International Food Research Journal 21(3): 1143-1148 (2014)
Journal homepage: *http://www.ifrj.upm.edu.my*

Effects of temperature variation in the simulation of the supply chain of poultry products

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Article history

Received: 4 November 2013
Received in revised form: 18 December 2013
Accepted: 29 December 2013

Keywords

Decay
Chicken based products
Sanitation
Temperature control
Supply chain

Abstract

The aim of this study was to investigate the effects of temperature variation in the deterioration of poultry products. For this, the shelf life of chilled chicken cuts was analyzed in samples subjected to real conditions and ground transportation, storage was simulated under different commercial and domestic storage temperatures. The results showed that during sample storage, a small increase in temperature caused changes in the kinetics of physical-chemical decay, as well as a pronounced acceleration in the growth of spoilage microorganisms and pathogens, rapidly reducing the shelf life of the products. These results provide support for the development of strategies aimed at the effective temperature control during the supply chain of fresh poultry products as a measure to reduce the contamination levels found in this study.

Introduction

Chicken meat is a food of animal origin, rich in proteins of high biological value and low cost (Mantilha *et al.*, 2011). Data released by the Department of Agriculture of the United States (USDA, 2012) show that these features have made the chicken one of the most important sources of animal protein to the world population, whose consumption per capita reached 14.6 kg in 2012.

Temperature is considered the main factor affecting the quality and safety of perishable food products (Karadag and Puhakka, 2010). To slow the growth of microorganisms and extend shelf life of poultry products, the cold chain is widely used (Shin *et al.*, 2010). However, the temperature control during transport, distribution and storage (commercial and domestic) is often flawed, with conditions other than those recommended by the manufacturer, with values that can pass the 15°C (Cárdenas *et al.*, 2008; Limbo *et al.*, 2010).

Most research studying the life-span of products made from chicken has been performed under ideal conditions of temperature (0 to 4 ± 1°C) (Chouliara *et al.*, 2008; Shin *et al.*, 2010; Cortez-Vega *et al.*, 2012), instead of evaluating real storage situations. The objective of this work was to investigate the effects of temperature variation in the deterioration of poultry products. For this, the shelf life of chilled chicken cuts was analyzed in samples subjected to real conditions and ground transportation, storage under different simulated commercial and domestic storage temperatures.

Material and Methods

The raw material used was chilled boneless chicken breast, supplied by two slaughterhouses under the Federal Inspection Service (FIS), located in Rio Grande do Sul / Brazil. The experiment was conducted at the Laboratory of Food Technology, located in the City Campus of the Federal University of Rio Grande (FURG), Rio Grande / RS / Brazil.

Evaluation of the logistics of transport for fresh poultry

The mapping of the temperature during distribution of fresh poultry food was evaluated in two land transportation routes . The first of approximately 100 km (route 1), and the other, about 430 km (route 2). These were chosen to represent monitoring of a land route of a short path and another of a long path.

The temperature was monitored using data loggers (Data Logger DHT5012, Perceptec, São Paulo, Brazil), which were used to measure muscle and environment temperatures in refrigerated truck. The position of the data collectors followed the study by Mai *et al.* (2011), whose results indicate that the worst condition was near the opening door of the trunk of the truck.

Storage simulation

After completing the trip, the products were unloaded at their final destination, and the samples were immediately transported in ice coolers, in less than twenty minutes, until the Laboratory of Food Technology, Federal University of Rio Grande

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(FURG) / RS / Brazil. In the laboratory, Simulations of temperature conditions during storage in commercial premises (point of sale) and household refrigerator were performed. For this, the samples were stored in three high-precision incubators (Model MA 415 / S, Marconi, Sao Paulo, Brazil) for twelve days (samples shelf life described in the packaging).

The temperatures measured were: 3.0 (ideal situation), 7.0 and 10.0 (abusive situation) ± 0.5°C, monitored every two minutes by data collectors. Products from the logistics route 1 were stored at 3.0 and 10.0 ± 0.5°C, while samples from Route 2 were maintained at 3.0 and 7.0 ± 0.5°C.

The temperature of 3°C was chosen because it represents the recommended condition for the storage of refrigerated products (0 - 4 °C) (Brazil, 1998). The others were based on the work performed by Limbo *et al.* (2010), Cárdenas *et al.* (2008), Nychas *et al.* (2008), Kennedy *et al.* (2005), whose studies featured temperatures of around 7 and 10°C as the temperature profiles that represent the actual conditions of the distribution chain of fresh meat products, from the producer to the final consumer.

Physical-chemical analyses

The physico-chemical analyses were conducted at 0, 1, 4, 7, 10 and 12 days of storage in triplicate for each condition of the storage temperature. The pH was determined using the digital potentiometer (Model PM 608, ANALION Devices and Sensors Industry and Trade Ltd., São Paulo, Brazil) measured in homogenized chicken muscle in distilled water, 1:1 w / v. The degree of lipid oxidation was quantified by the thiobarbituric acid reactive substances method (TBA), recommended by the Adolfo Lutz Institute (1985).

The color of the meat samples was determined using a colorimeter (Chroma Meter Model CR-400/410, Konica Minolta, Osaka, Japan) by the CIELab system (iluminate D65) obtaining the dimensions L^*, a^*, b^*. From these parameters color differences (ΔE^*) were calculated using Equation 1.

$$\Delta E^* = \sqrt{\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (1)$$

Where: $\Delta L^* = L - L_{zero}$; $\Delta a^* = a - a_{zero}$; $\Delta b^* = b - b_{zero}$.

Microbiological stability

Microbiological analyses were conducted on boneless chicken breast at 0, 1, 4, 7, 10 and 12 days of storage, for each stock condition, with the exception of *Salmonella* spp., done only at time zero. All analyses were performed in triplicate. The choice of microorganisms for this study was based on literature (Jay, 2005) and Brazilian legislation (Brazil, 1998). Analyses were performed using the total count of psychrotrophic aerobes; enumeration of *Staphylococcus* spp.; determination of thermotolerant coliforms at 45°C and *Salmonella* spp.

A sample (25 g) was taken aseptically from the boneless chicken 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) during 60s at room temperature, serial dilutions were then prepared in sterile 0.1% peptone water for the continuation of the analysis. For the enumeration of psychrotrophic microorganisms, *Staphylococcus* spp. and the detection of *Salmonella* spp. the classical methodology according to American Public Health Association (APHA, 2001) was used. Thermotolerant coliforms at 45°C were investigated according to the official methodology of the Ministry of Agriculture, Livestock and Supply (MAPA) (Brazil, 2003).

Results and Discussion

Evaluation of terrestrial logistics for fresh poultry

Figure 1 shows the temperature results measured by the data loggers for monitoring the logistic routes. Not was observed temperature deviation during route 1, the values measured in this route showed results below the Brazilian standard, 4 ± 1°C (Brazil, 1998). A different situation was observed in route 2, when the temperature of the truck came to a standstill for two hours at approximately 8°C. These shifts coincided with the delivery of products in the retail market of the destination city, caused by opening the trunk of the truck. Similar results were found by Rokka *et al.* (2004) and Smolander *et al.* (2004), describing temperature variations in the logistics chain of chilled cuts of chicken in the Republic of Finland from 2.9 to 8.3°C.

Besides the temperature oscillations of the truck, the product temperature remained below 4°C throughout the path, with average values of 1.0 ± 0.8°C and 2.1 ± 0.6°C for the products transported by route 1 and route 2, respectively, as shown in Figure 1. It should be noted that the monitoring of the logistic routes was conducted in the evening and early morning in May (route 1) and June (route 2), where the temperature measured showed values of 7.9 ± 0.8°C and 10.8 ± 1.5°C, respectively, a factor that may have influenced positively in the evaluation of the distribution chain of these products.

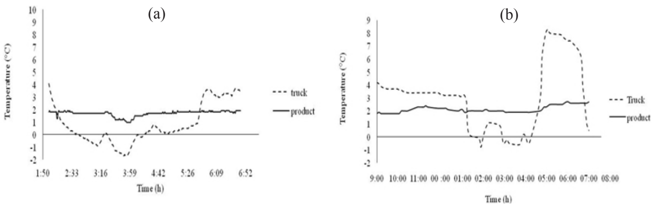

Figure 1. Temperature values measured by data loggers during: (a) route 1 (b) route 2.

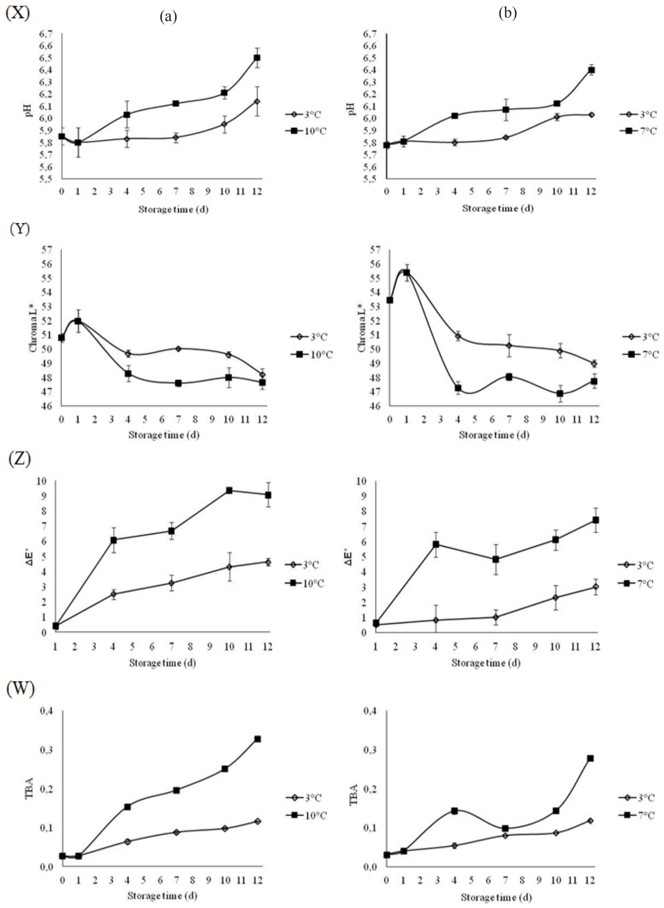

Figure 2. Results of physicochemical analysis, (X) pH, (Y) color expressed in *chroma* L*, (Z) color difference (ΔE), (W) TBA in $mg_{malonaldehyde}/kg_{sample}$, samples of boneless chicken breast stored under: (a) 3 and 10°C, (b) 3 and 7°C. The error bars represent the standard deviation of triplicates for each measurement.

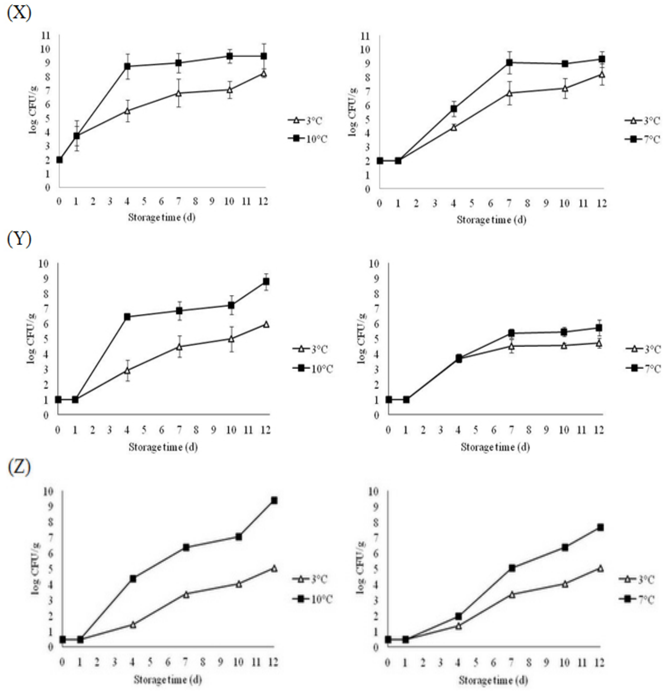

Figure 3. Results of microbiological analyses - (X) psychrotrophic, (Y) *staphylococcus* spp. (Z) thermotolerant coliforms - of the meat samples maintained at: (a) 3 and 10°C, (b) 3 and 7°C. The error bars represent the standard deviation of triplicates for each measurement.

Simulation of commercial and domestic storage

Physical-chemical analyses

Figure 2 shows the results of physicochemical analyses performed on samples of boneless chicken breast, along the twelve days of storage at different temperature conditions. The samples pH values measured at time zero characterized a raw material of good quality. Results of this parameter far above or far below 5.8 are considered abnormal because it will influence the quality, both functional and microbiological, of meat (Olivo, 2006).

Figure 2X shows an increase in the pH of the samples over storage time, a characteristic that is accentuated under abusive conditions of temperature (7 and 10°C), in the same manner to that reported by Mantilla *et al.* (2011). The pH increase can be attributed to the rapid growth of spoilage microorganisms. According to Nizimani *et al.* (2008), in foods stored under aerobiosis and high in protein and amino acids, such as chicken, it is common to increase the pH value as the count of spoilage bacteria increases, whose proteolytic activity results in compounds of alkaline character.

According to Allen *et al.* (1998) there is an inverse correlation between muscle pH of chicken and lightness values (*chroma* L*), a phenomenon observed in Figure 2X and 2Y, where the pH of the products increased, while the values of brightness decreased over time in storage. The reduction of the chroma L* indicated that the samples became darker during shelf life, the characteristic intensified with increasing temperature, similar to that reported by Cortez-Vega *et al.* (2012) and Kenawi *et al.* (2005). According to Scheuermann *et al.* (2004) browning of chicken meat is a serious defect, because the light color of the breast has great importance in the commercial appeal to the product as "white meat".

The color difference (ΔE*) of the samples was enhanced with increasing storage temperature where ΔE reached values close to 9.4 for products stored at 10°C, whereas those maintained at 3°C a maximum of 4.6 was obtained for ΔE (Figure 2Z). Results with lower values were observed by Shin *et al.* (2010), whose samples showed 1.3 ΔE in twelve days stored at 4°C. These differences can be attributed to the presence of myoglobin present in the muscle (Scheuermann *et al*., 2004). According to Olivo (2006), the intensity of color in chicken meat is proportional to the quantity of this pigment, and chemical changes, mainly caused by changes in pH and temperature causing the myoglobin to change its capacity to absorb or reflect the light beam incident on meat, allowing a wide possibility of color tones.

In Figure 2W, it is observed that the results of TBA samples experienced a slight increase with increasing storage temperature. However, the values obtained on the last day of expiration of the products, for all temperatures, was very low compared to other studies (Cortez-Vega *et al*., 2012), indicating little extent of lipid oxidation. According to Osawa *et al*. (2005) for samples of the same type of muscle but of distinct origins, outstanding variations in the amounts of TBA are the result of different methods of handling, storage conditions, age and origin of the samples.

Microbiological stability

All samples were negative for *Salmonella* spp., indicating good quality hygiene programs of farms and hatcheries, as well as proper hygienic and sanitary conditions during slaughter and processing of carcasses in the slaughterhouses in study. According to Brizio *et al.* (2013) and Funk *et al.* (2001), one of the main reasons for the low prevalence of *Salmonella* spp. in this product is in the identification of ways to reduce or eliminate the pathogen before slaughter, since the reduction of infection rates before slaughter results in increased safety of poultry products.

Figure 3 shows the results of microbiological enumeration of aerobic psychrotrophic microorganisms (Figure 3X), *Staphylococcus* spp. (Figure 3Y) and thermotolerant coliforms (Figure 3Z) in samples kept at different temperature for twelve days of storage. Psychrotrophic aerobic bacteria are among the microorganisms that exhibit good growth at refrigeration temperatures. This group includes species responsible for the deterioration of poultry products, the motive of its importance in the decrease of shelf life of food made from chilled chicken (Patsias *et al*., 2008). The International Commission on Microbiological Specifications for Foods (1978) considers out of range of the ideal sanitary conditions meat products in excess of 10^6 (6 $\log_{10}$) to 10^7 (7 $\log_{10}$) counts of colony forming units (CFU) / g for this bacteria group. Thus, respecting the standard limit of 7 $\log_{10}$ CFU/g, samples kept in ideal conditions of storage (3°C) obtained counts below the aforementioned limit by the tenth day of validity, while the product under isothermal conditions of 10°C and 7°C showed higher values before the fourth and fifth days of storage, respectively (Figure 3X).

The results found for the analyses of thermotolerant coliforms (Figure 3Z) at time zero were less than 3 CFU/g, low counts of these microorganisms indicate good sanitary conditions of food, and eliminate the suspicion of the presence of pathogens of enteric origin, coming from the same source of contamination (Dickens *et al*., 2004; De Paula *et al*., 2009). Following the Brazilian microbiological standard for thermotolerant coliform (Brazil, 2001), the only one for chicken, from $\leq 10^4$ (4 $\log_{10}$) CFU/g, the samples stored at 3, 7 and 10ºC, remained suitable for consumption until the tenth, fifth and third day of the storage, respectively.

Staphylococci are microorganisms forming part of the raw poultry meat microflora (Russell, 2002), work performed by Barbut (2002) reported that between 10^5 (5 $\log_{10}$) and 10^6 (6 $\log_{10}$) colony forming units of *Staphylococcus* per gram of food are required so that the toxin is formed at levels capable of causing intoxication. Considering this range, only the samples stored at 10°C, from the fourth day of storage could pose a risk to consumer health, if they were of enterotoxigenic strain (Figure 3Y).

The low prevalence of the bacteria analyzed at time zero indicated good process control through the steps of obtaining products, applying effectively the Good Manufacturing Practices (GMP's) by the slaughterhouses evaluated. However, the samples did not remain fit for consumption until the twelfth day of shelf life (data contained in the package). The microbiological shelf life of products at 3°C was ten days. It is up to manufacturers to reassess the expiration of this commercial product.

The results of the microbiological analyses showed that bacterial growth in the meat microflora was significantly delayed when maintained at lower temperature. While boneless chicken breast got a shelf life of ten days in ideal conditions of storage (3°C), samples stored at 7°C should be consumed before five days and those kept at 10°C from the third day of storage already represent a health risk if consumed.

Conclusions

Small temperature fluctuations measured during monitored inland logistics routes did not alter the quality conditions of the samples. However, the results of microbiological and physical-chemical properties during the simulation of commercial and domestic storage showed that a small increase in storage temperature is able to quickly reduce the shelf life of products made from chicken, constituting a risk to consumer health when ingested under these conditions. The results of this study are used to support the development of strategies to control the temperature during the supply chain of fresh poultry products as a measure to reduce the contamination levels of the microorganisms studied under simulated abusive conditions.

References

Adolfo Lutz Institute. 1985. Normas Analíticas Métodos químicos e físicos para análise de alimentos, 3rd Ed.,Vol. 1, São Paulo, Brazil.

Allen, C.D., Russell, S.M. and Fletcher, D.L. 1998. The relationship of broiler breast color to meat quality and shelf-life. Poultry Science 77:361–366.

American Public Health Association - APHA. 2001. Compendium of methods for the microbiological examination of foods, 4th Ed., Washington. DC.

Barbut, S. Poultry products processing: an industry guide. 2002. Boca Raton: CRC.

Brasil. Ministério da Agricultura Pecuária e Abastecimento. Portaria n°210, de 10 de novembro de 1998. Aprova Regulamento técnico de inspeção tecnológica e higiênico – sanitária de carnes de aves. Diário Oficial [da] República Federativa do Brasil. Brasília, DF, 26 de dezembro de 1998. Seção I, p. 226-272, 1998.

Brasil. Ministério da Agricultura, Pecuária e Abastecimento. Instrução Normativa nº62, de 26 de agosto de 2003. Aprova os Métodos analíticos oficiais para análises microbiológicas para o controle de produtos de origem animal e água. Diário Oficial [da] República Federativa do Brasil. Brasília, DF, 18 de setembro 2003. Seção I, p.21-32; 40-43; 51-67, 2003.

Brasil. Ministério da Saúde. Resolução RDC nº12, de 02 de janeiro de 2001. Aprova o Regulamento técnico sobre padrões microbiológicos para alimentos. Diário Oficial [da] República Federativa do Brasil. Brasília, DF, 10 de janeiro de 2001. Seção I, p. 46-53, 2001.

Brizio, A.P.R., Isolan, L.W., Salles, B. and Prentice, C. 2013. Correlação entre contaminação gastrointestinal e presença de *Salmonella* spp. em carcaças de frango industrializadas no Rio Grande do Sul. Revista de Agricultura 88:12-17.

Cárdenas, F.C., Giannuzzi, L., and Zaritzky, N. E. 2008. Mathematical modelling of microbial growth in ground beef from Argentina. Effect of lactic acid addition, temperature and packaging film. Meat Science 79:509-520.

Chouliara, E., Badeka, A., Savvaidis, I. N. and Kontominas, M. G. 2008. Combined effect of irradiation and modified atmosphere packaging on shelf life extension of chicken breast meat: Microbiological, chemical, and sensory changes. European Food Research and Technology 226:877–888.

Cortez-Vega, W.R., Pizato, S. and Prentice, C. 2012. Quality of raw chicken breast stores at 5°C and packaged under different modified atmospheres. Journal of Food Safety 32:360–368. 2012.

De Paula, N.R.F., Boas, E.V, RodrigueS, L.J., Carvalho, R.A. and Piccoli, R.H. 2009. qualidade de produtos minimamente processados e comercializados em gôndolas de supermercados nas cidades de lavras – MG, Brasília – DF e São Paulo – SP. Ciência e Agrotecnologia 33(1):219-227.

Dickens, J.A., Ingram, K.D. and Hinton JR., A. 2004. Effects of applying Safe2O poultry wash to broliler wings on shelf life, *Listeria monocytogenes*, Pseudomonads, *Staphylococcus* species, and phychrotrophic bacteria levels after three, seven and ten days of storange. Poultry Science 83:1047-1050.

Funk, J. A., Davies P.R, and Nichols m.A. 2001. Longitudinal study of *Salmonella enterica* in growing pigs reared in multiple-site swine production systems. Veterinary Microbiology 83:45-60.

International Commission on Microbiological Specifications for Foods (ICMSF). 1986. Microoganisms in Foods. Sampling for Microbiological Analysis: Principles and Scientific Applications, 2nd Ed.,Vol. 2, pp. 181–186,University of Toronto Press, Toronto.

Jay, J.M. 2005. Microbiologia de alimentos. 6. ed. Porto Alegre: Artmed.

Karadag, D. and Puhakka, J.A. 2010. Effect of changing temperature on anaerobic hydrogen production and microbial community composition in an open-mixed culture bioreactor. International Journal of Hydrogen Energy, v.35, p.10954 - 10959.

Kenawi, M.A., Abdel-Aal, H.A. and Abbas, H.M. 2005. Influence of potassium sorbate and sodium lactate in combination with modified atmosphere packaging on stability of refrigerated chicken breast muscle. Biotechnology in Animal Husbandry 21:337–347.

Kenneday, J., Jackson, V., Blair, I.S., McDowell, D.A., Cowan, C. and Bolton, D.J. 2005. Food safety knowledge of consumers and the microbiological and temperature status of their refrigerators. journal of food protection 68:1421–1430.

limbo, S., Tori, L., Sinelli, N., Franzetti, L. and Casiraghi, E. 2010. Evaluation and predictive modeling of shelf life of minced beef stored in high-oxygen modified atmosphere packaging at different temperatures. Meat Science 84:129–136.

Mai, N.T.T., Gudjónsdóttir, M., Lauzon, H.L., SveinsdóttiR, K., Martinsdóttir, E., Audorff, H., Reichstein, W., Haarer, D., Bogason, S.G., and Arason, S. 2011. Continuous quality and shelf life monitoring of retail-packed fresh cod loins in comparison with conventional methods. Food Control 22:1000-1007.

Mantilla, S.P.S., Santos, E. B., Vital, H.C., Mano, S.B., Freitas, M.Q. and Franco, R. M. 2011. Microbiology, sensory valuation and shelf life of irradiated chicken breast fillets stored in air or vacuum. Brazilian Archives of Biology and Technology 54:569-576.

Nizimani, A. G., Paleologos, E.K., Savvaidis, I. N. and Kontominas, M.G. 2008. Formation of biogenic amines and relation to microbial flora and sensory changes in smoked turkey breast under various packaging conditions at 4°C. Food of Microbiology 25:509-517.

Nychas, G.J. Skandamis, P.N., Tassou, C.C. and Koutsoumanis, K.P. 2008. Meat spoilage during distribution. Meat Science 78:77–89.

Olivo, R. 2006. O mundo do frango: cadeia produtiva da carne de frango. Criciúma, SC, Brazil.

Osawa, C.C. De felício, P.E. and Gonçalvez, L.G. 2005. Testes de TBA aplicados a carnes e derivados: métodos tradicionais, modificados e alternativos. Química Nova 28:655-663.

Patsias, A., Badeka, A.V., Savvaidis, I.N. and Kontominas, M.G. 2008. Combined effect of freeze chilling and MAP on quality parameters of raw chicken fillets. Food Microbiology 25:575–581.

Rokka, M., Eerola, S., Smolander, M., alakomi, H.L. and Ahvenainen, R. 2004. Monitoring of the quality of modified atmosphere packaged broiler chicken cuts stored in different temperature conditions B. Biogenic amines as quality-indicating metabolites. Food Control 15:601–607.

Russell, N.J. 2002. Bacterial membranes: the effect of chill storage and food processing. An overview. International Journal of Food Microbiology 79:27–34.

Scheuermann, G.N., Bilgili, S.F., Tuzun, S. and Mulvaney, D.R. 2004. Comparison of chicken genotypes: myofiber number in pectoralis muscle and myostation ontogeny. Poultry Science 83:1404-1412.

Shin, J., Harte, B., Ryser, E. and Selke, S. 2010. Active packaging of fresh chicken breast,with allyl isothiocyanate (AITC) in combination with modified atmosphere packaging (MAP) to control the growth of pathogens. Journal of Food Science 75:65–71.

Smolander, M., Alakomi, H.L., Ritvanen, T., Vainionpaa, J. and Ahvenainen, R. 2004. Monitoring of the quality of modified atmosphere packaged broiler chicken cuts stored in different temperature conditions. A. Time-temperature indicators as quality-indicating tools. Food Control 15: 217-229.

United States Department of Agriculture (USDA) - Annual report. Access: *http://www.usda.gov, mai/2013.*