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Quality assessment of cooked chicken breast meat at different storage temperatures

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Abstract

This study is aimed at estimating the shelf life of cooked chicken breast meat subjected to different storage temperatures. Analyses were carried out with industrialized cooked chicken breast stored at different temperatures (2, 4, 7, 10, 15 and 20°C). The shelf life was assessed through the presence of microorganisms: mesophilic, psychrotrophic, *Staphylococcus*, *Escherichia coli* and *Salmonella*. Analyses of color and cutting force were performed at each temperature studied. Sensory analysis was conducted under acceptability limits of 1.8. Temperature increase was found to reduce the microbiological shelf life. Industrialized cooked chicken breast had shelf life of 23, 14, 9, 6 days, 32 and 17 hours, when stored at 2, 4, 7, 10, 15 and 20°C, respectively. In the color analysis, luminosity and Chroma a* decreased while Chroma b* increased during the days of storage for all temperatures studied. Moreover, the cutting force of cooked chicken breast decreased during storage. The sensory shelf life was 11 days when stored at 2 °C and 2 days when stored at 20 °C. In conclusion can be say that the temperature changes have greater impact on microbiological growth, cutting force, color changes and sensory shelf life in industrialized cooked chicken breast meat.

Introduction

Production of chicken meat has undergone a remarkable growth in recent years, due to recent advances in animal technology. As a result of the growth in demand, meat producers began to diversify their products with a view to increasing its value and shelf life (Volpato *et al*., 2007). In poultry industry the determination of some microorganisms, such as aerobic mesophilic, psychrotrophic bacteria and *Staphylococcus* spp., are used as hygiene indicators in processing, storage quality and shelf life of products (Del Río *et al.*, 2007). The poultry meat has a high risk of contamination during processing. The main factors determining the deterioration of poultry meat are storage temperature, types and number of psychrotrophic bacteria (Tuncer and Sireli, 2008). With regard to the temperature changes over the supply chain, variation on microbial growth is an essential measure to predict the shelf life of foods, particularly with regard to spoilage microorganisms and assessed risk for pathogen-carrying food (Bobelyn *et al*., 2006). Many pathogens can be detected in the carcasses of poultry after processing (Newell *et al.*, 2001).

Psychrotrophic microorganisms are commonly found in food, which can grow even at cooling temperature and thus deteriorate meat. The aerobic mesophilic microorganisms can be used for assessing and monitoring the sanitary conditions of equipment and utensils during processing (Morton, 2001). *Staphylococcus* is prevalent during poultry slaughtering and processing and can be found in chicken skin and carcasses as well as the surface of machinery and equipment (Pepe *et al.*, 2006). One of the most often causes of Salmonella infection in humans is handling poultry carcasses and raw products parallel to consuming cooked chicken meat (Panisello *et al*., 2000). The coliforms are used to check the sanitary conditions of food (Suwansonthichai and Rengpipat, 2003).

The meat processing improves its palatability, enhancing the flavor and changing the cutting force, besides increasing the shelf life of products because many proteolytic enzymes get inactivated, which eventually reduces the appearance of unpleasant odors for a long time when stored under refrigeration. The chicken breast color is associated with the purchase intent and its softness influences the overall acceptability during the tasting (Zapata *et al*., 2006). Over the last decades, the determination of food shelf life has become a study and research topic (Manzocco and Lagazio, 2009). The biggest changes that occur in chicken meat when frozen are related

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to softness, color and off-flavors development (Yoon, 2002). The objective of this study was to estimate the microbial, color, cutting force and sensory shelf life of industrialized cooked chicken breast meat subjected to different storage temperatures.

Material and Methods

Raw material

Industrialized chicken breast was obtained from a poultry industry located in Chapecó - SC, Brazil, transported frozen at -20±2°C to the Laboratory of Food Technology at Federal University of Rio Grande - FURG, in Rio Grande - RS, Brazil, and then stored in incubation chambers under controlled temperature conditions (2, 4, 7, 10, 15 and 20°C). In order to characterize the product the following physicochemical analyses were carried out, according to the methodology recommended by AOAC (2000): pH, proximal composition, including determination of moisture, proteins, lipids and ash. Analyses of color and texture were also conducted.

The presence of aerobic mesophilic and psychrotrophic bacteria, *Staphylococcus* spp., *Salmonella* spp. and *Escherichia coli* was determined by microbiological analysis. The first analysis was undertaken as soon as the study temperature was reached. The incubation period depended on the time taken by microorganisms to reach the stationary growth phase. Sensory shelf life of cooked chicken breast at all temperatures studied was determined by sensory analysis.

Proximate composition

Moisture, ash, crude protein and crude fat contents were determined according to the methods described by AOAC (2000). Moisture was determined by the oven drying method at 110°C for 24 h; for cooked samples total water content was calculated as [100 - (total protein + total lipid + total ash)]. Total protein content was determined by the Kjeldhal method. Total lipids were evaluated by the Soxhlet method. Ash was determined by incineration in a muffle furnace at 550ºC.

Microbiological analysis

Each sample (25 g) was taken aseptically from each poultry fillet (breast), transferred aseptically to a stomacher bag (Seward Medical, London, UK), containing 225 mL of sterile 0.1% peptone water, and homogenized using a stomacher (Lab Blender 400; Seward Medical) for 60 s at room temperature. Serial dilutions were prepared in sterile 0.1% peptone water and surface plated in duplicate on standard plate count agar (SPCA, Difco) for the enumeration of aerobic mesophilic and psychrotrophic bacteria. Plates for mesophilic counts were stored at 35ºC for 48 h and plates for psychrotrophic counts were stored at 3.5ºC for 10 days.

Ten-fold serial dilution were prepared using sterile 0.1% peptone solution (9 mL), and spread plated (0.1 mL) in duplicate onto broths and/or agars for detection of typical colonies, biochemical confirmation and identification, and plate counting (*Salmonella* spp and *Staphylococcus)* or by the most probable number method (fecal coliform), according to classical methodology USDA (2005). *Salmonella* was isolated, initially, 25 g of sample were aseptically added to 225 mL of preenrichment medium, buffered peptone water (Oxoid, Basingstoke, 0020UK), and incubated for 18h at 37°C. The preenriched culture, 0.1 and 1 mL, respectively, was transferred to Rappaport –Vassiliadis broth (Oxoid) and Selenite broth (Difco Laboratories Detroit, MI) and incubated at 42 and 37°C, respectively. After 24 and 48 h of incubation, a loopful from each of the enriched broths was streaked onto plates of *Salmonella Shigella* agar (Difco) and XLD agar (Difco), and incubated at 37°C for 24 h.

pH

The pH was measured using a digital pH meter (Model PA 200, Marconi Instruments, Inc., Piracicaba, SP). About 10 g of sample (cooked chicken breast) was cut into small pieces to which 50 mL of distilled water was added and slurry was made using a blender (IKA,RW 20DZM.n model) and the pH was recorded.

Texture analysis

Texture analysis was carried out using a texture analyzer Model TA-XT2 plus (Stable Micro Systems, Surrey, England) calibrated for cutting speed of 2 mm/s, return speed of 5 mm/s and sensitivity of 0.250 N. Chicken breast samples were removed in the form of parallelepipeds of 1 x 1 x 1 cm, following the orientation of muscle fibers by Andrés *et al*., (2008) with values expressed in kgf. Samples were submitted to a cutting/shearing test using Warner-Bratzler work of shear (kgf), which indicated the total energy (work), required to shear (toughness).

Color

The color was evaluated using a Minolta Colorimeter, model Chroma Meter (CR400, São Paulo). Readings were performed for the three samples of cooked chicken breast of each treatment. The samples were evaluated in the L^*, a^* and b^* system.

Table 1. Proximal composition and pH of industrialized processed cooked chicken

Sample	Protein (%)	Moisture (%)	Crude fat (%)	Ash (%)	pH	Reference
Cooked breast	29.49±0.11	68.60±0.06	0.57±0.01	1.27±0.01	6.29±0.01	This work[a]
Cooked breast	61.70-70.0	27.90-35.70	1.10-3.20	0.70-1.30	6.10-6.20	Fletcher *et al*. (2000)*
Cooked breast	64.6 ± 0.2	30.8 ± 3.3	2.6 ± 0.2	1.1 ± 0.0	6.11	Galarz *et al*. (2010)

Average and standard deviation calculated from triplicate analysis of a sample
*Fletcher *et al.*, (2000) show value ranges

Assessment of sensory shelf life

In order to assess the sensory shelf life of meat, it was removed from the freezer and put in trays in a refrigerator to be thawed at 2°C for one night and then stored at different temperatures 2, 4, 7, 10, 15 and 20ºC. Afterwards, the samples were put in plastic plates for assessment of the sensory characteristics color, odor and texture. The panel was comprised of 12 previously trained judges who rated the sample following the attributes in the assessment form, where grade 3 was for "excellent quality" and grade 1 for "not acceptable quality". The days of analysis varied according to storage temperature. Following the method described by Bruckner (2010), analysis was performed on days 1, 2, 4, 7, 8, 9 and 11 of storage for all temperatures studied until grade 1.8 was reached, which was established as the sensory acceptability limit.

The grades given by judges to samples were rated according to each judge for each temperature studied. The rates assigned to samples were used to calculate the mean grade per attribute as recommended by Kreyenschmidt (2003) and Bruckner (2010). The means were used to calculate the Sensory Index obtained using Equation 1:

$$IS = \frac{2 \times C + 2 \times O + T}{5} \quad \text{Eq.1}$$

Where: IS = sensory index; C = color; O = odor; T= texture

Color and odor were measured twice compared with the texture due to the color and odor be the ones with the first most noticeable changes in the sensory quality of chicken breast. Such parameters were established by Bruckner (2010) and Kreyenschmidt *et al.* (2010). A chart of Sensory Index vs. Time was prepared for industrialized cooked chicken breast, indicating the 'acceptability limit' of 1.8 as the end of proper time of its shelf life. These values were assigned using the methodology described by Kreyenschmidt (2003).

Results and Discussion

Comparing the cuts Oda *et al.* (2004), found that chemical composition can be different depending on the muscular groups where the cutting is performed. In general Galarz *et al*., (2010), described several aspects that contribute to the variation in parameters of moisture, proteins, lipids and ashes, such as race, genetic group, sex, age and diet.

The percentage of protein found in the industrialized cooked chicken breast (IB) was 29.49 ± 0.11. This value is in accordance with Fletcher *et al*., (2000), who found in cooked chicken breast a percentage of protein ranging from 27.9 to 35.7%. However, such values do not agree with Faria *et al.*, (2008), who found in chicken breast a percentage of 21.43% protein, neither with Nunes (2003), who found in chicken breast fillets a percentage of 21.5 ± 0.4 of protein. Moreover, Danowska-Oziewicz *et al*., (2009) found in the analysis of protein in fresh turkey meat 22.44%. Values higher than those were found in chicken breast fillets used for the preparation of nuggets (25.5 ± 0.4) (Nunes *et al*., 2006).

The percentage of moisture in the industrialized cooked chicken breast was 68.6 ± 0.06. Table 1 shows the values of proximal composition and pH found in industrialized processed cooked chicken breast. The analysis of lipids in industrialized cooked chicken breast showed a value of 0.57 % ± 0.01, which agrees with Fletcher *et al.*, (2000). The value found for ash in industrialized cooked chicken breast was 1.27 % ± 0.01, which is consistent with Torres *et al*., (2000) (1.1%).

The mean pH for chicken breast meat is between 5.7 and 5.9 (Mendes, 2001). The pH value found in industrialized cooked chicken breast was 6.29 ±

Table 2. Values of cutting force and color for cooked chicken breast meat stored at 2°C

Time (hours)	Cuting Force (kgf/cm^2)	Color		
		L*	a*	b*
0	3.62±0.78^a	84.54±0.13^a	1.03±0.11^a	11.59±0.60^d
24	3.57±0.07^a	84.42±0.57^a	0.76±0.09^{ab}	11.65±0.39^d
72	3.14±0.54^{ab}	84.18±0.56^a	0.21±0.18^{bc}	11.96±0.55^{cd}
144	2.75±0.03^{ab}	83.23±1.29^a	0.06±0.25^c	12.50±0.66^{bcd}
216	2.86±0.39^{ab}	83.15±0.85^a	0.36±0.30^{abc}	12.52±0.23^{bcd}
288	2.75±0.19^{ab}	83.15±0.85^a	0.36±0.30^{abc}	12.52±0.23^{bcd}
360	2.54±0.51^{ab}	82.99±0.19^a	0.58±0.13^{abc}	13.15±0.68^{bc}
432	2.37±0.84^{ab}	82.91±0.16^a	0.63±0.31^{abc}	13.88±0.20^b
504	1.63±0.85^b	82.79±0.81^a	0.77±0.33^{ab}	16.01±0.67^a

Average and standard deviation calculated from triplicate analysis of a sample. Means followed by the same letter in the column did not differ by Tukey Test (P<0.05).

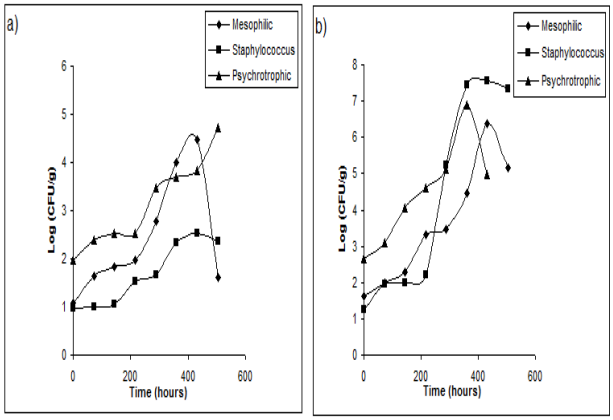

Figure 1. Growth curve of mesophilic microorganisms, *Staphylococcus* spp. and psychrotrophic spp. for industrialized processed cooked chicken breast stored at 2°C and 4°C. [where a) 2°C; b) 4°C].

0.01, which is above the values found by Mendes (2001). The values of this study were also within the range provided by the meat processing industry of cooked chicken breast (6.0 to 6.5). Quio *et al*. (2002) reported an increase in pH of chicken breast meat due to the accumulation of ammonia and amines by psychotropic bacteria. pH values of 5.9 ± 0.1, 5.8 to 5.9, and 5.96 were found in chicken breast by Nunes *et al.*, (2006) and Quiao *et al*. (2001) respectively. However, the pH values found by Fletcher *et al.,* (2000) and Torre *et al.* (2000) are consistent with the ones for industrialized cooked chicken breast found in this study. The pH being within the ranges considered good for chicken meat indicates a good meat quality, may have a shelf life longer than a chicken muscle, for example, that has the pH value of 7.2 (Fletcher *et al*., 2000).

Microbiological analysis

Microbiological analysis was performed to determine the shelf life in industrialized cooked chicken breast (IB) at all temperatures studied. Figure 1 shows the growth curves of mesophilic microorganisms, *Staphylococcus* spp. and *psychrotrophic* spp. for industrialized processed cooked chicken breast stored at 2 and 4°C. Differences in temperature can result in major deterioration of the product Dominguez and Schaffner (2007). The meat that exceeds mesophilic count of 106 CFU.g^{-1} is considered out of the ideal sanitary conditions (Al-Dughaym and Altabari, 2010). Based on this, the pattern established in this study was 106 CFU/g as the limit of determination of microbiological shelf life for mesophilic microorganisms. This agrees with Morshedy and Sallam (2009), who found for chicken carcasses in a zero-day storage average score of 4.62 log CFU/g but has obtained a higher score in the sixth and eighth days of storage at 2°C (7.08 and 8.63 log/CFU/g), respectively, exceeding the maximum required for aerobic mesophilic bacteria. Such values also disagree with those found in this study for cooked chicken breast stored at 2°C.

The maximum growth rate for aerobic mesophilic microorganisms in industrialized cooked chicken breast increased with increasing storage temperature in this study. It was found that the temperature of 20°C obtained a delta of microbial growth curve higher than the acceptable limit for this microorganism in 20 h. A longer shelf life was found at temperatures of 2°C and 4°C, which are less than the ideal for mesophilic microorganisms (20 to 45°C) (Madigan *et al.*, 2004). As temperature was increased from 4°C to 10°C the shelf life was found to reduce. At higher temperatures the shelf life of aerobic mesophilic microorganisms was reduced. This is consistent with Nunes (2003), who showed that at ambient temperatures (above

10°C) every 5°C the temperature rises the shelf life decrease half the time.

Jay (2005) found in pre-cooked chicken 3.9 log CFU/g of mesophilic microorganisms at a zero-day storage. This value is in disagreement with this study, which found lower values to all temperatures studied in the time of zero-day storage. Using a standard 10^3 (CFU/g) for *Staphylococcus* spp., industrialized cooked chicken breast at 2°C had a shelf life of approximately 552 h (around 23 days). The high presence of this microorganism is an indicator of potential danger to public health due to staphylococcal enterotoxin. Brazilian law permits a maximum limit of microbial growth of 10^3 (CFU/g) for coagulase-positive Staphylococcus in meat (Brasil, 2001). In this study the maximum count of 10^3 log (CFU/g) was also taken into account as a limit of microbial shelf life for Staphylococcus spp. in industrialized cooked chicken breast.

Freezing causes mechanical damage in the cell walls and membranes due to formation of intracellular crystals (Geiges, 1996), which leads microorganisms to death or leave them injured, thus leading to increased microbial shelf life. The industrialized processed cooked chicken breast had greater shelf life when stored at a temperature of 2°C due to the fact it is a temperature close to freezing (0°C) and the freezing temperature reduces microbial growth.

This study disagreed with Takano *et al.* (1989) and Nunes (2003), who showed that freezing process sometimes is not effective in reducing the microbial flora, but there is the possibility of spoilage or pathogenic bacteria to survive during frozen storage, causing food-borne toxinfections or food spoilage after thawing. Fallah *et al*., (2010) studied chicke\n breast meat stored at 4°C and found 5.59 (CFU/g) in the samples of aerobic mesophilic bacteria. After 15 days of storage they found 7.88 log (CFU/g) the same microorganisms. This value is above those found for mesophilic bacteria in cooked chicken breast stored at 4°C for both the initial and final counts in this study.

The mesophilic bacteria are considered the best indicators of microbiological quality of food and it can provides indications of the hygienic conditions for their preparation and storage as well as the potential health risks to consumers (Gomes and Furlanetto, 1987). Accordingly, it can be observed that the processing conditions of industrialized cooked chicken breast were appropriate. The industrialized cooked chicken breast at 4°C had a shelf life of approximately 336 h, and the microorganism with the highest growth log phase was *Staphylococcus* spp. Figure 2 shows graphs of growth curve of mesophylics,

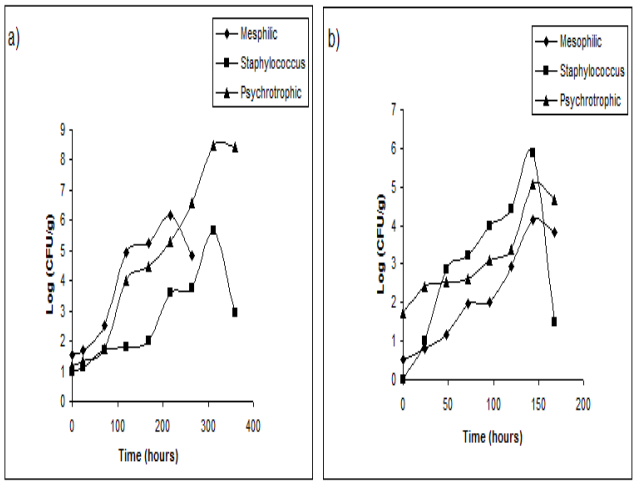

Figure 2. Growth curve of mesophilic microorganisms, *Staphylococcus* spp. and psychrotrophic spp. for industrialized processed cooked chicken breast stored at 7°C and 10°C [where a) 7°C; b) 10°C]

Staphylococcus spp. and psychrotrophic spp. found in industrialized processed cooked chicken breast stored at 7 and 10°C.

Under normal packing conditions, the shelf life of chilled meat is limited through multiplication and biochemical activity of aerobic mesophilic and psychrotrophic bacteria (Morshedy and Sallam, 2009). For poultry thighs in a zero-day storage period, Del Río *et al.*, (2007), found 5.10 ± 0.59 (UFC/g) for aerobic mesophilic bacteria and 4.37 ± 0.77 (UFC/g) for psychrotrophic microorganisms. In only one day of storage, the count of aerobic mesophilic bacteria has microbiologically expired in opposition to this study, which found low counts of aerobic mesophilic bacteria in the first day of storage. Industrialized cooked chicken breast presented a shelf life of 216 h at 7°C, considering that psychrotrophics had the highest log phase of multiplication among all microorganisms. Psychrotrophic bacteria are among the microorganisms that have good development at cooling temperatures (0-7°C) (Jay, 2005). However, this disagrees with this study, since the lower the storage temperature, the higher the shelf life found for both samples. The lower temperatures (2, 4 and 7°C) caused microbial growth to decrease, thus extending the product shelf life.

Smolander *et al*. (2004), studied pieces of chicken stored at 7ºC and verified that the count of aerobic mesophilic and psychrotrophic increased constantly until the count of 108 Log CFU/g in 9 days of storage. In this study, the microbial count throughout the storage increased as well. *Staphylococcus* spp. presented the biggest growth log phase for cooked meat stored at 10ºC. Industrialized cooked chicken breast had a shelf life of 6 days approximately, when stored at 10ºC. In this study, *Staphylococcus* spp.

Table 3. Values of cutting force and color for cooked chicken breast meat stored

Time (hours)	Cuting Force (kgf/cm^2)	Color		
		L*	a*	b*
0	4.27±0.67^a	83.36±0.72^a	0.97±0.15^a	13.33±0.90
24	3.41±0.53^{ab}	83.26±1.15^a	0.93±0.15^a	13.44±1.08
72	3.30±0.40^{ab}	83.06±0.86^{ab}	0.54±0.04^{ab}	13.76±1.08
144	3.14±0.32^{ab}	82.72±0.38^{ab}	0.03±0.25^b	14.11±0.85
216	2.98±0.13^{ab}	82.35±0.53^{ab}	-0.14±0.17^b	14.22±0.80
288	2.83±0.18^{ab}	82.07±0.50^b	-0.17±0.07^b	14.77±0.74
360	2.30±1.37^b	81.80±0.41^b	-0.22±0.09^b	15.16±0.47
432	2.14±1.01^b	81.53±0.69^{ab}	0.35±0.12^{ab}	16.23±1.15
504	1.98±0.67^b	81.26±0.57^b	1.08±0.75^a	17.95±0.44

Average and standard deviation calculated from triplicate analysis of a sample. Means followed by the same letter in the column did not differ by Tukey Test (P<0.05).

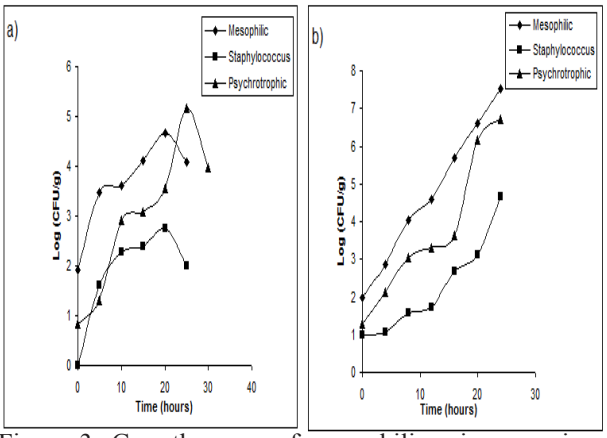

Figure 3. Growth curve of mesophilic microorganisms, *Staphylococcus* spp. and psychrotrophic spp. for industrialized processed cooked chicken breast stored at 15°C and 20°C [where a) 15°C; b) 20°C]

was found in cooked chicken breast. Schlegelova *et al.*, (2004) and Alvarez-Astorga *et al*., (2002), reported similar results with meat and chicken parts and processed chicken products, respectively. Figure 3 shows graphics of growth curve of mesophilic bacteria, *Staphylococcus* spp. and psychrotrophic spp. found in industrialized processed cooked chicken breast stored at 15 and 20°C.

Brazilian law does not specify patterns for psychrotrophic ssp. nor *Staphylococcus* spp. in chicken breast (Brasil, 2001). The ICMSF (1986), set a standard of 10^6 to 10^7 CFU/g as the end of shelf live in meats for aerobic psychrotrophic microorganisms. Based on this, in this study the limit set as the end of shelf life in industrialized cooked chicken breast was 10^6 CFU/g. Aerobic psychrotrophic bacteria can thrive well at cooling temperatures. The species responsible for the product deterioration and because of this they are important to the shelf life of chilled food (Miyagusku *et al.*, 2003). This study shows that psychrotrophic bacteria proliferated constantly when cooked chicken breast was stored at 15ºC, which means such microorganisms could develop at 15ºC due to the fact that they are close to their optimal multiplication temperature (20°C).

Shelf life of industrialized cooked chicken breast stored at 15ºC was 32 h approximately. Mesophilic bacteria had the highest log phase for industrialized cooked chicken breast. The mesophilic microorganisms had the highest exponential growth phase in industrialized cooked chicken breast, which can be explained due the fact that such microorganisms thrive at higher temperatures, such as 20 °C. When stored at 20°C industrialized cooked chicken breast (IB) had a shelf life of approximately 17 h. There was no detection of *Salmonella* spp. and *Escherichia* coli in the industrialized processed cooked chicken breast meat.

During storage meat are affected by several changes which can interfere with its quality attributes (Kinsman *et al.*, 1994; Liu *et al*., 2003). Such changes are reflected through color, tenderness, flavor, and juiciness of the meat. Among these, color is first attributes to be noticed (Liu *et al.*, 2003). Table 2 shows the values of cutting force and color found for industrialized cooked chicken breast (IB) stored at 2°C.

In Table 2 can be seen, that the cutting force

Table 4. Values of cutting force and color for cooked chicken breast meat stored

Time (hours)	Cuting Force (kgf/cm^2)	Color		
		L*	a*	b*
0	3.09±0.20^{a}	83.61±0.02^{a}	1.04±0.38^{a}	14.22±0.43^{c}
24	3.03±0.32^{a}	83.49±0.39^{a}	0.73±0.08^{ab}	14.44±0.71^{c}
72	2.92±0.20^{a}	82.49±0.39^{a}	0.50±0.05^{ab}	15.32±0.33^{c}
120	2.82±0.67^{a}	79.86±0.54^{b}	0.29±0.08^{ab}	17.31±0.40^{b}
168	2.74±0.47^{a}	78.39±0.75^{bc}	0.18±0.17^{b}	17.97±0.54^{b}
216	2.63±0.46^{a}	77.49±0.99^{cd}	0.13±0.20^{b}	18.53±0.02^{b}
264	2.41±0.61^{a}	76.73±0.57^{cd}	0.12±0.30^{b}	19.71±0.37^{b}
312	2.35±0.32^{a}	76.35±0.79^{d}	0.10±0.02^{b}	23.34±0.31^{a}
360	2.30±0.61^{a}	75.97±0.52^{d}	1.18±0.12^{ab}	24.14±0.28^{a}

Average and standard deviation calculated from triplicate analysis of a sample. Means followed by the same letter in the column did not differ by Tukey Test (P<0.05).

showed significant difference between the first and last day of storage. The cutting force decreased during storage from 3.62 to 1.63 kgf/cm2 for the industrialized cooked chicken breast. Such difference can relate to nutritional and physicochemical factors (Oda *et al.*, 2004). Was not observed significant difference during the study, for lightness and analysis of Chroma a* for the values of Chroma b* was observed a significant difference between the first and last day of analysis when cooked chicken breast meat was stored at 2°C.

The Chroma a* values decreased with storage days and tended to greenish color. The freezing seemed to produce a darkening increased with decreasing lightness of the color of raw chicken meat. This agrees with this study, which also found a lightness (L*) more pronounced for the industrialized cooked chicken breast. Such effect was observed by Lyon and Lyon (2002) both in the breast meat and the chicken leg. In this study there was an increase in Chroma b* during storage at 2°C, tending to yellowish color. This increase in Chroma a* and b* is consistent with Saláková *et al*., (2009), who found for cooked broiler chicken meat a L* ranging from 79.39 to 82.48, from 1.97 to 2.72 for Chroma a* and from 14.28 to 15.85 for Chroma b*.

Table 3 shows results of cutting force and color found for industrialized cooked chicken breast stored at 4°C. In relation the L * and Chroma b*, can be seen had significant difference between the evaluated days. Was observed a decrease in Chroma a*, but with the passing of days of storage this value increased again and not presented significant difference between the first and last day of storage. Moreover, Table 3 also shows that the values of luminosity (L*) and Chroma a* decreased during storage. The chicken breast tended to have a darker color for luminosity and tended to be greener for Chroma a* in both samples.

There was an increase in Chroma b* during storage at 4°C, which resulted in a tendency for a darker color. Nunes (2003) found an amount of 4.38 for red rate (a*) in analyses of broiler breast. The yellow rate (b*) was 0.51; -3.59 and 3.78 in average, minimum and maximum analyses respectively. Such values disagree with the ones found in this study, since the amounts were lower than the ones found by the author. Saláková *et al*. (2009) argued that the positive value of L* for cooked chicken breast and the loss during cooking are correlated.

In Table 3 can be observed, that the cutting force results obtained, showed significant difference during storage. The cutting force at 4°C also decreased throughout the storage period. The cutting force for cooked chicken breast processed in laboratory varied from 5.03 (0 hour) to 4.37 Kgf/cm^2 (360 h). Table 4 shows the results of cutting force and color for industrialized cooked chicken breast (IB) stored at 7°C. In relation to the analysis of color, lightness (L*) and Chroma b*, showed significant differences during the period analyzed. The values of Chroma a*, showed little variation, without significant differences between the evaluated days. There was a decrease in Chroma a* when the sample was stored at 7°C. Chroma b* increased in both samples, which tended to have a more yellowish color. According to Genot (2003), the meat darkening during conservation is due to the pigment oxidation of the muscle tissue, whose stability depends on the animal species,

Table 5. Values of cutting force and color for cooked chicken breast meat stored at 10°C

Time (hours)	Cuting Force (kgf/cm²)	Color		
		L*	a*	b*
0	3.65±0.7^{a}	82.0±1.03^{a}	1.22±0.43^{a}	12.18±1.16^{b}
24	2.91±0.42^{a}	81.85±0.2^{a}	-0.2±0.10^{b}	13.74±0.71^{ab}
72	2.83±0.46^{a}	81.55±0.62^{a}	-0.47±0.24^{b}	14.76±0.28^{a}
96	2.77±0.15^{a}	81.28±0.94^{a}	-0.58±0.12^{b}	15.01±1.12^{a}
120	2.72±0.64^{a}	81.08±0.37^{a}	-0.81±0.31^{b}	15.55±1.28^{a}
144	2.67±0.77^{a}	80.66±0.56^{a}	-0.95±0.16^{b}	15.70±0.35^{a}
168	2.35±0.68^{a}	80.25±0.68^{a}	-1.0±0.49^{b}	15.86±0.11^{a}

Average and standard deviation calculated from triplicate analysis of a sample. Means followed by the same letter in the column did not differ by Tukey Test (P<0.05).

Table 6. Values of cutting force and color for cooked chicken breast meat stored at 15°C

Time (hours)	Cuting Force (kgf/cm²)	Color		
		L*	a*	b*
0	3.53±0.03^{a}	81.11±1.11^{a}	0.98±0.30^{a}	13.88±0.66^{a}
5	2.67±0.07^{b}	80.80±0.86^{a}	0.90±0.42^{a}	14.62±1.17^{a}
10	2.41±0.23^{b}	80.70±1.11^{a}	0.80±0.30^{a}	15.19±0.66^{a}
15	1.74±0.01^{c}	80.60±0.8^{a}	0.60±0.12^{a}	15.55±0.86^{a}
20	1.11±0.38^{d}	80.35±1.05^{a}	0.36±0.32^{a}	15.67±1.18^{a}
25	0.96±0.13^{d}	79.92±0.54^{a}	0.26±0.40^{a}	15.79±0.88^{a}
30	0.81±0.14^{d}	79.81±0.73^{a}	0.21±0.57^{a}	16.14±0.12^{a}

Average and standard deviation calculated from triplicate analysis of a sample. Means followed by the same letter in the column did not differ by Tukey Test (P<0.05).

the biochemical characteristics of the muscle, and external parameters.

In Table 4, when the cooked chicken breast meat was stored at 7°C the cutting force was not changed with the passing of days of storage. The cutting force also decreased during storage at 7°C and varied from 3.09 to 2.30 for industrialized processed cooked chicken breast. Table 5 shows results of cutting force and color found for industrialized cooked chicken breast (IB) stored at 10°C. There was a decreased in the cutting force during storage; however, was not observed significant difference in relation the cutting force for cooked chicken breast meat stored at 10°C. Was observed a decrease in lightness (L*) and Chroma a* and an increase in Chroma b*. The parameter lightness (L*), not showed significant difference, already the values of Chroma a* and b* showed significant differences during the storage period.

Table 6 shows the results of cutting force and color found for industrialized cooked chicken breast (IB) stored at 15°C. There was a decrease in the cutting force, which went from 3.53 to 0.81 Kgf/cm² (0 to 30 storage hours respectively) and was observed significant difference during storage for the cutting force of cooked chicken breast meat. The main factor that influences the cutting force of chicken breast fillets is the age of the birds at slaughter (Northcutt *et al*., 2001). With the work of cutting force at higher temperatures, the meat fibers break more easily throughout the storage. In relation to analysis of color, all parameters not showed significant difference

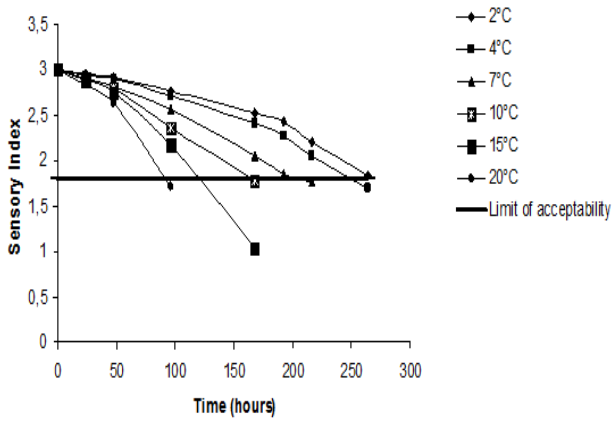

Figure 4. Analysis of sensory shelf life in industrialized cooked chicken breast at different storage temperatures

during the period of 30 h. There was L* rate of 81.11 in the industrialized cooked chicken breast at zero hour and 79.81 at 30 h of storage. There was a decrease in Chroma a* and an increase in Chroma b* during storage.

Table 7 shows the results of cutting force and color found for industrialized cooked chicken breast (IB) stored at 20°C. The cutting force decreased with the passing of storage time, showing significant difference between the study periods (24 h). The cutting force decreased during storage, but there was a high decrease at 20°C compared to the other temperatures studied, ranging from 3.13 to 0.98 Kgf/cm^2. The high decrease of the cutting force in chicken breast stored at 20°C was due to the fact that the industrialized processed meat underwent a freezing process. Even though the freezing was quick, there may have been formation of small ice crystals, which melted during storage at the temperatures studied and made the chicken breast meat more moist and the fibers less resistant to the cutting (Roça, 2000).

Chroma a* decreased, while Chroma b* increased at this temperature. The parameter of lightness (L*) showed significant difference during the study period, however for the parameters Chroma a* and b* was not observed significant difference, showing that in this period of study, changes were not pronounced. The changes in color at all the temperatures studied followed the changes observed during the period of sensory assessment of samples, which also had a decrease compared to color analysis.

Sensory shelf life

Figure 4 shows the curves found for the sensory shelf life analysis of industrialized cooked chicken breast. The curves show a inverse relation between values of sensory index and temperature. In other words, the lowest indexes were found for chicken breast meat stored at 20 and 15°C, and the highest indexes for breasts stored at 2°C. Accordingly

Table 7. Values of cutting force and color for cooked chicken meat stored at 20 °C

Time	Cuting Force	Color		
(hours)	(kgf/cm^2)	L*	a*	b*
0	3.13±0.29^a	82.07±0.58^a	0.87±0.24^a	14.21±0.68^a
4	2.12±0.54^{ab}	81.07±1.47^{ab}	0.62±0.87^a	14.47±0.36^a
8	2.07±0.27^{ab}	81.00±0.33^{ab}	0.58±0.50^a	15.36±0.12^a
12	1.36±0.95^b	80.89±0.87^{ab}	0.57±0.12^a	15.85±1.70^a
16	1.21±0.36^b	80.63±0.47^{ab}	0.56±0.09^a	16.03±0.70^a
20	1.09±0.80^b	80.45±1.04^{ab}	0.55±0.59^a	16.28±1.45^a
24	0.98±0.56^b	79.03±1.41^b	0.46±0.24^a	16.71±0.79^a

Average and standard deviation calculated from triplicate analysis of a sample. Means followed by the same letter in the column did not differ by Tukey Test (P<0.05)

Kreyenschmidt *et al*. (2010) showed that the sensory acceptability of cooked ham decreased during storage. Higher storage temperature resulted in faster decrease in sensory acceptability. Bruckner (2010) reported that microbial growth and shelf life are directly related. Such findings agree with this study, once the higher the temperature the lower the shelf life.

Comparing the curves and considering the value of the acceptability limit (1.8), it is possible to conclude that the temperature of 2°C was above the limit until day 11. The sensory shelf life at 4°C was nine days (216 h), and it was below the acceptability limit (1.8) on day 11. At 7°C, the sensory shelf life was eight days (192 h) and after this period it was below the acceptability limit (1.8). The sensory shelf life at 10°C and 15°C was 96 h (four days), while at 20°C it was only two days, when the analysis ceased.

It is possible to see a decrease in shelf life in all the temperatures studied, which is related to a decrease in microbiological shelf life. However, in this study the sensory shelf life was lower when compared to the microbial shelf life. This is related to the fact that several microorganisms cause a rapid development of odor and color due to its chemical reactions, which are undesirable for the product (Prändel *et al*., 1994). This implies that visually the product may no longer fit for consumption, but microbiologically it is still consumable.

Conclusion

The proximal composition analysis for industrialized cooked chicken breast showed values within the limits set by the industry. Microbial growth curve was higher at higher temperatures. As temperature was decreased, industrialized cooked

chicken breast had a longer microbiological shelf life. There was no detection of *Salmonella* spp. and *Escherichia coli* in the meat.

The freezing made the values of initial lightness (L^*) to decrease and all temperatures of the study to increase up to the Chroma b^*, showing that over the storage time the samples were degraded. The cutting force decreased for all temperatures studied during storage. The temperature of 20°C for industrialized cooked chicken breast showed the lowest resistance to shear force at the end of the analysis compared with the other temperatures.

The sensory shelf life of industrialized cooked chicken breast was lower at higher temperatures due to the increased microbial growth found at these temperatures. With the results of this study, it was concluded that both physical and microbiological characteristics were decreasing over storage time, showing the importance of this study to know the ideal storage temperature to have a chicken breast cooked meat with microbiological and sensory acceptable shelf life.

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