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Towards a Sustainable Future: Formulation and Characterization of Vegetable Meat from Chochocho and Soy Beans

Hacia un Futuro Sostenible: Formulación y Caracterización de Carne Vegetal a Base de Chocho y Soya

Montenegro Bosquez Gregory Leandro[1]
Gabriela Belén Arguello Armijo[2]
Alvaro Rafael Chafla Tenemaza[3]
Andrea Carolina Escudero Guevara[4]

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Correspondence author
gregory.montenegro@unach.edu.ec

Abstract: This study focuses on the creation of a sustainable and nutritious food alternative, developing a vegetable meat based on chocho and soybean. Through an experimental methodology, detailed bromatological analyses of the raw materials were carried out, evaluating aspects such as pH, humidity, titratable acidity, water retention capacity and protein content. Then, a vegetable hamburger was formulated with different proportions of chocho and soy. Two optimal treatments were identified: one with 88% chochocho, 12% soybean and Xanthan gum, noted for its high protein content; and another with the same proportions but with Guar gum, which obtained the best sensory evaluation. In addition, the shelf life of the refrigerated product was analyzed, and it was found that it can be kept for more than 17 days without the presence of microorganisms indicative of spoilage.

Keywords: Vegetable meat, Chocho, Soybean, Bromatological analysis, Sensory evaluation, Sensory evaluation.

[1] Agroindustrial Engineer, Master in Quality Management and Innovation, Universidad Nacional del Chimborazo. gregory.montenegro@unach.edu.ec, https://orcid.org/0000-0001-9136-3664
[2] Agro-industrial Engineering, CAPACITACIONES Y ASESORÍAS E&G S.A.S. gabeth22@gmail.com, https://orcid.org/0009-0004-9294-5729
[3] Agroindustrial Engineer, Master in Agroindustry, Mention in Quality Management and Food Safety", ZUMASUA CIA LTDA, alvaro.chafla@espoch.edu.ec, https://orcid.org/0000-0002-0569-2080
[4] Agroindustrial Engineer, Master in Food Science and Engineering. Independent researcher angie_20168@yahoo.es, https://orcid.org/0009-0003-1793-7844

Resumen: Este estudio se centra en la creación de una alternativa alimentaria sostenible y nutritiva, desarrollando una carne vegetal a base de chocho y soya. A través de una metodología experimental, se realizaron análisis bromatológicos detallados de las materias primas, evaluando aspectos como pH, humedad, acidez titulable, capacidad de retención de agua y contenido proteico. Luego, se formuló una hamburguesa vegetal con diferentes proporciones de chocho y soya. Se identificaron dos tratamientos óptimos: uno con 88% de chocho, 12% de soya y Goma Xanthan, destacado por su alto contenido proteico; y otro con las mismas proporciones pero con Goma Guar, que obtuvo la mejor evaluación sensorial. Además, se analizó la vida útil del producto refrigerado, encontrando que puede conservarse más de 17 días sin presencia de microorganismos indicativos de deterioro.

Palabras clave: Carne vegetal, Chocho, Soya, Análisis bromatológicos, Evaluación sensorial

Introduction

Increasingly, consumers are opting for special diets based on their principles and values. Most of them are motivated by concern for the environment, animal welfare and health. This growing interest in knowing the composition and origin of the products that reach the tables of Argentines is driving a growing trend. Consumers, better informed and more demanding, tend to avoid foods with an excessive amount of synthetic ingredients or additives, and look for products that are healthy, nutritious and meet "clean label" standards.

This trend, which initially related to vegetarians and expanded to vegans, now also encompasses flexitarians. This new category of consumers groups together those who, for various reasons, have decided to minimize their consumption of animal meat, and are known as "flexible vegetarians". According to a recent market study conducted by Innova Market Insights, a leading global food and beverage industry knowledge company, Germany leads this movement, with 69% of its population admitting to consuming meat once a week, followed by 53% in the United Kingdom and 38% in the United States (Perez, 2020).

In this regard, research on plant-based substitutes for meat has investigated potential plant-based ingredients that could be used for this purpose. To meet the demands of today's market, it is essential to have plant-based protein ingredients that can compete with or even surpass traditional animal protein ingredients in terms of quality and functionality, as noted in another recent study.

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Given the changing dietary patterns of many consumers and the potential economic advantages for processors, legume-derived ingredients are increasingly being used in the meat processing industry. This aligns with the focus on producing healthier foods, and to achieve this, various strategies are being applied in the food industry (Gutierrez Varas & Siche Jara, 2022).

In this context, chocho (Lupinus mutabilis) and soybean (Glycine max) emerge as potential sources of vegetable proteins with significant nutritional value and lower environmental impact.

Chocho, known by various names such as tarwi or lupin, is a legume native to the Andean zone of South America. Its cultivation and consumption have been an integral part of the diet in Andean regions for centuries (Martinez Flores et al., 2022). This versatile grain possesses outstanding nutritional characteristics, including a high content of protein, vitamins, minerals and fiber (Lllerena, 2022). In addition, chocho has proven to be a plant resistant to challenging climatic conditions, making it an attractive option for production in high altitude and mountainous areas.

On the other hand, soy has gained a prominent place in the global diet as a rich source of vegetable protein. Originating in Asia, soy has become widely available around the world due to its culinary versatility and nutritional benefits. Soy has also become an essential component of many vegetarian and vegan diets due to its ability to provide a complete source of protein (Diaz Franco et al., 2015).

In this theoretical framework, we will explore the nutritional characteristics and potential of these two plant ingredients, chocho and soybean, as sources of protein in the human diet. We will examine their nutrient profiles, their health benefits and their contribution to food and environmental sustainability.

Nutritional Characteristics of Chocho

Lupinus mutabilis, Lupinus mutabilis, stands out for its exceptional nutritional profile. It is especially known for its high protein content, which ranges from 35% to 40% of its dry weight. These proteins are considered to be of high quality, as they contain all the essential amino acids necessary for complete nutrition. This makes it a valuable source of protein for those seeking alternatives to meat and animal products (Moposita Vásquez et al., 2022).

In addition to its protein content, chocho is rich in dietary fiber, which makes it beneficial for digestive health. It is also an important source of minerals such as iron, calcium and magnesium, as well as vitamins, including B1 (thiamine) and B2 (riboflavin). These nutritional

components make chochocho a balanced food that can contribute significantly to a healthy diet.

Benefits of Soy

Soybean, Glycine max, is another source of vegetable protein that has gained worldwide recognition. Like chocho, soy contains a significant amount of protein, representing approximately 36% of its dry weight. These proteins are also considered to be of high quality, making it an excellent choice for those who follow vegetarian or vegan diets.

In addition to its protein, soy is known for its polyunsaturated fatty acid content, including omega-3 fatty acids. This makes it a source of healthy fats that can help maintain adequate blood cholesterol levels and promote cardiovascular health (Caicedo et al., 2019).

Soy is also rich in isoflavones, plant compounds that have antioxidant properties and may have benefits for hormonal health. Their role in reducing menopausal symptoms and their possible influence on the prevention of certain chronic diseases has been widely investigated (Vázquez-Frías et al., 2020).

Food and Environmental Sustainability

The choice of plant-based ingredients such as chocho and soy is not only based on their nutritional benefits, but also on their potential to promote food and environmental sustainability. Both crops have a lower environmental impact in terms of natural resource use, such as land and water, compared to animal meat production.

In addition, plant protein production tends to generate fewer greenhouse gas emissions, which contributes to climate change mitigation. Diversification of protein sources can also reduce pressure on ecosystems and biodiversity by reducing the demand for land devoted to livestock farming.

Materials and methods

The research was carried out in the Veintimilla Parish, Bolivar Province. Various experimental materials were used, such as chocho (Lupinus mutabilis Sweet), texturized soy protein, Guar gum and Xanthan gum. In addition, laboratory equipment such as a stainless steel table, thermometer, containers, balance, sealer, dehydrator, mill, food processor and cutter were used.

Inputs such as water, additives and seasonings were also used. Office tools such as a digital camera, calculator, computer and printing paper were used for data recording and analysis.

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The experimental design used was A x B with two replicates, and was applied in the Veintimilla Parish, Bolivar Province, with the objective of systematically exploring and evaluating the effects of the factors under study.

As for the procedure, an experimental unit of 200 grams was used, with two factors and six different treatments, each repeated twice, totaling 12 experimental units. A bifactorial Completely Randomized Design (CRD) with a specific mathematical model was applied.

Statistical analyses, such as Analysis of Variance (ADEVA) and Tukey tests, were performed to compare averages and evaluate the significance of factors and treatments. An economic analysis was also carried out using the benefit/cost ratio.

Specific analyses were performed at the raw material and finished product stages, including measurements of protein, water holding capacity, hydrogen potential, titratable acidity, moisture, ash and fat. A sensory evaluation was performed and shelf life was determined at the best treatment, which included microbiological analysis.

In addition, the procedure for the preparation of the chochocho was detailed, which included reception, selection, washing, shelling, grinding, weighing, sheathing, storage and options for consumption of the final product.

The procedure for the preparation of the chocho was carried out according to the following steps:

Receipt of raw material: The raw material was acquired in Guaranda canton, central parish, and was received at the food processing plant of the Agroindustrial Engineering Department, School of Agricultural Sciences, Natural Resources and Environment.

Selection: The raw material was carefully selected to ensure that it did not present physical or microbiological alterations.

Washing: The raw material underwent a washing process with potable water to eliminate any impurities that could contaminate the product.

Shelling: Shelling was carried out manually by immersing the seeds in water and removing the shells.

Milling: The seeds were manually crushed to facilitate their handling in subsequent processes.

Weighing: Seeds were weighed on a Roman balance in grams to determine yield.

Packaging: The product was packed in hermetically sealed polyethylene bags measuring 16.5cm x 14.9cm, in order to avoid possible contamination.

Storage: Finally, the product was stored at 4°C refrigerated temperature.

The vegetable meat preparation procedure was carried out as follows:

Receipt of raw material: All the ingredients necessary for the preparation of the vegetable meat were received and verified for use in the process.

Dosage of seasonings and additives: Each of the ingredients, including seasonings and additives, to be used in the different treatments of the research were accurately weighed.

Mixing: The ingredients were mixed and homogenized manually, kneading for approximately 15 to 20 minutes until the dough was completely homogeneous.

Weighing: After the mixing stage, the resulting product was weighed on a Roman scale in grams, in order to determine the yield of the process.

Sleeving: The vegetable meat was placed in polyethylene sleeves, acquiring a circular shape.

Storage: It was recommended to store the product at a refrigeration temperature of 4 °C for proper preservation.

Consumption: Vegetable meat could be consumed immediately after processing or after refrigeration. In addition, it had the versatility of being cooked in various ways, either fried or roasted, according to the consumer's preferences.

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3. Result

The bromatological analyses performed on the raw materials used in the preparation of vegetable meat were carried out following the guidelines of the INEN and AOAC standards. These analyses were aimed at determining various properties, such as pH, moisture content, titratable acidity, water retention capacity (WRC) and protein content.

The performance of these bromatological analyses is justified by the need to know the composition and nutritional value of raw materials. By obtaining this information, it is possible to combine the ingredients in a suitable way to produce a high quality final product that meets the consumer's standards and expectations.

Table 1. *Bromatological results obtained in* chocho *flour.*

		Chocho	
Component	**Unit**	**Value**	**Method**
Protein	%	47,46	Micro Kjeldahl
Titratable Acidity	Sulfuric Acid	0,15	NTE 0521
CRA	gar/gs	5,10	Rivera Flores, V. 2014
pH	------	5,67	NTE 0526
Humidity	%	5,77	AOAC 925.10

Source: (Own elaboration, 2017).

Table 1 presents the average values of protein content in chochocho, which reaches 47.46%. This compares with the results of a previous

study (Apunte and León, 2012) that reported a value close to 44.40%. The difference is explained because the study cited in the literature measured protein in the bitter kernel, while in this research it was evaluated in the unbittered kernel, known to have a higher protein content due to the unbittering process.

In addition, pH, moisture and acidity values were recorded for chocho, with results of 5.67 for pH, 5.77% for moisture and 0.154% sulfuric acid for acidity. These values are within the ranges previously reported in the scientific literature, which supports the consistency of the findings of this research.

Table 2 *Bromatological results obtained in texturized vegetable protein (TVP).*

	Textured Vegetable Protein (PVT)		
Component	Unit	Value	Method
Protein	%	63,21	Micro Kjeldahl
Titratable Acidity	sulfuric acid	0,09	NTE 0521
CRA	gar/gs	6,33	Rivera Flores, V. 2014
pH	------	6,84	NTE 0526
Humidity	%	6,72	AOAC 925.10

Table 2 shows the results obtained for the vegetable meat, which include a protein content of 63.21%, moisture of 6.72%, pH of 6.84 and titratable acidity of 0.090% sulfuric acid. These values compare with data previously reported in the scientific literature. According to Los Seibós in 2013, textured soy protein (TVP) can contain up to 70%

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protein with a moisture level of 8%. In addition, Herrera in 2012 reports pH values of 6.5 and titratable acidity of 0.064% sulfuric acid. The results of this research largely agree with the data cited in the literature, which supports its validity and consistency.

The bromatological analyses carried out on the finished product, the vegetable meat, included the measurement of pH, moisture, fat content, titratable acidity, protein and ash. The pH is a crucial factor for the growth of organisms, and most prefer a pH range between 6.8 and 7.5, although there are exceptions. These analyses provide valuable information on the characteristics of the final product and its compliance with established standards.

Analysis of variance for pH values.

Table 3 *Analysis of variance for pH in vegetable meat processing*.

Source of variation	Gl	Sum of Squares	Squares Media	Variance ratio	Probability
Main effects					
A:Percentage	2	0,0183167	0,00915833	2,60	0.1534 ns
B:Binder	1	0,0120333	0,0120333	3,42	0.1138 ns
Interactions					
AB	2	0,00451667	0,00225833	0,64	0.5588 ns
Waste	6	0,0211	0,00351667	-------	---------
Total (corrected)	11	0,0559667	----------	-------	---------

Coefficient of Variation (CV)= 1.02%.

ns = Not significant.

Table 3 shows the analysis of variance carried out for the variable pH during the processing of vegetable meat. The results indicate that neither factor A (Percentage of Chocho-PVT mixture), nor factor B (Type of binder), nor the interaction between both factors show statistically significant differences in the pH results. This suggests that the variation in these factors and their respective levels does not have

a significant impact on pH values. Furthermore, the low coefficient of variation of 1.02% indicates that the values are consistent and reliable.

Table 4 Tukey's ordered ranks test for pH treatments in vegetable meat processing**.**

Treatment N°	Coding	Media	Homogeneous Groups
T3	A2B1	5,84	A
T5	A3B1	5,84	A
T4	A2B2	5,83	A
T1	A1B1	5,80	A
T6	A3B2	8,78	A
T2	A1B2	5,69	A

Table 4 shows the Tukey's ordered ranks test performed to evaluate the differences in pH values. Although no significant differences were found between treatments, this test was carried out as a precaution. It was found that treatments T3 and T5, consisting of a mixture of 92% chocho and 8% PVT with Guar gum, and 88% chocho and 12% PVT with Guar gum, respectively, presented the highest pH values, with a value of 5.84. On the other hand, treatment T2, containing 96% chochoke and 8% PVT with Xanthan gum, has the lowest pH value, with 5.69. It is important to note that all these values are within the ranges established in RTE INEN 056, which establishes an acceptable pH range between 4.5 and 6.4 for meat.

Analysis of variance for protein percentage.

Table 5 *Analysis of variance for vegetable meat protein.*

Source of variation	Gl	Sum of Squares	Squares Media	Variance ratio	Probability
Main effects					

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A:Percentage	2	90,9113	45,4556	266,68	<0,0001 **
B:Binder	1	6,02083	6,02083	35,32	0,0010 **
Interactions					
AB	2	0,00406667	0,00203333	0,01	0.9882 ns
Waste	6	1,0227	0,17045	-------	----------
Total (corrected)	11	97,9589	----------	-------	----------

CV= 1.30 %.

ns = Not significant. **

Table 5 shows the analysis of variance performed in relation to the amount of protein in the vegetable meat. It is observed that factor A, which corresponds to the percentage of chocho and textured vegetable protein (TVP) mixture, as well as Factor B, which refers to the type of binder used, show a highly significant statistical difference. This indicates that both the proportion of chocho and PVT and the type of binder used have a significant impact on the protein levels present in the processed vegetable meat.

However, with regard to the interaction between factors A and B, no significant statistical difference was found. This suggests that the influence of these factors on protein content is independent when combined in the formulation. That is, there is no significant synergy or antagonism between them in relation to the amount of protein in the final product.

In addition, it is important to note that the coefficient of variation obtained is 1.30%, which indicates that the values obtained are reliable and consistent. This reinforces the validity of the results and the robustness of the conclusions drawn from this analysis.

Table 6 *Tukey's ordered ranks test for protein treatments in vegetable meat processing.*

Treatment N°	Coding	Media	Homogeneous Groups
T6	A3B2	35,81	A
T5	A3B1	34,40	A
T4	A2B2	32,73	B
T3	A2B1	31,27	B
T2	A1B2	29,05	C
T1	A1B1	27,68	C

Table 6 shows the Tukey rank test for protein in vegetable meat. The highest treatment was T6 (88% Chocho + 12% PVT + Xanthan Gum) with 35.81% protein, while the lowest was T1 (96% Chocho + 4% PVT + Guar Gum) with 27.68%. According to Beltran (2014), vegetable meat has 50% protein, and animal meat has 17.7%. In this research, we obtained 35.81% protein, lower than vegetable meat but higher than animal meat, due to the specific formulation used. In summary, T6 stands out for its protein content in vegetable meat.

The sensory evaluation involved a panel composed of 12 semi-trained persons, who were assigned the task of assessing the quality of the final product, which in this case is Vegetable Meat. The attributes evaluated included color, odor, flavor, texture and acceptability.

Color is a visual aspect that plays an important role in the quality perception of a product, as it can reveal possible defects or anomalies. It can also influence consumer attraction and preference for the product. In addition, color is linked to both the sensory characteristics and chemical composition of the product, which helps define its quality (Ramos et al., 2021).

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Table 6 *Analysis of variance for the vegetable flesh color attribute*.

Source of Variation	Gl	Sum of Squares	Squares Media	Reason for Variance	Probability
Treatment	5	1,0	0,2	0,50	0.7749 ns
Tasters	11	6,5	0,590909	1,48	0.1668 ns
Error	55	22,0	0,4	--------	-------
Total	71	29,5	----------	---------	--------

ns= Not significant.

Table 7 shows the analysis of variance applied to the results obtained from the sensory evaluation of the color attribute, where there is no significant statistical difference between treatments.

Table 7. *Tukey ordered ranks of the color attribute for vegetable meat.*

Treatment N°	Coding	Media	Homogeneous Groups
T2	A1B2	3,6	A
T6	A3B2	3,6	A
T3	A2B1	3,6	A
T1	A1B1	3,6	A
T5	A3B1	3,4	A
T4	A2B2	3,4	A

Table 8 shows the analysis of Tukey's ordered ranks test related to the color characteristic in vegetable flesh. Although no statistically significant differences were found in the analysis of variance, it was identified that several treatments (T1, T2, T3 and T6) obtained the highest values, which are at 3.6 according to the sensory evaluation scale (Palomar et al., 2020). These values are located in the category

ranging from "acceptable" to "good". In contrast, treatments T4 and T5 showed the lowest values, which are also in the category between "acceptable" and "good," with a value of 3.4.

The discussion of the results obtained in this research on the processing of vegetable meat from chocho and soybean reveals important findings and their relevance in the context of the production of highly nutritious alternative foods.

One of the main results that stands out is the significant influence of the addition of chocho and soy protein on the nutritional quality of the product. The verification of the hypothesis for protein content showed that treatments with different proportions of chochocho and soy protein had a significant impact on the protein content of the vegetable meat. Specifically, treatment T6, which contained 88% chocho, 12% Textured Vegetable Protein and xanthan gum, resulted in the highest protein content. This indicates that proper formulation can significantly increase the nutritional value of vegetable meat.

In addition, it was observed that the choice of binder, in this case xanthan gum, also influenced protein content and possibly other sensory characteristics. This suggests that careful selection of additional ingredients may play an important role in improving the nutritional and sensory quality of vegetable meat.

In terms of sensory characteristics, the results showed that the addition of chocho and soy protein significantly influenced the texture and acceptability of the product. The treatments that incorporated these ingredients obtained higher scores in the texture and acceptability tests, suggesting that vegetable meat may benefit from an improvement in texture and flavor through the inclusion of chocho and soy protein.

On the other hand, no significant statistical differences were found in color, odor and flavor characteristics between treatments. This indicates that the addition of chocho and soy protein does not negatively affect these sensory characteristics, which is essential for vegetable meat to be acceptable to consumers.

Taken together, these results highlight the potential of chocho and soy-based vegetable meat as a highly nutritious and sensorially appealing alternative to traditional meat. Proper formulation, including the right

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proportion of ingredients and binders, can significantly improve the nutritional and sensory quality of these products. This is especially relevant in the context of the search for more sustainable and healthier food options, as vegetable meat can play an important role in reducing animal meat consumption and promoting a balanced and more environmentally friendly diet. However, it is important to note that more research is needed to fully understand the impact of these ingredients in the formulation of vegetable meat and its acceptance by consumers.

4. Conclusions

In this study, the challenge of developing a sustainable vegetable meat alternative from natural ingredients such as chocho and soy has been addressed. Through a series of physicochemical analyses, sensory evaluations and microbiological tests, important conclusions have been reached that contribute to the goal of promoting a more sustainable future in the food industry.

The main conclusions of this research point to the feasibility of using a mixture of chocho and textured vegetable protein (TVP) in a specific proportion (88% chocho - 12% TVP) as a base for vegetable meat. In addition, guar gum has been identified as the most effective binder, which improves the sensory quality of the final product.

From a nutritional perspective, this developed vegetable meat has been found to be a significant source of protein, making it a valuable alternative from a dietary standpoint. In addition, its ability to remain microbiologically safe over an extended shelf life demonstrates its suitability as a food product.

These findings support the idea that the formulation and characterization of chocho and soy-based vegetable meat is not only possible, but can also make a significant contribution to promoting a sustainable future by offering a responsible consumption option that reduces reliance on traditional meat and its associated environmental impacts. This study represents an important step towards creating more sustainable and healthier foods for future generations.

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