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Pork meat matured for different periods of time in vacuum-packaging system

Carne suína maturada por diferentes períodos de tempo em sistema de embalagem à vácuo

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Abstract

The objective of this study was to evaluate the quality of pork meat when matured. The treatments evaluated were: meat no maturated; meat matured for 3 days; meat matured for 6 days. The pH, water loss percentage, and liquid lost in thawing displayed a decreasing linear regression while the fluid lost in cooking showed an increasing linear regression. The L*, a*, b* and chroma showed an increasing linear effect while the tone displayed a decreasing linear regression. The mesophilic and psychrotrophic bacteria counts were greater for the treatments that underwent maturation. The shear force decrease linearly with the increase in the maturation period. The MFI, lipid oxidation, and sensory analyses were not affected by treatments. The maturation of the pork meat improved the color, reduced the pH and increased the tenderness. There was no change in the lipid stability of the meat, nor sensory damage.
Key words: Tenderness, microbiology, pH

Resumo

O objetivo deste trabalho foi avaliar a qualidade da carne suína maturada por diferentes períodos de tempo. Os tratamentos avaliados foram: controle (carne sem maturação); carne maturada por três dias; carne maturada por seis dias. O pH, a porcentagem de perda de água e a perda de líquido no descongelamento apresentaram regressão linear decrescente. Para a perda de líquido na cocção foi observado regressão linear crescente em função do tempo de maturação. Para L*, a*, b* e croma houve efeito linear crescente, enquanto que a tonalidade apresentou regressão linear decrescente com o aumento do tempo de maturação. A contagem de mesófilos e psicrotróficos foram maiores para os tratamentos submetidos à maturação. A força de cisalhamento diminuiu linearmente com o aumento do período de maturação. O índice de fragmentação miofibrilar, oxidação lipídica e análise sensorial não apresentaram efeito significativo para o tratamento. A maturação da carne suína foi eficaz, pois melhorou a cor, sendo mais clara, com menor pH e melhor maciez. Não houve alteração na estabilidade lipídica da carne, e tampouco danos sensoriais.
Palavras-chave: Maciez, microbiologia, pH

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Introduction

Pork is the most widely consumed protein source in the world and is the most widely sold meat on the world market. Brazil is the fourth largest producer and exporter of pork, although the consumption of this meat in the country is still quite low compared to that of chicken or beef (MIELI; MACHADO, 2010).

At the moment of acquiring the product, the consumer may only evaluate the visual quality aspects of the meat, such as color, muscle-to-fat ratio, and marbling. However, tenderness is the most desirable attribute, and maturation of the meat improves this characteristic (BIANCHINI et al., 2007).

Characteristics such as flavor, water retention capacity, color, nutritional value, and food safety determine the quality of the meat. The greater or lesser importance of these factors is related to both the quality of the final product and the profile of the consumer (KOOHMARAIE; GEESINK, 2006).

Factors such as genetics, sex, maturity, the method of slaughter, the use of growth promoters, the cooling rate of the carcass post-slaughter, the rate of the decrease in pH, the final pH, and maturation may influence the tenderness (FELÍCIO, 1999; MONSÓN; SAÑUDO; SIERRA, 2004).

The principle behind the process of matured entails the prolonged action of the proteolytic enzymes that are naturally present in the muscles, (calpains), which leads the proteolysis of myofibrillar proteins. The result is a breakdown of the rigid myofibrillar structure, consequently leading to *rigor mortis*, which leads to greater tenderness of the final product (KOOHMARAIE, 1994).

The objective of this study was to evaluate the quality of vacuum-packaged pork matured for different periods of time.

Material and Methods

For this trial there was used 48 samples of Longissimus dorsi muscle, from Landrace x Large White animals that was slaughtered having an average weight around 109.12 ± 7.00 kg.

After the cooling period, a sample of the *longissimus dorsi* was removed from the left half of every carcass. The samples were packed in styrofoam and transported to the Laboratory of Animal Products of the State University of Londrina for analysis.

Each muscle was divided via the caudo cranial direction of the muscle into six samples. The first sample was analyzed to determine the pH, water loss percentage, and color; the second sample underwent sensory analysis; the third sample was analyzed to fluid lost in thawing, fluid lost in cooking, and shear force; the fourth sample was analyzed to lipid oxidation; the fifth sample was analyzed to the myofibrillar fragmentation index (MFI); and the sixth sample underwent microbiological analysis. Each sample was divided into 3 sub-samples to be distributed among the 3 treatments indicated below. All of the samples were individually vacuum-packed without oxygen.

The experimental treatments were as follows: control (meat no maturated); meat matured for 3 days; meat matured for 6 days. The meat was vacuum-packed and matured at a controlled refrigeration temperature of 5°C ± 2ºC.

For the control treatment (meat without maturation), analysis of the first sample was performed 24 hours after slaughter, while the rest of the samples were frozen for subsequent analysis. In the treatments with meat matured for 3 or 6 days, analysis of the first sample was performed at the end of the maturation period, and the other samples were frozen for subsequent analysis.

The pH was measured using a Testo 205 portable potentiometer with an insertion electrode.

The water loss percentage in the samples was calculated by the technique described by Barbut (1996), in which 2 g of each sample was weighed using a Mettler Toledo AB204 semi-analytic scale.

Each sample was placed between 2 pieces of filter paper and pressed between 2 acrylic plates with a 10-kg weight for 5 minutes. After the pressing, the sample was again weighed to calculate the water loss of the sample.

The color of the samples was analyzed 30 minutes after exposure to oxygen to check the reaction of myoglobin with the atmospheric oxygen using a Minolta® CR10 portable colorimeter device, which evaluated the components of L* (luminosity), a* (red-green intensity), and b* (yellow-blue intensity) according to the CIELAB system. The a* and b* values were used to calculate the chroma and tone of the meat. Color measurements were taken at 3 different points in each sample.

For the microbiological analysis of the meat, 25 g of each meat sample was aseptically weighed, crushed, and diluted in 225 mL sterile peptone solution after homogenization, which corresponded to a dilution of 10^{-1}.Then 1 mL of the first dilution was transferred to a flask containing 9 mL of peptone solution, thus obtaining a dilution of 10^{-2}. Additional serial dilutions were made in this manner until dilutions up to 10^{-7} were obtained. The total counts of mesophilic and psychrotrophic bacteria were determined as follows: 1 mL of each of the 7 dilutions of each sample was deposited into a sterile Petri dish. Then approximately 15 mL of melted plate count agar (PCA) was added, which was cooled to a temperature of approximately 45°C. After solidification of the agar, the Petri dishes were incubated at 37°C for 48 hours for the mesophilic bacteria and at 7°C for 72 hours for the psychrotrophic bacteria. After the respective incubation periods, the bacterial colonies were counted and presented as colony forming units (CFU)/g (APHA, 2001).

Samples were analyzed for fluid lost in thawing or cooking to evaluate the tenderness of the meat. Fluid lost in thawing was measured by weighing the samples when frozen and again 24 hours after thawing using a Shimadzu BL3200 H semi-analytic scale. Fluid lost in cooking was then measured by cooking the samples until an internal temperature of 72°C was reached using a Fischer Master 1323-10774 electric oven that was pre-heated to 180°C. The samples were weighed again and then stored for 24 hours at 4 ± 2°C. Six cylindrical sub-samples measuring 2.5 cm in height and 1.27 cm in diameter were removed using a cylindrical steel sampler. The shear force perpendicular to the orientation of the muscle fibers was measured using a Warner-Bratzler shear blade attached to a Stable Micro Systems TA-XT2i texture analyzer (WHIPPLE; KOOHMARAIE; DIKEMAN, 1990). A 5-mm/s velocity was used prior to and following the test, while a 2-mm/s velocity was used during the test.

The indirect proteolytic enzyme analysis was realized using the Myofibrillar Fragmentation Index (MFI), that was obtained by modifications in the methodology proposed by Culler et al. (1978) e Hopkins et al. (2000), with regard to the extraction of myofibrils using 4 g of muscle that was free from fat and connective tissue. The samples were homogenized in a Marconi MA102 Ultra-turrax dispersion unit at 9500 rpm in 20 mL of buffer solution at 2°C for 40 seconds. After homogenization, the samples were centrifuged at 3500 rpm for 15 minutes at 2°C, and the supernatant was discarded. The precipitate was re-suspended in 20 mL buffer solution, and the samples were again centrifuged and the supernatant discarded. The precipitate was then re-suspended in 10 mL of buffer solution and placed in an IKA Lab Dancer vortex shaker until the sample was homogeneous in preparation for subsequent filtration in a polyethylene-screen sieve (18 mesh) to remove the connective tissue. An additional 10 mL of buffer solution was added to clean the tube and to aid the filtration process. The extraction was conducted in duplicate.

Lipid oxidation was analyzed by the Indication of Thiobarbituric Acid-Reactive Substances (TBARS) method of Tarladgis, Pearson and Dugan (1964). The method entails spectrophotometrically determining the red color complex at 530 nm

as formed by the condensation of 2 moles of 2-Thiobarbituric Acid (TBARS) with 1 mole of malonaldehyde and/or other substances that react with TBARS. The spectrophotometer used was a 20 UV-Visible Cintra.

The sensory analysis was performed with a panel of 10 trained judges. The overall acceptability of the sample was judged on a scale from 1 to 9 (1 being extremely acceptable and 9 being extremely unacceptable), the flavor and juiciness were judged on scales from 1 to 5 (flavor: 1 being extremely intense and 5 having no flavor; juiciness: 1 being none and 5 being high), and tenderness was judged on a scale from 1 to 7 (1 being very hard and 7 being very tender). The samples were prepared by roasting them in a Fischer Master 1323-10774 electric oven pre-heated to 180°C until the meat reached an internal temperature of 72°C. The tasters evaluated samples from the 3 treatments, which consisted of maturation for 0, 3, or 6 days (ABNT, 1993).

Analysis of variance of the data with derivation of polynomials was performed using the SAEG program (Sistema de AnálisesEstatísticas e Genéticas. Versão 9.1, Viçosa).

Results and Discussion

Maturation led to significant changes in pH, water loss percentage, fluid lost in thawing, and fluid lost in cooking (Table 1).

Table 1. Value of pH, water loss percentage, fluid lost in thawing and fluid lost in cooking of pork meat according to the maturation time.

	Maturation time (days)				
Parameters	0	3	6	Regression	VC (%)
pH	5.65 ± 0.14	5.54 ± 0.07	5.54 ± 0.06	Linear [a]	1.73
Water loss percentage (%)	36.09 ± 2.94	30.12 ± 2.89	32.10 ± 2.84	Linear [b]	8.35
Fluidlost in thawing (%)	10.03 ± 2.66	10.27 ± 2.60	8.86 ± 4.42	Linear [c]	32.54
Fluid lost in cooking (%)	23.91 ± 4.38	25.45 ± 3.69	25.29 ± 3.56	Linear [d]	15.79

[a]Y=5.63239-0.0186458x (R^2 = 0.77) (P<0.05); [b]Y=34.764-0.0665555x (R^2= 0.43) (P<0.05);
[c]Y= 10.3032-0.193368x (R^2= 0.60) (P<0.07);[d]Y= 24.1884+0.231424x (R^2= 0.67) (P<0.08);
VC = Variation coefficient (%).
Source: Elaboration of the authors.

The pH values decreased as the maturation period increased; that is, they displayed a decreasing linear regression with maturation time. This fact could be explained by the growth of lactic acid bacteria, which optimally grow at pH < 6. These bacteria develop during the storage process of vacuum-packaged meats. As a result of the growth of these microorganisms, organic acids form and accumulate, which lowers the pH (FORSYTHE, 2002). In contrast, Oliveira, Soares and Antunes (1998), who tested the maturation of bovine *bíceps femoris* muscle at 24 hours, 14 days, 21 days, and 28 days post-mortem, observed an increase in pH. The authors attributed this increase to the greater susceptibility of this muscle to enzymatic attack during maturation due to the increased osmotic pressure of the medium as a consequence of the breakdown of proteins into smaller molecules and the intramolecular reorganization of these proteins, which undergo changes in their electric charges.

The water loss percentage presents a decreasing linear effect with maturation time; that is, the water retention capacity of the meat increased with the increase in the maturation time. During maturation, could not in fact be a slight increase in water retention capacity due to the proteolytic action

of cathepsins, which break down the enzymes of the myofibrillar structure, causing changes in the electrical charges of these proteins (OLIVEIRA; SOARES; ANTUNES, 1998). This breakdown in the ion-protein relationship increases the absorption of potassium ions (K^+) and the release of calcium (Ca^{++}) and sodium (Na^+) ions (LAWRIE, 2005). This exchange of ions during maturation causes better water absorption (ROÇA, 2000). These results are in agreement with those found by Apple et al. (2001), who tested the effect of refrigerated storage on the quality of vacuum-packaged pork loins and identified a reduction in the water loss of the loin with increasing storage time (0, 4, and 8 weeks).

The fluid lost in freezing present a decreasing linear relationship with maturation time. Due to the slight increase in the water retention capacity of the ageing meat, the fluid lost in freezing was also reduced.

Although maturation may improve the water retention capacity of proteins, the *post-mortem* denaturation of the proteins and the decline in pH considerably contribute to a loss of muscle exudates (LAWRIE, 2005). According to Miller et al. (1996), there is a greater loss of exudate during the refrigerated storage process, thus increasing the fluid lost during cooking.

The fluid lost in cooking presented an increasing linear regression with maturation time. With increasing storage period, the water retention capacity of the muscle increases, and therefore, during cooking, there was a greater percentage of fluid to be released. This result was similar to that found by Apple et al. (2001), who reported that the percentage of liquid lost due to cooking increased linearly with increasing maturation.

The luminosity (L*), the red intensity (a*), and the yellow intensity (b*) displayed an increasing linear effect with maturation time (Table 2).

Table 2. Values of meat colour (L*= luminosity, a*= red-green intensity, b*= yellow-blue intensity, c*= chroma and hº= tone) of pork meat according to the maturation time.

	Maturation time (days)				
Parameters	0	3	6	Regression	VC (%)
L*	53.61 ± 3.44	54.71 ± 3.57	55.03 ± 2.89	Linear [a]	5.19
a*	3.98 ± 0.95	4.62 ± 1.02	4.89 ± 1.29	Linear [b]	24.31
b*	8.74 ± 1.15	9.29 ± 0.97	9.38 ± 1.04	Linear [c]	11.53
c*	9.64 ± 1.26	10.41 ± 1.12	10.61 ± 1.40	Linear [d]	12.38
h°	65.64 ± 4.94	63.64 ± 4.92	62.78 ± 4.55	Linear [e]	7.47

[a]$Y = 53.7406 + 0.236667x$ ($R^2 = 0.91$) ($P<0.05$); [b]$Y = 4.04563 + 0.151389x$ ($R^2 = 0.95$) ($P<0.05$);
[c]$Y = 8.8135 + 0.10691x$ ($R^2 = 0.85$) ($P<0.05$);[d]$Y = 9.7304+0.163160x$ ($R^2 = 0.90$) ($P<0.05$);
[e]$Y = 65.4533-0.4777x$ ($R^2 = 0.95$) ($P<0.05$); VC = Variation coefficient (%).
Source: Elaboration of the authors.

With the increase in the maturation period, the meat became clearer, and there was also an increase in a* and b*. The increase in L* may be related to the decrease in the final pH of these meats, as L* displayed an inverse correlation with the pH, indicating that the lower the pH, the greater the luminosity, i.e., the muscle appears clearer (MAGANHINI et al., 2007).

The red intensity (a*) is directly linked to the state and amount of myoglobin present in the meat. The low oxygen tension in vacuum-packaged meats may have led to the oxidation of the myoglobin into metmyoglobin, thus increasing a* (TAYLOR,

1985). Low-pH conditions, such as those seen in meats with greater maturation times, cause a denaturation of globin, leaving the heme function unprotected, which leads to rapid oxidation of the metmyoglobin. According to Arima et al. (1997), the matured meat still displayed a different gradient when compared to the non-matured meat, even after equalizing the color, as the iron present in the myoglobin combined with the low oxygen tension turns into the oxidized form (Fe^{+++}), leading to metmyoglobin, which displays a dark color.

The yellow intensity (b*) increased with the increase in the maturation period. According to Sañudo (2004), the increase in the maturation time of the meat tends to make it darker and browner; in other words, b* tends to increase over time.

The chroma (saturation) of the meat, which indicates the purity of the color, increased linearly over the course of the maturation period (Table 2). The tone, which is calculated as a function of a* and b*, presented decreasing linear behavior with the maturation time (Table 2).

Upon analyzing the refrigerated storage time of vacuum-packed pork, Apple et al. (2001) also obtained similar results for L*, a*, b*, chroma, and tone, reporting that the color of the loin becomes more vivid and that there is a greater red intensity when the refrigerated storage time is increased. Similar results were also found by Frederick, Van Heugten and See (2006), who tested vacuum-packed and refrigerated pork for 0, 4, and 8 days.

As the maturation period increased, there was a linear increase in the mesophilic and psychrotrophic bacterial counts (Table 3).

Table 3. Values of mesophilic and psychrotrophic of pork meat according to the maturation time.

Parameters (log CFU/g)	Maturation time (days)				
	0	3	6	Regression	VC(%)
Mesophilic	2.92 ± 1.87	4.47 ± 2.45	4.45 ± 2.68	Linear [a]	59.77
Psychrotrophic	2.94 ± 1.91	4.36 ± 2.68	4.53 ± 2.53	Linear [b]	60.75

[a]Y= 3.17875+0.2550x (R^2= 0.74) (P<0.07); [b]Y= 3.15021+0.265208x (R^2=0.83) (P<0.06); VC=Variation coefficient (%).
Source: Elaboration of the authors.

The mesophilic microorganisms are important, as they are primarily acidifying microorganisms. Mesophilic microorganism counts are used to indicate the sanitary quality of foods, yet mesophilic bacteria do not represent a potential risk to human health (CAPTA, ALONSO-COLLETA; GARCÍA-ARIAS, 1999). Drehmer (2005) observed that the increase in the refrigerated storage of meat (0, 7, and 14 days) without using organic acids caused an increase in the mesophilic bacteria counts (2.72, 7.35, and 9.48 CFU/g with increasing refrigeration time). The bacterial load found in this study is within the standard established for meat fit for consumption. Mano, Pereira and Fernando (2002) reported that contaminated meat has a mesophilic bacteria index of greater than 10^7 CFU/g; the maximum found in this study was 4.47 log CFU/g, which is less than the indicated value for contamination.

Counts Psychrotrophic bacteria increase in refrigeration temperatures (7°C or less), which may cause deterioration of the meat. Thus, it is important to gauge the expiration date of the meat as a function of these bacteria. Concentrations above 7 log CFU/g modify the organoleptic characteristics of the meat (CAPTA, ALONSO-COLLETA; GARCÍA-ARIAS, 1999). Even with an increase in the psychrotrophic bacteria counts, the values found for all treatments were lower than 7 log CFU/g, meaning that the product is still fit for consumption.

The shear force presented decreasing linear behavior with maturation time; that is, it decreased as a function of the maturation time, making the meat tenderer. The MFI and lipid oxidation did not significantly change due to maturation (Table 4).

Table 4. Values of shear force, myofibrillar fragmentation index (MFI) and lipid oxidation of pork meat according to the maturation time.

	Maturation time (days)				
Parameters	0	3	6	Regression	VC (%)
Shear force (kgf)	3.85 ± 0.76	3.43 ± 0.73	3.33 ± 0.68	Linear [a]	19.25
MFI (%)	94.17 ± 8.88	92.88 ± 9.13	92.58 ± 7.57	NS [b]	9.18
Lipid oxidation (mg/kg sample)	0.10 ± 0.04	0.09 ± 0.04	0.09 ± 0.04	NS	42.69

[a]Y=3.79617-0.0871458X (R^2= 0.89) (P<0.05); [b]NS – No significant (P>0.05); VC=Variation coefficient (%).
Source: Elaboration of the authors.

The shear force may have decreased due to proteolysis of the myofibril structural components, which occurs during refrigeration (KOOHMARAIE; GEESINK, 2006). The values found indicate that maturation led to meats with a high degree of tenderness, and according to Boleman et al. (1997), shear force values for muscle less than 3.6 kgf/cm^2 indicate extremely tender meat. Evaluating the effect of maturation (0, 8, 12, 24, 48, and 72 hours) on the texture of the meat from broiler chickens, Kriese et al. (2005) found that the sheer force increased with the maturation time.

Even without a difference between the treatments, the MFI values for all of the treatments show that the pork was extremely tender. According to Culler et al. (1978), meats with an MFI greater than 60 are considered to have satisfactory texture. These results are consistent with those found by Komiyama et al. (2009), who did not observe an effect of the maturation time (0, 12, 24, and 48 hours) on the MFI when evaluating the effect of maturation on the quality of the meat and the structure of the muscle fiber of the breast meat from broiler chickens.

Extending the refrigerated storage period of the vacuum-packed pork did not change the lipid stability between the different treatments. However, Ohene-Adjei et al. (2004) evaluated the refrigerated storage (0, 3, and 9 days) of pork loins packaged with polyvinyl chloride (PVC) film and found an increase in lipid oxidation (1.58, 2.51, and 6.09 mg/kg sample) with storage time. These results show that the values found in this study are lower than those reported by the aforementioned authors. In a study by Herring et al. (2010), different concentrations of gelatin (0, 10, and 20%), which acted as a protective film for the pork, caused a concomitant increase in the lipid oxidation over the refrigerated storage period (0, 3, 5, and 7 days). The difference in these results may be the result of the use of vacuum-packaging, this type of packaging is more efficient at protecting meat against lipid oxidation.

There was no influence of the different maturation periods on the parameters evaluated in the sensory analysis (Table 5), indicating that even when the pork was refrigerated for up to 6 days, the fresh meat characteristics were preserved.

Table 5. Value of sensory analysis of pork meat according to the maturation time.

	Maturation time (days)				
Parameters	0	3	6	Regression	VC (%)
Odor	2.90 ± 0.74	3.70 ± 0.95	3.60 ± 0.84	NS [a]	24.93
Tenderness	5.90 ± 0.74	6.30 ± 0.67	6.00 ± 0.94	NS	13.08
Succulence	3.50 ± 0.97	3.80 ± 0.78	3.40 ± 1.26	NS	28.80
Global acceptance	6.60 ± 1.95	7.60 ± 1.35	7.60 ± 1.26	NS	21.38

[a]NS – No significant; VC=Variation coefficient (%).
Source: Elaboration of the authors.

Conclusion

Pork maturation caused a reduction in pH, which improved the color and reduced the risk of microbial contamination. Refrigerated storage and vacuum-packaging of pork for up to 6 days neither increased lipid oxidation nor damaged the sensory characteristics.

References

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS - ABNT. *NBR 12806*: análise sensorial de alimentos e bebidas. Rio de Janeiro: ABNT, 1993. 8 p.

AMERICAN PUBLIC HEALTH ASSOCIATION - APHA. Committee on microbiological methods for foods. *Compendium of methods for the microbiological examination of foods*. 4. ed. Washington: APHA, 2001, 676 p.

APPLE, J. K.; DAVIS, J. R.; RAKES, L. K.; MAXWELL, C. V.; STIVARIUS, M. R.; POHLMAN, F. W. Effects of dietary magnesium and duration of refrigerated storage on the quality of vacuum-packaged, boneless pork loins. *Meat Science*, Amsterdam, v. 57, n. 1, p. 43-53, jan. 2001.

ARIMA, H. K.; GARCIA, A. O.; YAMADA, E. A.; CIPOLLI, K. M. V. A. B.; MATTOS, J. C. A. Buffalo meat ageing at 0 to 2 C. In: WORLD BUFFALO CONGRESS, 5., 1997, Roma. *Proceedings*… Roma: Instituto Sperimentale per la Zootecnia, 1997. p. 452-456.

BARBUT, S. Estimates and detection of the PSE problem in young turkey breast meat. *Canadian Journal of Animal Science*, Ottawa, v.76, n. 3, p. 455-457, 1996.

BIANCHINI, W.; SILVEIRA, A. C.; JORGE, A. M.; ARRIGONI, M. B.; MARTINS, C. L.; RODRIGUES, É.; HADLICH, J. C.; ANDRIGHETTO, C. Efeito do grupo genético sobre as características de carcaça e maciez da carne fresca e maturada de bovinos superprecoces. *Revista Brasileira de Zootecnia,* Viçosa, MG, v. 36, n. 6, p. 2109-2117, 2007.

BOLEMAN, S. J.; BOLEMAN, S. L.; MILLER, R. K.; TAYLOR, J. F.; CROSS, H. R.; WHEELER, T. L.; KOOHMARAIE, M.; SHACKELFORD, S. D.; MILLER, M. F.; WEST, R. L.; JOHNSON, D. D.; SAVELL, J. W. Consumer evaluation of beef of known categories of tenderness. *Journal of Animal Science*, Champaign, v. 75, n. 6, p. 1521-1524, 1997.

CAPTA, R.; ALONSO-COLLETA, C.; GARCÍA-ARIAS, M. T. Aspectos de interés en la calidad microbiológica de la carne de pollo. *Eurocarne*, Madrid, v. 9, n. 73, p. 73-86, 1999.

CULLER, R. D.; PARRISH JUNIOR, F. C.; SMITH, G. C.; CROSS, R. Relationship of myofibril fragmentation index to certain chemical, physical and sensory characteristic of bovine longissimus muscle. *Journal of Food Science,* Chicago, v. 43, n. 4, p. 1177-1180, july. 1978.

DREHMER, A. M. F. *Quebra de peso das carcaças e estudo da vida de prateleira da carne suína*. 2005. Dissertação (Mestrado em Ciência e Tecnologia de Alimentos) - Universidade Federal de Santa Maria, Santa Maria.

FELÍCIO, P. E. de. Qualidade da carne bovina: características físicas e organolépticas. In: REUNIÃO ANUAL DA SBZ, 36., 1999, Porto Alegre. *Anais*... Rio Grande do Sul: Sociedade Brasileira de Zootecnia, 1999. p. 1-11.

FORSYTHE, S. J. *Microbiologia da segurança alimentar*. Porto Alegre: Artmed, 2002. 424 p.

FREDERICK, E.; VAN HEUGTEN, E.; SEE, M. T. Oxidative stability and quality of stored pork from pigs receiving magnesium supplementation through drinking water. *Journal of Animal Science*, Champaign, v. 84, n. 84, p. 185-190, 2006.

HERRING, J. L.; JONNALONGADDA, S. C.; NARAYANAN, V. C.; COLEMAN, S. M. Oxidative stability of gelatin coated pork at refrigerated storage. *Meat Science*, Amsterdam, v. 85, n. 4, p. 651-656, 2010.

KOMIYAMA, C. M.; MARTINS, M. R. F. B.; MENDES, A. A.; SANFELICE, C.; CAÑIZARES, M. C. S.; RODRIGUES, L.; CAÑIZARES, G. I. L.; ROÇA, R. O.; ALMEIDA, I. C. 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 Food Technology*, Campinas, II SSA, p. 89-93, 2009.

KOOHMARAIE, M.; GEESINK, G. H. Contribution of postmortem muscle biochemistry to the delivery of consistent meat quality with particular focus on the calpain system. *Meat Science*, Amsterdam, v.74, n. 1, p. 34-43, 2006.

KOOHMARIE, M. Muscle proteinases and meat aging. *Meat Science*, Amsterdam, v. 36, n. 3, p. 93-104, 1994.

KRIESE, P. R.; SOARES, A. L.; GUARNIERI, P. D.; SHIMOKOMAKI, M. Tenderização dos filés de frango durante a refrigeração. *Revista Nacional da Carne*, São Paulo, v. 29, n. 337, p .72-77, 2005.

LAWRIE, R. A. *Ciência da carne*. Tradução de Jane Maria Rubensam. 6. ed. Porto Alegre: Artmed, 2005. 384 p.

MAGANHINI, M. B.; MARIANO, B.; SOARES, A. L.; GUARNIERI, P. D.; SHIMOKOMAKI, M.; IDA, E. I. Carnes PSE (Pale, Soft, Exudative) e DFD (Dark, Firm, Dry) em lombo suíno numa linha de abate industrial. *Ciência Tecnologia de Alimentos*, Campinas, v. 27, p. 69-72, 2007. Suplemento 1.

MANO, S. B.; PEREIRA, J. A. O.; FERNANDO, G. D. G. Aumento da vida útil e microbiologia da carne suína embalada em atmosfera modificada. *Ciência e Tecnologia de Alimentos*, Campinas, v. 22, n. 1, p. 1-10, 2002.

MIELI, M.; MACHADO, J. S. Panorama da carne suína brasileira. *Agroanalysis*, São Paulo, v. 30, n. 1, p. 36-42, 2010.

MILLER, M. F.; CARR, M. A.; SCHLUTTER, A. R.; JONES, D. K.; MEADE, M. K.; RAMSEY, C. B. Distribution packaging method and storage time on microbiological characteristics and incidence of the pathogens *Listeria monocygenes* and *Salmonella* in pork. *Journal of Food Quality*, Oxford, v. 19, n. 5, p. 413-422, 1996.

MONSÓN, F.; SAÑUDO, C.; SIERRA, I. Influence of cattle breed and ageing time on textural meat quality. *Meat Science*, Amsterdam, v. 4, n. 68, p. 595-602, 2004.

OHENE-ADJEI, S.; BERTOL, T.; HYUN, Y.; ELLIS, M.; MCKEITH, F. K.; BREWER, M. S. Effect of vitamin E, low dose irradiation, and display time on the quality of pork. *Meat Science*, Amsterdam, v. 68, n. 1, p. 19-26, 2004.

OLIVEIRA, L. B.; SOARES, G. J. D.; ANTUNES, P. L. Influência da maturação da carne bovina na solubilidade do colágeno e perdas por cozimento. *Revista Brasileira de Agrociência*, Pelotas, v. 4. n. 3. p.166-171, 1998.

ROÇA, R. O. *Tecnologia da carne e produtos derivados*. Botucatu: Faculdade de Ciências Agronômicas, UNESP, 2000. 202 p.

SAÑUDO, C. Analisis sensorial - calidad organoléptica de la carne. In: CURSO INTERNACIONAL DE ANALISE SENSORIAL DE CARNE E PRODUTOS CÁRNEOS, 2004, Pelotas. *Anais*...Pelotas, 2004. p.45-68.

TARLADGIS, B. G.; PEARSON, A. M.; DUGAN JUNIOR, L. R. Chemistry of 2- thiobarbituric test for determination of oxidative rancidity in foods. II. Formation of the TBA- malonaldehyde complex without acid-heat treatment. *Journal of Food Science and Agriculture,* London, v. 15, p. 602-607, sept. 1964.

TAYLOR, A. A. Packaging fresh meat. *Meat Science*, Amsterdam, v. 3, n. 1, p. 89-113, 1985.

WHIPPLE, G.; KOOHMARAIE, M.; DIKEMAN, M. E. Evaluation of attributes that affect longissimus muscle tenderness in Bos Taurus and Bos indicus cattle. *Journal Animal Science*, Champaing, v. 68, n. 9, p. 2716-2728, 1990.