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Utilization of tara seed germ (*Caesalpinia spinosa*) in the development of a texturized meat analog

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Abstract– The research aimed to was to take advantage of the tara germ (Caesalpinia spinosa) as an industrial by-product, due to its protein contribution (> 40%) and to develop a textured vegetable as an component in the formulation and production of a meat analogue. During the texturing process, operating parameters were determined such as humidity of the mixture (maximum 15%), temperature in the twin screw extruder equipment (150 °C and 130 °C), feeding speed (18.35 rpm) and speed of the screws (50 rpm). The characterization of texturing includes physicochemical and nutritional tests and evaluation of the techno-functional properties that influence the development of a meat analogue. The study was able to define the viability and acceptance of textured tara germ as an alternative to animal protein.

Keywords-- By-product, vegetable texturing, meat analogue, hamburger.

I. INTRODUCTION

The highest quality protein source undoubtedly remains meat due to its nutritional contribution and sensory characteristics [1]. Today, the global population continues to grow, which also leads to an increase in meat consumption [2]. Meat production and its derivatives have a significant impact on the environment, due to issues such as deforestation, greenhouse gas emissions, and other environmental impacts [3, 4]. In response, measures were sought to address these problems, one of which points to the trend in meat consumption, which can vary by country, socioeconomic factors, cultural factors, among others. The arrival of COVID-19 generated economic and social consequences and changes in people's lifestyles [5], for example, modification of dietary habits and a preference for healthier foods, preferably from plant sources [6, 7]. This new style refers to the trend of leading a healthy life, which continues to grow steadily, due to its importance for people's health [8]. Currently, consumers are aware of the importance of knowing what they are eating and inform themselves about the nutritional content of products [9], seeking in this way foods low in fat, sodium, sugar, and calories [10]. In this context, there is a trend towards the consumption of alternative meats, due to concerns about healthy eating and sustainability, leading to the search for alternatives such as plant-based proteins like those from legumes or peas such as soy, lentils, and peas [11].

Another sustainable proposal involves utilizing tara germ (*Caesalpinia spinosa*), a byproduct from processing tara seed to obtain gum. Despite the tara germ, as a byproduct, having a high protein rate (>40%), it is currently marketed and used exclusively for animal feed. Food extrusion allows for the manufacturing of a variety of food products [12], offering the possibility to process mixes from different sources while adjusting the nutritional level, as well as inactivating enzymes and factors [13].

This method involves forcing a mix of ingredients through a die or nozzle with a specific shape to produce a continuous mass with a determined shape and texture, working at high temperatures in a short time, transforming a variety of foods [14, 15, 16]. Among the benefits it provides to the food is the increase in protein digestibility [17], reducing its microbial load and improving sensory attributes such as texture [18]. In this sense, the tara germ will undergo an industrial process called extrusion to enhance its applicability and nutritional contribution. With this type of process, it is possible to texturize proteins and create products similar to meat. Research shows that products obtained through this process are interesting, as the global consumption of meat is decreasing due to increased social, ecological, ethical, and health awareness [19]. The conversion of protein into a fibrous structure is achieved by subjecting the protein to a stress situation, causing its denaturation, orientation, and reorganization of the new aggregates. Meat analogs are a protein product where the main component is plant-based protein, responsible for offering an appearance and texture similar to animal muscle [19]. Texturized plant protein must present structural integrity and an identifiable structure so that each unit resists hydration and cooking, and other procedures used in the preparation of said food for human consumption [20].

With the aim of developing an alternative to traditional animal protein, the tara germ (a plant-based protein source) will be transformed into a texturized protein acquiring an appearance similar to meat, achieving better utilization of the agro-industrial byproduct. It is proposed to texturize destannified tara germ to obtain a meat analog product and apply it as a meat substitute in the preparation of food for human consumption.

II. METHODOLOGY

A. Plant material

The tara germ was provided by Exandal S.A.C. in the district of Puente Piedra, Province of Lima (Lima, Peru) as a byproduct of the processing of tara seed for the extraction of tara gum. The tara germ was previously destannified using a

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technique developed by the company. Specific information related to this technique is not available as Exandal S.A.C keeps it confidential. The tara germ has a protein content of at least 49% and a tannin content of less than 1%. Table I shows the nutritional profile of the destannified tara germ.

Table I. Nutritional profile of destannified tara germ

Component	Value
Proteins (%)	49.37
Carbohydrates(%)	24.70
Fats (%)	12.14
Ashes (%)	6.30
Dietary Fibe (%)	17.04
Total Starch (%)	1.14 ± 0.01
Tannins (%)	0.90 ± 0.01
Gluten	< 5.0 ppm

B. Definition of operational parameters in the texturizing process

From preliminary tests using a pilot-scale double-screw extruder (FAMAIC, Peru), three mixes were prepared with tara germ protein and 5% corn starch at three moisture levels (14%, 19%, and 24%). In the feeding cabin of the double-screw extruder, each of the mixes was placed and the resistances to temperatures, the product feed flow, and the screw speed were set according to what is described in Table II. To evaluate the rehydration of the texturized product, a test was conducted in water at 70°C for a sample immersion time of 15 minutes, after which it was allowed to drain.

Table II. Operational Parameters of the Texturizing Process

Mix	Feed Speed (rpm)	Screw Speed (rpm)	Temperature (°C)
N1 N2 N3	10 - 19	40 - 60	Zone 1: 140 - 160 Zone 2: 110 - 130

C. Production of texturized products from destannified tara germ

With the defined operational parameters, mixes were made to diversify the use of destannified tara germ as a meat substitute using color enhancers to give it an appearance similar to meat. Natural vegetable colorants based on anthocyanins, betalains, and norbixin were used. Three mixes were prepared: destannified tara germ (DTG) as the control mix, destannified tara germ with 5% starch (DTGS), and destannified tara germ with 5% starch and natural colorants (DTGSC), and they were processed under the same operational conditions in the double screw extruder.

D. Physicochemical and nutritional characterization of the texturized products

Moisture determination: Using the indirect gravimetric method by desiccation (AOAC 925.45). To determine the humidity of the sample, an oven (Memmert UN30, Germany) was used at a temperature of 130 ± 2 °C for a period of 4 hours from when the oven reached said temperature and subsequently the weight of the plates was monitored until reaching a constant value.

Determination of bulk and tapped density: The bulk density (ρa) of each sample will be determined by measuring its weight and corresponding volume. Approximately 10 g of the sample will be transferred to a 100 mL graduated cylinder, and constant vibration will be applied for 1 minute. The bulk density will be calculated by dividing the obtained mass by the volume occupied in the graduated cylinder, expressing the results in g/ml. In the case of tapped density (ρc), the graduated cylinder will be tapped at constant volume with a glass rod. The volume of the sample will be measured and used in the mass-over-volume calculation to obtain the tapped density. Modified method from (Jinapong, Suphantharika, & Jamnong, 2008).

Color determination: using the CIELAB model which is defined by three variables represented in Cartesian systems as L*, a*, and b*. The lightness or clarity (L*) can take values between 0 (black) to 100 (white) and the values of a* and b* are the chromaticity coordinates indicating the direction of colors: +a* is the direction of red, -a* is the direction of green, +b* is the direction of yellow, and -b* is the direction of blue. Measurements were made using a Colorimeter (SP-CLR301, CHINA) employing the D65 illuminant and an observer angle of 2°/10°.

E. Nutritional characterization

The nutritional characterization of the texturized products from destannified tara germ was carried out using official methods established by the AOAC (2005) [21].

F. *Characterization of the technofunctional properties of the texturized products*

Water solubility index (WSI) and water absorption index (WAI): 1 g of sample was mixed with 35 mL of distilled water, at room temperature. The mixture was homogenized with a vortex (KGEMMY Industrial Corp, VM300P, TAIWAN), at maximum level for 5 minutes, and then the solution was transferred to a previously weighed 50 mL centrifuge tube. It was allowed to rest at room temperature for 1 hour and centrifuged at 4500 rpm for 20 minutes in a centrifuge (THERMOFISHER, CL10, GERMANY). The tube was tilted at a 45° angle for 10 minutes and the contents were drained into a previously weighed petri dish. The supernatant from the petri dish was placed in an oven (Memmert UN30, Germany) for 12 hours at 105 °C or until constant weight and weighed (P1). The WSI is obtained by dividing the dry mass of the supernatant (P1) by the mass of the sample used in the test (P0), expressed as a percentage. The WAI is obtained as the difference between the mass of the centrifuged precipitate (P2) and the mass of the sample used in the test (P0) divided by the mass of the sample used in the test (P0) [22].

$$WSI(\%) = \frac{P_1}{P_0} x100$$

$$WAI = \frac{(P_2 - P_0)}{P_0}$$

Oil Retention Capacity: For oil retention capacity (ORC), 25 ml of olive oil was mixed with 1 g of sample (P0) inside a centrifuge tube and placed in a vortex mixer (KGEMMY Industrial Corp, VM300P, Taiwan) for 2 minutes and allowed to incubate at room temperature for 1 hour. The tube was centrifuged at 4390 rpm for 20 minutes. The supernatant was decanted and the tube was allowed to drain for 10 minutes at an angle of 45° [23]. The precipitate from the centrifuge tube is weighed (P3) and the ORC is defined as g of oil per g of sample as follows:

$$ORC = \frac{(P_3 - P_0)}{P_0}$$

Emulsion capacity: To evaluate this property, 3.5 g of the sample is weighed and homogenized for 30 seconds with 50 ml of distilled water using a Velp Scientifica magnetic stirrer. Subsequently, the mixture formed was added 50 mL of PRIMOR extra virgin olive oil and liquefied in a blender (Osterizer Blender) for 3 minutes, then it was poured into a falcon tube to be centrifuged at 1300 rpm for 5 minutes. The emulsion activity was expressed in percentage terms as the height of the emulsified layer with respect to the total liquid [24].

$$\text{Emulsion Capacity} = \frac{H_1}{H_0} x\ 100$$

Minimum gelation concentration: Dispersions were prepared at different concentrations (2%, 4%, 6%, 8%, 10%, 12%, 14%, 16%, 18% and 20% w/v). For the dispersions, 50 mL of distilled water was used and then adjusted to pH 7.0 ± 0.05 by adding 1N NaOH or 1N HCl drop by drop. Then, a 5 mL aliquot of each dispersion was poured into a clean, dry test tube. The test tubes were then heated at 99 °C for 1 hour in a thermal bath with water (Memmert W270, Germany). After heating, the test tubes were quenched with water for 10 minutes and then kept in a refrigerator at 4 °C for 2 hours. The strength of the clot formed was evaluated by inverting the tube. The minimum concentration of protein that forms a stable gel was considered as the minimum gelation concentration.

G. Technological application

In this phase, three formulations were prepared initially with 15% moisture and consisted of tara germ, corn starch, and natural colorants. The formulations differed in the starch percentage (M1: 5%, M2: 10%, and M3: 15%) and were texturized under the same operational conditions. The obtained texturized products were hydrated in a 2% brine at 70°C for an immersion time of 15 minutes, then drained in a colander and subsequently used in the preparation of a burger using a homemade recipe. The burger formulation is shown in Table III. All ingredients were integrated by kneading with a KitchenAid mixer, Model 5K45SS, Origin USA, at speed level No. 4. Subsequently, the doughs were divided into portions, shaping them into burgers with a diameter of 6 cm. They were then frozen for at least 30 minutes. The burgers were cooked over medium heat in a preheated pan until golden on both sides and cooked inside.

Table III. Experimental formulations for burger preparation

Component	Burger		
	T1	T2	T3
Hydrated Texturized		68.24%	
Egg Yolk (unit)		0.55%	
Ground Biscuit		19.11%	
Sofrito		6.55%	
Cilantro		2.73%	
Salt		1.36%	
Sugar		0.76%	
Garlic Powder		0.55%	
Cumin		0.11%	
Pepper		0.04%	

H. Sensory evaluation of the texturized products

The experimental formulations (burgers) were subjected to sensory evaluation in two stages: a discriminative ordering test and a descriptive test. In the discriminative ordering test, the burgers were provided randomly, coded, presented simultaneously so that each panelist evaluates each sample only once, and asked to order them from most to least preferred or satisfactory. Additionally, they were asked to drink water and eat unsalted crackers as a palate cleanser to avoid interference with the next sample. For data processing, a scoring scale from 1 to 3 was used, where a sample is scored with the number 1 if it is perceived to be the most preferred by the consumer and scored with the number 3 as the least preferred according to the sensory descriptor analyzed. The Friedman test was used as a non-parametric alternative to ANOVA ($\alpha = 0.05$), and the Kramer hierarchical ordering method was applied. On the other hand, the descriptive test was used to measure the magnitude of the main descriptors of the best treatment through a sensory panel. A standardized 9-point response scale was used, and the sensory evaluation response was represented through a simple radial graph, thus allowing the evaluation of the intensity rating of each attribute (Figure 1).

I. Statistical analysis

For the texturizing process, a simple random design was applied, keeping the temperature conditions and the feed speed in the double-screw extruder constant. For the production of texturized products, the analyses performed on the three obtained products were conducted in triplicate. The analysis of variance (ANOVA) and the Tukey test were carried out to determine if the treatments differed from each other, using a significance level of 5%. The results were expressed as mean and standard deviation, for which MS Excel was used.

III. RESULTS AND DISCUSSIÓN

A. *Operational parameters in the texturizing process*

The results of the texturizing process in the double-screw extruder equipment are shown in Table IV. Texturized products with moisture content less than 6% were obtained. Among the most common means of rehydration in food is immersion in water, where the immersion periods should be brief, and the purpose of this hydration is to help achieve a product with structural, chemical, and sensory characteristics similar to the fresh product or akin to a food of interest [25, 26]. The rehydration test resulted in the texturized product N1 absorbing 2.17 g of water/g of food, a value that exceeds the other two products. Additionally, a comparison was made with a commercial brand of vegetable meat, where it was found that its hydration value is 1.53 g of water/g of food under the same conditions.

Table IV. Results of the texturizing process after hydration

Product	Moisture (%)	Hydratión $\left(\frac{g_{agua}}{g_{alimento}}\right)$	Hydrated sample
N1	IM:14.01 ± 0.03 FM: 5.71 ± 0.14	2.17 ± 0.02	
N2	IM: 19.04 ± 0.11 FM: 5.95 ± 0.06	1.40 ± 0.03	
N3	IM: 24.02 ± 0.05 FM: 5.27 ± 0.02	1.56 ± 0.24	
Commercial product	5.5 ± 0.04	1.53 ± 0.08	

IM: Initial moisture of the untextured sample
FM: final moisture of the textured sample

From the foregoing, it can be inferred that product N1 absorbed more than twice the amount of water per gram of food and also retains more water compared to the other two mixes. Regarding the appearance of the texturized products, the structure can be appreciated due to the gelatinization of the product and the formation of fibers. What is sought in this type of technological process, where it operates at high temperature in a short time, is not the expansion of the product but the modification of the protein into a fibrous structure, analogous to animal muscle [27], in addition to granting it the ability to absorb and retain water due to the presence of a greater amount of gelatinized starch [28]. With the results of the best level of rehydration, the operational parameters were defined, considering an initial moisture content of 15% for the tara germ. On the other hand, creating products analogous to meat also involves achieving a similar appearance (shape, texture, color, etc.), therefore, prior to the texturizing process, vegetable colorants were integrated into the mixes to reinforce the color and improve the appearance.

B. *Tara germ texturized products*

Table V shows the results of the color analysis of the tara germ textured products. When evaluating the luminosity parameter (L*), the texturing made with destanified tara germ (DTG) presented a value of 17.51, which is lower compared to the texturings that have starch (DTGS) and vegetable dyes (DTGSC) whose The values found were 35.41 and 40.15 respectively, indicating that the addition of these components significantly increased the parameter (L*).Similarly, the values of parameters a* and b* showed an increase for the same reason. These results reflect a color change from dark olive green in the texturing made with destanified tara germ (DTG) to a slightly dark brown color in the texturing with the addition of vegetable dyes (DTGSC). On the other hand, the spraying of the textured samples allowed better homogeneity than their whole counterparts, since the a* and b* parameters also increased due to the addition of starch and natural colorants. In this way, better results were obtained compared to unsprayed textured products. The changes in the values found show how the color of the textured germ powder varies from a slightly dark brown color (DTG) to light brown or coffee color (DTGSC).

C. *Physicochemical and nutritional characterization of the tara germ texturized products.*

Table VI shows the results of the physicochemical characterization carried out on the three textured products, where humidity values of 4.21 to 4.43 were recorded, being higher for the textured products that contained natural colorants in the formulation (DTGSC). On the other hand, to find the relationship between the mass of the textured germ and its volume, the apparent density and the compacted density were determined after hitting the sample inside a graduated cylinder, allowing us to know the degree of compactness of the samples. Regarding the apparent density, the values found in the samples were close, being higher for the starch texturing (DTGS) whose value was 0.82 g/ml. The same relationship was found for the compacted density, with the lowest value found being 0.63 g/ml for the tara germ texturing (DTG).

D. *Technofunctional characterization of tara germ texturized products.*

The evaluation of the techno-functional properties of tara germ texturized products revealed interesting findings regarding the water solubility index (WSI), where values close to 14.36%, 14.09%, and 14.30% were observed among the three texturized products. This uniformity in WSI suggests a consistent solubility across different samples, which is essential for their integration into aqueous food systems [29]. Regarding the water absorption index (WAI) and oil retention capacity (ORC), both parameters are crucial for understanding the interaction of proteins with water and oil in foods, given their hydrophilic and hydrophobic properties. Specifically, the WAI showed an increase from 3.05 to 3.62 g water/g sample with the addition of starch to the destannified germ, indicating an improvement in water absorption capacity, although enrichment with natural colorants only produced a slight increase to 3.78 g water/g sample, not representing a significant change. These results underscore the importance of starch in modifying the techno-functional properties of tara germ, enhancing its compatibility in aqueous food formulations. The ability of proteins to effectively interact with water and oil not only influences the texture and stability of the final products but also their sensory perception and consumer acceptability.

On the other hand, the oil retention capacity of the texturized treatments showed no significant difference, recording values between 1.06 - 1.11 g oil/g texturized. Regarding the behavior of these indicators, research indicates that water absorption and fat retention capacity depend on the availability of polar and non-polar amino acids, establishing that a lower or low water absorption capacity is due to the little presence of polar amino acids [30]. Moreover, the presence of hydrophilic and polar amino acids on the protein molecule surface leads to a lower fat absorption capacity [31]. Other authors mention that protein isolates with a higher oil retention capacity present a higher number of non-polar side chains (hydrophobic groups) [32, 33].

The emulsifying capacity was not evident in the texturized products. This could be because the stability of the dispersed system depends on the formation of a rigid and viscoelastic film around the oil droplets; in this case, the protein fraction of the texturized does not participate in this interaction since the phases separated at the end of the test, indicating that there is no coalescence between them [34]. Moreover, it has been found that the coalescence process of emulsions stabilized with legumes is greatly influenced by the pH value and the protein extraction method, which could be considered since the tara germ protein is not a concentrate or protein isolate, but merely a protein treated by ultrasound. Likewise, in the measurement of emulsion capacity, the three texturized did not present this property [35, 36].

When evaluating the gelation capacity, it was observed that textured products with the addition of starch (DTGS) and vegetable dyes (DTGSC) have a better gelation capacity (12%); while the tara germ texturing (DTG) showed gelation starting at a concentration of 14%. The values found for the textured tara germ were similar to those reported for protein isolates from legumes (beans and soybeans), with values of 12% and 14%, respectively [24]. Research reports improvements in gel formation and texture using carbohydrates. Therefore, the addition of starch to the destanified tara germ favors the gelation processes, since starch is an important component in this processing technique and allows the formation of more stable complexes and is mainly responsible for the porous structure and expanded that characterizes extruded or textured products [37].

To develop a stable gel, the main forces involved are hydrophobic and hydrogen bonds, as well as disulfide bridges, which help form the gel structure [38]. Furthermore, if the gel development remains strong during and after heating, it means that the protein denaturation is high [39].

E. *Technological application and sensory evaluation*

In our study, presented in Table VII, images corresponding to the different treatments applied are displayed, upon which a color analysis was conducted using the L*, a*, and b* parameters both before and after frying in oil. In the pre-frying phase, it was observed that the L* values of the burgers did not show significant differences, indicating a uniformity in brightness among the treatments. Similarly, the a* and b* parameters did not align towards specifically red (+a) or yellow (+b) hues, suggesting that the treatments exhibited a generalized light lead color, a finding that underscores the chromatic homogeneity before cooking.

The process of cooking in hot oil significantly transforms the appearance of the burgers, evidenced by a darkening in the tone of each treatment. This change is reflected in the L* parameter values, which ranged between 12 and 15, indicating a reduction in brightness. Additionally, an increase in a* values was recorded, resulting in a color closer to dark brown, highlighting the significant influence of cooking on the visual perception of the product.

The sensory evaluation, supported by the Friedman test (Table VIII), revealed significant findings related to the "appearance" attribute, with a p-value less than 0.05. This result allows us to reject the null hypothesis of equality in sensory perception of appearance among the texturized with various starch contents. Consequently, it is confirmed that the addition of starch during the texturizing process of tara germ significantly affects the appearance of the burgers, more faithfully simulating the aspect of a homemade burger ($p<0.05$). However, for the rest of the sensory descriptors evaluated, no significant differences were found between the treatments ($p>0.05$), suggesting consistency in other sensory qualities despite the variation in composition.

Table V. Colometric analysis of the texturized tara germ

Product		DTG	DTGS	DTGSC
Whole textured				
Parámeter	L*	17.51 + 0.23[a]	35.41 + 1.68[b]	40.15 + 1.52[c]
	a*	3.23 + 0.14[a]	5.86 + 0.14[b]	6.42 + 0.28[c]
	b*	9.15 + 0.14[a]	15.12 + 0.49[b]	17.45 + 0.43[c]
Powder textured				
Parámeter	L*	35.32 + 0.43[a]	39.72 + 0.86[b]	38.46 + 0.07[c]
	a*	7.31 + 0.03[a]	7.76 + 0.18[b]	15.46 + 0.24[a]
	b*	19.19 + 0.10[a]	20.95 + 0.42[b]	28.32 + 0.68[c]

DTG (Texturing tara germ), DTGS (Texturing tara germ with starch), DTGSC (Texturing tara germ with vegetable dyes).

Table VI. Physicochemical attributes of tara germ texturized products

Component		DTG	DTGS	DTGSC
Moisture (%)		4.26 ± 0.09[a]	4.21 ± 0.10[a]	4.43 ± 0.10[b]
Tapped Density (g/mL)		0.63 ± 0.00[a]	0.67 ± 0.00[b]	0.64 ± 0.00[c]
Bulk Density (g/mL)		0.77 ± 0.00[a]	0.82 ± 0.00[b]	0.800 ± 0.00[c]
% Proteín (N x 6.25)		57.40 ± 0.09	54.48 ± 0.16	52.10 ± 0.01
% Fat		11.77 ± 0.10[a]	12.00 ± 0.02[a]	11.98 ± 0.03[a]
% Ash		6.62 ± 0.00[a]	6.03 ± 0.04[b]	5.99 ± 0.05[b]
% Crude fiber		2.13 ± 0.05[a]	2.49 ± 0.01[a]	2.01 ± 0.07[a]
% Carbohydrates (NFE)		17.31 ± 0.23[a]	17.98 ± 0.07[b]	20.69 ± 0.08[c]
Total Starch (%)		1.1 ± 0.02[a]	2.18 ± 0.02[b]	2.56 ± 0.01[c]
WSI (%)		14.36 ± 0.12[a]	14.09 ± 0.12[b]	14.30 ± 0.11[ab]
WAI (g water/g sample)		3.05 ± 0.06[a]	3.62 ± 0.10[b]	3.78 ± 0.03[cb]
ORC (g oil/g sample)		1.06 + 0.02[a]	1.11 + 0.04[a]	1.10 + 0.03[a]
Emulsifying Capacity (%)		Doesn't present	Doesn't present	Doesn't present
Minimum Gelation Concentration	2%	NG	NG	NG
	4%	NG	NG	NG
	6%	NG	NG	NG
	8%	NG	NG	NG
	10%	NG	NG	NG
	12%	NG	Gel	Gel
	14%	Gel	Gel	Gel
	16%	Gel	Gel	Gel
	18%	Gel	Gel	Gel
	20%	Gel	Gel	Gel

According to the Kramer Table for 3 types of samples and 18 panelists, the numbers that divide the three regions of acceptability were 29 and 43. This means that if any sample obtained values below 29, it can be said that this sample presents the best perception in the evaluated sensory attribute. Thus, in Table IX, the ranks achieved for the attributes appearance, aroma, softness, juiciness, chewiness, and flavor for the three tested tara germ texturized formulations included in the preparation of homemade burgers are reported. Only the texturized formulation containing an addition of 5% starch showed a significant difference in the "appearance" attribute, with a sum of ranks of 27.

For the other sensory attributes evaluated, no significant difference was observed between the treatments, allowing the "appearance" criterion to be used to define the tara germ texturized to be included in the preparation of homemade burgers.

Table VII. Colorimetric analysis of prepared burgers

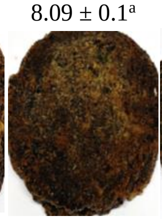
	M1	M2	M3
Before Frying			
L*	26.81 ± 0.2^{a}	27.43 ± 0.41^{a}	26.99 ± 0.32^{a}
a*	1.72 ± 0.2^{a}	1.57 ± 0.10^{b}	1.72 ± 0.12^{a}
b*	7.85 ± 0.26^{a}	8.09 ± 0.1^{a}	8.07 ± 0.14^{a}
After Frying			
L*	12.37 ± 0.23^{a}	15.04 ± 0.02^{b}	13.41 ± 0.08^{c}
a*	6.47 ± 0.20^{a}	5.37 ± 0.21^{b}	4.73 ± 0.25^{c}
b*	9.89 ± 0.34^{a}	13.82 ± 0.05^{b}	11.83 ± 0.15^{c}

Table VIII. Friedman statistics for sensory evaluation of prepared burgers

Descriptor	Q	p-value	Result
Appearance	8.11	0.02	*
Scent/Odor	2.33	0.31	
Softness	1.78	0.41	
Juiciness	2.11	0.35	
Chewiness	4.11	0.13	
Flavor	1.78	0.41	

Table IX. Sum of ranks for texturized tara germ formulations across different sensory descriptors

Descriptor	**5%**	**10%**	**15%**
Appearance	27	37	44
Scent/Odor	31	40	37
Softness	36	40	32
Juiciness	33	41	34
Chewiness	39	40	29
Flavor	40	36	32
Kramer (N1-N2) (3;19)		29-43	

The formulation of the most preferred burger (M3) underwent a sensory profile analysis, and the results are shown in Figure I. The sensory profile of the burger reveals that the attributes with the highest satisfaction from the judges are chewiness, softness, and consistency.

Figure 1. Graphical representation of the sensory profile of the burger made with DTGS containing 15% starch.

IV. CONCLUSIONS

The research has shown that destannified tara germ requires starch, preferably at a concentration of 5% corn starch, to facilitate the formation of a suitable structure for texturizing. Throughout the process, it was established that the optimal moisture content of the mix should not exceed 15%, a crucial parameter to ensure the quality of the texturizing.

From an operational standpoint, detailed experiments with the extruder allowed us to identify the optimal temperature conditions in the equipment zones: 150 °C for zone 1 and 130 °C for zone 2. Likewise, the ideal feed rate was defined as 18.35 rpm and the screw speed as 50 rpm, conditions that promote efficient compression of the samples, proper moisture reduction, and consequently, satisfactory texturizing of tara germ.

The results of our tests revealed that the final texturized products maintain a moisture content below 5%, indicating optimal stability for long-term storage. The addition of starch and vegetable pigments not only positively influenced the color, improving the brightness and overall appearance of the product but also had a significant impact on the water absorption index and improved the minimum gelation capacity, though without significantly affecting the Water Solubility Index and Oil Retention Capacity.

Surprisingly, the protein content of the DTG texturized exceeded 55%, surpassing initial expectations. However, the inclusion of corn starch to optimize techno-functional properties proportionally affected the protein content as the concentration of this starch source increased.

The sensory properties evaluation, especially appearance, chewability, and softness, stood out in our ranking tests, indicating that these attributes could be decisive for the acceptance of tara germ texturized in the preparation of food products, like homemade burgers.

Finally, the implementation of tara germ textured protein in the preparation of traditional foods, exemplified in the preparation of burgers, has demonstrated not only the viability of this vegetable ingredient but also its acceptance, marking a significant step towards innovation in the development of sustainable alternatives to animal proteins.

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REFERENCES

[1] Kumar S. Meat Analogs "Plant based alternatives to meat products: Their production technology and applications". Crit Rev Food Sci Nutr. 2016 Jul 20:0. doi: 10.1080/10408398.2016.1196162. Epub ahead of print. Retraction in: Crit Rev Food Sci Nutr. 2017 Mar 24;57(5):1059. PMID: 27438539

[2] Kim T, Miller R, Laird H, Riaz MN. Beef flavor vegetable hamburger patties with high moisture meat analogs (HMMA) with pulse proteins-peas, lentils, and faba beans. Food Sci Nutr. 2021 May 17;9(8):4048-4056. doi: 10.1002/fsn3.2172. PMID: 34401056; PMCID: PMC8358357.

[3] Gerber, P.J., H. Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. y Tempio, G. (2013), Tackling climate change through livestock – A global assessment of emissions and mitigation opportunities, Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO), Roma.

[4] Kaleda A, Talvistu K, Tamm M, Viirma M, Rosend J, Tanilas K, Kriisa M, Part N, Tammik M-L. Impact of Fermentation and Phytase Treatment of Pea-Oat Protein Blend on Physicochemical, Sensory, and Nutritional Properties of Extruded Meat Analogs. Foods. 2020; 9(8):1059. https://doi.org/10.3390/foods9081059.

[5] Nicola M, Alsafi Z, Sohrabi C, Kerwan A, Al-Jabir A, Iosifidis C, et al. The socio-economic implications of the coronavirus pandemic (COVID-19): A review. International journal of surgery. 2020; 78: 185-93. doi: 10.1016/j.ijsu.2020.04.018.

[6] Di Renzo L, Gualtieri P, Pivari F, Soldati L, Attinà A, Cinelli G, et al. Eating habits and lifestyle changes during COVID-19 lockdown: an Italian survey. J Transl Med. 2020; 18: 1-15. doi: 10.1186/s12967-020-02399-5

[7] Didinger C, Thompson H. Motivating Pulse-Centric Eating Patterns to Benefit Human and Environmental Well-Being. Nutrients. 2020; 12(11): 3500. doi: 10.3390/nu12113500.

[8] Murillo Serna, A. M., & Rodriguez Salazar, D. (2018). Alimentación saludable, la gran tendencia del consumo actual.

[9] Rodríguez, S. R. (2021). Consumidor consciente: Un recorrido por su toma de decisiones. ESIC Editorial.

[10] Baudín, F. A., & Romero, M. C. (2020). Comprensión de los consumidores del etiquetado nutricional para la compra de alimentos envasados. Revista española de nutrición comunitaria= Spanish journal of community nutrition, 26(3), 8. DOI:10.14642/RENC.2020.26.3.5331.

[11] Boza López, J. (1991). Valor nutritivo de las leguminosas grano en la alimentación humana y animal.

[12] Riaz, M. Extrusores en las aplicaciones de alimentos. España: Editorial Acribia, S.A. 2004.

[13] Apró, N., Rodriguez, J., & Gornatti, C. La extrusión como tecnología flexible de procesamiento de alimentos. Jornadas de Desarrollo e innovación. 2000.

[14] Rauwendal C. Understanding Extrusion. Hanser Publishers, Munich, 1998.

[15] González, R., Torres, R. & De Greef. Extrusión-Cocción de Cereales. Boletín de sociedad Brasileira de ciencia y tecnología de alimentos (sbCTA). Vol 36 (2): 83-136. 2002.

[16] Harper, J. Extrusion of foods. USA. Editorial CRC Press, Boca Ratón. 1981.

[17] Pérez, C., Cruz, R., Chel, L. y Betancur, D., Physical characterization of extrudates prepared with blends of QPM maize (Zea maiz L.) and lima beans flours (Phaseolus lunatus L.). Revista Mexicana de Ingeniería Química. Vol 5: 145-155. 2006.

[18] Singh, S.; Gamlath, S.; Wakeling, L. Nutritional aspects of food extrusion: a review. *International Journal of Food Science & Technology*. Vol 42: 916–929. 2007

[19] Samard, S. y Ryu, G-H. (2019). "A comparison of physicochemical characteristics, texture, and structure of meat analogue and meats" en Journal of the Science of Food and Agriculture, vol. 99, p. 2708-2715.

[20] Murillo González, R. (2020). Aplicación de la tecnología de extrusión en productos con alto contenido en proteína (Doctoral dissertation, Universitat Politècnica de València).

[21] A.O.A.C. Official methods of analysis of the Association of Official Analytical Chemists. 18 th Edition. Washington, DC. 2005.

[22] Rodríguez-Ambriz, S., Martínez-Ayala, A., Millán, F., & Dávila-Ortíz, G. (2005). Composition and functional properties of Lupinus campestris protein isolates. Plant Foods for Human Nutrition, 60(3), 99-107.

[23] Rodríguez-Ambriz, S., Islas-Hernández, J., Agama-Acevedo, E., Tovar, J., & Bello-Pérez, L. (2008). Characterization of a fiber-rich powder prepared by liquefaction of unripe banana flour. Food Chemistry, 107, 1515–1521.

[24] Brishti, F. H., Zarei, M., Muhammad, S.K.S., Ismail-Fitry, M.R., Shukri, R. & Saari, N. (2017). Evaluation of the functional properties of mung bean protein isolate for development of textured vegetable protein. Int. Food Res. J, 24(4), 1595-1605.

[25] Rastogi N.K. Nayak C.A. Raghavarao M.S. Influence of osmotic pre-treatments on rehydration characteristics of carrots, J Food Engineering 2004; 65: 287-292.

[26] Vega A. Estudio de la deshidratación y rehidratación del pimiento rojo (Capsicum Annuum L.) var. Lamuyo. (Tesis Doctoral) Departamento de Tecnología de Alimentos, Universidad Politécnica de Valencia (UPV), España, 2003.

[27] Murillo González, R. (2020). Aplicación de la tecnología de extrusión en productos con alto contenido en proteína (Doctoral dissertation, Universitat Politècnica de València).

[28] Martínez, M.M, Oliete, B., Gómez, M., (2013). Effect of the addition of extruded wheat flours on dough rheology and bread quality. Journal of Cereal Science, 57, 424-429.
[29] Butt, M. S. and Batool, R. 2010. Nutritional and functional properties of some promising legumes protein isolates. Pakistan Journal of Nutrition 9(4): 373–379.
[30] Kuntz, I. D. 1971. Hydration of macromolecules III. Hydration of polypeptides. Journal of American Chemical Society 93: 514-515.
[31] Sathe, S. K., Desphande. S. S. and Salunke, D. K. 1982. Functional properties of winged bean (Psophocarpus tetragonolobus) L. (DC) proteins. Journal of Food Science 47(2): 503
[32] Aguilera, Y. 2010. Harinas de leguminosas deshidratadas: caracterización nutricional y valoración de sus propiedades tecnofuncionales. Tesis Ing. Lima, Perú, UNALM.
[33] Eltayeb, A; Ali, A; Abou, A; Abu, F. 2011. Chemical composition and functional properties of flour and protein isolate extracted from Bambara groundnut (Vigna subterranean). African Journal of Food Science 5(2): 82-90
[34] Alamanou, S., & Doxastakis, G. (1997a). Effect of wet extraction methods on the emulsifying and foaming properties of lupin seed protein isolates (Lupinus albus ssp. Graecus). Food Hydrocolloids, 11, 409–413.
[35] Fidantsi, A., & Doxastakis, G. (2001). Emulsifying and foaming properties of amaranth seed protein isolates. Colloids and Surfaces B: Biointerfaces, 21, 119–124.
[36] Tsaliki, E., Pegiadou, S., & Doxastakis, G. (2004). Evaluation of the emulsifying properties of cottonseed protein isolates. Food Hydrocolloids, 18, 631–637.
[37] Cunningham, R. L. (1996). "Effect of processing conditions on intrinsic viscosity of extruded cornstarch" en Journal of Applied Polymer Science, vol. 60, núm. 2, p.181-186.
[38] Tiwari, B. K. and Singh, N. 2012. Pulse chemistry and technology. Cambridge: Royal Society of Chemistry.
[39] Berghout, J. A. M., Boom, R. M. and Van der Goot, A. J. 2015. Understanding the differences in gelling properties between lupin protein isolate and soy protein isolate. Food Hydrocolloids 43: 465-472.

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