Scientific Papers. Series D. Animal Science. Vol. LXVII, No. 1, 2024
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN Online 2393-2260; ISSN-L 2285-5750

# IMPACT OF BONE BROTH ON PROTEIN CONTENT, COLOR, AND CONSUMER PREFERENCES IN EMULSIFIED CHICKEN AND TURKEY FRANKFURTERS

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***Abstract***

*This study investigated the impact of incorporating beef bone broth into chicken and turkey frankfurters. Thus, diversification was achieved by the type of meat used and the level of bone broth introduced, resulting in the following samples: CC (control chicken frankfurter), C3% (chicken frankfurter with 3% bone broth), C6% (chicken frankfurter with 6% bone broth), C9% (chicken frankfurter with 9% bone broth), CT (control turkey frankfurter), T3% (turkey frankfurter with 3% bone broth), T6% (turkey frankfurter with 6% bone broth), and T9% (turkey frankfurter with 9% bone broth). After manufacture, the products were analysed in terms of chemical composition, instrumental colour and sensory perception. The addition of bone broth significantly increased moisture content and protein content (particularly at higher broth concentrations) compared to control sausages. Conversely, fat content decreased with increasing bone broth. The sensory evaluation revealed no significant changes in flavor, texture, or overall acceptability with broth addition, although some panelists perceived a sensory improvement. Instrumental color analysis showed minimal impacts on lightness and redness with broth addition, suggesting the broth's color did not substantially influence overall sausage color.*

***Key words****: beef bone broth, chicken/turkey sausages, frankfurters.*

## INTRODUCTION

Worldwide poultry meat consumption has steadily increased from 37,368.82 million tonnes in 2008, when it surpassed pork consumption, to 50,694.48 million tons in 2022 (OECD, 2023). In addition, according to the OECD/FAO projections 2023-2032, poultry meat consumption will increase the most globally, by 15% by 2032, accounting for 41% of animal protein intake (OECD/FAO, 2023).

Poultry meat consumption in the European Union is positioned as the second highest, following swine meat, at 1,003.33 million tons in 2022 (OECD, 2023). The pattern of pork consumption in Romania mirrors that of the European Union as a whole. On the contrary, poultry meat consumption exhibits a consistent upward trajectory, reaching an average of 27.9 kg per capita in 2022, as opposed to 20.1 kg per capita in 2014, according to Statista (2024).

Emulsified meat products, which consist of frankfurter sausages, bologna, Vienna sausage, and hot dogs, are among the most widely consumed meat products on a global scale. Primarily, this is attributed to their distinct flavor and nutritional composition. Furthermore, their affordability and convenience contribute to their widespread appeal among consumers (Sam et al., 2021; Cao et al., 2022).

Frankfurter sausages are widely consumed meat products that originate from various cultures. They are prepared using an emulsion method, are cooked-smoked, and consist of lean and fatty meat, water, and additional ingredients such as salts, ripening agents, and spices. The circumference of the sausage wrap is determined by the manufacturer and can be either natural pig membranes or collagen membranes (Feng et al., 2016; Bravo et al., 2020).

Frankfurter sausages possess a considerable lipid content, which comprises an estimated 20% to 30% of their overall composition. Fat is widely criticized and shunned due to the perceived dangers it presents and can be mitigated by choosing lean cuts of meat, removing fat entirely, modifying the diet to alter the composition of fatty acids, and regulating portions to decrease fat and calorie consumption. In recent years, there has been a notable emphasis on the development of meat products that incorporate various constituents that improve product quality and impart health benefits (Anchidin et al., 2023). Furthermore, the fat content accentuates the sensitivity to lipid oxidation, leading to degradation, rancidity, discoloration, a shorter shelf life, and the formation of hazardous chemicals (Bravo et al., 2020; Sam et al., 2021). To prevent this qualitative deterioration, intervention occurs in the actual manufacturing process of emulsified meat products through the use of a variety of additives, such as thickening agents, emulsifying agents, water/fat retention agents, and gelling agents. These additives have been used to improve the quality profiles of finished products and extend their storage life (Yuan et al., 2023).

In the case of emulsified varieties, the most important agents are binders and emulsifiers, as meat emulsion is considered a water-in-oil emulsion, heterogeneous composite materials composed of fat globules covered with proteins (oil droplets) dispersed in a matrix of myofibrillar protein gel (Santhi et al., 2015).

Emulsifying agents serve as an interface between immiscible components, responsible for forming stable emulsions. An emulsifier is a substance that enhances texture and palatability, inhibits separation of the food system, regulates rancidity processes, and either solubilizes or disperses flavors (Santhi et al., 2017; Surendran Nair et al., 2020).

Proteins derived from meat are excellent emulsifying agents. In order to avoid fat coalescence, the amino acids present in proteins interact with non-polar fat molecules and polar water molecules, thus establishing a continuous system in the meat mixture (Surendran et al., 2020). Additionally, the use of collagen leads to an increase in protein content within the emulsion, which in turn improves emulsion stability (Santana et al., 2011).

Bone broth is popular and appreciated for its distinctive flavor, delicious taste and multitude of water-soluble vital nutrients, including short peptides, minerals, vitamins and free amino acids. One of the primary nutrients found in bone broth is protein. As its primary protein components, bone broth primarily comprises chondroitin, collagen, and free amino acids (Zhang et al., 2014; Zhang et al., 2017; Meng et al., 2022).

In this context, the aim of the work was to obtain two assortments of meat products with emulsified structure, frankfurter type sausages from chicken and turkey meat, enriched with beef bone soup to improve protein intake. The experimental batches, as well as the control ones in each variety, were analyzed in terms of the proximate chemical composition and sensory perception, instrumental color, and also color changes that occurred during five days of storage at refrigerated temperature.

## MATERIALS AND METHODS

The research was conducted at the "Ion Ionescu de la Brad" Iasi University of Life Sciences, where the frankfurter sausages were manufactured in the Meat Processing Workshop. The analytical procedures were carried out in the laboratories dedicated to meat and meat products technology, as well as sensory analyses.

In order to accomplish the intended objective, an experimental protocol was devised that resulted in the fabrication of two varieties of frankfurter sausages, a total of eight batches: four containing poultry meat and four containing turkey meat.

The frankfurter sausages were prepared as described by Boișteanu et al. (2022), with some adjustments. Except for the beef bone broth, which was produced in the meat processing facility before the sausages, all constituents (meat, salt, spices, membranes) utilized in the production of the sausage batches were procured from local suppliers.

The production process of the batches involved the introduction of the following raw materials: chicken and turkey thigh meat, beef bone soup, salt, spices, as described in Table 1. Thus, four frankfurter formulations were prepared for each variety in the ratios (chicken or turkey thigh meat/beef bone broth) of 100:0; 97:3; 94:6 and 91:9.

Table 1. Formulations of poultry frankfurters added with different concentrations of beef bone broth (kg)

| | Control chicken (CC) | C3% | C6% | C9% | Control turkey (CT) | T3% | T6% | T9% |
|---|---|---|---|---|---|---|---|---|
| Lean chicken meat | 3.5 | 3.392 | 3.277 | 3.154 | - | - | - | - |
| Lean turkey meat | - | - | - | - | 3.2 | 3.105 | 3.003 | 2.894 |
| Beef bone soup | - | 0.108 | 0.223 | 0.346 | - | 0.095 | 0.197 | 0.306 |

The other ingredients were added as follows: salt 20 g/kg, sweet paprika 2 g/kg, coriander 1 g/kg, garlic powder 5 g/kg, pepper 2 g/kg.

The manufacturing technology followed the steps described in a previous study (Manoliu et al., 2023), with some specific modifications for frankfurter sausages. Hence, the raw meat was first grinded in a machine (Grinder WP - 105) using a sieve of 3 mm diameter, then fine minced, using a machine only used in food industry for mincing chilled or frozen meat (with a maximum temperature of -7ºC) and obtaining emulsions containing meat (Cutter Titane V 45L), until a fine, homogeneous paste was obtained. In this stage, the bone broth was added, which due to the low temperature, also helped to stop the temperature of the paste from rising during the operation. Throughout the process, the temperature of the paste was checked with a vertical thermometer to prevent it from rising above 12°C.

After the meat batter had the required consistency, all other ingredients and spices were weighed and then mixed with the batter until evenly distributed in the paste structure. The resulting paste was placed in natural pork membranes of 38-40 mm diameter, which have been previously hydrated to form elasticity.

The heat treatment carried out was the same for the eight batches of frankfurter sausages; the steps are shown in Table 2.

Table 2. Heat treatment steps for the frankfurter sausages added with beef bone broth

| **Heat treatment stage** | **Time** | **Temperature inside the cell** | **Temperature in the thermal centre** | **Humidity** |
|---|---|---|---|---|
| | minutes | °C | °C | % |
| **Air drying** | 30 | 60 | 52 | 30 |
| **Smoking** | 20 | 70 | 65 | 30 |
| **Boiling** | - | 78 | 72 | 99 |
| **Hot air drying** | 5 | 80 | 72 | 30 |

The final products underwent physicochemical and sensory assessments in the Meat and Meat Products Technology Laboratory and the Sensory Analysis Laboratory.

The instrumental color characteristics of the frankfurters were determined using a Chroma Meter CR-410 colorimeter (Konica Minolta Inc., Japan) on the CIELAB scale. These parameters were represented as L*-values, a*-values, and b*-values. The instrument was equipped with a D65 light source, which had a 2° angle of observation and a measuring area with a diameter of 8 mm. The illuminating area had a diameter of 50 mm. The determination of chroma (C*) and hue (H*) values was conducted using equations (1) and (2), as outlined in the study conducted by Long et al. (2024). The calculation of the total color difference (ΔE) was performed using equation (3), as described by Yuan et al. (2023). The values of L*con, a*con, and b*con were obtained from the control samples, while the values of L*s, a*s, and b*s were measured from frankfurters prepared with different quantities of beef bone broth.

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

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

$$\Delta E = \sqrt{(L*s - L*con)^2 + (a*s - a*con)^2 + (b*s - b*con)^2} \quad (3)$$

The chemical evaluation encompassed the utilization of a FoodCheck analyzer, which is a spectrophotometer that operates on infrared light beams, to ascertain the moisture, fat, protein, collagen, and sodium contents, respectively.

Historically, the assessment of food products through sensory evaluation involved the investigation, examination, understanding, and interpretation of responses generated by individuals through the utilization of the primary senses (visual, olfactory, gustatory, tactile, and auditory) on said products (Ciobanu et al., 2022; Ruiz-Capillas et al., 2021). The sensory assessment was conducted using a modified version of the procedure outlined by Boişteanu et al. (2023). In summary, for the purpose of sensory evaluation, a cohort of twenty-five graduate students (consisting of sixteen females and nine males) was chosen from the meat processing technology laboratory at the Iasi University of Life Sciences. The panel participated in a vocabulary development session and a training session prior to sensory evaluation. On the basis of the following nine-point descriptive scales (low intensity to high intensity): interior color (1 = light brown; 9 = pink), uniformity (1 = low; 9 = high), flavour (1 = least intense, 9 = most intense), and juiciness (1 = extremely dry; 9 = extremely juicy), each frankfurter batch was assessed using sensory descriptive analysis. In addition, the panelists assessed the overall acceptability of each frankfurter assortment (1 = low; 9 = high).

The mean values obtained for the proximate composition, colour parameters and sensory evaluation were compared using analysis of variance (ANOVA) followed by Tukey's test at 5% significance level ($p < 0.05$), using IBM SPSS Statistics v.21.

## RESULTS AND DISCUSSIONS

The results for proximate chemical composition expressed as mean value and standard deviation determined for the batches of frankfurter sausages produced are shown in Table 3. The moisture content of frankfurter sausage is an essential physicochemical attribute that has the potential to impact shelf life and sensory attributes, including texture. The alterations observed in the moisture content of the treated samples, which varied between 70.30% and 73.68%, were notably impacted by the incorporation of beef bone broth. Comparatively, the moisture content of the control products was considerably reduced ($p < 0.05$) in contrast to the enriched frankfurters formulated from chicken and turkey meat. The high moisture content observed in the beef bone broth-enriched samples was plausibly attributable to the inclusion that was introduced into the formulation. In general, bone broth comprises approximately 94.32% to 97.44% moisture (Yoon et al., 2015). This finding is consistent with earlier studies by Akullo et al. (2020), who reported a higher moisture content for tilapia and Nile perch sausages optimized with fish bone soup at 72.3% and 71.2%, respectively, compared to the control (69.7%).

The inclusion of beef bone broth in the chicken and turkey frankfurters formulation significantly affected the fat content with control samples from each group having the highest fat content, 8.72% (CC sample) and 5.24% (CT sample). The addition of bone broth therefore caused a decrease in lipid content, which was more pronounced in chicken frankfurters than in turkey frankfurters. Similar findings were reported by Akullo et al. (2020) for fish bone soup incorporated tilapia and Nile perch sausages; study that showed a decrease in crude fat content from 3.72% in the control sample to 2.13% in Talpia fish sausages.

As a recognized nutrient diluent, moisture tends to diminish the concentrations of numerous nutrients when present in excessive quantities. For example, there is a strong correlation between moisture and fat content in meat products, such that a high moisture content is indicative of a probable decrease in fat content (Sam et al., 2021). This trend was also present in the current study, as an inversely correlation between moisture content and lipid level was revealed.

While bone broth itself doesn't directly remove fat from sausages, its effect to lower overall fat content in the final smoked product may be due to the dilution effect, since bone broth is primarily water-based, containing very little fat. Adding broth to the meat batter dilutes the overall fat concentration in the mixture. This lowers the final percentage of fat in the finished sausage compared to one made solely with meat. Moreover, bone broth can contain gelatin, a protein derived from collagen in bones. Gelatin acts as an emulsifier, helping to disperse fat particles throughout the meat batter more evenly. This improves emulsification and allows for a more stable mixture with a lower overall fat content.

Protein is pivotal in determining the water-holding capacity of meat, as water molecules have a strong affinity for meat hemoproteins (Sam et al., 2021). A progressive rise in protein content was noted in frankfurter-type sausages with increasing levels of added beef bone broth. However, the increase was significant mainly for the higher level of addition (6% and 9%) for both chicken and turkey meat frankfurters. The collagen content (expressed as a percentage of total protein) was also directly proportional to the amount of protein. Thus, the highest protein level was reported for the 9% beef bone broth samples within each experimental group (chicken and turkey). These results can be explained by the intake of bone broth, which contains a certain amount of protein, and therefore collagen (from the raw material used to obtain it, i.e. bones with connective tissue and meat remains). Yoon et al. (2015) reported a protein content in beef bone broth between 2.08 and 4.04%, depending on the beef bone segmental (beef bone, woojok, tail). Furthermore, the collagen content can also be explained by the fact that about 90% of the protein in bovine bones is type I collagen, so the protein content of bone broth is also related to collagen solubilisation (Ma et al., 2023).

In addition to the differences impressed by the enrichment with bone broth in the two frankfurter sausages varieties, the prime material used (chicken and turkey meat) also impressed significant differences ($p < 0.05$) in the chemical composition of the finished products, in that turkey meat products showed higher water, protein and collagen content, and lower lipid content, compared to the corresponding chicken meat samples.

Table 3. Analysis of chemical composition and salt content of Frankfurt sausages

| Parameters/ Sample | Moisture (%) | Lipid (%) | Protein (%) | Collagen (%) | Salt (%) |
|---|---|---|---|---|---|
| **CC** | 70.30 ± 0.07 F | 8.72 ± 0.11 A | 20.38 ± 0.04 E | 18.60 ± 0.07 E | 2.52 ± 0.08 B |
| **C3%** | 70.46 ± 0.05 E | 8.50 ± 0.07 B | 20.44 ± 0.08 DE | 18.64 ± 0.05 DE | 2.56 ± 0.08 B |
| **C6%** | 70.88 ± 0.04 D | 8.02 ± 0.04 C | 20.50 ± 0.00 CD | 18.76 ± 0.05 CD | 2.34 ± 0.05 C |
| **C9%** | 71.00 ± 0.07 D | 7.86 ± 0.05 D | 20.58 ± 0.04 C | 18.78 ± 0.04 C | 1.86 ± 0.05 E |
| **CT** | 73.32 ± 0.04 B | 5.24 ± 0.04 E | 21.18 ± 0.09 B | 19.48 ± 0.10 B | 1.44 ± 0.05 F |
| **T3%** | 73.16 ± 0.05 C | 5.22 ± 0.04 E | 21.22 ± 0.04 B | 19.51 ± 0.04 B | 2.62 ± 0.08 B |
| **T6%** | 73.20 ± 0.01 BC | 5.02 ± 0.09 F | 21.24 ± 0.11 AB | 19.60 ± 0.04 AB | 3.24 ± 0.05 A |
| **T9%** | 73.68 ± 0.11 A | 4.60 ± 0.07 G | 21.30 ± 0.14 A | 19.62 ± 0.04 A | 2.18 ± 0.08 D |

Values are given as means ± SE from triplicate determinations; A-G in each column represent statistically significant differences ($p < 0.05$) determined by the Tukey test.

The assessment of frankfurters' quality heavily relies on the color determination, as the visual appeal of meat products has a direct impact on consumer preference. The comparison of the turkey meat and chicken groups' frankfurters indicates that the a*-values were significantly higher in the chicken group ($p < 0.05$), whereas the L* and b*-values were noticeably lower in the turkey meat group, as shown in Table 4. Conversely, the variation in bone broth quantity did not have a substantial impact on the L* and a*-values, although some variations were noted in the portions of turkey meat.

Furthermore, as the concentration of bone broth increased, the L*-values of chicken and turkey frankfurters exhibited a decline for the lower incorporations (3% and 6%). However, the lightness surpassed the control value at a 9% bone broth concentration.

All chicken sausages (CC, C3%, C6%, and C9%) retain considerably less redness than turkey frankfurter sausages (specifically CT and T6%). It is notable that the incorporation of beef bone broth into the chicken sausages (C3%, C6%, and C9%) did not result in a substantial augmentation of their coloration in comparison to the control chicken sausage (CC). This indicates that the beef bone fluid may not have significantly contributed to the red hue of these sausages. Frequently, paprika or nitrite are utilized to impart a red hue to sausages. Turkey meat may contain more red pigments by nature than poultry meat, which could account for the difference in inherent hue.

The b*-values of turkey frankfurters decreased with the increasing percentage of bone broth, while in the case of chicken sausages, the b*-value decreased until 6% bone broth added, and then increased at the higher broth addition (9%). Beef bone broth can have a slight yellow hue, but its impact on overall sausage color might be subtle, especially when added at lower concentrations (3%). Other ingredients in the sausages, like spices or fat content, could be contributing more significantly to yellowness variations.

The C* value indicates color saturation, which is the distance traversed by the central achromatic grey axis of the color space. The hue angle (H* value), on the other hand, signifies the chromaticity or tone of a color. The H* value ranges from 0° (redness)-90° (yellowness)-180° (greenness)-270° (blueness)-360° (redness) (Long et al., 2024).

The results for saturation index (C*) varied in the interval 18.91 - 19.93, the samples showing significant differences only between control turkey and 9% bone broth turkey frankfurters. The hue angle (h*) mean values varied in the interval 0.76-0.99, with significant differences only between turkey and chicken meat sausages. The low values registered for the hue angle places the products in the red quadrant (0-90°).

The ΔE-value is primarily utilized to detect color differences among various samples by considering combined changes in the L*, a*, and b* values, with a larger ΔE-value indicating a greater difference from the control group. As noted by Wibowo et al. (2015), the perceived color difference can be analytically classified as follows: not visible ($0 < \Delta E < 0.5$), slightly visible ($0.5 < \Delta E < 1.5$), visible ($1.5 < \Delta E < 3.0$), well visible ($3.0 < \Delta E < 6.0$), and great ($\Delta E > 6.0$). As presented in Table 4, the ΔE-values for all batches were below 1.5, indicating that the perceived color differences were slightly visible. However, the results obtained for the frankfurters made from chicken meat ranged from 0.58 to 0.78, which were smaller than those observed for the turkey meat batches (ranging from 1.36 to 1.44), suggesting that the addition of bone broth had a greater effect on color change in the case of frankfurters made with turkey meat.

Table 4. Color results for frankfurter sausages added with different concentrations of bone broth

| Parameters/Sample | L*(D65) | a*(D65) | b*(D65) | Chroma (C*) | Hue (h*) | ΔE |
|---|---|---|---|---|---|---|
| **CC** | $66.57 \pm 0.46^{A}$ | $10.73 \pm 0.13^{C}$ | $16.13 \pm 0.22^{AB}$ | $19.37 \pm 0.25^{ABC}$ | $0.98 \pm 0.00^{A}$ | - |
| **C3%** | $66.52 \pm 0.38^{A}$ | $10.99 \pm 0.30^{C}$ | $15.97 \pm 0.32^{AB}$ | $19.39 \pm 0.42^{ABC}$ | $0.97 \pm 0.00^{B}$ | $0.77 \pm 0.61$ |
| **C6%** | $66.25 \pm 0.33^{A}$ | $10.53 \pm 0.10^{C}$ | $15.79 \pm 0.10^{B}$ | $18.98 \pm 0.11^{BC}$ | $0.98 \pm 0.01^{AB}$ | $0.58 \pm 0.48$ |
| **C9%** | $66.90 \pm 0.45^{A}$ | $10.75 \pm 0.51^{C}$ | $16.40 \pm 0.51^{A}$ | $19.61 \pm 0.71^{AB}$ | $0.99 \pm 0.01^{A}$ | $0.72 \pm 0.35$ |
| **CT** | $62.79 \pm 0.98^{BC}$ | $14.43 \pm 0.13^{A}$ | $13.74 \pm 0.18^{C}$ | $19.93 \pm 0.11^{A}$ | $0.76 \pm 0.01^{C}$ | - |
| **T3%** | $61.61 \pm 1.00^{BC}$ | $13.82 \pm 0.27^{B}$ | $13.35 \pm 0.24^{CD}$ | $19.22 \pm 0.28^{BC}$ | $0.77 \pm 0.01^{C}$ | $1.44 \pm 0.47$ |
| **T6%** | $61.55 \pm 0.55^{C}$ | $14.04 \pm 0.18^{AB}$ | $13.23 \pm 0.04^{CD}$ | $19.29 \pm 0.15^{ABC}$ | $0.76 \pm 0.01^{C}$ | $1.43 \pm 0.59$ |
| **T9%** | $62.85 \pm 0.22^{B}$ | $13.58 \pm 0.14^{B}$ | $13.16 \pm 0.14^{D}$ | $18.91 \pm 0.18^{C}$ | $0.77 \pm 0.00^{C}$ | $1.36 \pm 0.51$ |

Values are given as means ± SE from five repeated determinations; A-G in each column represent statistically significant differences (*p* < 0.05) determined by the Tukey test.

The intensity of color changes that occur when products are stored at a cooling temperature and are influenced by air currents in the storage area is illustrated in Table 5. A notable reduction ($p < 0.05$) in the luminosity of L* was observed across all eight experimental groups throughout the five-day storage period. Conversely, the intensity of the red color increased significantly ($p < 0.05$) in the value of a*, with particular emphasis on the frankfurter samples with turkey meat. The value of b* exhibited a rising trend for the majority of samples until the third day of

storage, after which it declined for the following two days.
On the contrary, it was observed that the poultry frankfurter sample containing the greatest proportion of bone broth exhibited the least decrease in luminosity L* and the most minimal alteration in the intensity of the red (a*).
One of the variables that may influence the L*, a*, and b* color parameters of frankfurter samples stored in refrigeration currents is the oxidation of fats in the sausages' composition. This occurs when the fats react with oxygen in the air, resulting in the production of peroxides. The degradation of natural pigments in meat, such as myoglobin, by these peroxides can diminish its luminosity. Additionally, a reduction in luminosity may result from the release of moisture throughout the storage process. Because water reflects light, a reduced quantity of water will result in diminished light reflection. As a consequence, the samples containing the greatest quantities of bone broth exhibited a diminished degree of color change intensity.

Table 5. Color changes in five days storage at refrigerated temperature

| Parameters | Sample | Storage Period (Days) 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| L*(D65) | CC | 66.57 ±0.29 $^{ab,A}$ | 61.08 ±0.37 $^{b,B}$ | 53.96 ±0.70 $^{b,C}$ | 47.38 ±0.96 $^{cd,D}$ | 44.95 ±0.48 $^{c,E}$ |
| | C3% | 65.94 ±0.27 $^{b,A}$ | 57.85 ±0.87 $^{cd,B}$ | 52.13 ±0.93 $^{c,C}$ | 45.82 ±0.40 $^{de,D}$ | 44.00 ±0.16 $^{cd,DE}$ |
| | C6% | 66.84 ±0.30 $^{a,A}$ | 62.45 ±0.61 $^{b,B}$ | 57.52 ±0.61 $^{a,C}$ | 50.31 ±1.42 $^{b,D}$ | 47.24 ±0.59 $^{b,E}$ |
| | C9% | 66.81 ±0.32 $^{a,A}$ | 64.24 ±1.38 $^{a,B}$ | 56.76 ±0.87 $^{a,C}$ | 53.25 ±0.65 $^{a,D}$ | 51.80 ±0.58 $^{a,DE}$ |
| | CT | 61.37 ± 0.41 $^{d,A}$ | 58.55 ± 0.36 $^{c,B}$ | 51.67 ±0.96 $^{c,C}$ | 46.13 ±0.55 $^{de,D}$ | 44.04 ±0.63 $^{cd,E}$ |
| | T3% | 61.53 ±0.33 $^{d,A}$ | 54.78 ±0.71 $^{e,B}$ | 49.85 ±1.00 $^{d,C}$ | 44.74 ±1.55 $^{e,DE}$ | 43.12 ±0.65 $^{d,E}$ |
| | T6% | 61.92 ±0.10 $^{cd,A}$ | 57.23 ±0.48 $^{cd,B}$ | 52.26 ±0.30 $^{c,C}$ | 46.96 ±0.54 $^{cd,D}$ | 44.87 ±0.92 $^{c,E}$ |
| | T9% | 62.38 ±0.40 $^{c,A}$ | 56.64 ±0.76 $^{d,B}$ | 52.30 ±0.76 $^{c,C}$ | 48.86 ±1.38 $^{bc,D}$ | 44.05 ±0.82 $^{cd,E}$ |
| a*(D65) | CC | 11.72 ±0.24 $^{cd,D}$ | 13.58 ±0.28 $^{d,C}$ | 17.56 ±0.32$^{abc,AB}$ | 16.96 ±0.55 $^{c,B}$ | 17.76 ±0.20 $^{c,A}$ |
| | C3% | 11.79 ±0.20 $^{c,D}$ | 14.85 ±0.53 $^{c,C}$ | 17.15 ±0.54 $^{bc,B}$ | 17.51 ±0.26 $^{bc,B}$ | 19.63 ±0.26 $^{b,A}$ |
| | C6% | 11.39 ±0.13 $^{d,E}$ | 12.59 ±0.40 $^{e,D}$ | 13.73 ±0.37 $^{e,C}$ | 15.78 ±0.71 $^{d,B}$ | 18.41 ±0.65 $^{c,A}$ |
| | C9% | 11.43 ±0.24 $^{cd,C}$ | 11.97 ±0.48 $^{e,C}$ | 14.69 ±0.58 $^{d,B}$ | 14.89 ±0.43 $^{d,B}$ | 16.54 ±0.36 $^{d,A}$ |
| | CT | 14.65 ± 0.15 $^{a,D}$ | 15.13 ±0.26 $^{c,D}$ | 18.01 ±0.35 $^{ab,C}$ | 19.02 ±0.24 $^{a,B}$ | 20.47 ±0.34 $^{a,A}$ |
| | T3% | 14.78 ±0.10 $^{a,D}$ | 17.15 ±0.27 $^{a,C}$ | 18.42 ±0.37 $^{a,BC}$ | 19.31 ±0.44 $^{a,B}$ | 20.78 ±0.26 $^{a,A}$ |
| | T6% | 14.21 ±0.18 $^{b,E}$ | 15.51 ±0.36 $^{c,D}$ | 17.05 ±0.23 $^{c,C}$ | 18.63 ±0.29 $^{a,B}$ | 20.44 ±0.50 $^{a,A}$ |
| | T9% | 13.99 ±0.17 $^{b,E}$ | 16.34 ±0.49 $^{b,CD}$ | 17.38 ±0.50 $^{bc,BC}$ | 18.42 ±0.70 $^{ab,B}$ | 20.11 ±0.19 $^{ab,A}$ |
| b*(D65) | CC | 18.23 ± 0.41 $^{a,D}$ | 20.35 ±0.43 $^{a,C}$ | 24.19 ±0.63 $^{a,A}$ | 21.39 ±0.38 $^{a,BC}$ | 20.74 ±0.38 $^{a,C}$ |
| | C3% | 17.08 ±0.25 $^{c,C}$ | 20.01 ±0.68 $^{ab,B}$ | 21.20 ±0.58 $^{b,A}$ | 20.73 ±0.33 $^{c,AB}$ | 20.19 ±0.55$^{ab,B}$ |
| | C6% | 17.08 ±0.16 $^{c,C}$ | 19.40 ±0.19 $^{bc,B}$ | 20.41 ±0.22 $^{b,A}$ | 19.47 ±0.47 $^{b,B}$ | 19.21 ±0.55 $^{ab,B}$ |
| | C9% | 17.72 ±0.29 $^{b,D}$ | 18.74 ±0.50 $^{c,C}$ | 20.74 ±0.43 $^{b,A}$ | 19.25 ±0.20 $^{bc,BC}$ | 19.86 ±0.37 $^{b,B}$ |
| | CT | 13.40 ± 0.22 $^{de,BC}$ | 14.28 ±0.36 $^{e,B}$ | 15.20 ±0.15 $^{c,A}$ | 14.26 ±0.17 $^{de,B}$ | 14.22 ±0.23 $^{d,B}$ |
| | T3% | 13.47 ±0.19 $^{de,C}$ | 14.93 ±0.12 $^{e,AB}$ | 15.33 ±0.29 $^{c,A}$ | 13.99 ±0.42 $^{e,BC}$ | 14.40 ±0.35 $^{d,B}$ |
| | T6% | 13.18 ±0.10 $^{e,C}$ | 14.88 ±0.10 $^{e,B}$ | 15.54 ±0.24 $^{c,A}$ | 14.29 ±0.19 $^{de,B}$ | 15.53 ±0.39 $^{c,A}$ |
| | T9% | 13.69 ±0.17 $^{d,C}$ | 15.77 ±0.27 $^{d,A}$ | 15.94 ±0.30 $^{c,A}$ | 14.96 ±0.46 $^{d,B}$ | 14.28 ± 0.23 $^{d,BC}$ |

Values are given as means ± SE from five repeated determinations; means with different superscripts in a row orientation (uppercase alphabet) indicate significant ($p < 0.05$) differences between different storage days at the same bone broth addition level; means with different superscripts in a column orientation (lowercase alphabet) indicate significant ($p < 0.05$) differences between different bone broth addition levels at the same storage day.

Consumer behavior is influenced by psychological and environmental factors, including economic, social, cultural, and consumption context criteria. Neuroscience explains consumer satisfaction, leading to the concept of loyalty, which is defined into behavioral and attitudinal dimensions. The behavioral dimension refers to the frequency of repeated purchases, while the attitudinal dimension considers psychological commitment and beliefs about a product. These aspects influence consumers' decisions based on product characteristics and sensory quality (Ciobanu et al., 2023).
In this study, the sensory quality of the control samples and treatments C3%, C6%, C9%, T3%, T6% and T9% were evaluated after the production and cooling at the refrigeration temperature of 4°C. The data (Table 6) in the current study shows that adding beef bone

broth to chicken and turkey frankfurters did not cause significant changes in sensory perception ($p > 0.05$) of consumers, except for color and juiciness attributes, where the statistical differences were significant between all groups. Although for the attributes of flavor and texture, as well as for the general acceptability of the assortments, the differences noticed in the sensory perception of consumers were not significant, it was found that the addition of beef bone broth caused a sensory improvement. Thus, the sensory evaluation results described increasing average results correlated with the percentage of bone broth introduced for flavor, texture, juiciness attributes and overall acceptability, while sensory perception of color decreased with increasing the level of added broth.

Table 6. Sensory qualities of frankfurters sausages added with different concentrations of bone broth

| Attribute | Color | Flavor | Texture | Juiciness | Overall acceptance |
|---|---|---|---|---|---|
| **CC** | $6.92 \pm 0.81^{AB}$ | $6.28 \pm 0.68$ | $6.24 \pm 0.88$ | $5.88 \pm 0.83^{B}$ | $6.44 \pm 0.51$ |
| **C3%** | $6.68 \pm 0.69^{AB}$ | $6.36 \pm 0.70$ | $6.68 \pm 0.75$ | $6.40 \pm 0.93^{AB}$ | $6.64 \pm 0.64$ |
| **C6%** | $6.83 \pm 0.83^{AB}$ | $6.32 \pm 0.80$ | $6.88 \pm 0.78$ | $6.50 \pm 1.08^{AB}$ | $6.72 \pm 0.54$ |
| **C9%** | $6.58 \pm 0.87^{B}$ | $6.40 \pm 0.76$ | $6.72 \pm 0.79$ | $6.96 \pm 1.00^{A}$ | $6.52 \pm 0.51$ |
| **CT** | $7.44 \pm 1.17^{A}$ | $6.68 \pm 0.63$ | $6.60 \pm 0.91$ | $6.44 \pm 0.77^{b}$ | $6.88 \pm 0.67$ |
| **T3%** | $7.32 \pm 0.84^{AB}$ | $6.64 \pm 0.81$ | $6.68 \pm 0.90$ | $6.48 \pm 1.08^{AB}$ | $6.84 \pm 0.47$ |
| **T6%** | $7.04 \pm 0.93^{AB}$ | $6.44 \pm 0.82$ | $6.88 \pm 1.01$ | $6.80 \pm 1.04^{A}$ | $6.72 \pm 0.54$ |
| **T9%** | $7.04 \pm 0.83^{AB}$ | $6.56 \pm 0.82$ | $6.96 \pm 0.93$ | $7.00 \pm 1.00^{A}$ | $6.76 \pm 0.44$ |
| **p-value** | 0.007 | 0.579 | 0.076 | 0.001 | 0.088 |

Values are given as means ± SE; p-value expresses the statistically differences between groups determined by the ANOVA test; A-B represent statistically significant differences ($p < 0.05$) determined by the Tukey test.

## CONCLUSIONS

This study explored the feasibility of incorporating beef bone broth into chicken and turkey frankfurter sausages. The findings demonstrate that bone broth addition significantly increased moisture content and protein content at the highest concentration of addition, compared to control sausages. Conversely, a decrease in fat content (up to 0.86% lower in chicken samples and 0.64% lower in turkey samples) was observed with increasing bone broth. Sensory evaluation revealed no significant changes in flavor, texture, or overall consumer acceptability. However, some panelists perceived a sensory improvement with broth addition regarding color and juiciness, attributes that were significantly affected by bone broth. Sensory evaluators reported a decrease in perceived color and an increase in juiciness. Instrumental color analysis showed minimal impacts of bone broth on lightness and redness, suggesting the broth's color did not significantly influence overall sausage color. Additionally, turkey sausages inherently had higher redness and lower yellowness compared to chicken sausages.

In conclusion, this study demonstrates the potential of using beef bone broth in frankfurters as a means to increase protein and collagen content and juiciness while maintaining consumer acceptance for flavor and texture. However, a slight decrease in perceived color might be observed. Further research could explore optimizing the formulation and processing techniques to address potential color changes associated with bone broth addition while maintaining the observed benefits in protein content and juiciness.

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