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TECHNOLOGICAL CHARACTERIZATION OF POWDERED EGG AND ITS APPLICATION IN FOOD TECHNOLOGY

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ABSTRACT

This study aimed to characterize the technological properties of powdered eggs by analyzing three distinct commercial samples incorporated into two model food matrices: meatballs and analogue cheese. The powdered egg samples were subjected to a series of tests to assess their size distribution, color, gelatinization temperature, bulk density, settling behavior, viscosity and foaming capacity. These results were then compared to the properties of chickpea, pastry flour, modified cassava starch, pork protein and milk whey, which served as reference ingredients. All experiments were performed in triplicate, and the data were analyzed using descriptive statistics to ensure robustness. The powdered egg samples, classified as fine flour, exhibited a high gelatinization temperature (>80°C) and a low bulk density (<0.3 g/cm³), indicating their suitability for specific food applications. The absorption index of the powdered eggs ranged from 1.83 to 3.20, while the swelling power ranged from 2.34 to 3.64, reflecting a higher capacity to absorb water and swell compared to pork protein and milk whey, though lower than modified cassava starch and flour. The solubility index varied between 12.2 and 21.5 g soluble/g sample, showing a moderate level of solubility. These findings suggest that powdered egg has distinctive functional properties, making it a potential ingredient for use in various food products. Further investigation was conducted on the sensory characteristics of meatballs and analogue cheese prepared with the powdered egg samples. Sensory analysis, focusing on texture and color, revealed no significant differences across the various powdered egg samples. All products were positively received by a sensory panel, indicating that the powdered eggs did not adversely affect the acceptability of the food products. Powdered eggs showed promising technological properties that could be leveraged in a variety of food applications. Their functional properties, including high gelatinization temperature, moderate swelling power, and solubility, combined with their sensory acceptance, suggest that they could serve as an effective ingredient in meat and dairy analogues.

Key words: Egg, chickpea, pastry flour, modified cassava starch, pork protein, milk whey

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INTRODUCTION

Eggs are a significant dietary source, rich in essential nutrients including high-quality proteins, healthy fats, minerals and vitamins, making a substantial contribution to overall nutrition [1]. The protein derived from eggs boasts a high biological value and is abundant in essential amino acids [2]. Global egg consumption demonstrates an upward trend, passing from 86.3 million metric tonnes in 2020 to 87.1 million metric tonnes in 2021 [3], with China dominating the market at 35% of global egg production, yielding 466 billion eggs, trailed by the European Union, the United States, and India. According to the Organization for Economic Co-operation and Development - Food and Agriculture Organization of the United Nations -OECD-FAO Agricultural Outlook, there is a projected surge in global egg production by 8.0 million tonnes between 2020 and 2030. Per capita egg consumption in Mexico stands at 23 kg annually [4]. In Colombia, the National Federation of Colombian Poultry Farmers (FENAVI) indicates a per capita consumption of 315 units for the year 2022 [4]. However, the handling of fresh eggs represents a logistical challenge for the food industry due to their inherent fragility and posing risks to microbiological stability, among others [5]. To mitigate these risks, pasteurized and powdered egg products emerge as viable alternatives. Industrially produced from whole eggs, egg whites, or yolks, these egg products are used in various applications within the food industry [6]. As elucidated by Roseland [7], these products are available in liquid, frozen or powdered forms, offering heightened versatility, ease of incorporation, precise dosing control, elevated safety standards, and simplified handling protocols. This diversification not only enhances operational efficiencies but also fosters temporal and labor savings, thereby bolstering overall productivity. Moreover, central collection of eggshells and shell membranes presents future prospects for their enhanced utilization. Liquid and powdered whole egg products have similar properties as whole eggs, improving palatability by providing body and softness to food, good binding and emulsion properties, and texture and fluffiness, among other characteristics [8]. The daily consumption of 10 g of spray-dried egg powder is equivalent to a medium-sized egg and meets the reference values for children, for example, 100% for vitamin E, 24% for retinol, 61% for selenium and 22% for zinc [9].

The increasing demand for high-quality and diverse powdered food products positions the global powdered egg market for significant opportunities, with its value reaching $1.8 million USD in 2022 [10]. Looking to the future, the International Marketing Research Group (IMARC) expects the market to reach $2.5 million by 2028, showing a compound annual growth rate (CAGR) of 4.5% [10].

The objective of this study was to characterize commercial powdered eggs available in Colombia and compare their values with alternate products with similar applications, providing a new perspective on their use in two food matrices.

MATERIALS AND METHODS

This research was done in laboratories and pilot plant of the Faculty of Engineering at Universidad de La Salle Bogotá, Colombia. Three samples of commercial powdered egg from different Colombian poultry industries were used, they were provided by FENAVI and coded as sample 1 (576), sample 2 (072) and sample 3 (394). A three-number random coding system was created to avoid bias in the results and to keep the names of the companies supplying the different powdered egg samples confidential. All samples were obtained from the same production batch, processed using spray-drying techniques, and stored under controlled conditions in sealed packaging to prevent moisture absorption. To characterize and compare the properties of the three powdered egg samples, a series of tests were conducted. These included: particle size distribution [11] using a FRITSCH Model Spartan sieve with a 200 µm mesh, determination of color according to the CIELAB CR 400 model standard [12], gelatinization temperature determination [13] with a BRIXCO thermometer accurate to 0.01ºC, bulk density [14] calculated by measuring the volume occupied by a specific mass in kilograms, which was weighed using an Ohaus scale accurate to 0.0001 mg, settled density [15], Brookfield viscosity using a DV-2 digital viscometer with a 100 to 2,000,000 cp [16], foaming capacity and foam stability [17]. The results of these tests are detailed in Annex 1. To compare the technological properties of powdered egg, same tests, mentioned above, were conducted in chickpea flour, pastry flour, modified cassava starch, pork protein and whey protein. These ingredients, commonly used as additives or main components in various food industry processes, were all purchased from a Colombian national supermarket (Jumbo, Bogotá, Colombia).

Each of these tests was performed in triplicate and statistically analyzed using Analysis of variance (ANOVA) and Tukey tests ($p < 0.05$) to determine significant differences among the substitutions made to each product. Minitab 19 were used as statistical software. Products with varying percentages of powdered egg were preliminarily characterized using colorimetry analysis based on the CIELAB color space method, which quantifies color in three dimensions: L* (lightness), a* (red-green), and b* (yellow-blue). Additionally, texture analysis was conducted following the protocol established by the US Meat Animal Research Center. This method evaluates textural attributes such as firmness, cohesiveness, and chewiness, providing insights into the mouthfeel and structural integrity of the meatballs and analog cheese. Each of these tests was done in triplicate and analyzed statistically using ANOVA and the Tukey's test to determine significant differences between the substitutions made in each product.

Sensory analysis was conducted with a panel of 30 untrained panelists. The demographics of the panelists were as follows. Age: panelists ranged from 18 to 65 years old, with a mean age of approximately 35 years. Sex: the panel consisted of 15 males and 15 females, ensuring a balanced representation. Normal consumption: all panelists reported regular consumption of meat products and cheese alternatives, with at least 3 servings per week. Dietary preferences: the group included a mix of people with no individuals identifying as strict vegetarians or vegans. Familiarity with products: participants were familiar with both meatball and cheese products, having previously consumed similar items in the market. The attributes evaluated for both the meatballs and the analog cheeses were texture, color, odor, flavor and appearance, using a hedonic scale (1. dislike very much, 2. dislike, 3. neither like nor dislike, 4. like, 5. like very much).

RESULTS AND DISCUSSION

The three samples of powdered egg analyzed in the research (576, 072 and 394) were compared with chickpea flour, pastry flour, modified cassava starch, pork protein, and whey protein, finding the following results.

Particle size

Table 1 describes the results of particle size, where it can be observed that samples 576, 072, 394, whey protein, chickpea flour, pastry flour and modified cassava starch have a similar particle diameter, exceeding 180 and 150 µm, classifying them as fine flour. However, they are significantly different from each other ($p < 0.05$).

The importance of granulometric characterization is related to water diffusivity in particles, that is, the ability of flours to absorb water, which can vary depending on the size, leading to varying water absorption during raw material conditioning [18]. Results obtained in this study indicated that all powdered egg samples are considered coarse flours and may have a higher water retention capacity and swelling [19]. These characteristics are important in the food industry to maintain parameters related to firmness and juiciness [20]. For instance, in meats and pasta, these properties are significant.

Color

Table 2 provides a summary of the results related to color characterization for all the samples. Greater luminosity (as defined by the L* value in the CIELAB color space) was observed in the samples of modified cassava starch, followed by whey protein and pastry flour. All the samples in the study showed positive values for the b* coordinate, indicating a yellow color. Samples 394, 576, and 072 showed the highest

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values for this coordinate and also reported more reddish values for the a* coordinate due to the presence of carotenoids in the egg, which provide these hues and can be functional in the food industry for color stabilization in various food matrices [21].

Gelatinization temperature

The gelatinization temperature of the flours is influenced by the physical competition for water between protein gelation and starch gelatinization, and is also related to their different particle sizes and contents of proteins, carbohydrates, and lipids, and the interactions between them [22]. Additionally, there are reports that gelatinization occurs as a macromolecular consequence of protein denaturation. Figure 1 shows the results obtained for the different analyzed samples [23].

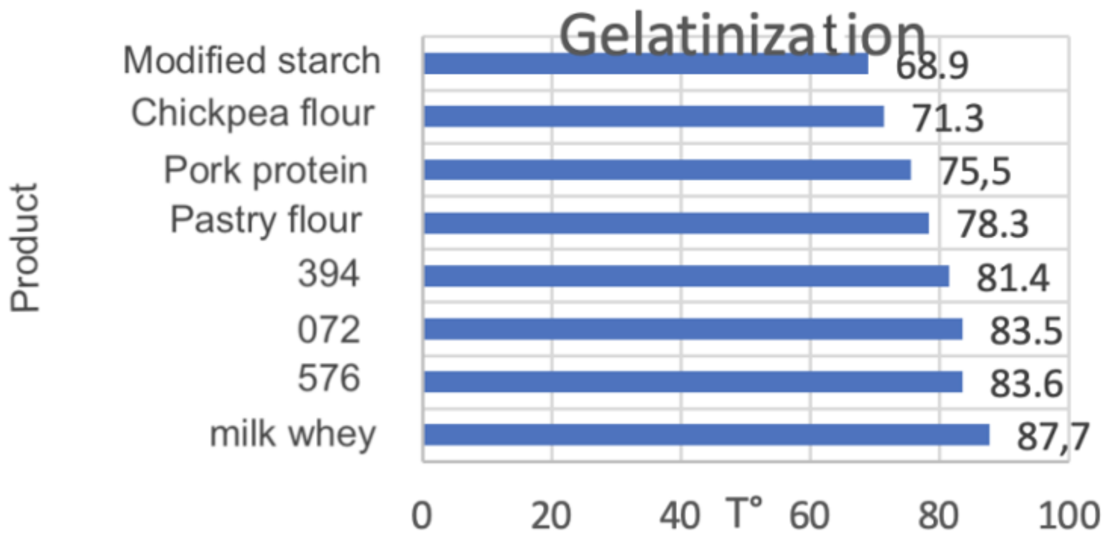

Figure 1: **Gelatinization temperature**

The egg samples analyzed showed a higher gelatinization temperature, which can be a technological advantage in industrial processes that require high temperatures and process stability [24]. This is not only important for the baking and pasta industries, but could also establish stable technological relationships in industries such as dairy or meat.

Apparent and settlement density

Apparent and settled density are directly related to the particle size of the samples. High density values suggest products with very fine particle sizes, and vice versa. This analysis is of importance because the formation of pores and the product's density can be significantly affected during the absorption of moisture or fats, reflecting in the homogeneity of the food matrix in which powdered egg yolk is intended to be included as a high-protein binder. The data obtained for the studied samples are reported in Figure 2.

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Whey protein showed high settled and apparent density, making it significantly different ($p < 0.05$) from the others. Pastry flour, modified cassava starch, and soy extract did not show significant differences among themselves. On the other hand, the powdered egg samples obtained the lowest results in this category, indicating a larger particle size (Table 1), which could be an advantage in the industry, such as in the baking industry for the stability of cookie and cake hardness [25].

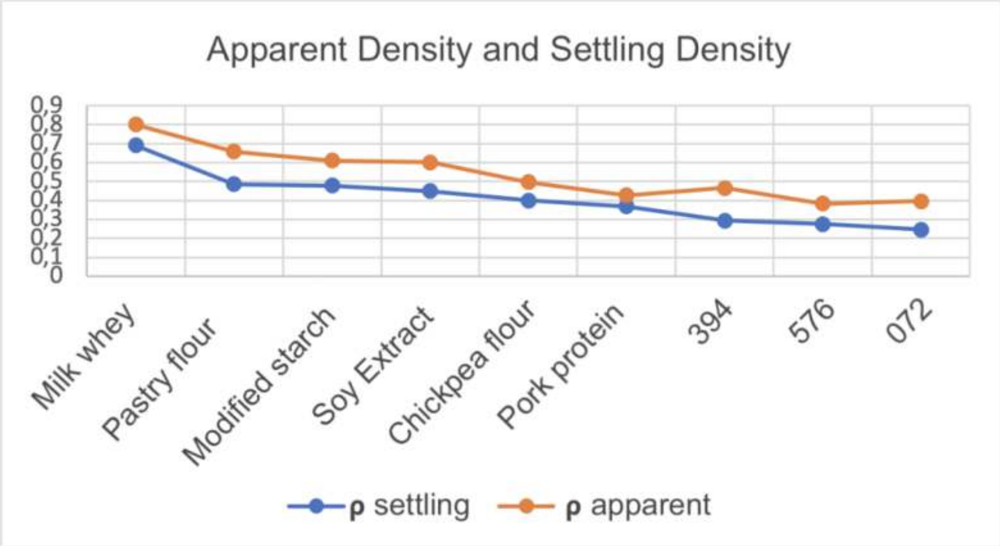

Figure 2: Apparent and settlement density (g*mL-1)

Viscosity

Viscosity determines the rheological behavior and its influence under different process conditions, making it a fundamental characteristic in the evaluated samples. The following Figure shows the viscosity results.

For the case of the powdered egg samples, 576, 394 and 072 showed significant differences ($p < 0.05$), however, the first two reported the highest viscosity results, surpassing the comparison products. This can be a technological advantage in industries that develop soups or thick liquid foods, as viscosity is a property with high commercial value for this type of food where both viscosity and high protein content are sought.

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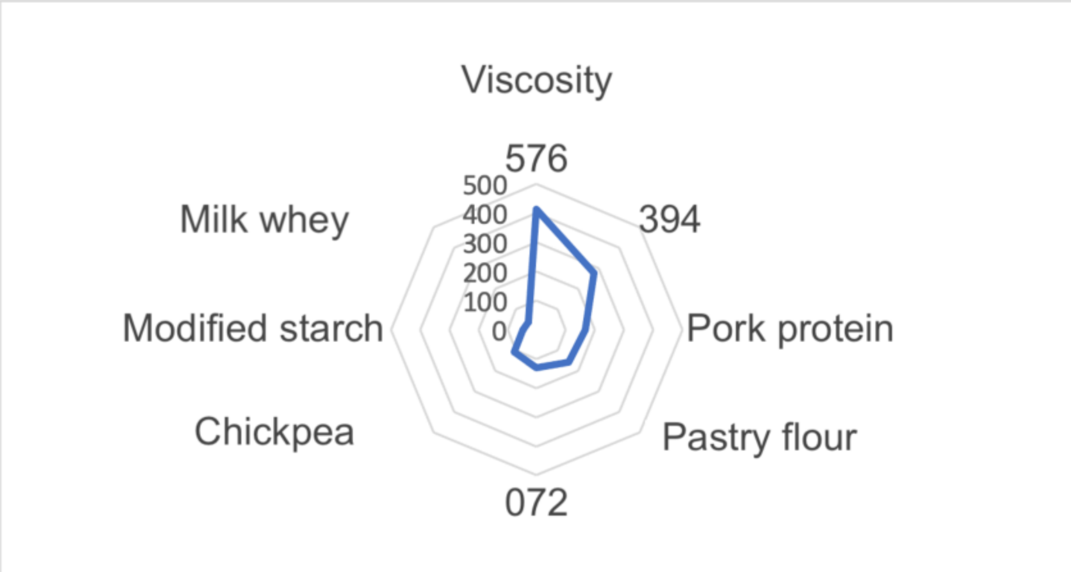

Figure 3: Viscosity results (mPa*s)

Water absorption index, solubility index and swelling power

The water absorption index, solubility index, and swelling power are essential indicators for defining the technological capacity of powdered foods used in various food matrices. During storage, this property is critical for microbiological stability since an increase in water activity (Aw) is directly related to the growth of molds and yeasts. Additionally, the water absorption capacity and swelling power are fundamental in the technological processing of food matrices that include powdered eggs. Table 3 shows the results of all the samples analyzed, modified starch had the highest water absorption index, with statistically significant differences compared to the other samples. The powdered egg samples 576, 394 and 072, while showing differences among them, had water absorption values close to those exhibited by chickpea flour and higher than those of pork protein or whey protein. These results can be significant in industries where water retention is important, such as in meat technology and pastry, among others [26].

Regarding the solubility index and swelling power, the powdered egg samples performed well in these indicators. However, modified starch, despite having a low solubility index, had a higher swelling power than all the other samples and showed statistical differences in these two aspects. The powdered egg samples 394 and 072 had higher solubility than 576, but in the swelling power indicator, the latter showed a higher value. Nevertheless, the powdered egg samples had higher values in these indicators compared to pork protein and whey protein, mainly due to their protein content. These characteristics can lead to good performance of powdered egg

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samples in foods that require emulsification during their preparation, such as sauces and meat derivatives, among others [27].

Foaming capacity and foam stability

In Table 4, it can be observed that samples 394, 072, and chickpea flour generate good foaming capacity (94.4 and 70.8 ml, respectively), with no significant differences found between them. The remaining samples show little foaming capacity, limiting their uses. The foaming capacity depends exclusively on the configuration of protein molecules since flexible proteins facilitate good foaming capacity, while globular molecules like those present in whey provide low foaming capacity because they are unable to reduce the surface tension of the air-water interface. Foaming ability in legume flours is a desirable characteristic for the production of some traditional foods, such as baked goods [28].

Foam stability is measured by the amount of foam that does not drain during a certain time (30 min), which is a very important characteristic because foam functionality depends on its capacity and stability. Instability is due to the temporary change in the gas and liquid distribution associated with processes such as drainage and coalescence [29]. For this study, it is perceived that the powdered egg samples 394 and 072 and chickpea flour meet both properties (foaming capacity and stability), which are attractive properties for the industry in the preparation of different foods.

Application of whole dehydrated egg in two food matrices

Based on the properties of powdered egg concluded after conducting the technological characterization tests, it was decided to include this product in the preparation of meatballs and analog cheese. These two products were chosen because they use powdered raw materials to bind and improve texture. In this case, powdered egg yolk, in addition to providing binding and texture properties, will increase the protein content of the selected food matrices. The selected egg sample for this application was 576, as it possessed the required technological characteristics to produce these products.

Meatballs

Three formulas were processed: a) 100-0 (chickpea-egg) coded as 976, 50-50 (chickpea-egg) coded as 529, and 0-100 (chickpea-egg) coded as 783. First, the meat and the pork back fat were cut into cubes to be ground in an 8mm disc. Subsequently, the meat and the meat back fat were mixed with 10% extender, 7% fat, 0.3% oregano, 0.2% black pepper, 0.2% bay leaf, 0.1% dehydrated garlic, and 2% salt. Finally, the meatballs were formed with a weight of 20g. The results of the analysis tests are described in Table 6, which shows that, for the color test, it is demonstrated that there are no significant differences ($p>0.05$) in the L*, a*, and b*

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coordinates for the different formulations, so it can be concluded that the incorporation of powdered egg in the evaluated substitutions does not affect the color parameter of the product.

On the other hand, based on Table 6 results, in the TPA analysis carried out on the meatball, it can be described that only the adhesiveness and rigidity attributes, presenting in the latter a higher rigidity parameter that is related to the absorption capacity, solubility, and swelling that the egg has and demonstrates in this incorporation, show significant differences between the samples, in the other attributes the samples have a statistically similar behavior.

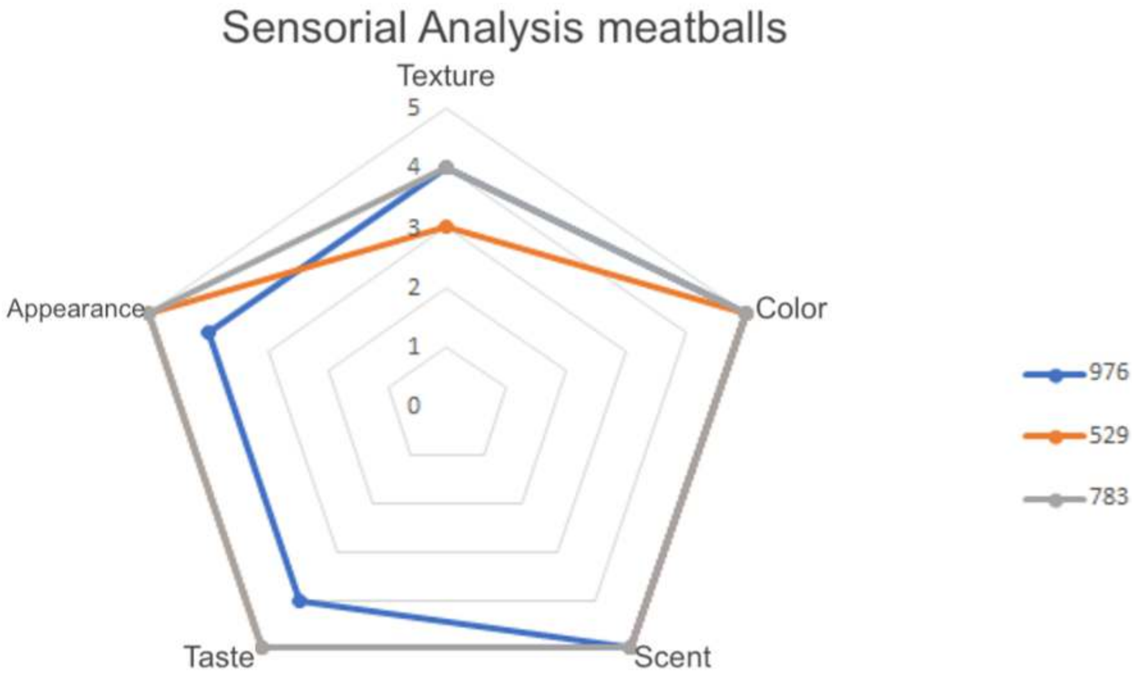

Figure 5: Sensorial analysis of meatballs

Therefore, it can be inferred that the incorporation of powdered egg in a meat formula (meatball) does not affect the color and texture parameters.
Regarding the sensory analysis (Figure 5), the attributes of color, odor and appearance did not show significant differences and were rated very favorably.
Regarding texture and flavor attributes, significant differences were found between formulations ($p<0.05$). In terms of texture, sample coded as 529 was the least preferred, while in terms of flavor, sample coded as 976 had the least acceptance. However, sample coded 783 had the highest acceptance in both texture and flavor.

Analog cheese
Three formulations were used for this product: 100-0 lecithin-egg coded as 655, 50-50 lecithin-egg coded as 306, and 0-100 lecithin-egg coded as 110. For the

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preparation of the analogue cheese, oil (10.2%) was heated to 85°C, at which point grated farmer's cheese (60%) was gradually incorporated. Subsequently, egg and/or lecithin (0.2%), phosphates (0.04%), salt (0.08%), and water (19%) were slowly added. Finally, caseinate (10.5%) was introduced to prevent the formation of lumps in the mixture. Once a homogeneous blend was achieved, the mixture was molded and refrigerated. The formulations were then analyzed using the tests described in the methodology. The results of the analytical tests are presented in Table 6. It can be observed that, in terms of color, the statistical analysis indicated that sample coded as 655 exhibited a significantly distinct behavior in the L* and a* scales, while for the b* scale, sample coded as 110 demonstrated statistical differences compared to other samples coded as 655 and 306.

On the other hand, the texture analysis showed that sample 110 differed from the others ($p < 0.05$) and necessitated greater force for food deformation, sample fracture, and showed higher rigidity. Cohesiveness was similar for samples 110 and 306 ($p \geq 0.05$) but distinct for 655 ($p < 0.05$), making them more resistant to a second deformation after the first deformation. Elasticity and adhesiveness did not vary between samples ($p \geq 0.05$), indicating that all samples possessed the same capacity to regain their initial shape after undergoing force.

In the sensory analysis (Figure 6), attributes such as color and odor exhibited no significant differences.

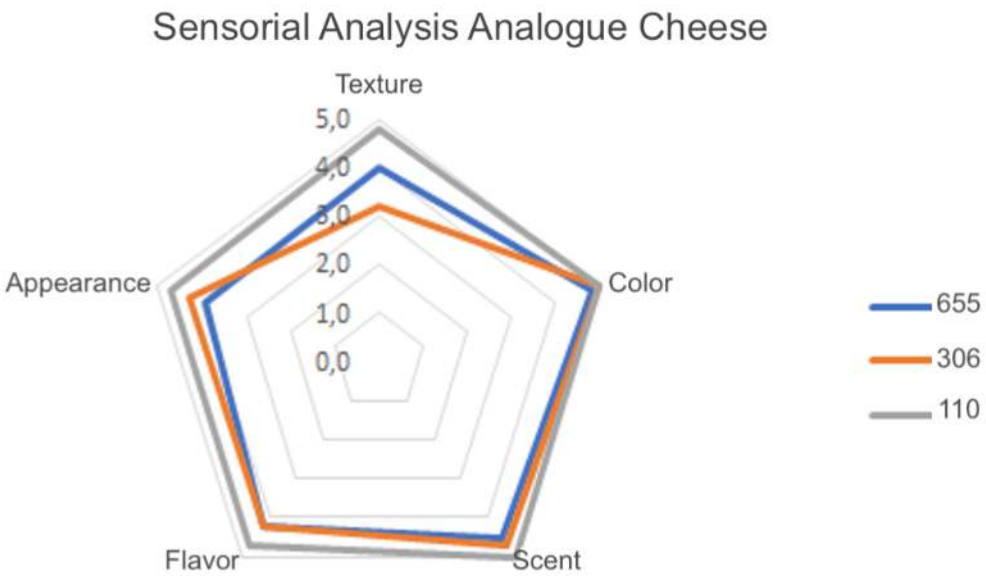

Figure 6: Sensorial analysis of Analogous cheese

Regarding the texture and flavor attributes, there were significant differences between the formulations ($p<0.05$), as evidenced by the fact that, for texture, panelists showed the least preference for sample 306, while for the flavor attribute, sample 110 had the highest acceptance and scored the highest in all sensory aspects evaluated.

CONCLUSION AND RECOMMENDATIONS FOR DEVELOPMENT

The technological characterization of commercial whole egg powder showed that it is classified as a coarse flour, with a characteristic color that makes it important for products that require this attribute. It was found that a high temperature is needed for gel formation, and it has a low density. The absorption index and swelling power obtained are low, while the solubility index is high, which allows it to maintain moisture and contributes to its adhesive property. Regarding foam capacity and stability, sample 783 showed the best results compared to the other samples used. In the development of meatballs, it was highly accepted by consumers, with no evidence of differences in color or most texture parameters. It also provides a greater contribution of both protein and unsaturated fat, which are beneficial to health, indicating that animal protein predominates over vegetable protein, with sample 783 showing significant differences compared to the other formulations, making it a highly recommended option for use as an extender in these meat products.

Regarding the analog cheese made with 100% egg emulsifier, it was sensorially accepted by consumers, allowing for the sale and consumption of a product that not only has sensory value but also nutritional value, as it has a significant protein contribution compared to that generated by lecithin, and a high content of unsaturated fatty acids, including Omega-3 acids. Regarding its texture, it requires more force to deform and fracture the sample, and it is more rigid and resistant.

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DISCLAIMERS

All the authors made significant contributions to the document and those who agree with its publication state that there are no conflicts of interest in this study.

Table 1: Particle size of samples

Sample	Absorbed weight (%) *	Mesh diameter (μm)
576	98,000 ± 0,788 a	180
SL	78,577 ±0,930 a, b	180
072	77,9 ±21,5 a, b	180
394	64,11 ±9,59 b,c	180
Chickpea flour	55,7 ±23,5 b, c	180
Pastry flour	54,14 ±2,42 b,c	180
Pork protein	37,070 ±0,637c	< 90
Modified starch	30,40 ±5,01 c	150

Table 2: Colorimetry for different analyzed samples

Sample	L* Coordinate	a* Coordinate	b* Coordinate
Modified starch	94,33 ± 0,029 a	-0,123 ± 0,064 d	1,573 ± 0,204 d
Milk whey	93,973 ± 0,024 a	-1,953 ± 1,062 e	15,40 ± 2,22 b
Pastry flour	92,130 ±0,019 a, b	-0,183 ± 0,021 d	10,167 ± 0,237 c
072	88,697 ± 0,009 b, c	2,437 ± 0,349 b, c	28,757 ±0,719 a
Chickpea flour	86,770 ±0,001 c	-0,720 ± 0,02 d, e	17,987 ± 1,445 b
394	86,133 ± 0,015 c	3,797 ± 0,290 a, b	32,533 ±0,825 a
576	85,280 ±0,014 c	3,407 ± 1,232 a, b	31,51 ± 2,73 a
Pork protein	73,91 ± 0,012 d	4,983 ± 0,446 a	14,317 ± 1,173 b

*The mean value of the flours with different letters has a significant difference according to the Tukey test with a significance level of α=0.05

Table 3: Colorimetry for different analyzed samples

Sample	Water Absorption Index	Solubility Index (soluble grams/sample grams)	Swelling power (g gel/g flour)
Modified starch	11,42 ± 0,43 a	1,87 ± 0,46 d	11,63 ± 0,49 a
Pastry flour	4,46 ± 0,18 b	19,47 ± 3,33 b	5,55 ± 0,25 b
Chickpea flour	3,33 ± 0,98 b, c	10,93 ± 1,85 c	3,74 ± 1,14 c
576	3,20 ± 0,27 b, c	12,20 ± 1,08 c	3,63 ± 0,34 c
394	2,06 ± 0,71 c, d	23,53 ± 5,53 b	2,67 ± 0,84 c, d
072	1,83 ± 0,17 d	21,50 ± 1,14 b	2,34 ± 0,25 c, d
Pork protein	0,96 ± 0,21 d, e	30,93 ± 0,46 a	1,39 ± 0,31 d, e
Whey	0,34 ± 0,01 e	33,33 ± 0,46 a	0,51 ± 0,02 e

*The mean value of the flours with different letters has a significant difference according to the Tukey test with a significance level of α=0.05

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Table 4: Foaming Capacity

Sample	Foam Capacity (mL0029	Foam stability (mL)
394	94,40 ± 25,5 a	90,99 ± 0,11 a
072	80,53 ± 4,79 a, b	69,55 ± 0,49 b
Chickpea flour	70,80 ± 18,4 a, b, c	69,23 ± 0.09 b
Pork protein	50,00 ± 10,00 b, c	29,96 ± 0,087c
Pastry flour	34,47 ± 16,76 c, d	29,32 ± 0,29 d
576	8,87 ± 1,96 d	2,81 ± 0.05 e
Snow flakes	3,33 ± 0,57 d	0,31 ± 0,05 f
Milk whey	3,22 ± 0,19 d	0,32 ± 0,005 f

*The mean value of the flours with different letters has a significant difference according to the Tukey test with a significance level of α=0.05

Table 5: Analyses results for meatballs

Test		Sample 976	Sample 529	Sample 783
Color	L*	61,36 ± 4,78 a	60,12 ± 3,81 a	58,62 ± 2,84 a
	a*	14,20 ± 3,75 a	10,68 ± 1,20 a	9,09 ± 1,73 a
	b*	16,34 ± 1,66 a	17,17 ± 1,39 a	19,85 ± 2,60 a
TPA Texture	Hardness (N)	5,618 ± 0,956 a	6,987 ± 0,088 a	6,656 ± 0,213 a
	Cohesiveness	0,324 ± 0,007 a	0,320 ± 0,001 a	0,311 ± 0,003 a
	Elasticity (mm)	2,414 ± 0,023 a	2,545 ± 0,034 a	2,541 ± 0,023 a
	Guminess (N)	1,828 ± 0,351 a	2,244 ± 0,032 a	2,089 ± 0,085 a
	Chewiness (Nm)	0,005 ± 0,001 a	0,006 ± 0,0001 a	0,005 ± 0,0002 a
	Max. Fracture Load (N)	0,893 ± 0,004 a	0,922 ± 0,014 b	0,928 ± 0,008 a
	Adhesiveness (Nm)	-0,00056 ± 0,0001 a	-0,00056 ± 0,00005 a	-0,0006 ± 0,0001 b
	Stifness (N/m)	2624 ±547 a	3568,3 ± 83,7 ab	3401,2 ± 40,9 b

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Table 6: Analyses results for analogue cheese

Test		Sample 976	Sample 529	Sample 783
Color	L*	79,323 ± 0,889 a	-1,543 ± 0,077 a	20,780 ± 0,294 c
	a*	75,017 ± 0,463 b	-3,377 ± 0,211 b	22,720 ± 0,225 b
	b*	75,093 ± 0,870 b -	-3,567 ± 0,005 b	23,960 ± 0,755 a
TPA Texture	Hardness (N)	138,47 ± 6,93 b	169,84 ± 13,95 b	246,7 ± 44,4 a
	Cohesiveness	0,219 ± 0,013 b	0,261 ± 0,013 a	0,282 ± 0,014 a
	Elasticity (mm)	2,321 ± 0,062 a	2,558 ± 0,184 a	2,689 ± 0,197 a
	Guminess (N)	18,741 ± 1,270 c	23,443 ±1,612 b	29,081 ± 1,500 a
	Chewiness (Nm)	0,0437 ± 0,003 c	0,057± 0,006 b	0,069 ± 0,003 a
	Max. Fracture Load (N)	5,403 ± 0,441 b	7,329 ± 0,914 b	12,38 ± 2,92 a
	Adhesiveness (Nm)	-0,00013±0,00005 a	-0,00010±0,00005 a	-0,00016±0,00006 a
	Stifness (N/m)	161003 ± 8789 b	199480 ± 20291 b	315407 ± 67564 a

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