 ml water/g sample) in relation to the leaf meal (14.56 ml water/g sample). For the WRC, the seed meal exhibited a higher value (27.84 g water/g sample) compared to the leaf meal (10.50 g water/g sample), and the solubility presented very little difference between the flours (0.44 g soluble portion/g sample and 0.47 g soluble portion/g sample for seed and leaf, respectively).

Table 3. Functional characterization of trupillo flours.

feature	Leaf flour	Seed flour
WRC (g water/g sample)	10.50	27.94
WAC (g water/g sample)	5.60	7.89
SC (ml water/g sample)	14.56	16.7
Solubility (g soluble portion/g sample)	0.47	0.44

Source: The authors.

The functional evaluation showed differences between the flours, demonstrating predictions of processing such as mass formation and its behavior in other food matrices such as meat products. In the SC and WAC, the seed meal (16.7 ml water/g sample) presented a higher value in relation to the leaf meal (14.56 ml water/g sample). This behavior can be explained by the fiber content, which plays an important role in volume gain through high water absorption [5]. For the WRC, the seed flour (27.94 g water/g sample) exhibited better value compared to the leaf flour (10.50 g water / g sample), results that share a relationship for the protein content of the seed, since the higher its protein content, the better the WRC [30], presenting better characteristics and meeting the requirements of agro-industrial interest. The solubility showed very little difference between the flours (0.44 g vs. 0.47 g soluble portion/g sample for seed and leaf, respectively).

D. *Physicochemical characterization of sausages*

Considering that the flour from the trupillo seed presented higher protein values, it was selected for inclusion in the food matrix (artisan sausages). According to the results obtained and presented in Table 4, formulation T obtained a higher protein content (13.7%) and acidity (0.158%) compared to the other formulations. Regarding formulation C obtained a high moisture content (75.38%) and a pH of 6.74. The CT formulation was characterized by a high ash content (3.10%).

Table 4. Comparative table between the three treatments.

content	Formulation C	CT formulation	Formulation T
Protein (%)	11.3	12.4	13.7
Humidity (%)	75.38 ± 0.003	70.66 ± 0.026	73.52 ± 0.022
Ashes (%)	2.85 ± 0.003	3.10 ± 0.001	2.74 ± 0.003
Acidity (%)	0.144 ± 0.0001	0.138 ± 0.0001	0.158 ± 0.0002
pH	6.74 ± 0.015	6.67 ± 0.086	± 0.044

Source: The authors.

After comparing and analyzing Table 4, it was determined that according to the physicochemical characteristics of the products, the best treatment consisted of the CT formulation (50% wheat flour and 50% trupillo flour).

Regarding the bromatological composition of the sausages, there were higher values for protein in the T formulation (13.7%), followed by the CT formulation (12.4%). These results comply with the provisions of Colombian regulations [25], which determine a minimum of 10% protein. However, lower data were presented than those reported by other investigators when evaluating the inclusion of extenders in sausages [2], [20], [1]. The variation between the formulations with wheat flour and trupillo flour could be related to the fact that the protein content of the trupillo is higher (13.9%) [35] compared to that of wheat flour, which is in a range between 10 at 12% [36].

The moisture content of the three formulations was kept within the range allowed by NTC 1325 [25], which determines a maximum of 90% for standard sausages. The results were lower than those presented by Unicartagena [1] for sausages with trupillo flour as an extender and greater than those obtained for sausages with *Lens culinaris* flour [2]. The high moisture content makes it convenient to include microbiological analyzes in future investigations focused at least on the detection of total and fecal coliforms, Salmonella, and molds, applied to raw materials, fresh finished products and at various intervals during the storage stage.

The percentage of ash was higher in those formulations that included wheat flour (formulation C and formulation CT), which may be due to the nutritional content, specifically the minerals that this cereal presents compared to those of trupillo flour. It should be noted that for greater accuracy in the interpretation of the ash results, a detailed analysis of the trupillo flour on these components would be complementary, for which the methodology followed by UO [37], who determined the iron content, could be followed., phosphorus, calcium and some antinutritional factors in flour from the rhizome of handsome (*Maranta arundinacea*).

The acidity in sausages is governed particularly by the characteristics of the raw material, in this case the meat, which also influences the functional properties of the emulsions such as WRC, protein solubilization, color and in the microbial growth [38].

The pH obtained for the three formulations was characterized by tending towards neutrality, corroborating the findings of universities in Portugal and the West Indies [39], who consider sausages as a low acid meat product (final pH > 5). In addition, they coincided with the ranges obtained by universities in Ecuador [40], when evaluating the use of rejected banana in the production of Frankfurt-type sausages. However, for the analysis of protein products, other researchers from UNAL (Colombia) [28] have controlled this parameter during a period under storage because these products tend to release amino groups that cause chemical reactions and microbial growth [41], [42]. Likewise, pH ranges close to neutrality have been identified as the ideal means for the development of microorganisms [42].

E. *Cooking losses (CL)*

In the cooking process, the CT formulation obtained a greater loss of cooking with a percentage of 3.40%, continuing with the C formulation that obtained a value of 2.30% and finally the T formulation with a percentage of 0.42%. Formulation T (100% trupillo) was the one that presented the best response to thermal processes with a lower percentage of weight loss (0.42%).

F. *Sensorial characterization*

The evaluations made to the panelists allowed determining different degrees of preference between the three formulations, highlighting, that better results were achieved for formulation C in the aspects of taste, smell, color, texture, and general acceptability, followed by the CT formulation with wheat flour. and trupillo. Specifically, regarding taste, 54% of those surveyed said “I like” formulation C, while the CT and T formulation obtained a higher percentage of 40% in “Disgust me”. According to the odor evaluation, 46% of those surveyed stated that they “like” the product of formulation C, compared to formulations CT and T, which obtained 38% of “I am indifferent”. In the characterization of the color, formulation C obtained with a 52% “Like” of the product; then followed by the CT formulation with 38% “I like” and finally the T formulation with 32% “I am indifferent” to the product. For the texture, 56% stated that they “like” formulation C, 30% indicated that they “like” the CT formulation, while 32% stated that “I really dislike” the texture of formulation T. Finally, acceptability, 54% of respondents accepted formulation C with better sensory characteristics; While the CT formulation obtained a rejection of 32% and the T formulation was not accepted with a percentage of 36% of the interviewees.

Although information on gender, age and stratum was considered for the segmentation of the market and the characteristics of the consumers, it was not possible to determine these parameters since the groups according to age and gender did not keep proportions in terms of members nor were there significant differences in the stratum that interfered in decisions. The rejection observed during the sensory analysis of sausages including trupillo flour could be due to the habit of consumers to commercial products and to the natural resistance that people have to ingest new foods due to poor adaptation [44]. The variations in texture in the sausages with trupillo flour could be the result of the higher WRC that this flour has compared to wheat flour as an effect of the absence of gluten in said legume [43]. The application of descriptive sensory tests is proposed for future research to describe the formulations in an objective and complete way and to understand the variations in texture of the emulsion and the final product and the color changes of the sausages.

V. Conclusions

The flours obtained showed typical characteristics of the raw materials, maintaining their color and smell. The yields for obtaining the flours were low compared to those of other legumes. The seed meal sample had higher protein, ash, and moisture contents. Regarding acidity, the leaf meal presented higher values while the pH of the seed meal was higher. However, both samples were found in adequate ranges in which it is not possible that there are modifications in the physical, chemical, and rheological properties of the masses or alterations by microorganisms. The seed flour showed higher values for SC, water absorption and WRC. Since the seed flour reflected better characteristics, it could be considered as an alternative in the food industry and would allow the agro-industrial use of the trupillo. It should be noted that in Colombia there is no specific regulation for alternative flours intended for human consumption, for which the results obtained in this research were based on the theoretical foundation in various authors. However, when using these raw materials as extenders, not only economic, technological, or sensory aspects must be taken into account, but also legal implications such as the identity of the products, the proportions used and the quality standards of the main product.

In the sausage formulations made, there were notable variations in the texture and color of the sausages. Of these, the one with the highest protein content was the trupillo sausage (13.7%), a value that is within the ranges allowed by Colombian regulations. Due to the high moisture content, the microbiological analysis of sausages is important for future research. The sensory test carried out indicated that the control sausage had greater acceptance by consumers, which may be due to the consumer's habit of commercial products.

Finally, despite the above, due to the high protein content, the sausage with trupillo flour as an extender could be included in the human diet.

Financing

Scientific research article derived from the undergraduate thesis "Elaboration of artisan sausages using trupillo flour (*Prosopis juliflora*) as a protein extender". Start year: 2018, end year: 2019.

Acknowledgments

To the Bioprocesses laboratory of the Universidad de la Costa (CUC) for carrying out the laboratory analyzes. To the AGROINCUC research hotbed for research training.

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