Effect of adding byproducts of chicken slaughter on the quality of sausage over storage

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ABSTRACT The use of byproducts generated by the food industry is a strategy that can have advantages in economic, technological, nutritional, and environmental terms. The aim of this study was to evaluate the influence of the addition of byproducts of chicken slaughter (skin and abdominal fat) on the quality of fresh sausage stored under freezing. Partial chemical characterization of the byproducts was performed. Three batches of chicken sausage were prepared with skin, abdominal fat, and with skin and abdominal fat added; thereafter were stored for 135 d in freezer. Partial chemical composition, physical characteristics, microbiological quality, and product acceptance were determined. Skin and abdominal fat are rich sources of fat. However, the addition of skin provided to sausage higher protein content, hardness, water retention capacity, and less cooking loss compared to added abdominal fat treatments. In contrast, the addition of abdominal fat provided higher lipid content to the sausages and displaying higher acceptability. The addition of byproducts in fresh sausage manufacture would be a great strategy to increase the chicken sausage value, with physicochemical quality improvement, and without sensory acceptability issues.

Key words: acceptability, byproducts, physicochemical composition, quality, storage

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INTRODUCTION

Brazilian poultry has been providing an important role in the national and global economy, due to investments in quality and research advances in the development of new technologies. This fact influences poultry production, and the utilization of carcasses and byproducts (da Silva et al., 2017).

As Galanakis (2012) reported, byproducts and food wastes can be recycled inside food chain as functional additives in different products. The byproducts of slaughter such as cartilage, internal organs, bones, dewlap, crest, blood, fat tissues etc., have a good quality of chemical composition (protein, fat, and iron). Abdominal fat, for example, has fatty acids such as oleic, palmitic and linoleic in its composition becoming a potential ingredient in the preparation of meat products (Centenaro et al., 2008). Another important byproduct is the skin, taken from the broiler chickens. This skin can be used in the manufacture of meat products intended to human consumption, whether or not has previously subjected to industrial thermal processing (França and Waszczynskyj, 2002).

This composition has a great potential for be used in the elaboration of processed products (Toldrá et al., 2012; Martínez-Alvarez et al., 2015). For this reason, meat processing industries have been looking for alternatives to transform byproducts and waste into useful and usable sources, producing new products or using them as ingredients with strong nutritional potential and quality value. Studies indicate that almost one-eighth of gross revenue derives from the effective use of byproducts (Lynch et al., 2018).

According to Normative Instruction n°. 04 of March 31, 2000 (Brasil, 2000), fat can be used as an ingredient in sausage manufacture, but it is not a mandatory component and has not defined origin. Skin and abdominal fat from chicken slaughter, for example, are lipid sources commonly used in industry and have potential application as a sausage ingredient.

Sausage is a product made by minced meat that has had a significant increase in consumption throughout the world due to its convenience and practicality

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(Jayawardana et al., 2015). Sausage is one of the most produced meat products, due to the low cost and not requiring sophisticated technology (Choe et al., 2013), being a product commonly stored in refrigerators and freezers (Lluch et al., 2003). The utilization of a lipid source in the preparation of meat products contributes to a number of quality attributes such as texture, appearance, creaminess, taste and technological properties. Fat has positively influenced the main sensory aspect of processed meat, juiciness, providing better rating and greater consumer acceptance (Brewer, 2012; Sousa et al., 2017).

Thus, there is a need to evaluate the potential application of byproducts of the meat processing industries in the formulation of food and its influence on the physicochemical and sensory quality. It should be noted that our research group has explored the viability of skin and abdominal fat in other meat matrices (Santos et al., 2020), as well as the study of their oxidative stability (Lima et al., 2020). However, the application of byproducts in chicken sausages has not been completely studied.

Therefore, this present study aimed to evaluate the feasibility of adding skin and abdominal fat, and both at the same time, to the formulation of fresh chicken sausage from the assessment of physicochemical, microbiological, and sensory quality during storage.

MATERIALS AND METHODS

Sausage Preparation

Chicken breasts, skin and abdominal fat from the Cobb lineage (males and females, aged between 36 and 44 d) were obtained from a commercial slaughterhouse, which follows slaughter procedures according to the criteria established by law no. 210 of November 10, 1998, of the Ministry of Agriculture and Livestock and Supply (Brasil, 1998). Raw materials (skin and abdominal fat) were collected along the chicken slaughter line. Three formulations of fresh sausages were processed (Table 1) in 3 different batches.

Cold chicken breasts, skin and abdominal fat were shredded, separately, in a scale-coupled mill (Model MC 160, Ibrasmak, São Paulo, Brazil). After grinding and weighing breasts, skin and/or fat, and additives were transferred to a mixer machine (Model ZJB750, Maxmac, Sao Paulo, Brazil) proceeding with the preparation of the meat mixture until a homogeneous product is obtained. Then the meat mixture was cured under storage in a cold chamber at 4°C for approximately 6 h. After the cure, sausages were embedded in natural porcine casing approximately 32 mm in diameter; using industrial sawmills (Model VF 612, Handtmann, Biberach, Germany). Finally, sausages with skin (**SS**), with abdominal fat (**SF**) and with skin and abdominal fat (**SFS**) were packed in polypropylene packaging, subjected to commercial freezer storage for 135 d. Samples were analyzed in triplicate, except for Warner−Bratzler shear force (**WBSF**) (in quadruplicate), with intervals of 45 d (0, 45, 90 and 135 d) in each processing batch.

Table 1. Formulation of fresh chicken sausages prepared with chicken breast, skin and/or abdominal fat.

Ingredients	Formulations (%)[1]		
	SS	SF	SFS
Chicken meat	52	52	52
Skin	30	-	15
Abdominal fat	-	30	15
Water	13	13	13
Soy protein	2.5	2.5	2.5
Salt	1.99	1.99	1.99
Additives and spices	0.51	0.51	0.51

[1]Information provided by Guaraves Guarabira Aves Ltda. Company. SS: Chicken Skin Sausage; SF: Sausage with added abdominal chicken fat; SFS: Sausage with added skin and abdominal fat of chicken.

Chemical Analysis of Chicken Raw Material and Sausage

The chemical composition of chicken raw material and fresh sausages was determined following the methodologies described by AOAC (2000) for moisture content (n°. 950.46.41), ashes (No. 920.153), proteins (n°. 928.08) and collagen (n°. 990.26). For the determination of lipid content, the methodology of Folch et al. (1957) was carried out.

Analysis Hydrogenionic Potential, Water activity, Water Retention Capacity and Cooking Weight Loss

The analysis hydrogenionic potential (**pH**) was determined according to AOAC methodology (2000), procedure n°. 981.12, in pHmeter Model Q400 AS (Quimis Scientific Instruments Ltda., Diadema, SP, Brazil). Water activity ($\mathbf{a_w}$) was measured according to AOAC procedure n°. 978.18 (Brasil, 2000), using an AQUALAB CX2 apparatus (Decagon Devices, USA).

The water retention capacity (**WRC**) was determined according to Barbut method (1996) and expressed as a percentage (%WRC). The cooking weight loss (**CL**) was measured according to the methodology described by Honikel (1998) and expressed as a percentage (%CL).

Instrumental Color and Warner−Bratzler Shear Force

The instrumental color was determined by the parameters L* (luminosity), a* (red/green intensity) and b* (yellow/blue intensity) using Konica Minolta digital colorimeter (Model CR-400, Osaka, Japan), in parameters determined by CIE (1986): C illuminate, viewing angle, 10° observer standard angle and specular included.

Warner−Bratzler shear force (WBSF) assessment was performed on a TA XT-2i texture-meter (Stable Microsystems, Godalming, Surrey, UK). Chicken sausage samples were cooked at 75°C, cooled and were cut in slices of dimensions 2 × 20 × 20 mm (thickness × length × width). Samples were cut with a Warner−Bratzler blade in a perpendicular direction to the sausage cylinders.

Microbiological Analysis

According to DRC No. 12 of the Technical Regulation on Microbiological Food Standards (Brasil, 2001), Coliform microorganisms were analyzed at 45°C, Coagulase positive *Staphylococcus, Clostridium* sulfite reducing and *Salmonella* spp. in chicken sausages; according to the methodologies described by APHA (2001).

Acceptance Analysis

The affective acceptability test was applied to evaluate the sensory perception of chicken sausage consumers using a 9-point structured hedonic scale, being number 1 (extremely disliked) to number 9 (extremely liked) (Meilgaard et al., 1991; Stone and Sidel, 2004). A total of 150 consumers evaluated the samples, aged between 18 and 60 yr, being men and women, students, and staff of the Federal University of Paraíba. For this analysis, the sausages were roasted on a preheated grill (model CKSTGR3007- China), cut into 1-cm thick cylinders, approximately 15 g, and served warm (55°C −60°C) in individual booths accompanied by a questionnaire and printed sensory analysis form. Panelists were requested to evaluate the acceptability of attributes color, aroma, taste, texture, juiciness, and the overall acceptance. Samples were coded with random 3-digit numbers and randomly sorted. Slice of English potato (*Solanum tuberosum*) and a glass of water (50 mL) were served between tasting of each sample.

All sensory sessions were held after approval by the Federal University of Paraíba Ethics Committee (CAAE 67651917.4.0000) and in accordance with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Statistical Analysis

Two-way analysis of variance (two-way) was carried out to verify the overall effects of time versus chicken sausage formulation. Tukey test was performed when ANOVA revealed significant differences ($P \leq 0.05$; $P \leq 0.001$; $P \leq 0.0001$) between treatments. The SPSS software (v. 23.0) was used to perform the statistical test. Pearson correlation coefficients and Principal Component Analyze (**PCA**) were generated to describe the relationship between all physicochemical parameters and sensory acceptance of fresh chicken sausages stored, determined by using XLSTAT 2014 (Addinsoft, Paris, France).

RESULTS AND DISCUSSION

Physicochemical Properties of Frozen Chicken Sausages as Affected by Addition of Byproducts

The chemical composition of the byproducts presented the following percentages on dry weight: protein (skin: 4.11%, abdominal fat: 1.12%), fat (skin: 83.3%, abdominal fat: 88.5%), ashes (skin: 0.2%, abdominal fat: 0.3%); with a moisture content (skin: 29.3% and abdominal fat: 13.5%).

Table 2 shows the chemical composition, instrumental color and textures of frozen chicken sausages as affected by addition of byproducts. As can be observed, the initial moisture of the SS sample was significantly higher than the SF and SFS samples. However, at the end of 135 days of storage, the SS and SFS samples showed significantly higher moisture values than the initial one. SS sample presented humidity values above the maximum limit recommended (70%) (Brasil, 2000). This fact could be correlated with the higher moisture of chicken with skin added in these formulations (SS and SFS).

Sausages with skin added showed higher protein concentrations than samples with only fat added ($P \leq 0.05$). This result correlated with the protein content of chicken skin, which is 3 times higher than in fat. All formulations increased the protein percentages in the last storage time. Chicken skin has positively influenced the protein parameter, owing to collagen represents 30% of the protein composition (Li et al., 2013). Therefore, a higher amount of collagen was found in SS and SFS. Toldrá et al. (2012) reported that the addition of edible byproducts in meat products increases the stability, technological functions (emulsions) and improves sensory quality (color, texture, and taste). Salejda et al. (2016) indicated that the highest protein content is directly related to the higher collagen content. This fact has a specific mechanical property which combined with high moisture content can increase hardness values in products.

Otherwise, sausages with abdominal fat added presented higher lipid content. SF sample has significantly presented higher fat values than the rest of formulations, while SS sample presented lower fat values. In addition, SF sample obtained an increment of 97% of fat values during storage. These results were, as expected, due to abdominal fat has a higher proportion of lipids in its composition, while chicken skin has other especially protein components, such as collagen (Ming et al., 2002). Time significantly influenced the quantity of fat found in the formulations. The last storage time showed higher fat values than the other days of analysis. However, the widest differences found in the storage time of SF and SFS sausages can be attributed to the heterogeneity of the sausage. It was observed that the fat content, on wet weight (SF: 40.27−79.53%; SFS: 32.25−44.53%) were above the maximum limit of 30% established by the current Brazilian legislation (Brasil, 2000) and can directly influence product yield. Finally, it is observed that the combined effect of adding skin and abdominal fat gives the SFS sausage intermediate values of moisture, protein and fat, however during storage these values vary differently according to what was discussed for each one. of these physicochemical properties.

Indicators of Quality of Frozen Chicken Sausages

The results of some quality indicators evaluated as color (L^*, a^* and b^*), WBSF, WRC, CL, pH, and a_w are presented in Table 2. Significant differences ($P \leq 0.05$) were

Table 2. Chemical composition, instrumental color and textures of frozen chicken sausages as affected by addition of byproducts (mean ± standard deviation).

Parameters	SS	SF	SFS	F	T	F/T
Moisture (%)						
0	66.17 ± 2.47^{bA}	61.59 ± 0.66^{aB}	62.34 ± 0.76^{bB}			
45	72.53 ± 0.36^{aA}	59.10 ± 0.70^{bC}	65.81 ± 0.47^{aB}	***	***	***
90	71.03 ± 1.10^{aA}	61.25 ± 1.79^{aB}	63.78 ± 0.13^{bB}			
135	71.46 ± 1.925^{aA}	61.33 ± 0.97^{aC}	67.09 ± 2.84^{aB}			
[1]Protein (%)						
0	51.89 ± 5.88^{bA}	33.97 ± 1.67^{bC}	40.69 ± 6.84^{bB}			
45	59.75 ± 4.05^{aA}	37.49 ± 2.74^{aC}	44.14 ± 0.42^{bB}	***	***	**
90	57.41 ± 5.74^{aA}	34.05 ± 1.72^{cC}	41.36 ± 0.83^{cB}			
135	59.89 ± 2.35^{aA}	39.08 ± 4.58^{aC}	49.47 ± 3.29^{aB}			
[1]Fat (%)						
0	20.13 ± 2.69^{bC}	40.27 ± 5.23^{dA}	32.25 ± 3.83^{cB}			
45	16.72 ± 5.72^{cC}	52.93 ± 3.01^{cA}	40.72 ± 4.11^{bB}	***	***	*
90	15.09 ± 1.14^{cC}	60.48 ± 2.72^{bA}	33.07 ± 2.81^{cB}			
135	27.06 ± 11.12^{aC}	79.53 ± 28.07^{aA}	44.53 ± 12.44^{aB}			
L* (luminosity)						
0	61.56 ± 3.40^{bB}	63.87 ± 0.40^{cA}	63.77 ± 1.00^{cA}			
45	71.45 ± 3.76^{aA}	72.23 ± 0.37^{aA}	67.19 ± 1.52^{bB}	***	***	***
90	62.63 ± 1.60^{bB}	71.35 ± 1.65^{aA}	70.20 ± 1.11^{aA}			
135	60.58 ± 1.11^{cC}	69.96 ± 1.73^{bA}	66.54 ± 0.41^{bB}			
a* (redness)						
0	1.54 ± 0.24^{cA}	1.66 ± 0.40^{bA}	1.57 ± 0.42^{aA}			
45	7.56 ± 0.87^{aA}	6.19 ± 0.48^{aB}	5.53 ± 0.49^{aB}	***	***	***
90	1.940 ± 0.64^{bA}	-0.32 ± 0.15^{cC}	0.22 ± 0.98^{cB}			
135	1.33 ± 0.27^{cB}	2.25 ± 0.25^{bA}	0.52 ± 0.12^{cC}			
b* (yellowness)						
0	18.35 ± 0.42^{aA}	19.34 ± 0.53^{aA}	19.57 ± 0.02^{aA}			
45	19.55 ± 0.68^{aA}	19.21 ± 0.85^{aA}	15.96 ± 0.99^{cB}	***	***	***
90	18.14 ± 0.27^{aB}	20.22 ± 1.48^{aA}	18.67 ± 0.26^{aB}			
135	16.64 ± 0.82^{bC}	18.25 ± 1.01^{bA}	17.15 ± 0.93^{bB}			
WBSF (N)						
0	16.52 ± 1.54^{aA}	14.84 ± 1.05^{aA}	15.93 ± 2.66^{aA}			
45	14.23 ± 0.70^{cA}	12.88 ± 0.37^{bA}	13.92 ± 0.51^{dB}	***	***	***
90	13.93 ± 1.38^{bA}	12.57 ± 0.15^{bB}	13.32 ± 1.24^{bA}			
135	11.65 ± 0.95^{bA}	11.57 ± 0.40^{cB}	11.32 ± 1.04^{cB}			
WRC (%)						
0	40.02 ± 0.01^{aA}	32.21 ± 0.03^{bC}	36.83 ± 0.60^{aB}			
45	40.03 ± 1.12^{aA}	37.80 ± 0.04^{aAB}	29.34 ± 1.90^{bC}	***	***	***
90	38.19 ± 1.09^{abA}	28.53 ± 1.41^{cC}	29.46 ± 1.12^{bBC}			
135	27.07 ± 1.90^{cA}	19.43 ± 1.76^{dB}	22.11 ± 1.13^{cB}			
CL (%)						
0	5.36 ± 0.50^{abBC}	20.28 ± 3.58^{bcA}	4.72 ± 1.22^{cC}			
45	4.87 ± 1.23^{abB}	21.70 ± 2.04^{bA}	5.37 ± 1.12^{bcC}	ns	ns	ns
90	4.02 ± 0.74^{bB}	10.70 ± 1.17^{dA}	3.65 ± 0.72^{cB}			
135	8.49 ± 1.01^{aC}	27.11 ± 0.82^{aA}	17.05 ± 0.53^{aB}			
pH						
0	6.07 ± 0.03^{bA}	5.78 ± 0.04^{bcB}	5.63 ± 0.05^{cC}			
45	5.83 ± 0.03^{cA}	5.73 ± 0.06^{cAB}	5.74 ± 0.05^{bB}	***	***	***
90	5.81 ± 0.01^{cdA}	5.77 ± 0.01^{bcAB}	5.72 ± 0.02^{cBC}			
135	6.38 ± 0.05^{aA}	6.26 ± 0.03^{aB}	6.26 ± 0.02^{aB}			
a_w						
0	0.98 ± 0.00^{aA}	0.98 ± 0.00^{aA}	0.98 ± 0.00^{aA}			
45	0.94 ± 0.00^{cA}	0.94 ± 0.00^{cA}	0.94 ± 0.00^{cA}	ns	ns	ns
90	0.97 ± 0.00^{bA}	0.96 ± 0.01^{bB}	0.96 ± 0.00^{bAB}			
135	0.97 ± 0.01^{bA}	0.96 ± 0.00^{bA}	0.96 ± 0.00^{bA}			

Lowercase averages in the same column mean the difference in storage time in each formulation and the uppercase letters in each row the differences between formulations in each storage time. Significant difference by Tukey test * $P \le 0.05$; ** $P \le 0.001$; *** $P \le 0.0001$; ns: no significant difference.

Abbreviations: F, Formulation; SS, Chicken Skin Sausage; SF, Sausage with added abdominal fat of chicken; SFS, Sausage with added skin and abdominal fat of chicken. T, Time.

[1]Data on dry weight (g/100g).

showed between the formulations and during the storage time for the three colors parameters L*, a*, b*. In general, it was observed that the SF and SFS sample presented higher luminosity (L*) and yellowness (b*) values in comparison with SS sample. This result was already expected due to the presence of lipid content in the raw material used in the sausages preparation. The luminosity increased significantly ($P\le 0.05$) at the end of the storage time for samples with a higher fat content (SF and SFS).

The sausages SF and SS showed higher L* values at day 45, while sample SFS presented the highest values at d 90. After maximum values in all formulations, significant reductions were found ($P \le 0.05$) of L* at the last day of storage (135). SS presented the highest decrease L* between d 45 and 90 (12.34%), being the faster luminosity degradation in this treatment (Table 2).

Redness parameter (a*), at d 0 did not show significant difference ($P < 0.07$) between the sausages. All treatments presented higher redness values at d 45 (Table 2), followed by a great reduction at d 135. These results are coherent with the scientist literature, due to Silva et al. (2018) reported the effect of storage on color parameters in jerky chicken, showing that during storage, the levels of redness were reduced by 40% in this salted chicken product. The decrease in redness induces the meat discoloration, which during storage could be attributed to the oxidation of oxymyoglobin (Fe^{2+}) to ferric metmyoglobin (Fe^{3+}). This fact facilitates the production of prooxidants that can induce lipid and protein oxidation (Zhang et al., 2013). The oxidative processes that occurred in chicken sausages can be correlated with these factors. These processes occur scarcely after processing owing to the high content of unsaturated fatty acids in poultry fat, if this meat is stored under refrigeration (Alves et al., 2012) or even pigment changes due to cold applied during storage (Sohaib et al., 2017).

Considering parameter b* (Table 2), significant differences were also displayed between formulations and among storage days (90 and 135). The SF sample obtained higher values of yellowness at day 90, while SS at d 45, followed by reduction to the end of storage. These results showing a reduction in redness (a*) and an increment in yellowness of the product, showing a probably relation to meat oxidation during storage (Silva et al., 2018). The higher content of fat in SF sample could also explain the reduction of redness (a*) and the increment increase in yellowness (b*) at d 90.

Significant differences ($P \leq 0.05$) in WBSF values were observed between chicken sausage formulations and freezing storage times. The force values applied ranged from 16.52 to 11.32 N. SS sample showed higher shear force values. Regarding time, lower shear force values were found at the end of storage for the three formulations. The quantity of fat found in the SF and SFS samples could explain the lower WBSF values obtained. According to Baer and Dilgear (2014), the presence of fat provides greater softness to the product and consequently better palatability. The quantity of collagen found in SS sample (2.84 g/100 g) also supports this hypothesis, and indicate that collagen provides greater resistance to the product (Sousa et al., 2017), being the texture of chicken meat one of the most important quality attribute for the consumer, which is directly affected by WRC of these products.

A significant decrease ($P \leq 0.05$) was found in WRC during storage for the three formulations (Table 2). SS sample obtained higher WRC values in comparison to SF and SFS samples. This fact in SS formulation could probably be due to its higher content of protein and collagen, which facilitate the connection between water molecules and amino acid residues. Additionally, SFS provided intermediate values of WRC. The loss of WRC can cause texture changes and consequently to influence sensory parameters (Huff-Lonergan and Lonergan, 2005). Because it is a parameter influenced by several factors, the WRC levels found generally vary widely, such as the variation reported in traditional sausage stored under freezing of 21.54 to 30.98% (da Rocha et al., 2020).

SF sausage showed ($P \leq 0.05$) greater CL during the storage times evaluated in comparison to the other formulations. It was also observed that SF formulation presented a higher fat and water loss, as a result of the high temperature effect applied to the cooking process. In addition, storage time provided the sausages a higher weight loss ($P \leq 0.05$) regardless of the lipid source used in the preparation. Among other factors that influence this parameter, the freezing and thawing process itself decreases the WHC of the meat, consequently increasing the weight loss in the cooking process (Mohammed et al., 2021). This set of factors explains the variations frequently reported during the storage of this type of product.

SS sample obtained, in general, higher pH values than SF and SFS sausages. Considering SF and SFS samples, no statistical differences were found. Three samples presented higher pH values in the last day of storage (d 135), regardless the ingredient used for sausage manufacture. The increase in pH at 135 days of storage is associated with the development of psychrotrophic microorganisms, which produce protease, caused by the storage time (Scapin et al., 2015). This increase was also recorded in a study by da Rocha et al. (2020) after the time of 120 d.

As expected, a_w values were not influenced by formulation and storage. Since these products are fresh and they did not subject by any treatment that could change the a_w values.

Microbial Counts of Frozen Chicken Sausages as Affected by Addition of by Products

The microorganism counts analyzed in the sausages are presented in Table 3. It can be observed that among the microorganisms studied, Coliforms at 45°C, *Staphylococcus* Coagulase Positive, *Clostridium* Sulphite Reducer and *Salmonella* spp., were below the limits established by the Brazilian legislation on food microbiological standards (Brasil, 2001). However, at d 90 of storage, the three formulations of fresh sausages presented presence of *Salmonella* spp. The development of this microorganism can be attributed to the high a_w of

Table 3. Evolution of microbial count during freezing storage at −20°C, for 90 d in fresh sausage.

Microorganisms	Time	SS	SF	SFS	Pattern[1]
Coliforms at 45°	0	3.6	1.5×10^1	4.3×10^1	5×10^3
(NMP/g)	45	9.3×10^1	2.3×10^1	2.3×10^1	
	90	2.3×10^1	9.2	4.3×10^1	
Staphylococcus	0	4×10^3	9×10^2	8×10^2	5×10^3
Positive coagulase (UFC/g)	45	1.5×10^3	2.9×10^3	1.3×10^3	
	90	1.9×10^3	1.5×10^3	1.3×10^3	
Clostridium	0	$<1\times10^3$	$<1\times10^3$	$<1\times10^3$	3×10^3
Reducing Sulphite (UFC/g)	45	$<1\times10^3$	$<1\times10^3$	$<1\times10^3$	
	90	$<1\times10^3$	$<1\times10^3$	$<1\times10^3$	
Salmonella spp.	0	absent	absent	absent	absent
	45	absent gift	absent	absent gift	
	90		gift		

Abbreviations: SS, Chicken Skin Sausage; SF, Sausage with added abdominal fat of chicken; SFS, Sausage with added skin and abdominal fat of chicken.

[1]RDC n°. 12/2001 (Brazil, 2001).

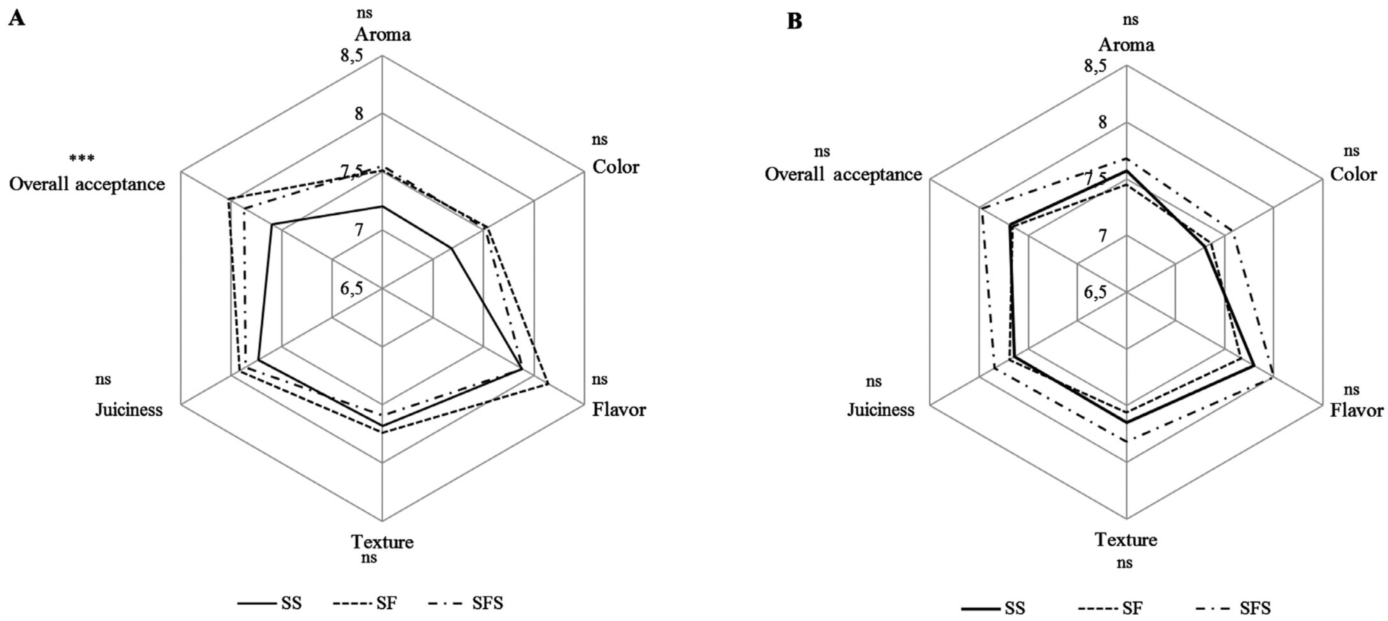

Figure 1. Acceptance test evaluation of fresh chicken sausages added with freezing chicken skin and/or abdominal fat in times of 0 d (A) and 45 d (B). *Footnote*: *** indicates significant difference ($P \leq 0.05$) (Tukey Test). ns indicates no significant difference between formulations ($P > 0.05$). Abbreviations: SS , Sausage with added chicken skin; SF, Sausage with added abdominal chicken fat; SFS, Sausage with added chicken skin and abdominal fat.

the product and the lack of a heat treatment phase in the sausage production. Contamination by *Salmonella* spp. limited the application of sensory evaluation of last days of storage (90 and 135).

Sensory Profile of Frozen Chicken Sausages as Affected by Addition of Byproducts

The acceptance test for chicken sausages showed that among the six sensory parameters evaluated during frozen storage (0 and 45 d to ensure the safety of the consumer), only the overall acceptance attribute showed statistical differences ($P \leq 0.05$) at d 0. The SF formulation displayed greater acceptance, with score between 'like very much' and 'like extremely' (8.03 ± 0.98), being different significantly ($P \leq 0.05$) in comparison to SS sample (7.60 ± 1.30), while SFS sausage (7.87 ± 1.11) did not present differences with the rest of formulations with score between 'like moderately' and 'like very much' (Figure 1). The lower acceptance value for the SS formulation could be attributed to its higher shear force. This fact suggests that the higher protein/collagen content found in SS provided to a greater resistance, due to collagen changes the mechanical properties of the product. In addition, higher protein content and moisture mean values, increasing the hardness parameter (Salejda et al., 2016). Therefore, these factors can negatively affect the acceptance of the products, although in the present study the addition of skin or skin and fat did not cause the product to be rejected. Moreover, it should be considered, that the addition of skin in the formulation of this sausage category has the ability to promote a lower lipid and protein oxidation process during freezing (Lima et al., 2020).

The addition of fat to SFS sausage caused intermediate shear force results that can be provided a good acceptance (SFS 7.87 ± 1.11) for this formulation in comparison to SS and SF samples. Although the addition of fat in meat products such as chicken sausage is not a mandatory ingredient (Brasil, 2000), this component influences directly to juiciness, being a very important parameter for consumer acceptance (Brewer, 2012; Rabeler and Feyissa, 2018). Notably that the better acceptance of the SF formulation can be explained by the appearance characteristics (for example brightness), and juiciness that fat provides to the chicken sausage, influencing positively to consumer assessment and acceptance (Brewer, 2012). The quantity of abdominal fat added also can change the color parameter. Alves et al. (2016) reported that the amount of fat in sausages can significantly change the color, aroma, taste and texture attributes, and overall acceptance.

The noticeable changes in physicochemical parameters and color attributes (L*, a* and b*) did not influence, generally, the sensory quality of chicken sausages. Excellent scores were observed in all parameters evaluated with mean values above 7 (ranging from 7.18 to 8.14 on a 9-point scale). Therefore, these results did not show significant differences between the sausages for sensory parameters, except in overall acceptance at 0 freezing day. Sousa et al. (2017) did a sensory evaluation of frankfurter-type sausages with partial fat replacement by hydrolyzed collagen, showing no significant difference among the four formulations considering appearance, aroma and general acceptance. Madruga et al. (2019) reported that there were not significant differences between chicken sausages with normal breast, woody breast and the mixture of both, showing sensory parameter values below 6.

PCA and Pearson Correlation of Fresh Chicken Sausages of Sensory and Physicochemical Analysis

PCA was generated to indicate correlations of physicochemical characteristics and sausage sensory effects for 0 and 45 days of freezing storage (Figure 2). The first Principal Component (PC1) explained 38.61% of the total variation between samples and second one (PC2) explained 28.21% of the variability between the parameters. Similar samples were located closer in Figure 2, being characterized by the vectors that represent the evaluated parameters. The proximity of vectors indicates higher correlations. This correlation was carried out by Pearson's test with a significance level of 95%.

The sensory attributes were located at the positive PC1 axis. These parameters were positively correlated and better described SFS sausage at d 0 and 45, and SF sample at d 0. This profile indicates that the addition of fat in sausage formulation can positively influence the sensory parameters and overall acceptance of this product. On the other hand, the addition of skin can negatively influence. The aroma for example was highly correlated to SFS sample after storage (d 45). The quantity of fat in this type of meat product can significantly influence on the attributes of color, aroma, taste, texture and overall acceptance (Alves et al., 2016). However, many factors influence consumer behavior in meat products, due to they are heterogeneous product and are not only dependent on the meat appearance and sensory properties (Font-i-Furnols and Guerrero, 2014).

Physicochemical attributes such as, a_w, fat, and CL, were positively correlated with PC1 and could positively influence sensory parameters. In addition, CL was the least descriptive vector. Considering the rest of physicochemical parameters (pH, WRC, WBSF, protein, moisture, a*, b* and L*), were positioned on the negative axis of PC1, being better descriptors for the SS samples at d 0 and 45 and the SF sample at d 45.

Significant Pearson correlations ($P \leq 0.05$) were identified among the parameters evaluated (Table 4). The overall acceptance sensory parameter, for example, correlated positively with the other sensory attributes, color, flavor and juiciness. These results showed that the higher acceptability of these parameters, higher was the overall acceptance. Color and overall acceptance showed negative correlations with WRC parameter. Thus, when there were higher WRC values, color and overall acceptance presented lower values. According to Huff-Lonergan and Lonergan (2005) WRC can negatively influence by palatability of meat products due to changes in texture that can lead the hardness of the meat, and thus decrease the juiciness in the product.

In addition, there were other physicochemical parameters correlated significantly with each other. For example, protein content obtained a strong positive correlation with moisture, but presented a negative correlation with fat content. These correlations show that when higher fat content added in the sausage formulation, lower were the protein and moisture content. According to Salejda et al. (2016), the higher collagen content and intermediate values of moisture, causes a juiciness decrease. However, in our study, significant differences were not found in the correlation with sensory parameters.

Regarding the instrumental color parameters, there was a positive correlation between a* and L*, and negative among a* and WBSF and a_w. These results indicate that when increase redness (a*) and luminosity (L*) values, causes a decrease of WBSF and a_w values. Attributes a* and L* described better the SF sample at d 45 (Figure 2). Finally, the attributes aroma, texture, and

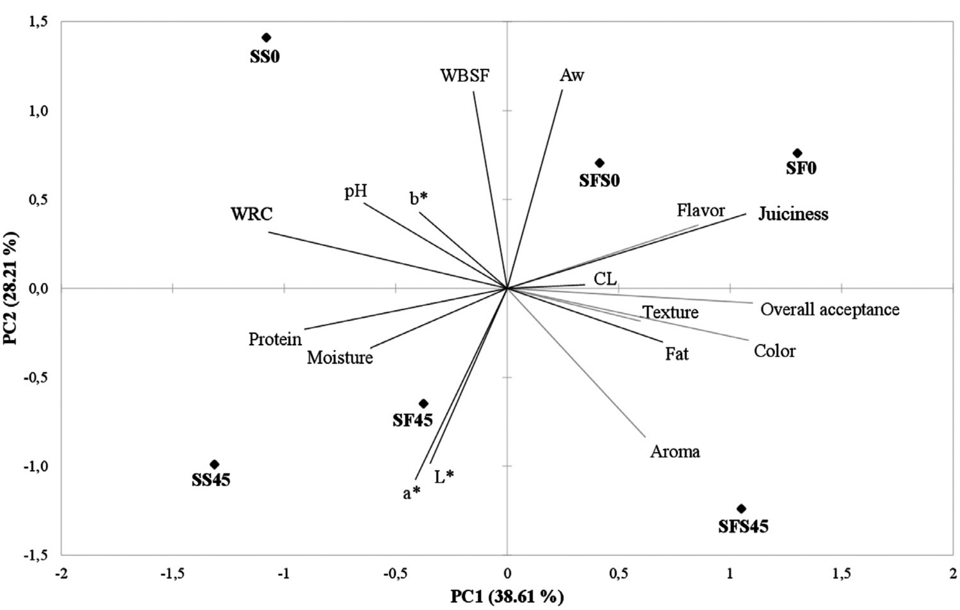

Figure 2. Principal Component Analysis of sensory and physicochemical analysis of the sausages with different compositions at 0 and 45 days. Abbreviations: SS, Sausage with added chicken skin; SF, Sausage with added abdominal chicken fat; SFS, Sausage with added chicken skin and abdominal fat.

Table 4. Pearson's correlation coefficients∗ between physicochemical and sensory parameters during sausage storage.

Variables	Aroma	Color	Flavor	Texture	Juiciness	Overall acceptance	Moisture	Protein	Fat	a[1]	b[1]	L[1]	WBSF	pH	a_w	WRC	CL
Aroma	1																
Color	0.787	1															
Flavor	0.230	0.580	1														
Texture	0.319	0.409	0.767	1													
Juiciness	0.291	0.792	0.842[1]	0.467	1												
Overall acceptance	0.663	0.934[1]	0.825[1]	0.602	0.884[1]	1											
Moisture	0.113	−0.373	−0.036	0.270	−0.474	−0.253	1										
Protein	−0.148	−0.641	−0.332	0.011	−0.699	−0.576	0.931[1]	1									
Fat	0.286	0.546	−0.014	−0.043	0.341	0.369	−0.836[1]	−0.852[1]	1								
a*	0.454	−0.115	−0.541	−0.058	−0.672	−0.270	0.415	0.413	0.074	1							
b*	−0.270	−0.293	−0.287	−0.760	−0.199	−0.283	−0.117	−0.034	−0.168	−0.148	1						
L*	0.424	−0.064	−0.632	−0.305	−0.627	−0.266	0.144	0.173	0.282	0.937[1]	0.096	1					
WBSF	−0.722	−0.321	0.061	−0.453	0.205	−0.216	−0.360	−0.210	−0.204	−0.820[1]	0.593	−0.665	1				
pH	−0.782	−0.780	−0.001	0.194	−0.372	−0.547	0.391	0.520	−0.557	−0.174	−0.109	-0.345	0.282	1			
a_w	−0.494	0.000	0.496	−0.038	0.568	0.185	−0.284	−0.282	-0.236	−0.971[1]	0.332	−0.901	0.885	0.223	1		
WRC	−0.623	−0.867[1]	−0.703	−0.748	−0.751	−0.888[1]	0.290	0.561	−0.540	0.085	0.639	0.140	0.458	0.419	0.079	1	
CL	−0.079	0.155	−0.003	−0.200	0.141	0.144	−0.705	−0.711	0.741	0.004	0.314	0.268	0.105	−0.194	−0.035	−0.172	1

[1]Values with different from 0 with a significance level $P \leq 0.05$.

parameters CL and b* did not show significant correlations with the rest of parameters evaluated during 45 days of storage.

CONCLUSIONS

The use of chicken skin and/or abdominal fat in the preparation of fresh sausage had an impact on physical characteristics and chemical when the products were stored under freezing for a period of 135 d. This fact suggests that the addition of skin increases positively the protein content, decreases the quantity of fat, shows higher WRC values, and shows lower cooking loss values. Regarding the addition of fat, this component provides a greater luminosity and lower shear force values even over storage time. However, consumers did not notice any major differences between fresh chicken sausages as the addition of skin and/or abdominal fat ensured a high level of acceptance. In view of these results, the addition of skin and/or abdominal fat in the manufacture of chicken sausage could be a potential strategy for the meat processing industry, with possible advantages in economic, technological, nutritional, and environmental fields.

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DISCLOSURES

The authors declare that they have no conflict of interest.

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