

Influence of ageing time on yield and texture of marinated chicken breast cooked using a continuous process

Influência do tempo de maturação no rendimento e textura de peito de frango marinado cozido em processo contínuo

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■ Summary

The objective of this study was to evaluate the influence of different ageing times before deboning (deboning time) and ageing times after deboning (holding time) on the quality (sensory attributes and texture) and cooking loss of chicken breast marinated, cooked and frozen using a continuous process. The following 3^2 experimental design was used (3 deboning times: zero, 6 and 12 hours; and 3 holding times: zero, 12 and 24 hours). Brine absorption, chicken breast pH and cooking loss were evaluated, a sensory analysis was carried out and the shear force was determined. The deboning and holding times did not significantly influence brine absorption and pH, but did significantly influence cooking loss, where the lowest value obtained was a mean of 19.72% for deboning times of 6 or 12 hours and a holding time of 24 hours. A deboning time of 6 hours was sufficient to improve tenderness as measured by a sensory analysis and shear force determination.

Key words: *Chicken breast; Ageing; Cooking loss; Tenderness.*

■ Resumo

O objetivo deste trabalho foi avaliar a influência de tempos de maturação pré-desossa (tempo de desossa) e tempos de maturação pós-desossa (tempos de espera) na qualidade sensorial (atributos sensoriais e textura) e nas perdas de peso por cozimento do peito de frango marinado, cozido e congelado em processo contínuo, utilizando planejamento experimental 3^2 (3 tempos de desossa: zero, 6 e 12 horas; e 3 tempos de espera: zero, 12 e 24 horas). Foram realizadas análises de absorção de salmoura, pH do peito de frango, perda de cozimento, análise sensorial e força de cisalhamento. Os tempos de desossa e tempos de espera não influenciaram significativamente a absorção de salmoura e pH. Os tempos de desossa e tempos de espera influenciaram significativamente as perdas de peso por cozimento, em que a menor perda obtida foi média de 19,72% com tempo de desossa de 6 ou 12 horas e tempo de espera de 24 horas. O tempo de desossa de 6 horas foi suficiente para melhorar a maciez, medida por análise sensorial e força de cisalhamento.

Palavras-chave: *Peito de frango; Maturação; Perdas de cozimento; Maciez.*

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1 Introduction

The segment of chicken parts is one of the fastest growing worldwide, because it complies with current trends for products of high protein value, practicality, with attractive price. The consumer concern about food safety and convenience has increased the demand for fully cooked products (LEONHARDT et al., 2004; SOUZA et al., 2005).

During the manufacture of cooked chicken breast, a widely used process is the marination, consisting in applying in the meat a solution of water, salt and additives. The salts used act by solubilizing the myofibrillar proteins which increases muscle water retention capacity (ALVARADO and MCKEE, 2007; LEMOS, 2008).

The cooked chicken breast presents problems of nonuniformity of tenderness and low process yield, due to the weight loss in the cooking process. Ageing is an alternative to reduce these problems, consisting in exposing the meat to controlled temperature (0 to 4°C) for a determined period of time (6 to 24 hours) (KOMIYAMA et al., 2009; NORTH CUTT et al., 2001; LIU et al., 2004; LEE et al., 2008). The ageing time before deboning is one of the most important factors for the final texture of the meat (SOUZA et al., 2005). According to Koohmaraie (1992), myofibrillar proteins from proteolysis carried out by natural enzymes of meat is one of the responsible mechanisms for changes during storage post-mortem, resulting in loss of structural integrity of the muscle. Proteolysis of miofibrilae proteins tenderizes the meat by weakening intra and inter myofibrillar bonds (KOOHMARAIE, 1994). It was demonstrated that increase in ageing time from zero to 12, 24 and 48 hours causes desestruturation in muscle fibres, resulting in major espace between fibres (KOMIYAMA et al., 2009).

Industrially, due to the high cost of the ageing process prior to deboning, the practice of ageing after deboning is common, but few studies have compared the effects of ageing performed before and after deboning (LYON et al., 1992). Thus, the overall objective of this study was to evaluate the influence of different ageing times pre-deboning (deboning time) and maturation times post-deboning (holding time) and its consequence in the texture and cooking loss of marinated chicken breast cooked in continuous process.

2 Material and methods

2.1 Raw material

Broiler chicken breast fillets (*Pectoralis major*), boneless and skinless, were collected directly from an industrial slaughterhouse. The Cobb broilers, male sex, aged from 45 to 46 days, 3 kg middleweight, total fasting of 12 hours before slaughter, were electrically

stunned (80-120 volts, 100mA, 15 seconds). Chilling was performed in immersion chiller with ice water for 80 minutes, within a period of 2 hours between slaughter and cooling.

2.2 Ageing

After chilling, the carcasses were cut in front halves and stored in plastic boxes in cold chamber in temperature of 3 to 5°C for zero, 6 or 12 hours. After each deboning time, the breasts were removed from the carcass (deboned) and stored in plastic bags in cold chamber at temperature of 3 to 5°C for zero, 12 or 24 hours. Tests were conducted on the months of July and August. The sampling of each treatment was 13 chicken breast fillets according to CODEX Alimentarius (1969 apud VOLPATO, 2005).

2.3 pH Analysis

pH was analyzed in chicken breast after deboning and holding times, by the potentiometric method with electrode coupled to pHmeter Micronal, model B375, according to Instruction No. 20 (BRASIL, 1999).

2.4 Marination by tumbling

Brine was prepared containing 93.33% of water and 6.66% of sodium chloride. In the 20L capacity experimental tumbler (Inject Star), it was added chicken breast (85%) and brine (15%). The product was massaged for 60 minutes using vacuum of 0.8 mmHg and rotation of 11 rpm. Absorption was calculated by dividing the pickling drained weight after tumbling by weight of the fillets and brine before tumbling, expressed in percentage (Brine Absorption (%) = (drained weight after tumbling/ inicial weight) x 100).

2.5 Cooking

Cooking was carried out in a continuous spiral steam oven in an industrial line (Koppens). The product was cooked by time of 18 minutes, air temperature of 88°C, air speed of 400 rpm and steam pressure of 4.0 kgf to achieve minimum temperature of 78°C in the product core. The temperature of the fillets after cooking was measured in the geometrical center of the product using thermometer needle accuracy of 0.1°C (Testo). Cooking loss was calculated by the difference between the breast fillets weight in cooking process, expressed as percentage of initial weight (Cooking loss (%) = (water loss during cooking/weight before cooking) x 100). The increased thickness of the fillets were measured in the pieces thickest portion by the difference of thickness before and after cooking using caliper rule (Moyoto), expressed in percentage (Thickness Increase (%) = [(final thickness - initial thickness)/initial thickness] x 100). After

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cooking, the fillets were frozen in continuous tunnel until internal temperature in the core reached -18°C .

2.6 Sensory analysis

All tests were compared with a standard sample (commercial sample produced in production line, same slaughter house, deboning time zero and holding time of 10 hours) to identify significant differences of treatments using multiple comparisons tests method (GATCHALIAN, 1981 apud VOLPATO, 2005). The samples (5 pieces) were thawed, heated for 10 minutes in boiling water, cut into 2×2 cm cubes and served to 11 trained evaluators in duplicate, receiving grades from 1 to 9, where 1 stands for extremely inferior to the standard, 5 stands for equal to standard and 9 for extremely higher than standard, in color (cooked chicken breast characteristic color), flavor (cooked chicken breast characteristic flavor, off-flavours absence and salt), juiciness (marinated cooked chicken breast characteristic juiciness) and tenderness (cooked chicken breast characteristic tenderness) attributes. Results were expressed as average of evaluation of 11 evaluators, in duplicate.

2.7 Shear force analysis

For each treatment, three pieces of cooked chicken breasts were thawed and cut into two parallelepipeds $2 \times 1 \times 1$ cm removed from the center of the fillet in the parallel direction of the muscle fibers (FERNANDES, 2011). The measurements were performed in texturometer Warner Bratzler (Model 235 6X, brand Salter Brecknell), speed of 3 mm/s, distance of 30 mm, and 5g force. Results were expressed as average of 6 measures for each treatment.

2.8 Experimental design and statistics analysis

It was used 3^2 experimental designs, with two variables (deboning time (DT) and holding time (HT)) on

three levels, resulting in nine experiments performed in triplicate for determination of cooking loss, 13 chicken breast fillets each experiment according to CODEX Alimentarius (1969 apud VOLPATO, 2005). For statistical analysis of the data the Minitab 15 software was used and subjected the data to variance analysis (ANOVA) and Tukey's test at a significance level of 5% for the comparison of the averages of the responses.

3 Results and discussion

Table 1 shows the pH values found after the deboning time (pHi) and after holding time (pHt). The pHi values ranged from 5.92 to 6.19 and pHt from 5.92 to 6.18, according to expected range for the final pH of chicken meat (ODA et al., 2003). It was observed pHi at zero time of 6.15 (average pHi of treatments 1, 2 and 3), 6.04 in 6 hours (average pHi of treatments 4, 5 and 6) and 6.05 in time of 12 hours (average treatment pHi 7, 8 and 9). Similar values were reported by Young et al. (1999) that had found pH 6.19 after deboning and pH 5.96 to 6.08 for deboning times of 2 to 6 hours. Lee et al. (2008) found a decrease in pH from zero to 6 hours, time which the muscle had reached its final pH (*rigor mortis*). Thielke et al. (2005) observed pH decrease during the first 5 hours of aging, 6.83 to 5.91. For deboning time zero (T1, T2, T3), it was observed a decrease of pHt between zero and 12 hours (from 6.09 to 5.94) with an increase from 12 to 24 hours (from 5.94 to 6.09), however difference is not statistically significant. The 5.9 pH is indicative of the onset of *rigor mortis* in chicken breast (BRESSAN and BERAQUET, 2004). The behavior data of pHi and pHt for deboning time zero suggest that the chicken breast of this study has reached *rigor mortis* installation at the time of 6 hours. Therefore, only Treatment 1 was processed before the onset of *rigor mortis*.

The brine absorption values of each treatment vary from 95.14% to 97.26% (Table 1), therefore, statistically, the results do not show a significant difference, in

Table 1. Results of pH after deboning time and holding time, brine absorption in tumbling, cooking loss and increased thickness in the cooking of marinated chicken breasts subjected to different ageing times.

Treatment	DT	HT	pHi	pHt	BA (%)	CL (%)	Tf ($^{\circ}\text{C}$)	IT (%)
1	0	0	6.09 ^a	6.09 ^a	95.14 ^a	17.78 \pm 0.67 ^a	74.6 \pm 1.03 ^a	93.75 \pm 13.75 ^a
2	0	12	6.16 ^a	5.94 ^a	97.14 ^a	23.89 \pm 0.40 ^b	80.2 \pm 1.83 ^b	68.37 \pm 3.06 ^b
3	0	24	6.19 ^a	6.09 ^a	96.87 ^a	22.12 \pm 0.95 ^c	78.7 \pm 1.37 ^b	55.88 \pm 5.88 ^b
4	6	0	5.92 ^a	5.92 ^a	96.00 ^a	22.97 \pm 0.88 ^c	80.5 \pm 1.38 ^b	49.02 \pm 4.49 ^b
5	6	12	6.03 ^a	6.10 ^a	97.14 ^a	21.16 \pm 0.20 ^d	78.5 \pm 2.26 ^b	51.89 \pm 4.32 ^b
6	6	24	6.16 ^a	6.18 ^a	95.95 ^a	19.95 \pm 0.21 ^e	79.5 \pm 1.00 ^b	61.70 \pm 4.48 ^b
7	12	0	6.0 ^a	6.10 ^a	97.26 ^a	22.65 \pm 0.32 ^c	79 \pm 1.00 ^b	52.04 \pm 6.37 ^b
8	12	12	6.10 ^a	6.13 ^a	96.38 ^a	21.00 \pm 0.59 ^{ed}	79.8 \pm 0.98 ^b	47.22 \pm 5.56 ^b
9	12	24	6.06 ^a	6.04 ^a	96.09 ^a	19.49 \pm 1.15 ^e	78.5 \pm 2.17 ^b	54.90 \pm 4.49 ^b

Different letters in the same column indicate significant difference ($P \leq 0.05$) between the values found. DT = ageing time before deboning (hours); HT = holding time after deboning (hours); pHi = pH measured after deboning; pHt = pH measured after holding time, immediately before; BA (%) = brine absorption in tumbling. CL (%) = Cooking loss; Tf ($^{\circ}\text{C}$) = final temperature in product core; IT (%) = increased thickness during cooking.

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agreement with Young and Lyon (1997), who found that the deboning times 0 to 4 hours did not impact in the brine absorption formulated with water and salt.

The values of cooking loss, final product temperature and increased thickness are shown in Table 1. In treatment 1, the temperature reached inside the product was 74.67 °C, significantly lower than the other treatments (78 to 80°C). All treatments were processed at the same cooking time (18 minutes) and temperature, however this condition was not sufficient to achieve minimum of 78°C. The thickness increase during cooking was significantly higher in treatment 1 (93.75%) than the other treatments (44.22% to 68.37%), thus demonstrating greater shrinkage of the fiber. This fact may have caused the low temperature in product core in treatment 1. Chicken breast muscle removed from the carcass before the *postmortem* period results in area loss and subsequent increase in the thickness (PAPA and LYON, 1989). The treatments 2 and 3, although they were removed from carcass at time zero, they were subjected to holding times of 12 and 24 hours, allowing the time to complete the *rigor mortis*.

It was observed that the ageing treatments had statistically significant influence on cooking loss. The weight loss in this treatment 1 (17.78%) was lower than the other treatments (19.49% to 23.89%), but this result can not be compared since such treatment does not reach the required minimum temperature (78°C). Regardless of holding time (HT), no significant difference in cooking loss were observed for deboning time of 6 or 12 hours, the result shown in Figure 1 comparing treatments 4 and 7, 5 and 8, 6 and 9. Weight loss for deboning time zero was significantly higher compared to the times 6 or 12 hours. There was a significant decrease in cooking loss, as the holding time increased from zero to 24 hours, regardless of deboning time (Figure 1). The lower cooking loss occurred in breasts aged for 6 hours or 12 hours prior deboning and holding time of 24 hours (treatments 6 and 9), showed in Figure 1 and Table 2. These results are in agreement with Northcutt et al. (2001), which reported an improvement in the cooking yield of boneless fillets after ageing time of 2, 4 or 6 hours compared to zero deboning time, Liu et al. (2004) who observed an increase in yield as the pre-deboning ageing time increased from 2 to 24 hours, Huez et al. (2007), who observed reduction in cooking loss between 0 and 24 hours before deboning and Battula et al. (2008) that noted this reduction between 0,75 and 4 hours deboning time. Other authors have reported that the ageing time did not influence or increase

cooking loss (YOUNG et al., 1999; PETRACCI et al., 2001; VOLPATO, 2005; SOUZA et al., 2005; SCATOLINI et al., 2006; KOMIYAMA et al., 2009).

The shrinkage of the fibers after cooking makes pressure on the free water located between the fibers and forcing the output of the same by evaporation. One influence of ageing is increase the space between the muscle fibers (KOMIYAMA et al., 2009). Thus, in treatments with longer ageing time (T6 and T9), the pressure on the humidity was lower during cooking, resulting in lower weight loss.

Sensory analysis results and shear force are shown in Table 3. The results for color evaluation, measured to zero, 6 or 12 hours deboning time, showed no significant difference between them. In relation to holding time, it was found that there was significant difference between 24 hours and the other times (T3, T6 and T9), being evaluated as lighter than standard, agreeing with Scatolini et al. (2006).

In flavor and juiciness attributes, only treatment 1 was significantly different when compared to other treatments, with the lowest score. This treatment presented lower brine absorption, which may have impacted both the juiciness and flavor of the product. For aged treatments (treatments 2 to 9), ageing time did not affect the perceived flavor, in agreement with Lyon et al. (2003) who found no difference in taste between not marinated chicken breasts, cooked and aged for 2, 4, 8 or 24 hours. Treatment 1 has

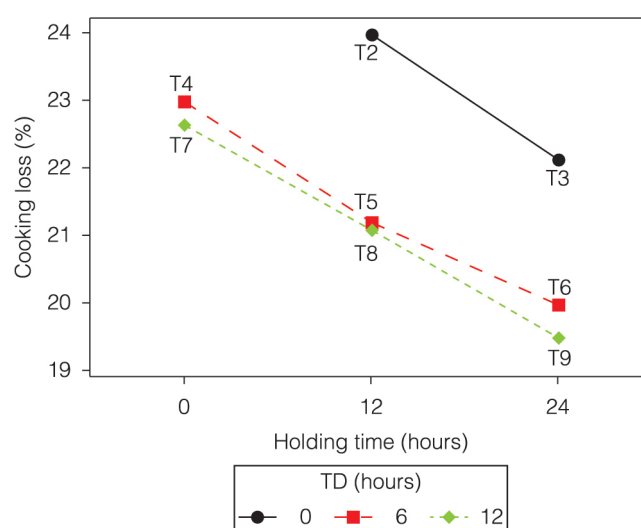


Figure 1. Cooking loss in dependence of deboning time (DT) and holding time (HT).

Table 2. Cooking loss in dependence of deboning time (DT) and holding time (HT).

	DT0	DT6	DT12	HT0	HT12	HT24
CL (%)	23.01±0.65 ^a	21.36±0.43 ^b	21.05±0.68 ^b	22.81±0.60 ^a	22.02±0.60 ^a	20.52±1.16 ^c

Different letters for the same parameter indicate significant difference ($P \leq 0.05$) between the values found. DT_{0,6,24} = ageing time before deboning (hours) of zero, 6 and 24 hours; HT_{0,12,24} = holding time after deboning (hours) of zero, 12 and 24 hours

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Table 3. Sensory analysis and shear force.

Treatment	DT	HT	Color	Flavour	Juiciness	Tenderness	SF (kgf)
1	0	0	5.23±0.43 ^a	3.83±0.85 ^a	3.82±1.47 ^a	1.77±0.75 ^a	5.22±2.18 ^a
2	0	12	4.59±0.59 ^b	4.89±1.04 ^b	4.41±1.14 ^b	5.22±1.15 ^b	0.83±0.43 ^b
3	0	24	4.41±0.80 ^c	4.36±0.85 ^b	4.50±0.74 ^b	5.59±0.96 ^c	0.82±0.27 ^b
4	6	0	4.70±0.66 ^b	4.45±0.60 ^b	4.50±1.00 ^b	4.75±1.07 ^d	1.00±0.32 ^b
5	6	12	5.14±0.77 ^a	4.18±0.85 ^b	4.65±0.90 ^b	4.64±1.14 ^d	1.03±0.31 ^b
6	6	24	4.23±0.69 ^c	4.23±0.75 ^b	4.82±0.80 ^b	5.50±0.74 ^c	0.77±0.27 ^b
7	12	0	5.18±0.73 ^a	4.27±0.46 ^b	4.41±0.96 ^b	5.23±0.75 ^b	0.83±0.27 ^b
8	12	12	5.00±0.56 ^{ab}	4.05±0.94 ^b	4.45±0.76 ^b	4.75±0.91 ^d	0.64±0.17 ^b
9	12	24	4.23±0.75 ^c	4.73±0.70 ^b	4.18±0.85 ^b	5.36±0.90 ^c	1.02±0.38 ^b

Different letters in the same column indicate significant difference ($P \leq 0.05$) between the values found. DT = ageing time before deboning (hours); HT = holding time after deboning (hours); Color, Flavour, Juiciness, Tenderness = average of evaluation of 11 evaluators, in duplicate. Grades 1 to 9: 1 means extremely inferior to the standard; 5 means equal to standard; 9 means extremely higher than standard. SF (kgf) = average of 6 measures for each treatment.

presented a less tender texture than the other treatments on sensory evaluation and shear force value significantly higher. According to Fletcher (1999) if the muscle is removed from the carcass before the resolution of *rigor mortis*, the muscle fibers will contract and shorten the muscle, resulting in less tender meat. The treatments 1, 2 and 3 were removed from the carcass at the same time, although the treatments 2 and 3 were processed after 12 and 24 hours, respectively, allowing the development of the ageing and softening of the meat. It was observed that the tenderness improved, with increasing time of 6 hours deboning time, in agreement with Thielke et al. (2005) that suggested deboning time of minimum 6 hours in order to obtain tender texture. Regardless of the deboning time, the treatments with holding time of 24 hours were evaluated as more tender than the standard (treatments 3, 6 and 9), which is in agreement to other authors (LYON et al., 1992; NORTH CUTT et al., 2001; LIU et al., 2004; PETRACCI et al., 2001; SOUZA et al., 2005; HUEZO et al., 2007; BATULLA et al., 2008; THIELKE et al., 2005), that reported an increase in tenderness, as ageing time increased before and after the deboning.

For deboning time zero, it was observed that the holding time had significant effect on the tenderness and shear force (treatments 1, 2 and 3). These results are consistent to other reports. Perlo et al. (2010) founded significant differences in shear force between deboning times zero and 6 hours, but no difference from this time to 24 hours, in marinated chicken breast.

4 Conclusion

Deboning time and holding time influenced cooking loss, thus reducing cooking losses between deboning times zero and six hours, but no difference was observed between 6 and 12 hours. The increase in holding time from zero to 12 and 24 hours resulted in reduced weight loss, regardless of the deboning time. The best results in cooking loss were obtained for 6 or 12 hours of deboning and 24 hours of holding time. Six hours of ageing

before the deboning and 24 hours of holding time were sufficient to achieve a tenderness equal or superior to the standard. Based on these results, it is concluded that the best treatment is deboning time of 6 hours followed by holding time of 24 hours, where the product achieved good tenderness and the minor cook loss.

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References

- ALVARADO, C.; MCKEE, S. Marination to improve functional properties and safety of poultry meat. **Journal of Applied Poultry Research**, Champaign, v. 16, n. 1, p. 113-120, 2007. <http://dx.doi.org/10.1093/japr/16.1.113>
- BATTULA, V.; SCHILLING, M. W.; THAXTON, Y.; BEHREND, J. M.; WILLIAMS, J. B.; SCHMIDT, T. B. The effects of low-atmosphere stunning and deboning time on broiler breast meat quality. **Poultry Science**, Champaign, v. 87, n. 6, p. 1202-1210, 2008. PMID:18493012. <http://dx.doi.org/10.3382/ps.2007-00454>
- BRASIL. Ministério da Agricultura, Pecuária e Abastecimento - MAPA. **Instrução Normativa n. 20**. Brasília: MAPA, 1999. cap. V: Métodos Quantitativos.
- BRESSAN, M. C.; BERAQUET, N. J. Tratamentos de pré-resfriamento e resfriamento sobre a qualidade de carne de peito de frango. **Ciência e Tecnologia de Alimentos**, Campinas, v. 24, n. 2, p. 230-235, 2004. <http://dx.doi.org/10.1590/S0101-20612004000200012>
- FERNANDES, R. P. P. **Avaliação da Estabilidade Física e Química e Microbiológica de Carne Ovina Embalada a Vácuo Estocada Sob Refrigeração e Congelamento**. 2011. 172 f. Dissertação (Mestrado)-Faculdade de Zootecnia e Engenharia de Alimentos, Universidade de São Paulo, Pirassununga, 2011.

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- FLETCHER D. L. Broiler breast meat color variation, pH, and texture. **Poultry Science**, Champaign, v. 78, n. 9, p. 1323-1327, 1999. <http://dx.doi.org/10.1093/ps/78.9.1323>
- HUEZO, R.; NORTHCUTT, J. K.; SMITH, D. P.; FLETCHER, D. L. Effect of chilling method and deboning time on broiler breast fillet quality. **Journal of Applied Poultry Research**, Champaign, v. 16, n. 4, p. 537-545, 2007. <http://dx.doi.org/10.3382/japr.2006-00121>
- KOMIYAMA, C. M.; MARTINS, M. R. F. B.; MENDES, A. A.; SANFELICE, C.; CAÑIZARES, M. C. S.; RODRIGUES, L.; CAÑIZARES, G. I. L. Avaliação da técnica de maturação sobre a qualidade da carne e estrutura da fibra muscular do peito de matrizes pesadas de descarte de frangos de corte. **Brazilian Journal of Food Technology**, Campinas, v. 15, II SSA, p. 89-93, 2009.
- KOOHMARAIE, M. Effect of pH, temperature and inhibitors on autolysis and catalytic activity of bovine skeletal muscle M-Calpain. **Journal of Animal Science**, Champaign, v. 70, n. 10, p. 93-104, 1994.
- KOOHMARAIE, M. Muscle proteinases and meat ageing. **Meat Science**, Barking, v. 36, n. 10, p. 3071-3080, 1992.
- LEE, H. L.; SANTÉ-LHOUTELLIER, V.; VIGOUROUX, S.; BRIAND, Y.; BRIAND, M. Role of calpains in *postmortem* proteolysis in chicken muscle. **Poultry Science**, Champaign, v. 87, n. 10, p. 2126-2132, 2008. PMID:18809876. <http://dx.doi.org/10.3382/ps.2007-00296>
- LEMOES, A. L. S. C. **Marinação e Empanamento**. Campinas: Avicultura Industrial, 2008. Disponível em: <<http://www.aviculturaindustrial.com.br/site/dinamica.asp?id=203>>. Acesso em: dd jan. 2008.
- LEONHARDT, C.; SANTOS, H. C. P.; MARCZAK, L. D. F.; NORENA-ZAPATA, C. P. Otimização do cozimento de filé de peito de frango empanado em forno de injeção direta de vapor. **Ciência e Tecnologia de Alimentos**, Campinas, v. 24, n. 1, p. 43-46, 2004. <http://dx.doi.org/10.1590/S0101-20612004000100009>
- LIU, Y.; LYON, B. G.; WINDHAM, W. R.; LYON, C. E.; SAVAGE, E. M. Principal component analysis of physical, color, and sensory characteristics of chicken breast deboned at two, four, six and twenty four hours *postmortem*. **Poultry Science**, Champaign, v. 83, n. 1, p. 101-108, 2004. <http://dx.doi.org/10.1093/ps/83.1.101>
- LYON, C. E.; LYON, B. G.; PAPA, C. M.; ROBACH, M. C. Broiler tenderness: effects of postchill deboning time and fillet holding time. **Journal of Applied Poultry Research**, Champaign, v. 1, n. 1, p. 27-32, 1992. <http://dx.doi.org/10.1093/japr/1.1.27>
- LYON, B. G.; LYON, C. E.; SAVAGE, E. M. Effect of postchill deboning time on the texture profile of broiler breeder hen breast meat. **Journal of Applied Poultry Research**, Champaign, v. 12, n. 3, p. 348-355, 2003. <http://dx.doi.org/10.1093/japr/12.3.348>
- NORTHCUTT, J. K.; BUHR, R. J.; YOUNG, L. L.; LYON, C. E.; WARE, G. O. Influence of age and postchill carcass ageing duration on chicken breast fillet quality. **Poultry Science**, Champaign, v. 80, n. 6, p. 808-812, 2001. <http://dx.doi.org/10.1093/ps/80.6.808>
- ODA, S. H. I.; SCHNEIDER, J. P.; SOARES, A. L.; BARBOSA, D. M. L.; IDA, E. I.; OLIVO, R.; SHIMOKOMAKI, M. Detecção de cor em filés de peito de frango. **Revista Nacional de Carne**, São Paulo, v. 321, p. 31-33, 2003.
- PAPA, C. M.; LYON, C. E. Shortening of the *pectoralis* muscle and meat tenderness of broiler chickens. **Poultry Science**, Champaign, v. 68, n. 5, p. 663-669, 1989. <http://dx.doi.org/10.3382/ps.0680663>
- PERLO, F.; BONATO, P.; FABRE, R.; TEIRA, G.; TISOCCO, O. Meat quality evaluation of broiler breast fillets affect by ageing time and marination. **International Journal of Poultry Science**, Champaign, v. 9, n. 11, p. 1063-1068, 2010. <http://dx.doi.org/10.3923/ijps.2010.1063.1068>
- PETRACCI, M.; FLETCHER, D. L.; NORTHCUTT, J. K. The effect of holding temperature on live shrink, processing yield, and breast quality of broiler chickens. **Poultry Science**, Champaign, v. 80, n. 5, p. 670-675, 2001. <http://dx.doi.org/10.1093/ps/80.5.670>
- SCATOLINI, A. M.; SOUZA, P. A.; SOUZA, H. B. A.; BOIAGO, M. M.; PELICANO, E. R. L.; ODA, A. Efeito do período de desossa e do tempo de armazenamento sob refrigeração na qualidade de carne de peito de frangos. **Revista Portuguesa de Ciências Veterinárias**, Lisboa, v. 101, n. 559-560, p. 257- 262, 2006.
- SOUZA, P. A.; KODAWARA, L. M.; PELICANO, E. R. L.; SOUZA, H. B. A.; OBA, A.; LEONEL, F. R.; NORKUS, E. A.; LIMA, T. M. A. Effect of deboning time on the quality of broiler breast meat (*Pectoralis major*). **Brazilian Journal of Poultry Science**, Campinas, v. 7, n. 2, p. 123-128, 2005.
- THIELKE, S.; LHAFI, S. K.; KUHNER, M. Effects of ageing prior to freezing on poultry meat tenderness. **Poultry Science**, Champaign, v. 84, n. 3, p. 606-612, 2005.
- VOLPATO, G. **Otimização do Processamento de Peito de Frango Cozido**. 2005. 109 f. Dissertação (Mestrado em Engenharia de Alimentos) - Universidade Federal de Santa Catarina, Florianópolis, 2005.
- YOUNG, L. L.; LYON, C. E. Effect of postchill ageing and sodium tripolyphosphate on moisture binding properties, color and warner-bratzler shear values of chicken breast meat. **Poultry Science**, Champaign, v. 76, n. 11, p. 1587-1590, 1997. <http://dx.doi.org/10.1093/ps/76.11.1587>
- YOUNG, L. L.; BUHR, R. J.; LYON, C. E. Effect of polyphosphate treatment and electrical stimulation on postchill changes in quality of broiler breast meat. **Poultry Science**, Champaign, v. 78, n. 2, p. 267-271, 1999. <http://dx.doi.org/10.1093/ps/78.2.267>