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ORIGINAL ARTICLE

Quality attributes and consumer acceptance of new ready-to-eat frozen restructured chicken

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Abstract The aim of the present study was to develop a new restructured product, cooked and frozen ready-to-eat product that was prepared with boneless chicken meat (breast and drumstick) and mechanically separated chicken meat (MSCM). Non-meat ingredients, such as transglutaminase (TG) and egg albumin powder, were tested to obtain a better strength of adhesion between the meat particles. Five formulations for restructured chicken were developed as follows: T1 (1 % transglutaminase), T2 (1 % transglutaminase and 15 % MSCM), T3 (1 % egg albumin powder), T4 (1 % egg albumin powder and 15 % MSCM) and T5 (1 % transglutaminase, 1 % egg albumin powder and 15 % MSCM). The results of the experiment showed a greater luminosity (L*) in the treatments with TG (T1) and albumin (T3). The treatments without MSCM (T1 and T3) presented significantly lower mean values for redness (a*) when compared to treatments with MSCM (T2, T4 and T5) ($p \leq 0.05$). No significant differences were noted between the treatments ($p \geq 0.05$) when analyzing the percentage of total saturated fatty acids (SFA), polyunsaturated fatty acids (PUFA) and cholesterol content. Consumer testing showed a high acceptance of the restructured products in all evaluated attributes. Similarly, with regard to the purchase intention, consumers mostly expressed that they would probably or certainly buy the products, for treatments T1, T2, T3 and T5. Moreover, the meat cuts with no commercial value, can transform into new ready-to-eat products that have a high probability of success in the market.

Keywords Processed food · Sensory analysis · Transglutaminase · Albumin · Mechanically separated chicken meat

Introduction

The poultry production chain is of utmost importance to the Brazilian economy, with a total production of thirty million tons of chicken meat in 2012. Annual Brazilian chicken exports exceed 3.9 million tons (1.57 million tons of whole chickens and 2.2 million tons of meat cuts), and annual Brazilian per capita chicken consumption is 40.8 kg. These productivity and consumption levels make Brazil the largest exporter of poultry meat and the world's second largest poultry consumer market.

Special and industrialised cuts (represented by sausages and ready-to-eat meals) are the products that drive the expansion of chicken consumption, and they are designed for the consumer who seeks new ready-to-eat food options to reduce the time spent on food preparation (Mielnik et al. 2002; Perlo et al. 2006). This need has demanded adjustments from the poultry industry for the development of ready-to-eat products that are easy to prepare and that meet consumer requirements while offering attractive prices compared to other types of meat (Contreras-Castillo et al. 2008; Keeton 2001). Therefore, one aim of the meat processing industry is to develop quality products with a higher added value to accompany the changes in the patterns of consumption, which require products with lower processing costs with positive attributes related to food safety, practicality and appearance. An illustration of this

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market is the wide range of options for processed meat, as represented by sausages and bologna sausages (Arora and Kempkes 2008; Pearson and Gillett 1996).

Formed products stand out among those offered by the meat industry. These products are moulded in several ways from whole muscles or parts with the purpose of using available muscle pieces to add a higher commercial value (Barbut 2002). However, the formed product must have similar characteristics to those of the intact muscle, which is a feature desired by consumers and the main obstacle to transforming secondary parts of the carcass into formed products.

Salt and tumbling are traditionally required to produce formed meat, thus allowing for the extraction of myofibrillar proteins from the meat. This process (salt + tumbling) reduces firmness and increases juiciness, but the addition of salt leads to an increased amount of sodium in the food. To meet the market's interest for reducing salt content, non-meat ingredients are added to these products to improve the functional properties of the natural proteins as well as to increase its water-holding capacity and gel formation, which results in products with enhanced juiciness, structure and texture that are similar to those of intact muscles (Barbut 2002; Dimitrakopoulou et al. 2005; Lu and Chen 1999).

The gelling ability and physical properties of proteins are important for processed foods (Lanier, 1998). Egg albumin (EA), as an example of isolated proteins, has been used as functional ingredient in ground, formated and emulsified products due to meat binding properties (Tabilo-Munizaga and Barbosa-Canovas 2004) and positive effect on texture. However, other studies on EA effect have been contradictory regarding its binding and textural properties (Carballo et al., 1995). Other authors (Lu and Chen 1999) showed EA powder is an excellent non-meat protein because its application increased the binding strength of chicken meat and probably contributed to the formation of a harder protein matrix (Carballo et al., 1995). Its addition causes minor changes in the color of restructured meat (Lu and Chen 1999).

Transglutaminase (TG) showed capacity to cross-link between different food proteins, peptides and some other primary amines (Payne, 2000). The microbial transglutaminase (MTG) is an enzyme that catalyzes covalent cross-link formation of food proteins (Carballo et al., 2006). When the ε-amino group of lysine residues in proteins can mediate as an acyl-acceptor, both intra-and intermolecular ε-(γ-glutamyl) lysine cross-links are formed between food proteins (Kuraishi et al., 1997). These TG are active within the temperature range of about 0–60 °C with an optimal activity around 50–55 °C (Motoki and Seguro, 1998). This enzyme plays an important role in food processing due to its aggregation and gelation properties and can improve of rheological properties of food proteins (Carballo et al., 2006; Lennon et al., 2010). Comercial microbial TG can be mass produced by aerobic fermentation procedures and show stability between pH 5–9 (Boles, 2011 and Kuraishi et al., 1997). This MTG could be a cold-binder agent in restructured beef, chicken, fish, and other meats and low sodium restructured meats and generally used as a liquid or as a powder application. After application in both ways, the product is refrigerated for 4–24 h to allow the chemical reaction to occur. TG binding results from cross-linking myosin and actin (Ramirez-Suarez and Xiong, 2003; Tammatinna et al. 2007) and it has also been used to improve texture or mechanical properties of products that contain soluble proteins for reaction substrates (Boles, 2011). The addition of this enzyme does not modify appearance, color and flavor of chicken restructured products (Tseng et al., 2000).

Consumption of poultry meat and poultry meat products is currently growing and increased production of cut-up and processed meat has provided considerable quantities of parts with lower commercial value. The mechanically separated meat (MSM) is obtained by mechanical grinding and separation of bones, carcasses or parts of carcasses of poultry, beef and swine intended for the preparation of specific meat products. Poultry slaughterhouses produce a considerable amount of residues and the alternative for this (e.g., carcasses, back and neck) is mechanically deboned chicken meat (Perlo et al., 2006). MSM of poultry can be used to process several products, such as sausages, mortadella, nuggets, cooked hamburgers, meatballs and other cooked meat products (Field, 1998). The MSM, particularly, is used in the manufacture of emulsion products where the emulsifying capacity is the most important property for meat products. Another property of MSM, the water holding capacity (WHC), is important because MSM retains water within the matrix due to the high pH, presence of mineral from bones, skin and collagen, in addition to the cooking and freezing processes used (Al-Najdawi and Abdullah 2002).

Other reports (Serrano et al., 2004; Canto et al., 2014) showed that the products were mechanically suitable (meat particle binding) for handling in the raw state, but when used in fresh and cooked products, water and binding properties were inadequate.

The current challenge of the meat industry is to achieve a cost reduction by using meat cuts of no commercial value, such as the dorsum back of chicken, to obtain products of a higher commercial value. Therefore, the present study aimed to develop a new, restructured, cooked and frozen ready-to-eat product that has a similar sensorial quality to that of the intact chicken fillet using boneless breasts, thighs, breast shavings, thigh shavings, mechanically separated chicken meat (MSCM) and non-meat ingredients such as transglutaminase (TG) (which has the ability to improve the physical properties of the food and promote the adherence of meat pieces) and egg albumin.

Material and methods

Raw material Furcula bones obtained from the boning of the breast and bones with meat trimmings from the back and neck, without skin and following the maximum removal of visible fat, were used to produce MSCM from recently slaughtered poultry at the Fricock slaughterhouse (Rio Claro, São Paulo). These bones (back, neck and furcula bones) were frozen and sent to the pilot plant of the University of São Paulo in Pirassununga, SP on the same day for the removal of the MSCM, which was then placed in a deboning machine (model HT 250; HIGH TECH SOLUÇÕES, Chapecó, Santa Catarina) with an axis that has a setting at the tip to determine the size of the bone fragments in the mass. In this experiment, the setting at the output of the machine was standardised for all the extractions.

After the extraction, the MSCM was manually homogenised, packed in polyethylene bags, placed in an ultra-fast freezer at−40 °C and transported frozen to the pilot plant of the Laboratory of Meat Quality and Processing of University São Paulo/ESALQ in Piracicaba, SP to process the restructured product. Boneless and skinless poultry meat (breast and drumstick), which originated from the same slaughterhouse from animals slaughtered the previous day (approximately 42 days of age), was transferred under refrigeration to the laboratory's pilot plant for the processing of restructured products.

Ingredients for increasing the strength of adhesion (transglutaminase and egg albumin) Activia BP® transglutaminase (Ajinomoto do Brazil Ind. e Com. de Alimentos Ltda, São Paulo, Brazil) was used, and pasteurised dehydrated egg whites with 80 % albumin (Salto's Alimentos Ltda, Salto, São Paulo, Brazil) were used as the source of albumin.

Formulation The following non-meat ingredients were used for the restructured product: 0.15 % onion powder, 0.10 % garlic powder, 0.03 % white pepper, 0.20 % sugar, 0.80 % sodium lactate, 0.25 % sodium erythorbate, 0.5 % smoke flavour, 1.5 % salt and 10 % water. The non-meat ingredients were kept constant for all treatments. The amounts of MSCM, TG and albumin varied according to each treatment as follows: T1 and T3 had 42.74 % chicken breast, 42.74 % deboned drumsticks and 13.53 % non-meat ingredients with 1 % transglutaminase added to T1 and 1 % egg albumin powder added to T3; T2 and T4 had 35.74 % chicken breast, 35.74 % deboned drumsticks, 13.53 % non-meat ingredients and 15 % MSCM with 1 % transglutaminase added to T2 and 1 % egg albumin powder added to T4; and T5 had 34.74 % chicken breast, 34.74 % deboned drumsticks, 13.53 % non-meat ingredients, 15 % MSCM, 1 % transglutaminase and 1 % egg albumin powder.

Restructured preparation The final cleaning for the removal of pieces of cartilage and excess visible fat from the chicken meat (drumstick and breast) was performed at the Laboratory of Meat Quality and Processing. The meats were ground separately in a grinder (HOBART 4B22–2) using a #12 disk to grind the thighs and drumsticks and a #3 disk to grind the still-frozen, cubed MSCM. To reduce the impact on colour change resulting from the addition of MSCM, chicken breast was added at a ratio of 1:1 during grinding. The restructured product was prepared in a mixer for a mixing period of 5 min in the following order: ground chicken meat, MSCM, seasoning, treatment ingredients, salt (to lower the extraction of myofibrillar proteins) and sodium erythorbate. The products were then packed in nylon polyethylene bags using a manual packaging machine (17 cm×12 cm), producing portions of 100 g each, which were then vacuum sealed.

Thermal treatment The pre-packaged restructured products were subjected to cooking in water (82 °C) until an internal temperature of 82 °C was achieved. This process was designed in order to ensure the microbial inactivation standard proposed by Thippareddi and Sanchez (2005), as well as guarantee the appropriate sensorial and cooking properties. After the heating and retention periods, the products were then cooled to 32 °C under running water and immediately placed in a freezer at−18 °C. The internal temperature was recorded using PT-100 sensors, installed both in the product cold spot and in the processing environment, which were coupled to a datalogger (My PCLab Datalogger; NOVUS Produtos Eletrônicos, Porto Alegre, Rio Grande do Sul). To obtain the thermal destruction curve, the following parameters were set.

Experimental design To collect the physicochemical data, a completely randomised design was used, which considered each processing as a replication. The five experimental treatments (formulations shown in Table 1) were as follows: T1 (1 % transglutaminase), T2 (1 % transglutaminase and 15 % MSCM), T3 (1 % egg albumin powder), T4 (1 % egg albumin powder and 15 % MSCM) and T5 (1 % transglutaminase, 1 % egg albumin powder and 15 % MSCM). Four replications of each treatment were performed, and the following analyses were performed to determine the instrumental colour, pH, fatty acid profile, cholesterol content and microbiological evaluation.

To generate sensory data, a Latin Square experimental design was used to control the effects of the sample presentation order. Consumers assessed the acceptance of the colour, flavour, tenderness, juiciness and overall quality of the restructured products as well as their intention to purchase the products.

Physicochemical and microbiological analysis After cooking and freezing, the samples from the five restructured product

Table 1 Colour CIELab* (parameters L* and a*) and pH for each treatment

Treatments	L*	a*	pH
T1	68.72^{b}±2.11	3.81^{c}±0.79	6.34^{b}±0.07
T2	62.69^{e}±3.48	6.48^{ab}±1.18	6.40^{a}±0.07
T3	72.24^{a}±1.95	3.72^{c}±0.61	6.30^{c}±0.05
T4	65.41^{c}±3.69	6.06^{b}±1.02	6.38^{a}±0.05
T5	63.89^{d}±4.26	6.73^{a}±1.17	6.39^{a}±0.09

Results are the mean ± standard deviation. The means followed by the same lowercase letters in the columns comparing parameters L*, a* and pH among treatments do not differ according to Tukey's test ($p>0.05$)

T1 Restructured with transglutaminase; *T2* Restructured with MSCM + transglutaminase; *T3* Restructured with egg albumin powder; *T4* Restructured with MSCM + egg albumin powder; *T5* Restructured with MSCM + transglutaminase + egg albumin powder

formulations were thawed in a commercial refrigerator for 12 h (5±2 °C) so that the following analyses could be performed at room temperature. The analysis was performed on five samples from each treatment after 48 h of freezing with five readings for each sample.

Instrumental colour The instrumental colour was determined by a colorimeter (Konica Minolta, CR-400 chromameter, Mahwah, New Jersey, USA) using the following parameters: L* (luminosity) and a* (redness) (CIELAB). The parameters were calibrated in a standard white porcelain container with Y=93.7, x=0.3160 and y=0.3323 as well as a measurement area of 8 mm in diameter, an observation angle of 2° and a C illuminant.

pH The pH was determined directly on samples using a pH metre (Oakton pH 300, series 35618, Vernon Hills, Illinois, USA) with automatic temperature compensation and a glass penetration electrode (Digimed, São Paulo, Brazil). The analysis was performed on five processed samples of each treatment after 48 h of freezing, using five readings for each sample.

Fatty acid profile Lipid extraction was performed according to the method described by Folch et al. (1957). The fatty acids were converted into fatty acid methyl esters using the method described by Hartman and Lago (1973). The fatty acid profile was determined by high-resolution gas chromatography (GC) using a gas chromatograph (HP 5890) equipped with a SUPELCO SP-2560 capillary column (100 mm×0.25 mm) coupled to a flame ionisation detector. The temperature program was set as follows: 130 °C (1.0 min) to 170 °C (6.5°/min), 170 °C to 215 °C (2.75 °C/min), 215 °C (12 min), 215 °C to 230 °C (40°/min) and 230 °C (6 min). The injector and detector temperatures were 270 °C and 280 °C, respectively. The samples (0.3 μl) were injected by the direct injection technique. Saturated and unsaturated fatty acids containing 6, 8, 10, 12, 14, 15, 16 (cis and trans), 17, 18 (cis and trans), 20, 22 and 24 carbon atoms were identified by comparison with the data obtained for the GC of authentic methylated standards eluted under the same conditions.

Cholesterol content The cholesterol content was measured by direct saponification with 2 % KOH in absolute ethanol (Bragagnolo and Rodriguez-Amaya 2003; Jiang et al. 1991). Following the extraction, the samples were dried under nitrogen gas and resuspended in 2 ml of petroleum ether, and 5 or 10 μl was injected into a Shimadzu liquid chromatography with an automated injector that was coupled to a photodiode array detector at 210 nm and a C18 reversed-phase column (250 mm× 4.6 mm) with a particle size of 5 μm. The mobile phase consisted of acetonitrile/isopropanol in isocratic mode.

Texture profile analysis (TPA) The TPA of the samples was performed at room temperature (22 °C) using a TA.XTA2i texture analyser (Stable Micro Systems, Godalming, UK) equipped with a cylindrical probe with a 50 mm diameter. This procedure involved cutting slices approximately 2.5 cm thick, which were then compressed twice to 30 % of their original height. Force-time curves were recorded at a cross-head speed of 2 mm/s. Hardness (N) and chewiness (Ncm) were evaluated 48 h after processing.

Thiobarbituric acid reactive substances (TBARS) The TBARS values were determined in duplicate using the extraction method described by Vyncke (1970) and Jorgensen and Sorensen (1996), with modifications. The absorbance was measured at 532 nm and 600 nm by a spectrophotometer (Shimadzu, UV–Vis mini 1240, Chiyoda-ku, Tokyo, Japan). The difference (A532 nm–A600 nm) was used as the absorbance value, corrected for turbidity. The results were calculated from the standard curve of TEP and expressed as mg of malonaldehyde per kg of meat (MDA/kg). The TBARS value determination was performed 48 h after processing.

Microbiological evaluation Microbiological evaluations were made after the samples were cooked to verify the hygienic quality of the sample processing according to the limits specified by Brazilian law for raw, cooked, cooled or frozen meat products as follows: coliforms at 45 °C/g (5×10^3 CFU/g), sulphite-reducing clostridia at 46 °C/g (3×10^3 CFU/g) and Salmonella sp. (absence in 25 g). Analyses for Staphylococcus aureus and Listeria sp. as well as the total count of mesophilic bacteria were also performed. Microbiological analyses were performed after cooking and 48 h of storage at−18 °C.

Sensory analysis

Consumer panel Habitual chicken fillet and/or nugget consumers of different ages and from different regions were recruited from the Institute of Food Technology (ITAL) in Campinas, Brazil. Among the 52 consumers recruited, 69 % were female and 31 % were male, with ages ranging from 21 to 60 years. The frequency of chicken fillet and/or nugget consumption of the recruited consumers was as follows: 48.10 % consumed chicken fillet and/or nugget every 15 days, 23.10 % consumed chicken fillet and/or nugget once a week, 19.20 % consumed chicken fillet and/or nugget twice a week, and 9.60 % consumed chicken fillet and/or nugget at least 3 times a week. To determine whether the addition of MSCM, albumin or transglutaminase affected the sensory characteristics of the restructured steaks, an acceptance test was performed.

Consumer testing The sensory tests were performed in the Sensory Analysis Laboratory (LAFISE), ITAL. The consumers were placed in individual tasting booths, where they received instructions on the use of the scale, the nature of the products and the type of evaluation to be carried out. The five grilled restructured samples, which were served in a monadic way according to the sample presentation order, were evaluated under white light on disposable white plastic plates coded with random three-digit numbers. The respondents were instructed to cleanse their pallets with mineral water and unsalted crackers before each sample evaluation.

After the colour acceptance evaluation, the consumers were requested to taste the product and evaluate how much they liked or disliked each sample with respect to the odour, flavour, tenderness, juiciness and overall acceptance by using a nine-point hedonic scale (1=disliked extremely, 5=neither liked/nor disliked and 9=liked extremely). Finally, the consumers evaluated their purchase intention of the tested products by using a five-point structured scale (1=certainly will not buy, 3=may or not may buy and 5=certainly will buy).

Statistical analysis The physiochemical measurements of the experimental treatments were analysed using a one-way ANOVA ($p \leq 0.05$). The acceptance responses of the evaluated attributes were analysed using a three-way ANOVA ($p \leq 0.05$), which considered the effects of the consumers, sample presentation order and samples. To evaluate the differences in physicochemical characteristics and acceptance among the samples, paired comparisons of the means were carried out using Tukey's HSD test ($p \leq 0.05$). The statistical data analysis was performed using SAS and StatisticaTM software (Statsoft Inc., Tulsa, Oklahoma, USA).

Results and discussion

pH and colour In the pH analysis, treatments containing MSCM (T2, T4 and T5) presented statistically significant differences ($p \leq 0.05$) compared to treatments without MSCM (T1 and T3). However, the differences observed in the pH values did not represent changes in this parameter (Table 1).

The ANOVA results for luminosity (L*) and redness (a*) showed significant differences ($p \leq 0.05$) among treatment means (Table 1). The restructured products without MSCM (T1 and T3) presented the highest luminosity and the lowest redness values in comparison to the restructured products with MSCM (T2, T4 and T5), which presented the lowest luminosity and highest redness values. Thus, MSCM addition affected the colour parameters. These results suggested that the addition of MSCM should occur in small proportions to prevent the colour from darkening in restructured products. The darkness caused by the addition of MSCM was due to the release of bone marrow and large amounts of haemoglobin when the bones were broken in the production of MSCM. The presence of haemoglobin in this meat (MSCM) confers a brownish colour after cooking and increased redness (Contreras-Castillo et al. 2008; Hecer and Sozen 2011; McMindes and Siedler 1988).

When comparing the treatments without MSCM (T1 and T3), the formulation containing egg albumin (T3) presented higher values of luminosity than the formulation containing transglutaminase (T1), which may be due to the water-retaining and gel-forming properties of albumin, thereby conferring a lighter colour to the product, as also reported by Lu and Chen (1999). Thus, due to this characteristic, it was expected that the addition of egg albumin powder in combination with MSCM would produce restructured products with redness and lightness close to a product without MSCM. In this study, however, there was greater whitening ($p < 0.05$) when only egg albumin powder (T3) was added and less luminosity when egg albumin was added in combination with MSCM. Thus, further studies will be required to optimise the best combination of egg albumin powder and MSCM.

Fatty acid profile, cholesterol content and thiobarbituric acid reactive substances (TBARS) For the analysis of the total percentage of saturated fatty acids (SFAs), polyunsaturated fatty acids (PUFAs) and cholesterol, no statistically significant differences were noted among treatments ($p \geq 0.05$), thereby verifying that the addition of MSCM did not negatively affect the fatty acid profile of the restructured products in T2, T4 and T5 when compared to the restructured products based on the drumstick and breast fillet (T1 and T3). The mean values of SFAs, PUFAs and cholesterol ranged from 28.31 to 30.57 %, 68.94 to 71.26 % and 65.04 to 76.84 mg/100 g, respectively (Table 2). These results were similar to values indicated by the

Table 2 Values of fatty acids, cholesterol content and TBA in the experimental treatments

Treatments	Fatty acids (%)		Cholesterol (mg/100 g)	TBARS (mg MDA/kg)
	Saturated	Polyunsaturated		
T1	29.70[a] (±1.64)	69.78[a] (±1.72)	65.37[a] (±12.90)	0.34[a] (±0.19)
T2	28.85[a] (±2.08)	70.64[a] (±1.68)	74.70[a] (±7.68)	0.24[a] (±0.10)
T3	28.63[a] (±1.25)	70.31[a] (±1.61)	65.04[a] (±7.58)	0.23[a] (±0.06)
T4	28.31[a] (±1.48)	71.26[a] (±1.26)	70.74[a] (±8.67)	0.20[a] (±0.10)
T5	30.57[a] (±3.07)	68.94[a] (±3.13)	76.84[a] (±7.97)	0.22[a] (±0.10)
Overall mean	29.21 (±1.97)	70.19 (±1.94)	70.54 (±9.69)	0.25 (±0.19)

Results are the mean ± standard deviation. The means followed by the same lowercase letters in the columns comparing fatty acids, cholesterol and TBA among treatments do not differ according to Tukey's test ($p>0.05$)

T1 1 % transglutaminase; *T2* 1 % transglutaminase and 15 % MSCM; *T3* 1 % egg albumin powder; *T4* 1 % egg albumin powder and 15 % MSCM; *T5* 1 % transglutaminase, 1 % egg albumin powder and 15 % MSCM

United States Department of Agriculture (USDA) for "Chicken, roasting, light meat, meat only, cooked, roasted", which prescribes values of 69.4 % for PUFAs, 30.6 % for SFAs and 74 mg/100 g for cholesterol. Studying the quality of chicken meat under different rearing systems, (Aguiar et al. 2008) found SFA and PUFA values of 36.3 % and 62.9 %, respectively, in fillets from chickens reared using the conventional method. Therefore, the results showed that the fatty acid profile and cholesterol content of the restructured products were within acceptable levels for products made with chicken meat. This result is favourable because the food industry aims to develop new products with low levels of SFAs and higher contents of PUFAs to increase the nutritional value of food.

Regarding the lipid oxidation of the restructured products, non-significant differences ($p\geq0.05$) were found among the treatments (Table 2). This analysis was conducted to ascertain the impact of MSCM addition on the oxidation of the restructured products after cooking. The results indicated that MSCM addition did not adversely affect the sensory quality with respect to rancidity. These results showed low values of TBARS, indicating that the product was preserved while maintaining its distinctive flavour. Rhee et al. (2005) verified a correlation between an increase in the TBARS value and the perception of off-flavours by consumers. Moreover, Campo et al. (2006) defined the limiting threshold with respect to beef lipid oxidation as 2.0 mg malonaldehyde/kg sample, which was a relatively high value compared to the value found in the present study (0.22–0.34 mg MDA/kg).

Thus, the results showed that removing excess fat and skin in the production of MSCM from drumsticks and breasts for the preparation of restructured products reduced TBA values, which produced higher oxidative stability. This fact was verified by the consumer sensory evaluation results (Table 2), in which the smell and flavour attributes had high acceptance, and no negative comments were made about rancid odour or taste with regard to the restructured products.

Texture profile analysis (TPA) The use of TG alone or in combination with egg albumin (T1, T2 and T5) produced restructured products with significantly higher values ($p\leq0.05$) of hardness and chewiness when compared to restructured products containing egg albumin powder (T3 and T4) (Table 3).

As the objective of this study was to obtain restructured products with texture characteristics similar to those of a chicken fillet, the results showed that addition of the TG enzyme refined the MSCM by cross-linking actomyosin (Akamittath and Ball 1992). This result corroborated the results described by Keeton (2001), who reported that TG influences the texture of meat products, and these authors also stated that TG is used to improve the rheological properties of food and can be applied in combination with other ingredients, such as salt, phosphates and alkali curing.

Table 3 Texture profile analysis of hardness and chewiness in the experimental treatments

Treatments	Texture Profile Analysis	
	Hardness (N)	Chewiness
T1	36.91[a] (±8.09)	2,544.45[a] (±711.41)
T2	32.64[ab] (±6.94)	2,258.90[a] (±503.22)
T3	25.93[b] (±5.66)	1,644.54[b] (±542.02)
T4	25.06[b] (±2.42)	1,682.84[b] (±375.78)
T5	32.96[ab] (±6.52)	2,337.74[a] (±548.22)

Results are the mean±standard deviation. The means followed by the same lowercase letters in the columns comparing the texture profile analysis among treatments do not differ according to Tukey's test ($p>0.05$)

T1 1 % transglutaminase; *T2* 1 % transglutaminase and 15 % MSCM; *T3* 1 % egg albumin powder; *T4* 1 % egg albumin powder and 15 % MSCM; *T5* 1 % transglutaminase, 1 % egg albumin powder and 15 % MSCM

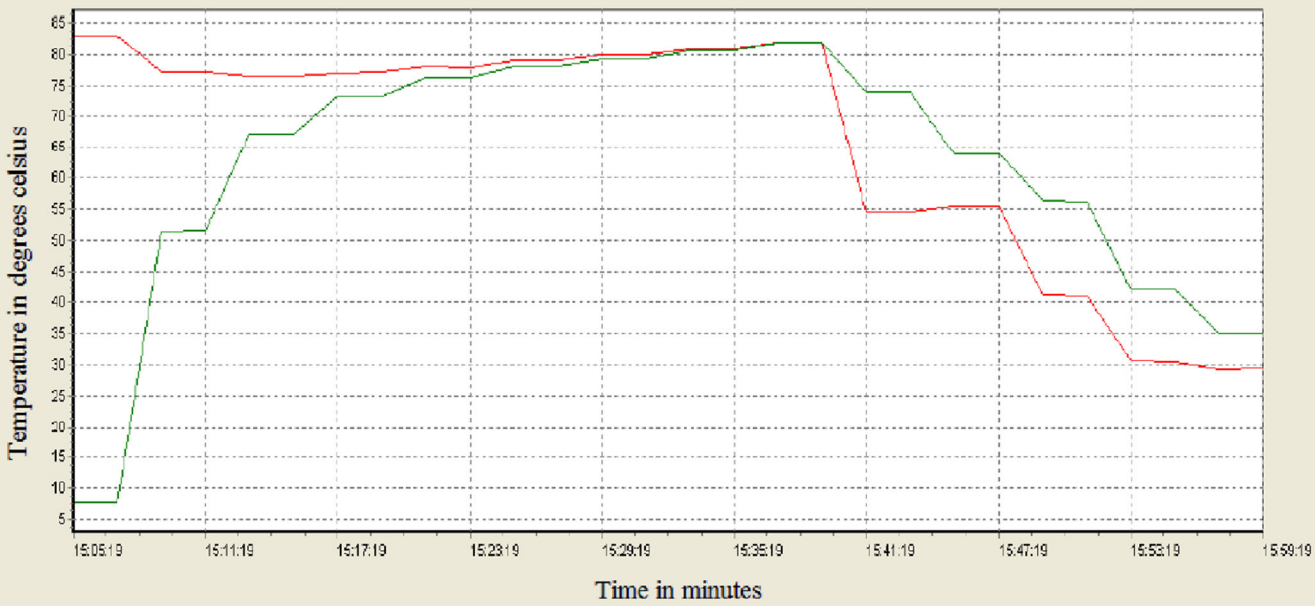

Fig. 1 Heat treatment parameters of the restructured product. *Red line* represents the temperature of the cooking water, and the *green line* represents the temperature inside the restructured product

Microbiological evaluation The results from the analyses of the processed products with all treatments were in agreement with Brazilian legislation. The results indicated the absence of Salmonella and Listeria sp. Moreover, sulphite-reducing clostridia (<1.0×10 CFU/g), coliforms at 45 °C (<3.0 MPN/g) and Staphylococcus aureus (<1.0×10^2 CFU/g) were not detected. With regard to total aerobic mesophiles, scores between 1.0×10 and 1.9×10^2 CFU/g were observed, indicating that the heat treatment process at 85 ° C for 34 min (Fig. 1) had the desired effect. Further, the calculated microbial reduction, based on the logarithmical reduction proposed by Thippareddi and Sanchez (2005; inactivation of at least seven logarithm cycles of *Salmonella* spp.) also confirms the final product safety.

Sensory analysis The analysis of variance (ANOVA) of acceptance data (Table 4) showed non-significant differences ($p \geq 0.05$) among the mean values of acceptance for colour ($p=0.088345$), odour ($p=0.1236$), flavour ($p=0.0710$), tenderness ($p=0.1170$), juiciness ($p=0.6165$) and overall quality ($p=0.1174$). As shown in Table 4, all attributes had a mean acceptance of 7 (moderately liked), with the exception of colour, which obtained a mean acceptance of 6.3 (slightly liked), thereby indicating that the restructured poultry products had a high acceptance among the consumers who evaluated the product. The reason for the lower scores for colour acceptance was likely the combination of the meat ingredients (drumsticks, chicken breast and MSCM) in the formulation of the restructured product, which gave it a slightly non-uniform

Table 4 Acceptance values for colour, odour, flavour, tenderness, juiciness, overall quality and purchase intention for the five restructured chicken meat product formulations

	T1	T2	T3	T4	T5	Overall Average
Overall Quality	$7.1^{a}\pm1.3$	$6.7^{a}\pm1.6$	$6.8^{a}\pm1.5$	$7.1^{a}\pm1.2$	$6.8^{a}\pm1.5$	$6.9^{a}\pm1.4$
Colour	$6.4^{a}\pm1.6$	$5.9^{a}\pm1.8$	$6.6^{a}\pm1.6$	$6.4^{a}\pm1.8$	$6.4^{a}\pm1.9$	$6.3^{a}\pm1.8$
Odour	$6.9^{a}\pm1.3$	$6.6^{a}\pm1.6$	$6.9^{a}\pm0.9$	$7.0^{a}\pm1.2$	$7.1^{a}\pm0.9$	$6.9^{a}\pm1.2$
Flavour	$7.1^{a}\pm1.2$	$6.6^{a}\pm1.6$	$6.9^{a}\pm1.5$	$7.1^{a}\pm1.2$	$7.0^{a}\pm1.3$	$6.9^{a}\pm1.4$
Tenderness	$7.2^{a}\pm0.9$	$6.7^{a}\pm1.5$	$7.0^{a}\pm1.2$	$7.2^{a}\pm1.1$	$7.1^{a}\pm1.2$	$7.0^{a}\pm1.2$
Juiciness	$6.9^{a}\pm1.1$	$6.7^{a}\pm1.7$	$6.8^{a}\pm1.3$	$7.0^{a}\pm1.3$	$6.7^{a}\pm1.5$	$6.8^{a}\pm1.4$
Purchase intention	$3.9^{a}\pm1.1$	$3.3^{bc}\pm1.3$	$3.8^{ab}\pm1.2$	$3.7^{ab}\pm1.2$	$3.7^{ab}\pm1.0$	

The means followed by the same letters in the row comparing the acceptance among treatments do not differ according to Tukey's test ($p>0.05$)

T1 Restructured with transglutaminase; *T2* Restructured with MSCM + transglutaminase; *T3* Restructured with egg albumin powder; *T4* Restructured with MSCM + egg albumin powder; *T5* Restructured with MSCM + transglutaminase + egg albumin powder

colour. The consumers in the present study were accustomed to eating chicken products as nuggets, fillet and hamburger. In the case of chicken nuggets, the coating masks the colour of the product, and in the case of chicken hamburger, the greater comminution of the chicken meat with fat gives the product a more uniform colour. It is interesting to note that among all the attributes assessed, there were no significant differences between the acceptance of the restructured products containing MSCM and those without MSCM, thereby suggesting that the MSCM did not alter the sensory characteristics of the restructured products. This result indicated that the meat-processing industry would be able to produce ready-to-eat products for the consumer market that are safe, nutritious and highly accepted in addition to having a high commercial value and considerably lower costs relative into currently available products.

In restructured chicken meat the substitution of 15 % of chicken meat (breast and drumstick) by MSCM results in a reduction of 14 % (approximately) in the final price of the product, because the price of kg of breast and drumstick for the industry is US$ 1,68 and US$ 1,88 respectively and the cost of MSCM elaborated with neck and back (including furcula bone) is US$ 0,20. Many authors (Ozkececi et al 2003, Guerra-Daros et al. 2005) describe the benefits of using MSCM in the formulation of industrialized meat products because of the low prices when compared with other kinds of meat.

Purchase intention The results of the ANOVA showed significant differences ($p \leq 0.05$) among the mean purchase intention values of the restructured products. The results showed that most of the treatments obtained mean purchase intention values of approximately 4 (probably will buy), indicating that the probability of purchase for the restructured products was high, except for treatment T2, which obtained an average of 3.3 (may or not may buy). The lower purchase intention for treatment T2 may be associated with the addition of MSCM because MSCM gave the product a darker colour, as evidenced by the instrumental analysis (Table 1), which showed that treatment T2 had the lowest average luminosity (L*) among the all treatments. These results indicated that colour is an important attribute for consumers and may influence their purchase intention of these products.

Conclusions The results of the present study showed that transglutaminase and egg albumin powder are useful ingredients in the formulation of restructured chicken meat products because they do not alter the physicochemical and microbiological quality and their use results in high sensory acceptance among consumers. The use of processed trimmings in MSCM together with albumin and/or TG was satisfactory; the restructured product containing both MSCM and albumin showed a slight advantage, as albumin positively influenced the colour of the product. TG addition was advantageous because it produced restructured products with greater firmness and binding capacity. For the sensory evaluation, there were no differences regarding the acceptance of texture and other evaluated attributes. One advantage of the addition of albumin is related to the low cost of this ingredient and the resulting improvement in colour for restructured products. Moreover, the use of MSCM in restructured chicken meat products produced positive results because it did not interfere with the sensory quality of the restructured product and it contributed to a considerable reduction in the product cost.

Therefore, the products developed in the present study are a viable alternative for the meat processing industry. These products would allow the transformation of cuts with no commercial value into new, ready-to-eat products with high added value and high sales potential in the consumer market.

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