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SUBSTITUTION OF SOYBEAN WITH CHICKPEA IN THE DEVELOPMENT OF A FUNCTIONAL POULTRY MEAT PRODUCT

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Abstract

Healthier meat foods are gaining in popularity and consumers are receptive to various plant-based protein sources, especially pulses. Pulses are highly versatile and a rich source of essential nutrients. They are also a source of high-quality protein, suitable for people of all ages and comparable to other protein-rich foods. Soya, which is the legume most commonly used in meat products, and its derivatives are among the most allergenic of a variety of foods that can cause negative reactions. Although chickpeas also belong to the same class as soya, the legumes, they are such a very common allergen. For this reason, we substituted soybean with chickpea in poultry meat products with heterogeneous and emulsion structure to observe the qualitative differences imprinted on the final products and the behaviour upon heat treatment. The obtained products were studied by physico-chemical analyses (pH, colour-texture, fat, protein, protein, moisture, salt content) and the obtained results were subjected to statistical tests to observe the existing differences.

***Key words**: chicken meat product, experimental design, food formulation, meat processing, meat product development.*

INTRODUCTION

One of the main sources of vital nutrients for the human body is meat (Ciobanu et al., 2025). These nutrients, which serve a variety of purposes in the human body, include proteins, lipids, vitamins and minerals (Manoliu et al., 2023; Manoliu et al., 2024). These are essential for carrying out physiological and metabolic processes in a normal state, boosting immunity and fighting diseases such as malnutrition (Anchidin et al., 2024b; Ciobanu et al., 2023a), but also due to the fact that plant products and their derivatives do not provide these nutrients easily (Anchidin et al., 2024a). The benefits of meat are also present in meat products (Ciobanu et al., 2024). Due to its nutritional qualities, meat and meat products are recognized as necessary components of the human diet (Boișteanu et al., 2023). Nutritional and dietetic value are the main elements influencing consumer behavior when it comes to the consumption of meat and meat products (Ciobanu et al., 2023b).

Approximately 38% of global meat production was made up of chicken meat in 2021, with 135.4 million tons produced globally, an increase of 3.5% compared to 2019 (Tudorache et al., 2022), even if new dietary trends, predominantly Western societies, support the reduction or replacement of meat in the diet (Flocea et al., 2024).

Due to its numerous advantages, including its affordability, safety and influence on health through its protein intake, compatibility with processing and lack of religious restrictions on consumption, public interest in poultry meat production has increased (Tudorache et al., 2022), and the popularity of chicken-derived products has also led to this increase (Boișteanu et al., 2025).

Beyond financial limitations and the current energy crisis, one of the main problems of livestock farming and meat industry is its substantial contribution to air pollution (Popa et al., 2022). Under these circumstances, adding plant additives to animal products is a promising way to improve their nutritional and functional qualities while reducing the meat industry's environmental impact. In addition, the demand for natural, and especially organic, ingredients is growing as food and feed markets increasingly shift towards sustainable and natural products (Grigore et al., 2023), which supports the incorporation of these plant-based substances into animal product formulations. Such incorporation could be achieved by partially replacing meat with legumes. The modification would facilitate addressing food security concerns and is in line with the advice of climate change experts (Lemken et al., 2019).

Legumes account for 27% of primary plant production worldwide (Smýkal et al., 2015). They are edible seeds belonging to the second largest family of seed plants, the *Leguminosae*, which has about 13,000 species and 600 genera. The word 'leguminous' comes from the Latin legere, meaning 'to gather', and refers to the manual collection of seeds. Pulses, derived from the latin *puls*, meaning "food made from flour", is another name for legumes. Soya is the world's most widely grown legume crop. Other legume crops include groundnut, dry bean, dry pea, chickpea, broad bean, field bean, lentil, maize, misc. bean, lupin and Bambara bean (Augustin et al., 2024).

Health risks associated with legume consumption are an increasingly important topic in both industrialized and developing countries. Numerous studies have shown that legume consumption can have both negative and positive health effects (Gupta et al., 2017). Despite being recognized as an important source of protein, soybeans and their derivatives are considered one of the main allergenic foods among the many foods that cause negative reactions (Ogawa et al., 2000). Although chickpeas also represent allergenic compounds, their allergenic potential and allergic reactions have a much lower prevalence than that of soybeans and other legumes, such as peanuts which have the highest allergenic potential among legumes (Cabanillas et al., 2018).

Chickpea, an increasingly important field crop, represents a sustainable and healthy plant component with added value for the food and nutraceutical industry (Augustin et al., 2024). Chickpeas are considered to have the richest nutritional content of all legumes on the market. Proteins and amino acids, simple carbohydrates, easily and poorly digestible polysaccharides (including dietary fiber), lipids, vitamins of different groups, and macro- and micro-nutrients are among the biogenic components found in this natural plant source, all of which are present in ideal amounts (Dzhaboeva et al., 2021). It is one of the most cost-effective sources of plant protein (25-30% protein) (Ghribi et al., 2018), being a cheap source for them and with very good bioavailability (Herrera & Gonzalez, 2021). This, as well as consumers' high desire for new products, allows companies to create new products that satisfy the market for goods with increased nutritional value (Herrera & Gonzalez, 2021; Anchidin et al., 2023a), given that consumers' food preferences are changing and are more complicated than manufacturers anticipate (Ciobanu et al., 2022; Pogurschi et al., 2018).

Chickpeas are large, salmon-white in color, and rich in protein (21.70-23.40%) and carbohydrates (41.10-47.42%). About 83.9% of all carbohydrates are composed of starch, making starch the main source of nutrition in chickpeas. Chickpea seeds are high in complex carbohydrates (low glycemic index), with high protein digestibility, rich in vitamins and minerals, and relatively free of antinutritional agents (Mittal et al., 2012). They have a fat content ranging from 3.10 to 5.67%, depending on the type, which is more than found in other legumes and some cereals, but lower than other oil legumes such as soybean and groundnut. Chickpea fat is composed of about 15% saturated fatty acids, 19% monosaturated fatty acids and 66% polyunsaturated fatty acids (Grasso et al., 2022).

The use of chickpeas in various forms (paste, flour, protein isolate) in meat products has been reported by various authors, with prevalence especially in the last 5 years, indicating an increased and topical interest in this type of addition in meat products: Verma et al., 1984; Sanjeewa et al., 2010; Ghribi et al., 2018; Wang et al., 2023a; Kasaiyan et al., 2023a; Wang et al., 2023b; Kasaiyan et al, 2023b; Mariod & Abd Elagdir, 2024. As part of contemporary food processing, various food quality enhancers are used (Zugravu et al., 2017) and chickpeas, as the literature has shown us so far, can be an excellent quality enhancer for meat products. Technological developments in the meat sector also enable the production of more sustainable and healthier food.

Our aim was to replace soy-based vegetable protein with chickpeas in meat products with heterogeneous and emulsion structure, because soy protein is a common allergen with a high prevalence in the population.

Chickpeas were chosen because they share many of the technological qualities of soybeans, as they belong to the same class of legumes, but chickpeas are not considered a common allergen.

We also wished to observe the qualitative differences imprinted by chickpeas on the finished products.

MATERIALS AND METHODS

The experimental batches were made from boneless chicken thigh purchased from S.C. Fermador S.R.L. in Iasi County, and the plant-based additives (soy and chickpeas) were purchased from S.C. Lidl Discount S.R.L. The seasoning mix used and the membranes used for the experimental batches were purchased from a local company in Iasi, S.C. Rocas FDS S.R.L. The raw materials and ingredients used in the batches studied are presented in Table 1 in percentage form.

Tabel 1. The experimental batches' composition and the thermal treatments that were used

<table>
<tr><th rowspan="2">Experimental batches</th><th colspan="7">Raw materials and ingredients (%)</th></tr>
<tr><th>Chicken thigh</th><th>Chopped boiled soybeans</th><th>Chopped boiled chickpeas</th><th>Salt</th><th>Ground pepper</th><th>Sweet paprika</th><th>Garlic powder</th></tr>
<tr><td>MES</td><td rowspan="4">90</td><td rowspan="2">10</td><td rowspan="2">-</td><td rowspan="4">0.2</td><td rowspan="4">0.2</td><td rowspan="4">0.2</td><td rowspan="4">0.5</td></tr>
<tr><td>MMS</td></tr>
<tr><td>CE</td><td rowspan="2">-</td><td rowspan="2">10</td></tr>
<tr><td>CM</td></tr>
</table>

MES - sample with heterogeneous structure and added soybean protein; MMS - sample with emulsion structure and chickpea protein; CE - sample with heterogeneous structure and added chickpea protein; CM - sample with emulsion structure and added chickpea protein.

Depending on the type of structure of the products (heterogeneous or emulsion) a differentiated heat treatment was used. The stages were drying, smoking and boiling. The temperature values and times of these stages are given in Table 2.

Table 2. Stages and parameters of the thermal regime applied to experimental plots

Structure type of the products	**Heat treatment**							
	Drying I		Smoking		Boiling		Drying II	
	T°C	t (min)	T°C	t (min)	T°C	t (min)	T°C	t (min)
Heterogeneous	55	20	80	25	78	30	80	5
Emulsion	60	30	70	20	78	30	80	5

The technological process consisted of coarse grinding (in the form of shreds) of deboned chicken pulp through the 0.8 mm diameter sieve of the volf for samples with heterogeneous structure. For samples with an emulsion structure, the coarse grind was further subjected to a fine grinding process by cutterization. These were mixed with the plant-based additives according to the experimental batch and the seasoning mix (Table 1). The obtained compositions were dosed into cellulose membranes (samples with heterogeneous structure) and collagen membranes (samples with emulsion structure) with a diameter of 45 mm, obtaining products with a length of about 20 cm. These were placed on racks and subjected to the heat treatment described in Table 2. After completion of the heat treatment, the samples were cooled, vacuum-packed and stored under refrigerated conditions (2-4°C).

The laboratory analyses carried out for the studied batches consisted of physico-chemical analysis, as follows: analysis of chemical parameters, pH measurement, color determination and texture evaluation.

Analysis of the crude chemical composition included determination of moisture, dry matter, protein, collagen, fat and salt content using the FoodCheck automated infrared analyzer (Bruins Instruments GmbH, KPM Analytics).

The physical measurements included: 1. Measuring the pH of the samples using the pH meter HI98163, with electrode FC2323 special for meat (S.C. Hanna Instruments S.R.L.) (Anchidin et al., 2023); 2. Measuring the color indicators in the three-dimensional CIE color space which consisted of the parameters lightness (L*), redness (a*) and yellowness (b*) (Gucianu et al., 2023), using the Konica Minolta Chroma Meter CR-410 color analyzer (Konica Minolta, Inc.). Hue (H°) and Chroma (C*) parameters were calculated using formulas (1) and (2), based on the CIELAB parameters determined using the model of Anchidin et al. (2024a); 3. Textural profile analysis (TPA) was performed with the TA1+1K Plus texturometer (Ametek, Inc.) and the textural parameters hardness, elasticity, cohesiveness, gumminess, adhesiveness, chewiness were determined.

$$H^\circ = tan^{-1} \times \frac{b^*}{a^*} \quad (1)$$

$$C^* = \sqrt{(a^*)^2 + (b^*)^2} \quad (2)$$

In addition to the determinations described above a statistical test - Principal Component Analysis (PCA) which is a useful tool for assessment of correlations between the physical and chemical parameters studied contributing to the differentiation of the studied batches (Cozzolino et al., 2019; Boișteanu et al., 2024).

RESULTS AND DISCUSSIONS

The analyses carried out mainly focused on the influence of the type of structure (heterogeneous and emulsion), the influence of the type of vegetable additive (soy and chickpea) and the influence of these two influencing factors (type of structure*vegetable additive) on the overall quality of the samples studied (Table 3).

The moisture content of the analyzed samples showed significant differences ($p < 0.05$) in the interaction between the two tracked factors and for both types of vegetable addition. The heterogeneous structure type showed highly significant differences ($p < 0.001$), while the emulsion structure showed significant differences ($p < 0.05$). Mean moisture values were higher in the chickpea-added batches for both texture types. However, we can observe that the emulsified samples showed higher values for this parameter regardless of the vegetable addition, suggesting the major influence of the product structure on this parameter, but also the influence of the vegetable addition, which was not as significant. Our results are in slight contradiction with those obtained by Pennells et al. (2024) who looked at the functionality of some legume extruded ingredients. They showed that chopped soybean has a higher water-holding capacity than chickpeas. However, samples of unchopped chickpea extrudates showed a higher value of the same parameter than soybean within the same type of structure.

As with the moisture parameter, significant differences ($p < 0.05$) between the factors analyzed in this study (structure type*plant-based additive) were observed for the dry matter parameter. The type of plant-based additive showed highly significant differences ($p = 0.000$) in both the heterogeneous and emulsion structures. The heterogeneous structure type also showed the same trend as the vegetable additive type for this parameter, with highly significant differences being identified within the heterogeneous structure type ($p = 0.000$), but in the emulsion structure the differences were only significant ($p = 0.013$). The mean values of the studied batches for this parameter show that the addition of soybean leads to a slight increase in this parameter, especially in the heterogeneous structure, where this difference is more evident.

For the parameters protein, collagen, salt and pH no significant differences were found ($p > 0.05$), as can be seen in Table 3. In the case of protein the average values obtained were slightly lower with the addition of chickpeas, especially in the case of heterogeneous structure. As Messina (1999) also shows us, the protein content of soybean is almost double that of chickpeas, thus giving the products to which this chemical parameter is added a slightly higher value. However the differences were extremely small within the products, where soybean showed a protein value 0.08% higher for the heterogeneous structure and 0.02% higher for the emulsified products. The collagen content did not show differences, as it is not found in the plant-based products, nor did they influence this parameter in any way. Also, the salt content did not show significant differences between the analyzed batches ($p > 0.05$), regardless of the type of addition. This is due to the extremely low sodium content in legumes, as observed by Meiners et al. (1976). Even if they showed that the sodium content is in much lower amount in the soybean, being at trace level, we observed this aspect in our study only relatively, since the highest average value was obtained by the product with heterogeneous structure and soybean addition (1.53 ± 0.67%), but also the lowest value for the emulsified product with the same addition (1.48 ± 0.08%). In the case of the chickpea-added samples, its content was constant in both types of structures (1.50 ± 0.07%).

Table 3. Mean values, standard deviations and significance levels of the physicochemical parameters for the analyzed samples

Analyzed parameters	Structure type	Plant-based additive	Mean ± standard deviation of mean	Significance for the plant-based additives (soy - chickpea) (*p*-value)	Significance for the type of structure, heterogeneous-emulsion (*p*-value)	Significance between type of structure*plant-based additive (*p*-value)
Humidity (%)	Heterogeneous	Soy Protein	70.91 ± 0.12	0.000***	0.000***	0.035*
		Chickpea Protein	71.30 ± 0.12	0.000***		
	Emulsion	Soy Protein	72.16 ± 0.05	0.000***	0.013*	
		Chickpea Protein	72.34 ± 0.09	0.000****		
Dry Matter (%)	Heterogeneous	Soy Protein	29.09 ± 0.12	0.000***	0.000***	0.035*
		Chickpea Protein	28.70 ± 0.12	0.000***		
	Emulsion	Soy Protein	27.84 ± 0.05	0.000***	0.013*	
		Chickpea Protein	27.66 ± 0.09	0.000***		
Protein (%)	Heterogeneous	Soy Protein	21.08 ± 0.08	0.710^{ns}	0.150^{ns}	0.434^{ns}
		Chickpea Protein	21.00 ± 0.07	0.461^{ns}		
	Emulsion	Soy Protein	21.06 ± 0.11	0.710^{ns}	0.710^{ns}	
		Chickpea Protein	21.04 ± 0.05	0.461^{ns}		
Collagen (%)	Heterogeneous	Soy Protein	19.08 ± 0.13	1.000^{ns}	0.430^{ns}	0.457^{ns}
		Chickpea Protein	19.14 ± 0.11	0.297^{ns}		
	Emulsion	Soy Protein	19.08 ± 0.13	1.000^{ns}	0.791^{ns}	
		Chickpea Protein	19.06 ± 0.09	0.297^{ns}		
Fat (%)	Heterogeneous	Soy Protein	6.32 ± 0.04	0.000***	0.000***	0.457^{ns}
		Chickpea Protein	5.96 ± 0.11	0.000***		
	Emulsion	Soy Protein	5.16 ± 0.15	0.002***	0.002**	
		Chickpea Protein	4.88 ± 0.13	0.002***		
Salt (%)	Heterogeneous	Soy Protein	1.53 ± 0.67	0.297^{ns}	0.527^{ns}	0.457^{ns}
		Chickpea Protein	1.50 ± 0.07	1.000^{ns}		
	Emulsion	Soy Protein	1.48 ± 0.08	0.297^{ns}	0.672^{ns}	
		Chickpea Protein	1.50 ± 0.07	1.000^{ns}		
pH	Heterogeneous	Soy Protein	6.42 ± 0.11	0.251^{ns}	0.303^{ns}	0.490^{ns}
		Chickpea Protein	6.49 ± 0.02	0.849^{ns}		
	Emulsion	Soy Protein	6.50 ± 0.10	0.251^{ns}	0.949^{ns}	
		Chickpea Protein	6.50 ± 0.12	0.849^{ns}		

The mean ± standard deviation is used to display the values (n = 5). Statistical significance is indicated as follows: $^{ns}p \geq 0.05$ – not significant; $*p < 0.05$ – statistically significant; $**p < 0.01$ – highly significant; $***p < 0.001$ – extremely significant.

For the pH parameter, the highest mean values, irrespective of the type of additive, were found in the emulsified structure, being identical for both types of additives (6.50), and within the heterogeneous structure, the chickpea sample showed a slightly higher value of this parameter (6.49 ± 0.02%) compared to the soy containing sample (6.42 ± 0.11%). From this we can deduce that the structure had a slight influence on this parameter, but extremely low and insignificant.

In terms of crude fat content, both the type of structure and the type of vegetable addition showed highly significant ($p < 0.001$) and, for the type of emulsifying structure, highly significant ($p < 0.01$) effects on the crude fat content, but the interaction of all these variables was insignificant ($p > 0.05$). The chickpea-added samples obtained slightly lower mean values in this analysis, which may be correlated with the higher moisture content in the chickpea-added samples. Our results are in agreement with the literature showing higher fat content in soybeans (Perkins, 1995) compared to chickpea (Iqbal et al., 2006). However, the feed matrix (heterogeneous or emulsion) also plays an obvious role in the case of this parameter, as it can be observed that the fat content in the soy emulsified sample is lower than in the chickpea heterogeneous sample, but higher than in the chickpea emulsified sample. These results show both the influence of the vegetable addition on the fat content, but also the influence of the structure, which in this case is significant but not major.

The instrumental color analysis of the experimental plots is shown in Table 4 and includes the parameters L*, a*, b*, h° and C*.

The analyzed samples showed extremely significant differences ($p < 0.001$) in the correlation between type of structure*plant-based additive for most parameters (CIE L*, CIE a* and H°), highly significant differences ($p < 0.01$) were observed only within the CIE b* parameter, and in the case of C* the differences were insignificant ($p = 0.388$). The brightness of the samples (L*) showed higher average results in the case of emulsified samples, this fact being due to the higher homogeneity of the samples and the higher moisture content of the emulsified samples (Table 3). Research conducted on chicken meat color by Qiao et al. (2001) showed that chicken meat samples with a lighter color (higher brightness) also showed a significantly higher moisture content compared to chicken meat samples with a lower brightness. Also, within the same type of structure, extremely significant differences ($p = 0.001$) were identified depending on the type of plant-based addition, with higher average values being observed for products with chickpea addition compared to samples with soy addition, this fact being correlated with the higher water retention capacity of samples with chickpea addition, regardless of structure. Even though the plant-based addition had a great influence on the colorimetric parameter L*, the type of structure showed extremely significant differences between the studied batches ($p = 0.001$), regardless of the type of plant-based addition. This trend is also observed in the case of the chemical parameter humidity, where the emulsified samples recorded higher values in the emulsified samples than in the heterogeneous ones.

The CIE a* parameter (referring to the red-green component), compared to the CIE L* colorimetric parameter values, showed an inversely proportional trend of increase or decrease. This trend of decrease in the a* parameter following the increase in the L* parameter was also observed in a previous study conducted by Anchidin et al. (2023c) on pork.

Thus, samples with heterogeneous structure presented higher average values than those with emulsified structure, with extremely significant differences being recorded between the two types of structures studied ($p < 0.001$). Also, the type of plant-based addition presented extremely significant differences in the case of all four batches studied ($p < 0.001$).

The highest values for the CIE parameter a*, 11.07±0.27 and 11.60 ± 0.09, were observed in samples with heterogeneous structure for soybean addition and chickpea addition, respectively. In case of emulsion structure the average results obtained were 10.20 ± 0.10 for soybean and 9.80 ± 0.12 for chickpea.

As can be seen, even though in the case of heterogeneous structure, the chickpea addition showed a higher value than soybean and the tendency, according to the cited work and our results is to decrease the degree of red color, in this case it increases proportional to the increase in the brightness value, being the only case of this kind in our study. The emulsified sample with added chickpeas, on the other hand, which presented the highest brightness value (67.41 ± 0.26), also obtained the lowest value in the colorimetric parameter a* (9.80 ± 0.12), results that are in line with the literature.

Table 4. Mean values, standard deviations and significance levels of the colorimetric parameters for the analyzed samples

Analyzed parameters	Structure type	Plant-based additive	Mean ± standard deviation of mean	Significance for the plant-based additives (soy - chickpea) (*p*-value)	Significance for the type of structure, heterogeneous-emulsion (*p*-value)	Significance between type of structure*plant-based additive (*p*-value)
CIE L*	Heterogeneous	Soy Protein	61.64 ± 0.27	0.000***	0.000***	0.000***
		Chickpea Protein	62.20 ± 0.13	0.000***		
	Emulsion	Soy Protein	65.68 ± 0.09	0.000***	0.000***	
		Chickpea Protein	67.41 ± 0.26	0.000***		
CIE a*	Heterogeneous	Soy Protein	11.07 ± 0.27	0.000***	0.000***	0.000***
		Chickpea Protein	11.60 ± 0.09	0.000***		
	Emulsion	Soy Protein	10.20 ± 0.10	0.000***	0.001***	
		Chickpea Protein	9.80 ± 0.12	0.000***		
CIE b*	Heterogeneous	Soy Protein	15.66 ± 0.31	0.204^{ns}	0.378^{ns}	0.004**
		Chickpea Protein	15.56 ± 0.10	0.003**		
	Emulsion	Soy Protein	15.52 ± 0.10	0.204^{ns}	0.001***	
		Chickpea Protein	15.94 ± 0.09	0.003**		
h^{o}	Heterogeneous	Soy Protein	35.25 ± 1.11	0.000***	0.002**	0.000***
		Chickpea Protein	36.71 ± 0.38	0.000***		
	Emulsion	Soy Protein	33.33 ± 0.38	0.000***	0.000***	
		Chickpea Protein	31.57 ± 0.20	0.000***		
C*	Heterogeneous	Soy Protein	19.18 ± 0.17	0.000***	0.006**	0.388^{ns}
		Chickpea Protein	19.41 ± 0.03	0.000***		
	Emulsion	Soy Protein	18.57 ± 0.07	0.000***	0.069^{ns}	
		Chickpea Protein	18.71 ± 0.13	0.000***		

CIE L* - luminosity of the samples; CIE a* - red-green component; CIE b* - yellow-blue component; H° - hue angle indicating the direction of color in the chromatic space; C* - chroma, indicates color saturation values. The mean ± standard deviation is used to display the values (n = 5). Statistical significance is indicated as follows: $^{ns}p \geq 0.05$ – not significant; $*p < 0.05$ – statistically significant; $**p < 0.01$ – highly significant; $***p < 0.001$ – extremely significant.

As for the colorimetric parameter CIE b*, it was not significantly influenced by the addition of soy, its influence being insignificant (p > 0.05). Despite these results, the addition of chickpea protein had a very significant influence on this parameter (p < 0.01). The samples with heterogeneous structure showed insignificant differences (p = 0. 378) within this parameter, while differences between samples with emulsified structure were highly significant (p = 0.001). Statistical differences concerning the correlation between structure type and plant-based addition were highly significant (p = 0.004) for this parameter, this was less significant than those for the parameters CIE L* and CIE a*. The average results obtained for parameter b* did not show a certain linearity or order due to the type of plant addition or the type of structure and can be considered slightly chaotic, without a clear trend.

The hue angle (h°), as well as the b* parameter, showed the same slightly chaotic trend of the average results, depending on the type of plant-based addition. However, a trend is observed in the case of the type of structure of the samples: samples with heterogeneous structure recorded higher average values (35.25 ± 1.11 for soybean and 36.71 ± 0.38 for chickpea) than samples with emulsion structure (33.33 ± 0.38 for soybean and 31.57 ± 0.20 for chickpea) which indicates a very slightly more reddish color of the emulsified samples, compared to the heterogeneous ones, which have a slightly more yellow tint, as we can see on the colorimetric wheel presented by Cantrell et al. (2010). The types of plant-based additives added in all samples (soybean/chickpea) show highly significant differences ($p < 0.001$), as well as in the interaction between the type of palnt-based additive and the product structure. The differences between the type of structure for the analyzed samples are highly significant ($p = 0.002$) while the emulsified structure shows highly statistically significant differences ($p = 0.000$). Chroma (C*), which represents the perceived color saturation, showed higher average values in the case of samples with heterogeneous structure than in the case of those with emulsion structure. Also, they were lower in the case of samples with added soy protein (19.18 ± 0.17 – heterogeneous sample and 18.57 ± 0.07 – emulsified sample) than in the case of samples with added chickpea protein (19.41 ± 0.03 – heterogeneous sample and 18.71 ± 0.13 – emulsified sample). The differences recorded by the type of plant-based addition within all the samples studied are extremely significant ($p < 0.001$). Regarding the type of structure, the differences observed are insignificant in terms of emulsified samples ($p = 0.069$) and very significant in heterogeneous samples ($p = 0.006$). The correlation type of plant-based addition*type of structure for the C* parameter showed that the differences are not significant between the samples studied ($p > 0.05$).

Texture profile analysis for the 4 batches analyzed is presented in Table 5 and consists of the following textural parameters: hardness, adhesiveness, elasticity, cohesiveness, gumminess, chewiness.

The hardness of the samples showed no significant influence ($p > 0.05$) on the type of plant-based additive added or the structure of the samples. The highest average value of this parameter was identified in the case of the batch with heterogeneous structure and soybean addition (12.88 ± 1.55 N), and the lowest value was identified within the same type of structure, but with the addition of chickpea (11.22 ± 0.88 N). Despite these results, in the case of the emulsion structure, the highest hardness value was identified in the sample with the addition of chickpea protein (11.93 ± 2.67 N), the emulsified sample with the plant-based additive of soybean obtaining the value of 11.22 ± 0.88 N, which is very close to the value of the heterogeneous sample with the addition of chickpea.

Regarding the adhesiveness of the samples, higher average values were observed in the case of meat samples with the addition of soy vegetable protein, both with heterogeneous structure (86.76 ± 6.57 mJ) and with emulsion structure (62.03 ± 7.41 mJ), this fact being also observable by the extremely significant differences of the samples with this type of plant-based addition ($p < 0.001$). The samples with the addition of chickpea protein showed lower average values, the lowest being identified within the batch with emulsified structure (47.81 ± 4.31 mJ). The addition of chickpea led to the lack of statistically significant differences in adhesiveness in the batches containing it ($p > 0.05$). However, the type of structure showed extremely significant statistical influences in the case of heterogeneous structure ($p < 0.001$) and very significant in the case of emulsified structure ($p < 0.01$). The interaction between the type of structure and the addition of plant-based protein reported very significant differences ($p = 0.004$). The same interaction in the case of the textural parameter elasticity did not present statistical differences ($p = 0.538$). This was more influenced by the type of structure, being identified similar average results in the case of the emulsified structure with the addition of soy (0.60 ± 0.03) and with the addition of chickpeas (0.54 ± 0.03), the statistical differences within this structure for elasticity being insignificant (p = 0.066). For the heterogeneous structure, the elasticity parameter showed significant differences between the two analyzed samples (p = 0.011), these reporting lower results than within the emulsified structure and with greater differences between the average values obtained (0.46 ± 0.05 – sample with added soy and 0.37 ± 0.08 – sample with added chickpea).

Table 5. Mean values, standard deviations and significance levels of the texture profile analysis (TPA) of the tested samples

Analyzed parameters	Structure type	Plant-based Additive	Mean ± standard deviation of mean	Significance for the plant-based additives (soy – chickpea) (*p*-value)	Significance for the type of structure, heterogeneous-emulsion (*p*-value)	Significance between type of structure*plant-based additive (*p*-value)
Hardness (N)	Heterogeneous	Soy Protein	12.88 ± 1.55	0.167^{ns}	0.141^{ns}	0.156^{ns}
		Chickpea Protein	11.22 ± 0.88	0.519^{ns}		
	Emulsion	Soy Protein	11.34 ± 1.00	0.167^{ns}	0.586^{ns}	
		Chickpea Protein	11.93 ± 2.67	0.519^{ns}		
Adhesiveness (mJ)	Heterogeneous	Soy Protein	86.76 ± 6.57	0.000***	0.000***	0.004**
		Chickpea Protein	53.17 ± 6.87	0.204^{ns}		
	Emulsion	Soy Protein	62.03 ± 7.41	0.000***	0.003**	
		Chickpea Protein	47.81 ± 4.31	0.204^{ns}		
Elaticity	Heterogeneous	Soy Protein	0.46 ± 0.05	0.000***	0.011*	0.538^{ns}
		Chickpea Protein	0.37 ± 0.08	0.000***		
	Emulsion	Soy Protein	0.60 ± 0.03	0.000***	0.066^{ns}	
		Chickpea Protein	0.54 ± 0.03	0.000***		
Cohesiveness	Heterogeneous	Soy Protein	0.66 ± 0.03	0.000***	0.001***	0.759^{ns}
		Chickpea Protein	0.55 ± 0.05	0.001***		
	Emulsion	Soy Protein	0.78 ± 0.04	0.000***	0.000***	
		Chickpea Protein	0.65 ± 0.05	0.001***		
Gumminess (N)	Heterogeneous	Soy Protein	8.50 ± 1.02	0.734^{ns}	0.001***	0.265^{ns}
		Chickpea Protein	6.18 ± 0.94	0.065^{ns}		
	Emulsion	Soy Protein	8.80 ± 0.58	0.734^{ns}	0.312^{ns}	
		Chickpea Protein	7.89 ± 2.29	0.065^{ns}		
Chewiness (J)	Heterogeneous	Soy Protein	3.90 ± 0.81	0.015*	0.005**	0.421^{ns}
		Chickpea Protein	2.24 ± 0.44	0.001***		
	Emulsion	Soy Protein	5.29 ± 0.60	0.015*	0.055^{ns}	
		Chickpea Protein	4.23 ± 1.20	0.001***		

The mean ± standard deviation is used to display the values (n = 5). Statistical significance is indicated as follows: $^{ns}p \geq 0.05$ – not significant; $*p < 0.05$ – statistically significant; $**p < 0.01$ – highly significant; $***p < 0.001$ – extremely significant.

The type of plant-based addition, in terms of elasticity and cohesiveness of the samples, had an extremely significant influence on all the analyzed samples ($p < 0.001$). In the case of cohesiveness, the same extremely significant differences were also observed in the case of the two types of structures targeted in our study ($p < 0.001$). However, the correlation between the type of structure and the plant-based addition in the analyzed samples was insignificant ($p > 0.05$). For the same parameter, the samples with soybean addition presented higher average values (0.66 ± 0.03 – heterogeneous structure; 0.78 ± 0.04 – emulsified structure) than those with chickpea (0.55 ± 0.05 – heterogeneous structure; 0.65 ± 0.05 – emulsified structure), but the structure also had an important influence, with higher values being observed for the emulsified samples. A higher cohesiveness of some meat emulsions with plant-based addition of soy, but in the form of soybean oil, was observed in the study of Shao & Tang (2014) who motivated this by increasing the resistance of the protein gel. Our study shows that not only soybean oil has this property, but soybean itself. As the results show us, chickpea does not have the power to form a very strong cohesiveness, but the results are satisfactory and the products have an appropriate cohesiveness.

Gumminess and chewiness both showed higher mean values in the case of samples with soybean addition, especially in the case of heterogeneous structure, as can be seen in Table 5. Gumminess and chewiness showed extremely significant differences ($p < 0.001$) and, respectively, significant ($p < 0.01$) in the case of heterogeneous structure and insignificant in the case of emulsion structure ($p > 0.05$). Also, the interaction between the type of structure of the samples and the added plant-based ingredients did not show significant differences between the analyzed samples ($p > 0.05$). The same result was obtained in the case of the type of plant-based addition in the case of the textural parameter gumminess, where the differences were insignificant regardless of the plant-based addition ($p > 0.05$). However, the same results were not obtained in the case of chewiness, where the results were highly significant for the plant-based addition of chickpea protein ($p < 0.001$) and significant for the addition of soy protein ($p < 0.05$).

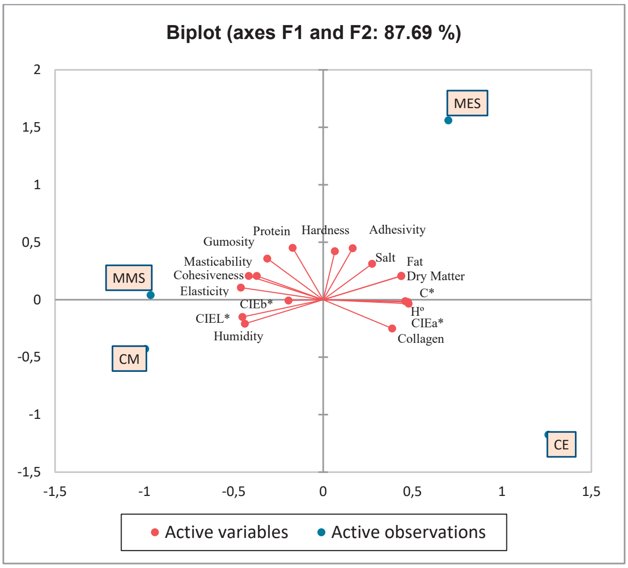

Figure 1. Relationships between the physico-chemical attributes studied by using the Principal Component Analysis (PCA). MES - sample with heterogeneous structure and added soybean; MMS - sample with emulsion structure and soybean; CE - sample with heterogeneous structure and added chickpea; CM - sample with emulsion structure and added chickpea

Figure 1 presents the correlations between all the physical and chemical parameters analyzed in this study to observe the positive or negative influence between them. The PCA biplot covers 87.69% of the total variability. The sample with emulsified structure and soy protein addition (MES) is correlated with the attributes hardness, adhesiveness, fat and dry matter, mainly, highlighting results with higher values for these physicochemical characteristics. The emulsified sample with soy addition (MMS) is characterized, in particular, by better cohesiveness, elasticity, chewiness and gumminess. In contrast, the protein content between these two samples is very similar being positioned relatively median between the 2 analyzed samples.

The sample with chickpea addition and heterogeneous structure is characterized by a higher content of collagen, dry matter, fat, but also higher values of the colorimetric parameters CIE a*, h° and C*. In contrast, the sample with chickpea addition and emulsified structure correlates very positively with the MMS sample and is characterized by physicochemical characteristics such as: humidity, high brightness (CIE L*), yellow color (CIE b*), elasticity, cohesiveness, chewiness and gumminess.

The results obtained in the case of the PCA biplot also show the superiority of the textural characteristics of the samples with the addition of soybean (MES and MMS), compared to those with the addition of chickpea (CM and CE). However, the sample with the addition of chickpea and with a texture closer to that imprinted by the addition of soy in meat products is the emulsified sample (CM), which correlates positively with the textural characteristics elasticity, chewiness, cohesiveness and, to a lesser extent, gumminess. Also, a positive correlation can be observed between the samples with the same type of structure, these presenting many common characteristics, especially in the case of the samples with emulsified structure, regardless of the type of plant-based addition (MMS and CM). They present strong correlations between the analyzed physico-chemical characteristics. These results show us that the type of structure has the greatest influence on the physico-chemical characteristics of the analyzed samples. These results are especially valid for samples with emulsified structure. Although in samples with heterogeneous structure, regardless of the type of plant-based addition, the physicochemical characteristics are positively correlated, they are not as close and similar as in the case of the emulsified structure type. The type of structure shows positive and weakly positive correlations in the case of samples with soybean addition (MES and MMS). In contrast, the samples with chickpea addition (CE and CM) show weakly positive correlations or they are neutral. Strong negative correlations are observed between samples with different structure types and different plant-based addition, such as CM - MES and MMS - CE which show strong antagonism.

CONCLUSIONS

The replacement of soybean by chickpea in chicken meat products with heterogeneous structure and emulsion structure was aimed to follow the effects of this modification on some of the most important physico-chemical parameters of interest for meat products. Our research focused both on the differences imparted by the plant-based addition and those imparted by the type of product structure.

As a result of our quantitative research and especially with the help of correlations realized by Principal Component Analysis (PCA), it was found that both the type of structure and the plant-based addition have an important influence on the physico-chemical parameters studied. Samples with the same type of structure, even if they have different types of additions, show similar results in most of the analyses.

The samples with emulsion structure showed very significant similarities highlighting the fact that the influence on the classic product (the one with added soybean) of the chickpea addition is not major and can be easily substituted by it. As for the samples analyzed with heterogeneous structure, it cannot be said that the homogeneity of the results between the two is as high as in the case of the emulsified ones, but the differences are not major, with a few exceptions.

The physical results revealed significant differences in the color of the samples as a function of both the added mixture and the structure of the samples. On the other hand, the texture of the samples did not show differences for the correlation between these factors, except for the adhesiveness where differences were observed especially between the two types of additions.

The chemical parameters showed that the addition of chickpea had a very positive influence on the water holding capacity, as evidenced by the obvious increase in moisture content in the lots containing this type of addition. The protein content, although lower in chickpeas than in soybeans, did not affect the protein content in the samples analyzed except by a very slight decrease of this constituent to a negligible extent. A very positive effect of added chickpeas was observed in the decrease in the fat content of the samples, which is in line with current industry trends.

From the results we can conclude that the addition of chickpeas instead of soybean is a promising option for the industry that does not affect to a large extent the classical (soy-added) products, but even leads to quality improvements.

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