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Improvement of the physicochemical, textural and sensory properties of meat sausage by edible cuttlefish gelatin addition

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ABSTRACT

The effects of cuttlefish skin gelatin (CSG) addition at different levels on meat emulsion stability, physicochemical properties, water holding capacity, textural properties, color and sensorial properties of formulated and cooked turkey meat sausage, were investigated. The results obtained showed that CSG addition increased meat emulsion stability, water holding capacity, hardness, adhesivity and chewiness of the formulated sausage samples and contributed to the final product lightness. Hedonic analysis showed that gelatin addition had no significant effect on sausages taste using trained panel. Further, sausage sliceability, texture and global acceptability were markedly improved. These results suggest that CSG might be an alternative source of protein additive for the improvement of the physicochemical, textural and sensory properties of meat sausages.

1. Introduction

The production and preparation of various food products, such as sausage, have provided considerable quantities of meat parts which are suitable for being mechanically deboned. The mechanical process is an efficient method of harvesting meat from parts left after hand deboning and from poor quality poultry (Pereira et al., 2011). Several functional ingredients, known for their capacity to improve water binding properties and to modify texture, are of interest for meat processors. Due to their gelling and water binding properties, functional proteins and polysaccharides, even used at low levels, can stabilize shrinkage and increases cooking yields, (Schilling, Mink, Gochenour, Marriott, & Alvarado, 2003; Tarté, 2009; Ayadi, Kechaou, Makni, & Attia, 2009; Huda, Putra, & Ahmad, 2011). Those proteins are widely used in meat formulations, because of their capacity to impart the functional properties of meat products by two mechanisms: the first one is the formation of gel shape that improve texture and water binding capacity, and the second is their ability to improve the emulsification and foaming capacity, enhance the cohesion and adhesion, and stabilize the colloidal systems (Cheng & Sun, 2008; Gomez-Guillen, Gimenez, Lopez-Caballero, & Montero, 2011; Jridi et al., 2013; 2015).

One of the most interesting proteins, which could be used in meat industries, is gelatin. Gelatin is currently used in a wide variety of meat products such as aspics, canned hams, canned sausages. Generally, type A gelatin stabilizes shrinkage and promotes cooking yields owing to their gelling and water binding properties (Prabhu & Doerscher, 2000; Schilling et al., 2003). Santana, Huda, and Yang (2012) reported that the addition of fish gelatin could improve the gel strength and lower the expressible moisture. By adding biopolymers possessing gel-forming or binding capacity, it becomes possible to develop a large variety of analogs based upon modification of the functional and textural properties of sausage. In this context, a part of a Tunisian project to valorize fish waste in meat and food product, CHAHIA's Company (Tunisian turkey manufacturer), was proposed to ameliorate the techno-functional qualities of mechanically separated turkey meat (MSTM) sausage commercialized. In previous work, gelatin has been extracted from the skin of cuttlefish generated, as by-products with a low market value, from fish industry transformation in Tunisia (Jridi et al., 2013), and functional and textural properties were compared to those of bovine halal gelatin.

The objective of this study was to determine the effect of CSG

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addition at different levels on techno-functional properties (emulsion stability, water holding capacity, textural and physico-chemical parameters, color and sensorial) of mechanically separated cooked turkey meat sausage.

2. Materials and methods

2.1. Materials

Mechanically separated turkey meat (MSTM) sausage products were formulated using mechanically separated turkey meat obtained from a local turkey manufacturer (Chahia, Sfax Tunisie). Reagents: NaCl, $NaNO_2$, ascorbic acid and sodium tripolyphosphate (STPP) were of food grade. Cold distilled water (4 °C) was used in all formulations.

2.2. Gelatin extraction

Gelatin was extracted from the skin of cuttlefish as previously described (Jridi et al., 2013). Skin from cuttlefish was obtained from the fish market of Sfax City, Tunisia. Cuttlefish skin was firstly cut into small pieces (1 cm × 1 cm) and then soaked in 0.05 M NaOH (1:10 w/v). The mixture was stirred for 2 h at 4 °C. To remove non-collagenous proteins the alkaline solution was changed every 30 min. The alkaline-treated skins were then washed with distilled water until a neutral pH of wash water was obtained. The alkaline-treated skin was soaked in 100 mM glycine–HCl buffer, pH 2.0 with a solid/solvent ratio of 1:10 (w/v) and subjected to hydrolysis with pepsin at different levels of 5 units/g of skin. The mixture was stirred for 18 h at 4 °C. The pH of the mixture was then raised to 7.0 using 10 M NaOH. The treated skin mixture was then incubated at 40 °C for 4 h with continuous stirring to extract the gelatin from the skin. The mixture was centrifuged at 10,000*g* for 30 min using a refrigerated centrifuge (XTR refrigerated centrifuge, Thermo Scientific, USA) to remove insoluble material. Filtrate was freeze-dried (Moduloyd Freeze dryer, Thermo Fisher, USA). Gelatin obtained was used for turkey meat sausage formulation.

2.3. Turkey meat sausage preparation

The control sausage formulation (g/100 g sausage) consisted of MSTM (proximate composition of 65% water, 14% proteins, 20% fat and 1% ash), 60; cold water, 23.6 (ice and cold-water (8 °C), with a ratio of 1:2 (w:v); turkey fat, 5.1, modified starch, 8, sodium chloride, 2; nitrite salt, 0.8 and sodium triphosphate (STPP) 0.5. Nitrite salt is a mixture of sodium chloride and nitrite and the final concentration of nitrite in the sausage is 150 ppm. Cold water was added to frozen MSTM, which was then minced in a commercial food processor (Moulinex, Paris, France), equipped with a 5 cm blade for 5 min at 360 rpm (highest speed). Salts, fat, and other ingredients were slowly added to the minced MSTM while processing. Gelatin powder from cuttlefish skin (proximate composition of 89.9% protein, 0.35% fat and 8.48% moisture) was added in the sausage formulation at different levels (0%, 0.25%, 0.5%, 0.75%, 1% and 1.5%) by replacing MSTM with an equal weight (Table 1).

After that, modified starch was incorporated until completely blended (2–3 min). Stuffing was carried out manually into 27 mm-diameter reconstituted collagen casings and hand-linked to form approximately 8 cm-long chubs. Then, sausages were heat-processed in a temperature controlled water-bath (Haake, Kalsruhe, Germany) maintained at 90 °C until a final internal temperature of 74 °C was reached. The temperature was measured by using a type-T (copper–constantan) thermocouple inserted into the center of a sausage. Packaged sausages were then cooled immediately using tap water and then stored at 4 °C until analysis. All the process was replicated twice. Proximate composition, color and sensory evaluation of sausages were realized without chilled storage.

2.4. Meat batter emulsion stability

The effect of gelatin addition on meat emulsions stability before cooking was evaluated by estimating the size distribution of the oil droplets observed using an optical microscope employing a 100 × objective lens. For each samples, immediately after homogenization, about 100 emulsion selected particles were measured as described by Ayadi et al. (2009). Droplet size measurements were made using the 10 and 50 μm scales.

The emulsion stability (ES) was determined by the centrifugation of samples (30 g) at 11,000*g* for 30 min at 4 °C and calculated as described by Huang, Kakuda, and Cui (2001)

$ES\ (\%) = (W_2/W_1) \times 100$

where W_2 is the weight of meat emulsion after centrifugation minus exudates and W_1 is the weight prior to centrifugation.

2.5. Proximate composition

Sausages were submitted to chemical analysis of total moisture, protein, lipid and ash contents according to the AOAC (1990). All measurements were performed in triplicate.

2.6. Cooking loss and sausages water holding capacity (WHC)

Cooking loss was determined by weighting the meat preparation before and after cooking. The influence of gelatin addition on sausage WHC and stability was determined as described by Verbeken, Neirinck, Meeren, and Dewettinck (2005). Ten grams of each sausage sample was centrifuged at 12,000*g* for 30 min at 4 °C. The water holding capacity (WHC) was evaluated after 0, 20 and 40 days of chilled storage and value was calculated as a percentage of retained water, using the following equation:

$WHC\ (\%) = (W_2/W_1) \times 100$

where W_2 is the weight of sausage sample after centrifugation and W_1 is the weight prior to centrifugation.

2.7. Color evaluation

The internal color of sausages was determined using a

Table 1
Composition of different turkey meat sausages formulated with different gelatin levels.

	Gelatin (%)	MST meat (%)	Turkey fat (%)	Water (%)	Sodium triphosphate (STPP) (%)	Nitrite salt (%)	Modified starch (%)
Control	0	62.00	5.1	23.6	0.5	0.8	8
F1	0.25	61.75	5.1	23.6	0.5	0.8	8
F2	0.5	61.50	5.1	23.6	0.5	0.8	8
F3	0.75	61.25	5.1	23.6	0.5	0.8	8
F4	1	61.00	5.1	23.6	0.5	0.8	8
F5	1.5	60.50	5.1	23.6	0.5	0.8	8

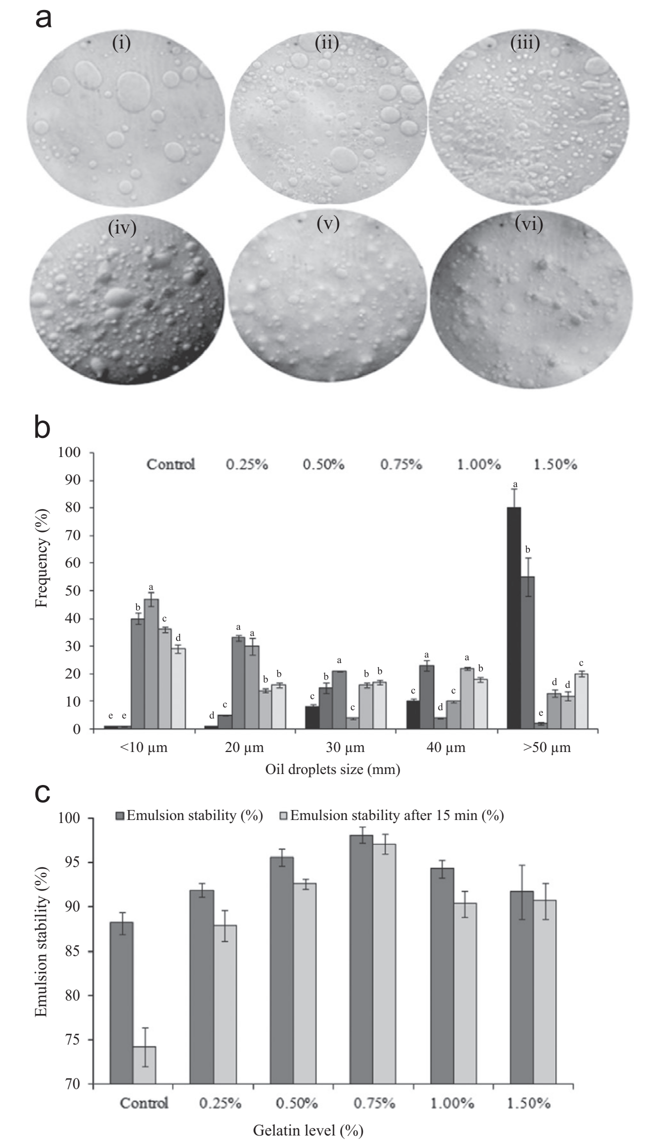

Fig. 1. Effect of CSG addition on meat batter emulsion. (a) Optical microscopic observation of meat batter emulsion containing different levels of cuttlefish skin gelatin. (i) Control (0%), (ii) 0.25%, (iii) 0.5%, (iv) 0.75%, (v) 1% and (vi) 1.5%, (b) oil droplets size distribution and (c) stability of meat batter emulsion. [a,b] Different letters in the same gelatin concentration indicate significant differences ($p < 0.05$).

ColorFlex spectrocolorimeter (Hunter Associates Laboratory, Inc., Reston, VA, USA) equipped by Xenon Lamp. The instrument was standardized using standard white plates. An average value was determined by taking observations from five different cut surfaces of the same sausage with angle of 45°. CIE lightness (L^*), redness (a^*) and yellowness (b^*) were recorded. Chroma (C^*) was calculated with the following equation:

$$C^* = (a^{*2} + b^{*2})^{1/2}$$

2.8. Textural profile analysis (TPA)

In a meat system, texture is used to evaluate not only the consumer desirability of the products but also the structural integrity of the protein matrix. The stability of the protein matrix can be tested by "deformation, disintegration and flow" or "mechanical, geometrical and surface attributes" (Bourne, 1978). TPA of turkey sausages were tested by TPA according to the method of Bourne (1978), using a texturometer (Texture Analyzer, TAXT Plus, LLOYD instruments, England). Samples (2 cm in diameter and 2 cm length) were cut manually using cylindrical form from the center of the links and compressed twice to 50% of their original height. In these experiments hardness, cohesiveness, elasticity, chewiness and adesiveness of child stored sausages at 0 and 40 days were determined in two repeat measurements and performed at least in triplicate.

2.9. Sensorial analysis

The sensory properties of sausage without chilled storage were evaluated according to the method of Murray et al. (2001). Twenty panelists, experienced in sensory evaluation of foods (member on CHAHIA Company), were asked to evaluate the products for texture, taste, color, sliceability and overall acceptability using a five-point hedonic scale ranging from 5 (like extremely) to 1 (dislike extremely) for each sensory attribute. Sausage slices of 3 mm thickness were distributed in white polystyrene plates and presented to the panelists with codes in random order. Experiments were conducted in an appropriately designed and lit room and water was served for the purpose of cleaning the mouth between samples. The sensory analysis was conducted in an appropriately designed and lighted room and a mean score was estimated for each product. In order to evaluate the sliceability, 3 slices of 2 mm thickness from each were made and the score of non-perfect (1: incoherent) to perfect (5: coherent) slices was registered.

For global acceptability, samples were evaluated by 50 non-trained panelists of our institute who used ranking tests to order the samples according to the sensory perception and according to acceptability. One way ANOVA was applied to acceptability data from consumer's tests.

2.10. Statistical analysis

All analytical determinations and measurements were performed at least in triplicate. Values were expressed as the mean ± standard deviation ($n = 3$). Analysis of variance was conducted, and differences between variables were tested for significance by one-way analysis of variance using SPSS software, 17.0 (Statistical Package for the Social Sciences, The Predictive Analytics Company, Chicago, IL, USA). A difference was considered statistically significant when $P \leq 0.05$.

3. Results and discussion

3.1. Effect of gelatin addition on meat batter emulsion

Microscopic observations of meat batter emulsions containing different concentrations of CSG show that the size of the oil (fat) droplets dispersed in the aqueous phase decreased with increasing gelatin concentrations (Fig. 1a). In fact, high protein concentrations in bulk facilitated more protein adsorption at interface (Yamauchi,

Table 2
Proximate analysis values and yield process of turkey meat sausages, without chilled storage, formulated with different gelatin levels.

Gelatin level (%)	Protein (%)	Moisture (%)	Fat (%)	Yield process
Control 0	8.29 ± 0.10^c	67.90 ± 0.05^d	9.78 ± 0.21^d	91.67 ± 2.67^c
0.25	8.72 ± 0.14b	68.0 ± 0.10^c	10.44 ± 0.31^c	96.04 ± 0.48^{bc}
0.5	8.78 ± 0.07^b	68.03 ± 0.09^c	11.1 ± 0.16^b	96.7 ± 0.62^b
0.75	9.29 ± 0.30^a	68.5 ± 0.04^b	11.08 ± 0.15^b	96.4 ± 0.35^b
1	9.45 ± 0.08^a	$68.3 \pm 0.16^{a,b}$	$11.27 \pm 0.13^{a,b}$	$97.1 \pm 0.75^{a,b}$
1.5	9.57 ± 0.10^a	68.4 ± 0.05^a	11.42 ± 0.11^a	98.2 ± 0.96^a

[a,b]Different letters in the same column indicate significant differences ($p \leq 0.05$).

Shimizu, & Kamiya, 1980). It can be seen from Fig. 1a that once gelatin was added at high concentration in emulsion-type sausage, the droplets oil–water interface became obscure and the average diameter of the emulsion apparently decreased. At 1% and 1.5% concentrations, microstructures were also formed by the closely packed oil droplets and the average droplet diameters were about 26 and 28.4 μm, respectively. Furthermore, samples possessed a closed compact structure due to their smaller size and more packing of the oil droplets at high gelatin concentrations.

Particle size distribution for the six batter emulsions expressed as a cumulative function showed that the size of emulsion droplets ranged from 10 to 50 μm (Fig. 1b). For control sausage, oil droplets with diameter ranged between 30 and 50 μm present an average more than 95%. However, 40% and 45% of oil droplets diameter in meat emulsion sample containing 0.5% and 0.75% of gelatin, respectively, were ranged from 10 to 30 μm. Turkey meat batter emulsions containing more than 1% of gelatin exhibited homogenous distribution of oil droplets size.

The evolution of stability of meat batter emulsion containing different gelatin concentrations indicated clearly that the emulsion stability increased with the increasing of gelatin concentrations (Fig. 1c) reached a maximum with 0.75% of CSG, and then decreased. Emulsion of turkey meat batters prepared with gelatins was more stable than control sausage. After 15 min, the emulsion stability was slightly decreased for all the formulations, except that of the control sample which was reduced from 88% ($t=0$) to 74% (after 15 min). The stabilization of emulsion against coalescence/flocculation was greatly dependent on the electrostatic repulsions between the adsorbed proteins on the interfacial protein film.

Many proteins were used as emulsifiers due to their hydrophilic and hydrophobic side chains. Efficiency of a protein as an emulsifier depends not only on the type and the state (native or unfolded) of protein but also on the pH of solution, presence of other emulsifiers, ionic strength and type of oil added (Hermansson, 1994).

3.2. Effect of gelatin addition on cooked Turkey meat sausage

3.2.1. Proximate analysis and process yield

The proximate composition and process yield of turkey meat sausages (TMS) prepared with different concentrations of CSG are shown in Table 2. Overall, there was an increase in protein, fat and moisture content with the increasing of CSG concentration. Our results are in accordance with Pereira et al. (2011) who reported that the addition of collagen in the formulation of chicken frankfurters affects the chemical composition. However, no significant differences ($p < 0.05$) were observed for pH values of the different sausage samples (data not shown).

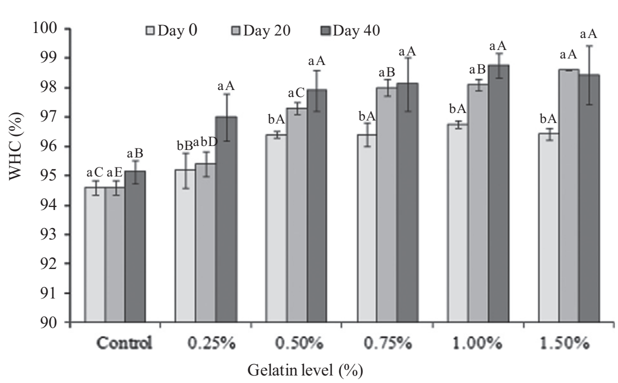

Fig. 2. Effect of CSG addition and storage time on water holding capacity of sausages. [a,b] Different letters in the same gelatin concentration indicate significant differences ($p < 0.05$). [A,B] Different capital letters in the same time of storage indicate significant differences ($p < 0.05$).

Table 3
Color of turkey meat sausages, without chilled storage, formulated with different gelatin levels.

Gelatin level (%)	L^*	a^*	b^*	C^*
0	53.27 ± 0.21^f	22.53 ± 0.11^a	$11.82 \pm 0.\ 6^a$	20.30 ± 0.02^e
0.25	54.67 ± 0.04^e	21.29 ± 0.05^b	12.36 ± 0.8^a	23.21 ± 0.03^d
0.5	54.76 ± 0.11^d	22.25 ± 0.00^a	12.34 ± 0.12^a	23.60 ± 0.09^c
0.75	55.41 ± 0.03^c	20.12 ± 0.14^c	11.52 ± 0.80^a	25.05 ± 0.04^a
1	$56.38 \pm 0.\ 03^b$	19.65 ± 0.12^d	11.56 ± 0.60^a	25.22 ± 0.2^a
1.5	60.15 ± 0.33^a	16.51 ± 0.22^e	12.06 ± 0.79^a	25.55 ± 0.01^a

[a,b]Different letters in the same column indicate significant differences ($p \leq 0.05$).

The yield process of the control and the sausage added with different concentrations of CSG ranged from 92% to 98%, indicating that gelatin participated in water holding capacity. The proportional relationship between yield process and gelatin level contributes to the reduction of water losses and, consequently, weight losses during sausages cooking. Obtained results advanced that CSG could be used in meat products to retain exudates lost.

Lower cooking loss typically represents good quality products (Hoogenkamp, 2004). According to NovaProm (2006), collagen retains water chemically through a protein matrix, due to the physical form of the protein matrix. Results are in agreement with Pereira et al. (2011), who reported a decrease in cooking loss of frankfurter type sausages with increasing collagen levels, providing cost savings in product formulation. So the addition of gelatin as a binder in turkey meat sausages has been considered to be advantageous by improving cooking yield.

3.2.2. Effect of gelatin addition on WHC

As shown in Fig. 2, matrix formed in turkey meat sausage had high capacity to entrap water. It can be seen that increasing the gelatin concentration from 0% to 1.5% caused an increase in WHC of about 2.5%, after 40 days of chilled storage. Moreover, during storage at 4 °C for 20 and 40 days, the increase of WHC for all formulation, may be due to the firmness of sausage matrix caused by protein–protein interaction. It was found that WHC of sausage with addition of cuttlefish gelatin showed the highest percentage because of the gelatin capacity increasing in WHC in processed products. Gelatin chains (α-chains) can be covalently cross-linked to form matrices capable of swelling in the presence of aqueous solutions, forming a gelatin-network. No significant interaction was detected between gelatin concentration and storage time.

The effects of collagen and protein on the WHC of different formulations of meat products have been extensively studied. Schilling et al. (2003) reported a decrease in syneresis of hams, coarse ground comminuted sausage products and finely ground comminuted sausage products with increasing collagen levels providing cost savings in product formulation.

3.2.3. Color evaluation

Color of turkey meat sausage added by different gelatin concentrations is shown in Table 3. Control sausage (without gelatin) had lower values of L^* (lightness), a^* (redness) and C^* (Chroma), but higher b^* (yellowness) value than those prepared with different gelatin levels ($p < 0.05$).

As gelatin was added in the formulation of sausage, there was an increase in the L^* values (Table 3). The increased of L^* value may be due to the increase in light scattering caused by the swelling of gelatin in contact with water. In addition, this effect can be due to fat–protein interactions and the emulsion stability during meat emulsion manufacturing (Alvarez et al., 2007). Our results are in accordance with those proved by Pereira et al. (2011), who reported that low emulsion stability and increased cooking loss were

Table 4
Textural parameters of turkey meat sausages formulated with different gelatin levels.

Day	Gelatin level (%)	Hardness (N)	Cohesiveness	Elasticity (mm)	Adhesivity (N)	Chewiness (N mm)
Day 0	**0**	5.61 ± 0.43^{eb}	$0.50 \pm 0.01^{a,A}$	$7.10 \pm 1.59^{a,A}$	1.64 ± 0.30^{db}	11.65 ± 0.75^{eb}
	0.25	5.76 ± 0.01^{eB}	$0.37 \pm 0.13^{b,A}$	$8.98 \pm 1.01^{A,a}$	1.78 ± 0.36^{dB}	15.92 ± 0.1^{dB}
	0.5	6.18 ± 0.17^{dB}	0.33 ± 0.01^{cB}	$7.45 \pm 1.46^{a,A}$	2.18 ± 0.12^{cB}	17.25 ± 1.59^{cdB}
	0.75	6.87 ± 0.19^{cB}	0.29 ± 0.02^{db}	$6.55 \pm 1.54^{a,B}$	$2.32 \pm 0.88^{a,b,A}$	17.69 ± 4.33^{cB}
	1	$7.36 \pm 0.41^{b,B}$	0.29 ± 0.00^{db}	$7.09 \pm 0.97^{a,A}$	$2.89 \pm 0.01^{b,B}$	$25.69 \pm 1.1^{b,B}$
	1.5	$8.96 \pm 0.40^{a,B}$	0.26 ± 0.07^{db}	$9.30 \pm 2.1^{a,A}$	$2.92 \pm 0.01^{a,B}$	$27.15 \pm 0.4^{a,B}$
Day 40	**0**	6.10 ± 0.58^{eb}	$0.51 \pm 0.02^{a,A}$	$7.80 \pm 1.17^{A,a}$	1.33 ± 0.49^{cb}	10.41 ± 2.05^{eb}
	0.25	7.79 ± 0.05^{db}	$0.35 \pm 0.01^{b,A}$	$8.94 \pm 0.18^{a,A}$	$3.23 \pm 0.54^{b,A}$	25.27 ± 0.88^{db}
	0.5	8.80 ± 0.62^{cdb}	$0.36 \pm 0.03^{b,B}$	$8.17 \pm 0.05^{a,A}$	$3.09 \pm 0.46^{b,A}$	26.35 ± 1.31^{cb}
	0.75	9.45 ± 0.36^{cb}	0.26 ± 0.07^{cb}	$8.33 \pm 0.30^{a,A}$	$3.44 \pm 0.23^{b,A}$	$28.70 \pm 0.92^{b,A}$
	1	$10.09 \pm 0.45^{b,A}$	0.21 ± 0.01^{dB}	$8.12 \pm 0.31^{a,A}$	$3.24 \pm 0.41^{b,A}$	$28.92 \pm 0.43^{b,A}$
	1.5	$10.7 \pm 0.03^{a,A}$	$0.32 \pm 0.03^{b,A}$	$9.15 \pm 2.47^{a,A}$	$4.86 \pm 0.37^{a,A}$	$44.37 \pm 1.06^{a,A}$

[a,b]Different letters in the same column within the same day of storage indicate significant differences ($p \le 0.05$).
[A,B]Different letters in the same gelatin level within different day of storage indicate significant differences ($p \le 0.05$).

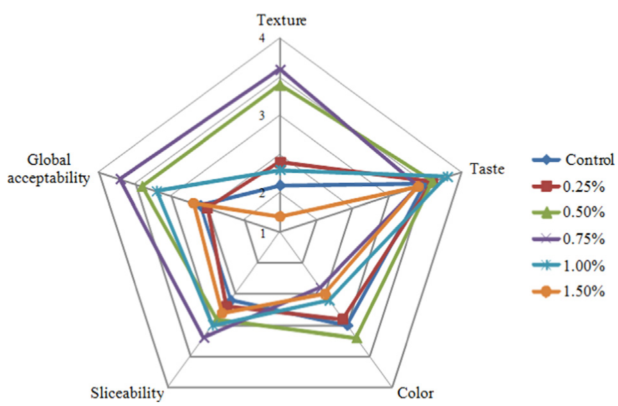

Fig. 3. Sensory average scores of sausages formulated using different cuttlefish skin gelatin concentrations.

accompanied with reducing in L^* values during the emulsification process.

The redness (a^*) values decreased with the addition of gelatin to the sausage formulation. The decrease may be due to the interaction between amino (NH_2) with carbonyl groups in gelatin via Maillard reaction, particularly during cooking. When mechanically separated turkey meat was substituted by 1.5% of gelatin, sausage became less red compared to the corresponding all meat. Atughonu, Zayas, Herald, and Harbers (1998) reported a significant decrease in a^* value when whey protein was added to beef and pork frankfurters sausage. Schilling et al. (2003) did not report any difference in the colors of cooked ham formulated with pork collagen. There was no significant different in yellowness values between different formulations. As observed for L^*, chroma (C^*) values increased by adding gelatin in turkey meat sausage at different levels. Thus, the addition of gelatin improved the color saturation.

3.2.4. *Effect of gelatin addition on texture parameters of sausage*

Table 4 shows texture parameters of turkey meat sausage added with different concentrations of gelatin and stored at 4 °C during 1 and 40 days. Significant differences ($p < 0.05$) were found in hardness, cohesiveness, chewiness, and adhesivity values within the six levels of added gelatin. However, no significant interaction was detected between gelatin concentration and storage time.

As shown in Table 4, hardness of sausages stored at at 4 °C during 40 days increased by increasing the gelatin amount. The increase of hardness during refrigeration period could be due to water loss from the product (purge) storage resulting in the formation of a solid matrix (Andrès, Zaritzky, & Califano, 2006). Indeed, hardness of sausages was varied from 6 to 9 N when gelatin concentration varied from 0.25% to 1.5%, respectively. In this context, Freitas, Silva, Mano & Chaves (2004) reported that the increased hardness with protein addition is desirable because it is an important textural attribute in the determination of acceptable sausages with a fine and mushy consistency. The use of gelatin in turkey meat sausage could bring to the cooked product melt-in-the-mouth property.

The adhesiveness parameter cannot be high in sausages because they should be characterized with a smooth, firm surface without adherence to touch (Ayadi et al., 2009). The lower adhesiveness values might be explained by the lower emulsion ability which contributes to a greater loss of liquid during compression in the TPA test. In addition, sausage cohesiveness decrease with increasing gelatin concentration and reached a lowest value at 0.75% ant then remained. Further, cohesiveness was not affected during storage for 40 days at 4 °C.

There was no significant difference in elasticity of all the sausages with or without gelatin addition while adhesivity and chewiness of sausage added with cuttlefish gelatin were significantly higher ($p < 0.05$) than the product without gelatin addition. Since these exudates contain proteins and hydrocolloids, they have a sticky consistency, and the adhesion of the food surface on with the probe may be greater when larger amounts of exudates were released (Pereira et al., 2011). Well, storage have a significant ($p < 0.05$) effect on the textural parameters except the elasticity. Indeed, the addition of gelatin to the meat protein during preparation of the sausage induced the change of microstructure products by the formation of gelatin–meat protein matrix. Thereafter, gelatin addition caused the change in textural parameters of resulted sausage.

3.2.5. *Sensory evaluation of sausages*

The sensory evaluation of cooked sausages (Fig. 3) indicates a significant ($p < 0.05$) effect of gelatin addition at different levels from all the evaluated attributes. Texture, color, sliceability and overall acceptability were lower ($p < 0.001$) in control sausage (without gelatin) than those characterizing in the other turkey meat sausage, regardless of gelatin addition. Nevertheless, sausage taste was similar in all the formulations ($p < 0.05$). In fact, attributed score of taste was not affected by the addition of gelatin at different concentrations. While, average scores for texture, sliceability and overall acceptability of sausages formulated with 0.5%

and 0.75% of gelatin showed higher panelist acceptability.

Thus, generally, when considering all attributes, sensorial evaluation shows that sausage formulated with 0.75% of gelatin is the most acceptable product to the panelist. In addition, texture value of samples prepared with 0.75% of gelatin after 40 days of storage showed similar values to the samples with 1.5% of gelatin without storage. The texture and overall acceptability of sausages formulated without or with 1% and 1.5% of gelatin were very disliked by panelists, which may be related to the higher value of hardness. Thus, the addition of gelatin at 1% and 1.5% caused the change in textural parameters of resulted sausage, especially hardness, due to the formation of gelatin–meat protein matrix (Pereira et al., 2011).

4. Conclusion

Cuttlefish skin gelatin addition had a significant impact on several quality characteristics formulated and cooked turkey meat sausage, including meat emulsion stability, physicochemical properties, water holding capacity, textural properties, color and sensorial properties. The addition of CSG increases emulsion stability, yield process and water binding capacity of sausage. As gelatin was incorporated in the formulation of sausage, there was an increase in the lightness (L^*) values and color saturation (C^*). Indeed, gelatin addition caused the change in textural parameters of resulted sausage (hardness, cohesiveness and chewiness) due to the formation of gelatin–meat protein matrix. Sensory analysis showed that gelatin presence had no significant effect on sausages taste, while, the sausage sliceability, texture and global acceptability were markedly superior.

Conflict of interests statement

All authors declare that there is no conflict of interests regarding the publication of this article.

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