Research Article

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Protein and iron enrichment on functional chicken sausage using plant-based natural resources

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Abstract: This study investigates the potential of spinach flour (SF) and chia seed flour (CSF) incorporation as replacements for tapioca flour (TF) in chicken sausages to enhance nutritional content, especially iron (Fe) and protein. Five formulations were tested: C0 (control, 12 % TF), C1 (9 % TF, 0.5 % SF, 2.5 % CSF), C2 (6 % TF, 1 % SF, 5 % CSF), C3 (3 % TF, 1.5 % SF, 7.5 % CSF), and C4 (2 % SF, 10 % CSF). The sausages were evaluated for physical, chemical, and sensory attributes. Results indicate declining physical quality parameters in terms of water holding capacity (WHC) and color (whiteness), while chemical quality (Fe, protein, fiber, fat, and water) were increased ($p < 0.05$) across all experimental groups compared to the control. The C1 formulation showed the highest consumer acceptability, while C4 demonstrated potential as a functional sausage with elevated protein and iron levels, though sensory acceptance needs to be underlined. The study concludes that the combination of CSF and SF can enhance both the nutritional value and overall quality of chicken sausages, offering a beneficial dietary option, but balancing both ingredients in the practical application needs to consider the consumer preferences for the acceptance of the product.

Keywords: chicken sausage; spinach flour; chia seed flour; physical and chemical quality; consumer acceptance

1 Introduction

Meat products, particularly sausages, play a significant role in fulfilling daily nutrient requirements [1] due to their high protein content and substantial amounts of essential nutrients. Given their widespread consumption and relatively low production costs, sausages represent a convenient and practical food choice for consumers globally [2]. These products are often loaded with vitamins, minerals, and other bioactive compounds crucial for maintaining optimal health [3]. However, there is a growing need to enhance the nutritional profile of sausages while maintaining their appeal to consumers as reported in the earlier study [4]. In this context, plant-based ingredients have gained significant attention as sources of functional components [5] that can improve the overall quality and health benefits of meat products [6]. Recognizing the potential of plant-based ingredients, researchers and food manufacturers have begun exploring their incorporation into meat products to develop functional alternatives [7]. Moreover, this approach not only addresses the growing concerns related to the overconsumption of meat but also taps into the potential of plant-based diets to offer substantial health advantages, including a reduced risk of cardiovascular disease and type II diabetes [8].

Among the various plant-based options available, two ingredients have shown particular promise, that are spinach and chia seed which can provide high-quality, easily accessible functional meals derived from plants [9, 10]. These ingredients offer promising opportunities for enhancing sausage quality, aiming to create functional meat products that meet consumer demands for healthier options [11]. Spinach, rich in vitamins, minerals, and fiber, can contribute to the overall nutritional value of sausages and may also impart a desirable green color, appealing to health-conscious consumers seeking visually attractive plant-enriched meat products [12–14]. Chia seeds, known for their high omega-3 fatty acid content and antioxidant properties, can improve the nutritional profile of sausages while potentially enhancing texture [15–17].

The addition of spinach flour (SF) to meat sausages offers several benefits, including enhanced nutritional content, such as vitamins A, C, and K [5, 18], minerals, such as magnesium, manganese, folate, and iron [19], increased fiber [20], bioactive compounds, improved antioxidant activity [1], and better

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water holding capacity [21]. SF can also aid in preventing and treating anemia due to its high iron content [20, 22]. However, there are limitations to its use, such as potential negative effects on color and flavor when added in excessive amounts. The addition of SF may also result in a less dense microstructure, affecting the sausage texture, for which careful consideration of the appropriate amount is necessary to balance these benefits with potential sensory impacts [20, 23].

The addition of chia seed flour (CSF) to sausage products offers numerous benefits, including enhanced nutritional profiles with increased fiber, protein, polyunsaturated fatty acids, minerals, vitamins, and antioxidants [24–27], and better physicochemical and sensory qualities [28, 29]. Additionally, chia seeds can improve physicochemical properties, sensory qualities, and potential health benefits such as cardiovascular support and anti-inflammatory effects [25, 27, 30]. However, limitations exist in terms of optimal incorporation levels, as excessive amounts may negatively impact consumer acceptability [31], texture [31, 32], and color [33]. Earlier study suggest that lower levels of CSF are more favorable for maintaining desirable sensory attributes while still providing nutritional enhancements [31].

Several studies have been undertaken to examine how SF and CSF affect the quality of sausage products, but in single addition. In this study, we used both the combination of SF and CSF, which distinguishes it from earlier studies, to get the combination of both advantages. The addition of CSF is expected to alleviate some of the downsides of utilizing SF, especially in terms of physical quality and preferences. This is because CSF has the advantage of being able to improve the physical quality and preferences of meat products. Furthermore, sausages are manufactured with higher nutritional content, particularly protein and iron, allowing them to be consumed as part of a healthy diet. The combination of SF and CSF is expected to improve the quality of chicken meat sausages to some extent. Therefore, this study aims to examine the synergistic effects of SF and CSF on chicken meat sausages' quality attributes. The study assessed the impact of these plant-based additives on physical and chemical characteristics, textural properties, nutritional content (focusing on protein and iron), and consumer acceptability. Additionally, it explored whether combining SF and CSF can mitigate adverse effects associated with using SF alone and evaluate their potential as natural additives for developing healthier and more functional meat products.

2 Materials and methods

2.1 Materials

The major ingredients required to manufacture sausages are chicken breast meat, tapioca flour (TF), SF, and CSF. These key components are sourced from local markets to ensure freshness and better control over quality. Merck Germany manufactures all the chemicals and reagents used in this study, unless otherwise noted.

2.2 Formulation and preparation of chicken sausage

Five compositions (C0 to C4) with different chicken meat sausage ingredients were prepared with specific formula as shown in Table 1. In this study, TF as filler is replaced with the combination of SF and CSF in different percentages in each formula. The process began by dividing ground boneless chicken meat into five parts, which were then evenly mixed with salt, ice cubes, and additional spices using a mixer. The dough then placed in the edible casing, steamed for 30 min at 70–80 °C, cooled, and then stored at −21 °C for further quality test. The physical and chemical qualities of the sausages were assessed in five replicates [34].

Table 1: Chicken sausage formulas.

Ingredients	Formula (%)				
	C0	C1	C2	C3	C4
Chicken meat	62.25	62.25	62.25	62.25	62.25
Tapioca flour	12	9	6	3	0
Spinach flour	0	0.5	1	1.5	2
Chia seed flour	0	2.5	5	7.5	10
Albumen flour	1	1	1	1	1
Skim milk powder	3	3	3	3	3
Carrot flour	4	4	4	4	4
Ice	13	13	13	13	13
Spices					
– Garlic	2.2	2.2	2.2	2.2	2.2
– White pepper	0.4	0.4	0.4	0.4	0.4
– Coriander	0.25	0.25	0.25	0.25	0.25
– Salt	0.7	0.7	0.7	0.7	0.7
– Chicken broth	1.2	1.2	1.2	1.2	1.2
Total	100	100	100	100	100

2.3 Physical quality evaluation

2.3.1 pH

In this study, the pH analysis follow the method in earlier study [35]. To achieve homogeneity, 10 g of refined sausage was mixed in 10 mL of H_2O, and the pH was measured using a digital pH meter (Hanna pH Tester HI98107, Italy).

2.3.2 Water holding capacity

The Hamm method [36] was used to determine water holding capacity (WHC). A 0.3 g sausage sample was placed on filter paper (Whatman paper 100 × 100 mm), sandwiched between two glass plates, and subjected to a 1 kg ballast for 5 min. The wet area indicated by pressed stains was measured using millimeter block paper, calculating the distance between the pressed meat and the larger stain corresponding to the water absorbed by the filter paper. To account for value variance, 10 parallel measurements were performed.

2.3.3 Cooking loss

The calculation of cooking loss involved a precise methodology to assess the moisture and fat retention in sausage samples during the cooking process according to the previous study [37]. To begin with, 25 g of sausage samples were carefully weighed and placed in polypropylene plastic containers. These containers were chosen for their heat resistance and ability to maintain the sample's integrity during cooking. The samples were then submerged in boiling water and cooked for a duration of 30 min. Throughout the cooking period, the internal temperature of the sausages is monitored using a food thermometer to ensure they reach and maintain 80 °C. This specific temperature is crucial as it simulates typical cooking conditions and ensures consistent results across samples.

After the cooking process, the samples were removed from the water bath and allowed to cool slightly. Once cooled enough to handle, the sausages were carefully removed from the plastic containers and reweighed. The difference in weight before and after cooking was then calculated and expressed in percentage as cooking loss. This percentage represents the amount of moisture and fat lost during the cooking process, which was an important factor in determining the quality and yield of the sausage product. A higher cooking loss percentage generally indicates a greater loss of moisture and potentially a less juicy final product.

2.3.4 Tenderness

To determine the tenderness of the sausage, a Wartner-Blatzer penetrometer (Penetrometer Universal H-1200, Humboldt, Illionis, USA) was used [38]. The penetrometer's chart speed was 250 mm/min. Sausage samples measuring 1 cm in length, height, and width are placed under the penetrometer's needle, and the lever was turned on for 10 s. The tenderness was determined by number shown on the penetrometer, the higher the tenderness value means the more tender the sausage. The unit for tenderness measurement was using a penetrometer unit (PU).

2.3.5 Color test

The color of sausages was tested using the Commission Internationale de l'Eclairage (CIE) chromatometer (Chromameter Konica Minolta CR-400). The standard color measurements were based on the KONICA MINOLTA precision color Communication Book. Lightness (L^*) was measured on a scale of 0–100, representing white. The red (a^*) color was measured between 0 and 60, and green was between 0 and −60. The yellow (b^*) color was measured between 0 and 60, and the blue was between 0 and −60 [39]. The color quality then calculated using formula as Whiteness = $100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]1/2$ as described in the previous study [40].

2.4 Chemical quality evaluation

The chemical quality of sausages, including protein, fat, and water, was evaluated using the food scan tool (FoodScanTM Meat Analyzer, FOSS, SCANCO, Costa Rica) and the Near Infrared Reflectance Spectroscopy (NIRs) method [41]. A 25 g sample of sausage, homogenized through grinding, was placed in a test dish and subsequently inserted into the FoodScan NIR spectrophotometer, ensuring uniform petri dish height for each sample tested. The samples were analyzed by inserting them into the prepared FoodScan. The operator identification was entered, and the scanning process was initiated by pressing the start button. Results were generated in approximately 50 s per sample. In this study, all measurements were conducted with five replications for each sausage formula.

Crude fiber content was determined using gravimetric methods [42]. The crude fiber content was quantified by utilizing gravimetric techniques. A 2 g sample of homogeneously ground sausage was placed in an Erlenmeyer flask containing 200 ml of H_2SO_4 (0.255 N) solution, positioned inverted, covered with a condenser, and boiled for 30 min.

The suspension from the Erlenmeyer flask was filtered using filter paper, and the residue remaining in the flask was rinsed with boiling water. The residue on the filter paper was washed until it was no longer acidic. Subsequently, the residue on the filter paper was returned to the Erlenmeyer flask with a spatula, washed with 200 ml of NaOH (0.313 N), and boiled for another 30 min. The boiled residue was filtered using filter paper of known constant weight and washed with 10 % K_2SO_4. The residue was then washed with boiling water and 15 ml of 95 % alcohol. The residue on the filter paper was dried in an oven at 110 °C, ashes in a furnace at 500 °C, cooled in a desiccator, and weighed. The crude fiber content was calculated using the formula: % fiber content = (fiber weight/sample weight) × 100 %.

Iron (Fe) analysis was done using atomic absorption spectrophotometry (AAS) with equipment from Analytic Jena GmbH, Germany. This followed the method mentioned in the earlier report [43]. A standard iron solution of 1,000 mg/L was prepared by diluting it in deionized water and concentrating nitric acid (5 ppm in 2 % HNO_3). A calibration blank solution used 2 % HNO_3. One gram of meat sausage was weighed and put into a digestion vessel. This vessel was placed in a fume hood with concentrated HNO_3 (5 mL) and ultra-pure DI water (4 mL). The vessel was left open for 30 min to let gas escape. After digestion, samples were diluted to fit the calibration range. Spike samples were made similarly to reach a spike concentration of 2 ppm. This method was used for blank and spike samples. After digestion, samples were diluted again to fit the calibration range. The final solution was measured with AAS at a wavelength of 248.3 nm, band pass 0.2 nm, background correction D2, and lamp current 75 %. The signal was measured continuously for 4 s.

2.5 Hedonic test

The hedonic test was designed to describe the level of consumer acceptability and satisfaction with the sausage product. For this test, 35 semi-trained panel members were recruited using questionnaires to assess their knowledge about chicken sausages, with each response assigned a score. Prior to the evaluation, the panelists received training on how to conduct organoleptic tests and completed consent forms.

To prepare for the test, the sausages were warmed for about 15 min before being placed in sealed containers labeled with three random 3-digit numbers. Panelists then conduct hedonic tests on each sample from each sausage formula, rating them on a 9-point scale (1 being the lowest and 9 being the highest). Hedonic assessment score described as 1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, and 9 = like extremely [44]. The assessment of sausages includes evaluation of aroma, color, flavor, taste, tenderness, and texture [45]. The forms for panelist's selection, consent form and how to conduct the hedonic testing were included in Supplementary Material.

2.6 Informed consent

Participants are invited to join this research voluntarily, with a comprehensive understanding of its purpose, procedures, potential risks, and benefits. Before participating, all individuals received clear and appropriate information, either verbally or in writing. Consent was documented through signed forms.

2.7 Statistical analysis

The statistical analysis for comparing the means of different sausage compositions was performed using a one-way analysis of variance (ANOVA). In this experiment, five replicates were employed for each data measurement. When significant differences were detected, post hoc comparisons were performed using Duncan's New Multiple Range Test. All statistical analyses were carried out using R software version 4.4.2. Differences were considered statistically significant at $p < 0.05$.

3 Results

The results of physical quality analysis conducted on various sausage formulations incorporating different percentages of SF and CSF were presented in Table 2. Statistical analysis revealed significant differences ($p < 0.05$) in water holding capacity (WHC) and color (whiteness) among the formulations. However, no statistically significant differences ($p > 0.05$) were observed for pH, cooking loss, and tenderness parameters across the groups. Notably, the C4 formulation, which included both SF and CSF, exhibited a significantly lower WHC ($p < 0.05$) compared to the other experimental groups.

Table 3 shows the effects of incorporating SF and CSF on the chemical parameters of the sausage formulations. Statistical analysis revealed significant differences ($p < 0.05$) across all chemical quality criteria when compared to the control group (C0). The data demonstrates

Table 2: Physical quality parameters of different chicken sausage formula.

Parameter	Chicken sausage formula					*p*-Value
	C0	C1	C2	C3	C4	
pH	6.25 ± 0.07	6.39 ± 0.07	6.40 ± 0.08	6.41 ± 0.04	6.34 ± 0.07	0.09
Water holding capacity (%)	0.41 ± 0.04^{a}	0.45 ± 0.04^{a}	0.43 ± 0.05^{a}	0.38 ± 0.04^{a}	0.21 ± 0.02^{b}	2.32×10^{-05}
Cooking loss (%)	1.82 ± 0.72	1.96 ± 0.34	1.68 ± 0.36	1.86 ± 0.8	2.09 ± 0.42	0.53
Tenderness (mm/g/s)	9.01 ± 1.17	10.85 ± 1.66	10.10 ± 0.56	10.15 ± 1.10	8.41 ± 0.92	0.29
Color (whiteness)	95.90 ± 0.67^{d}	97.70 ± 0.17^{b}	96.46 ± 0.20^{c}	98.57 ± 0.05^{a}	98.75 ± 0.16^{a}	2.26×10^{-14}
– *L** (Lightness)	42.19 ± 3.05	42.21 ± 1.24	40.54 ± 2.36	40.17 ± 0.69	40.17 ± 0.98	0.14
– *a** (red)	6.75 ± 1.16^{a}	5.43 ± 0.38^{b}	4.31 ± 0.24^{b}	2.62 ± 0.14^{c}	2.52 ± 0.20^{c}	1.44×10^{-7}
– *b** (yellow)	23.90 ± 2.03^{a}	21.22 ± 0.60^{b}	20.07 ± 1.46^{bc}	18.13 ± 0.81^{d}	18.55 ± 0.38^{cd}	2.86×10^{-7}

[a,b,c,d]Means with different superscripts in the same row indicate significant differences ($p < 0.05$).

a gradual increase in iron (Fe) content with the increasing addition level of SF to the sausage formulations. This incremental pattern was mirrored in the protein, fiber, and fat content, while an inverse trend was observed in water content, which decreased progressively from C0 to C4 formulations. Notably, protein content in formulations C3 and C4 exhibited significantly higher percentages ($p < 0.05$) compared to formulations C0 through C2. The C4 formulation demonstrated the highest fiber content ($p < 0.05$) among all treatments, while simultaneously exhibiting the lowest water content ($p < 0.05$), indicating a potential correlation between fiber addition and moisture retention in the sausage matrix.

A comprehensive visualization of the results obtained from the hedonic test analysis was illustrated in Figure 1. The hedonic test patterns for samples C0 and C1 exhibit similarity across all observed parameters, with a notable exception in the tenderness attribute, which demonstrates a slight increase in consumer liking. The graphical representation clearly illustrates that sample C4 receives the lowest consumer acceptance, as evidenced by the consistently lower preference values across all evaluated parameters. In contrast, sample C2 demonstrates superior consumer preference when compared to samples C3 and C4, as indicated by the higher ratings observed across the various sensory attributes assessed in the study.

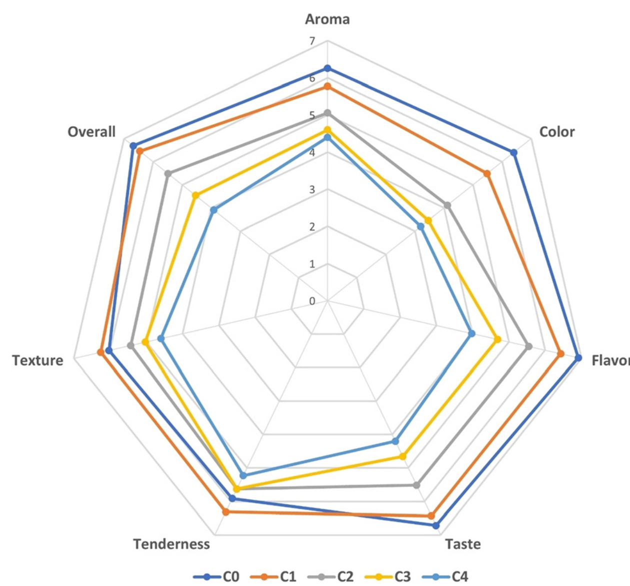

Figure 1: The radar chart of hedonic quality in different chicken sausage formulas.

4 Discussion

The incorporation of SF into poultry meat sausages presents both opportunities and challenges in terms of nutritional enhancement and sensory acceptance. Spinach flour

Table 3: Chemical quality parameter of different chicken sausage formula.

Parameter (%)	Chicken sausage formula					*p*-Value
	C0	C1	C2	C3	C4	
Fe	7.17 ± 0.92^{c}	8.66 ± 2.18^{c}	14.60 ± 0.14^{b}	23.77 ± 0.25^{a}	23.92 ± 1.15^{a}	4.08×10^{-13}
Protein	21.73 ± 0.30^{bc}	21.53 ± 0.37^{c}	22.02 ± 0.16^{b}	22.54 ± 0.25^{a}	22.73 ± 0.27^{a}	8.59×10^{-07}
Fiber	0.24 ± 0.06^{e}	0.84 ± 0.08^{d}	1.45 ± 0.39^{c}	2.11 ± 0.24^{b}	2.64 ± 0.17^{a}	4.32×10^{-16}
Fat	4.57 ± 0.41^{c}	4.65 ± 0.29^{c}	5.01 ± 0.33^{c}	6.06 ± 0.09^{b}	6.64 ± 0.15^{a}	2.26×10^{-10}
Water content	66.04 ± 0.87^{a}	63.54 ± 1.72^{b}	62.70 ± 0.81^{b}	63.48 ± 0.59^{b}	60.55 ± 1.07^{c}	5.28×10^{-06}

[a,b,c,d]Means with different superscripts in the same row indicate significant differences ($p < 0.05$).

increases the nutritional profile of sausages due to its richness in micronutrients, particularly in terms of fiber, protein, calcium, iron content, and various antioxidants [22, 46]. This aligns with the growing consumer demand for healthier meat alternatives and functional foods [47]. However, the addition of SF to sausages can lead to changes in physicochemical properties. Then, to overcome the adverse effect of SF addition to the sausage, fortification with CSF becomes an option to enhance the physicochemical and sensory quality [20, 23] as a strategy to balancing the nutritional enhancement and sensory appeal.

The decrease in WHC in the C4 formula (Table 2) cannot be retained when compared to the other formulations. Similar to other plant-based additives like lupin flour, SF may increase emulsion stability and decrease cooking loss in sausages [48]. However, it's important to note that the addition of SF can affect color parameters of the final product, potentially decreasing whiteness values [22]. The found in color test indicated that C3 and C4 formulations demonstrated the highest levels of whiteness (Table 2) compared to the remaining groups ($p < 0.05$). The findings revealed that the parameters in the control study changed at a specific degree of treatment, with a decrease in the intensity of colors in whiteness. The L^* value indicates the intensity of coloring; and is red and green, and b^* is yellow and blue [39], and whiteness is the brightness level [49]. As shown in Table 2 the more percentage of SF and CSF in the sausage formula significantly ($p < 0.05$) lowering red (a^*) and yellow (b^*) color intensity compared to the control (C0) formula. Except for the addition of spinach, the intensity of sausage color is determined by the vegetable ingredients added and can increase in value [23]. According to [50], chia seed mucilaginous exudate has a bright yellow or brown color. Chia seed can be used to create a more concentrated and stable emulsion, allowing incoming light to propagate back to the surface and affect color intensity. As a result, this brightness value can compensate for the negative impact of color intensity [51]. In this case, the negative effect of spinach on color intensity can be mitigated by patching up to C2 treatment with CSF, causing a decrease in C3 and C4. Furthermore, as compared to the control, all the formulations show better colors represented by higher whiteness level.

The lowest ($p < 0.05$) WHC (Table 2) and highest ($p < 0.05$) fiber (Table 3) content were found in C4 compared to C0 and the other sausage formulation groups. When fiber is added to a specific capacity, meat products become more tender, pH rises, and WHC falls. According to earlier report [52], the amount of fiber added influences the level of sausage hardness because insoluble fiber can affect emulsion and binding moisture content in sausages, increasing the value of the shear press (sausages become tender). This can be explained due to fiber's porosity allows it to bind water and fat [53]. In this study, adding CSF as fiber source up to 10 % in C4 shows no effect to tenderness and cooking loss (Table 2) which means all the formula have ability to retain the water and fat during cooking.

The addition of CSF can boost the chemical content of sausages. The result of this study shares parallels and differences with several others. For example, adding up to 15 % CSF to chicken sausages can boost fat, fiber, and protein levels [29] as demonstrated in Table 3. The addition of chia seed mucilage at 5 % can increase moisture, protein, and ash content while decreasing fat content in emulsified meat products [51]. Chemical tests on grilled chicken sausages with up to 4 % CSF added revealed that the fat content increased [28].

The increasing percentage of SF added to the sausage formula significantly ($p < 0.05$) affects the color of the product, as shown by a higher whiteness value in C4 when compared to C0–C3 (Table 2). Moreover, this color change then impacts consumer perception and acceptance of the product as shown in the hedonic test (Figure 1), which shows that a higher percentage of SF in sausage affects less acceptance from consumers of the product as measured in color, flavor, taste, tenderness, texture, and aroma. This comparative analysis of the hedonic test results provides valuable insights into the relative acceptability and sensory characteristics of the different samples evaluated in this research.

Interestingly, while SF addition may alter the sensory profile of sausages, studies have shown that moderate levels of incorporation can maintain consumer acceptability. For instance, a 7.5 % substitution level of spinach powder in wheat-based products was found to have an optimum effect on overall acceptability [22]. However, in this study we only use a maximum of 2 % (C4) of SF in the sausage (Table 1). This suggests that careful formulation is crucial to balance the nutritional benefits with sensory appeal. However, higher levels of SF may introduce stronger herbaceous flavors, which could affect consumer preference, as observed in pasta enrichment studies [54].

The hedonic tests revealed that adding up to 4 % CSF to chicken sausages had an influence on overall acceptability, texture, odor, taste, or color (Figure 1). However, the results at 6 % differed, demonstrating that general acceptability, odor, and color were reduced when compared to controls. Meanwhile, the texture and flavor remain identical to the control [28]. According to an earlier study [55], the addition of 1 % CSF to restructured ham-like products results in equal consumer acceptance across all treatments (odor, color, texture, flavor, juice, and overall). The addition of up to 2 % SF to chicken meatballs can increase the value of appearance, flavor, texture, and overall palatability, but there is a decrease with a 3 % addition compared to the control [56]. When compared to a control, the addition of up to 3 % spinach flour to beef sucuk (fermented beef sausage) can reduce hedonic tests on color, appearance, odor, taste, texture, and general acceptability [57].

The main ingredients used in the production of sausages influence their hedonic fondness [58]. Chia seed is combined with mucilage, which aids in the sensory enhancement of foods such as sausage [50]. When compared to other vegetable sources, the addition of SF to sausages can reduce sensory value [23, 59]. The addition of spinach, especially if it is associated with WHC, can reduce color quality, whereas a decrease in WHC can lead to a reduction in color quality [60]. Thus, the water holding capacity (WHC) of meat is an important parameter for assessing meat quality [61]. The oxalic acid content in spinach causes a bitter taste [62], so it can reduce the taste of sausages in research. Rancid aroma is present due to the presence of lipoxidase [63] and volatile organic compounds due to oxidation processes, such as dimethylsulfide, which causes a fishy aroma [64], which reduces the aroma of research sausages. Taste-related metabolites are connected to aroma [65], meaning that taste results from a combination of both aroma and taste. As the aroma and taste diminish, the overall flavor also decreases.

5 Conclusions

The addition of a combination of CSF and SF can be used to improve overall quality based on physical, color, and hedonic properties of chicken sausage. The finding in this study suggests that the incorporation of SF and CSF in specific proportions significantly influences certain physical properties of sausages, particularly WHC and color, while leaving other parameters relatively unaffected. In sausage production, CSF and SF can be beneficial ingredients in formulations; however, the balance between both must be considered to ensure consumer acceptance, particularly due to the resulting texture.

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Conflict of interest: The authors affirm that the publication of this manuscript is devoid of any conflicts of interest.
Data availability statement: The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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