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Dietary Supplementation of Barbatimão (Stryphnodendron Adstringens) and Pacari (Lafoensia Pacari) Extracts on the Oxidative Stability and Quality of Chicken Meat

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ABSTRACT

In order to evaluate the antioxidant effects of *barbatimão* (BAR) or *pacari* (PAC) on chicken meat oxidative stability and quality, seven dietary treatments containing in three different BAR and PAC concentrations (200, 400 and 600ppm) plus a negative control (CONT) were fed to 350 broilers from 1 to 41 days of age. Ten birds per treatment were slaughtered to collect breast and thigh meat to evaluate pH, color (L*, a*, b*), cooking weight loss (CWL), and shear force (SF) 24 hours *postmortem*, and TBARS levels in precooked meatballs stored chilled for 8days. The dietary supplementation with BAR and PAC extracts did not affect pH and color, but reduced ($p<0.05$) SF in breast meat compared with CONT suggesting improved tenderness. PAC200 increased ($p<0.05$) L* and protected ($p<0.05$) yellow pigments (b* values) of thigh meat from degradation compared with the CONT diet. At the end of the chilled storage period, BAR600 and PAC600 significantly reduced ($p<0.06$) MDA concentrations in breast meatballs compared to the CONT. The dietary supplementation of BAR and PAC improved ($p<0.03$) oxidative stability of thigh meatballs, except for BAR200. In conclusion, the dietary addition of BAR and PAC extracts may improve meat quality and prevent lipid oxidation in white and dark precooked and chilled chicken meatballs.

INTRODUCTION

Consumer demands for the quality of meat and meat products has changed. Poultry meat consumption has increased due its relatively low fat concentration and high nutrient density (Barroeta, 2007; Pereira & Vicente, 2013). In addition, chicken meat has a higher percentage of monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA) compared to other meats, including a beneficial *n*-6:*n*-3 PUFA ratio (Grashorn, 2007). Human health studies demonstrated a positive influence of MUFA and PUFA consumption on the prevention and treatment of cardiovascular diseases (Ander *et al*., 2003; Harris *et al*., 2009).

On the other hand, high meat PUFA levels in meat and processing techniques, such as grinding, cooking, and salt addition increase the susceptibility of meat to degradation and cause lipid oxidation. Lipid oxidation causes oxidative stress, which is the imbalance between pro-oxidant and antioxidant substances, resulting in meat rancidity (Araújo *et al*., 2007; Panda & Cherian, 2014).

Lipid oxidation is a chain-reaction process that damage lipids, inducing meat rancid off-flavor and odor, reducing its juiciness and tenderness, in addition of increasing meat spoilage and reducing its shelf life (Adams, 1999; Delles *et al*., 2014). The dietary supplementation with natural antioxidants may be an alternative to prevent meat deterioration by improving its antioxidant balance and promoting lipid

stability. Consequently, there is a growing body of research on effective and safely natural antioxidants for poultry meat (Milani *et al*., 2010).

Brazilian plants naturally occurring in the Cerrado biome, such as *barbatimão* (*Stryphnodendron adstringens*) and *pacari* (*Lafoensia pacari*), have been used by the local population for decades as medicines due to their empiric effects (Lorenzi, 2000). Recently published studies demonstrated a strong antioxidant capacity of these plants related to the presence of phenolic compounds, including tannins, flavonoids, terpenes, ellagic acid, and others (Solon *et al*., 2000; Souza *et al*., 2007; Sampaio & Leão, 2007; Galdino *et al*., 2009; Oliveira & Vanzeler, 2011). This study aimed at evaluating the antioxidant capacity of the dietary supplementation of *barbatimão* and *pacari* extracts on chicken meat quality and lipid oxidation.

MATERIALS AND METHODS

Barbatimão and *pacari* alcoholic extracts

Barks from *Stryphnodendron adstringens* and *Lafoensia pacari* trees were macerated for 24 hours (80:20 alcohol:water), and distilled. The distilled extracts were reduced using a rotary evaporator cold trap (R-300, Buchi Brazil Ltda, Valinhos, SP) until reaching 20% solid residues with 43.6% (*barbatimão*) and 35% (*pacari*) total tannin content.

Birds and diets

A total of 350 one-d-old male Cobb500® broiler chicks were distributed into seven treatments with five replicates, totaling 35 experimental units with 10 birds each. Birds were housed at the experimental facilities of the Department of Animal Science, Veterinary School, Federal University of Goiás (UFG) in galvanized steel battery cages (0.5 m x 0.4 m x 0.4 m), equipped with trough drinkers and feeders. Water and feed were provided *ad libitum*. A lighting program of 23 hours of light plus one hour of darkness was adopted. Birds were brooded until 14 days of age using 60W lamps, and the room environment was controlled by side plastic curtain management.

The basal diets were fed as mash and were based on corn and soybean meal and formulated to supply the birds' nutritional requirements during the pre-starter, starter, and grower phases, according to Rostagno *et al*. (2011) and contained 2,960; 3,050 and 3,150 kcal/kg apparent metabolizable energy (AME); 22.4, 21.2, and 19.8 crude protein (CP), and 1.34, 1.217 and 1.131 digestible lysine, respectively. The composition of the diets is shown in Table 1.

Table 1 – Ingredient composition and calculated nutritional values of the basal diets

Ingredients	Pre-starter (1-7days)	Starter (8-21 days)	Grower (22-41 days)
Ground corn	54.43	56.86	59.82
Soybean meal 45%	38.77	35. 93	32.36
Soybean oil	2.220	3.100	4.000
Dicalcium phosphate	1.910	1.550	1.320
Limestone	0.798	0.843	0.803
Salt	0.458	0.437	0.416
DL-Methionine 99%	0.348	0.294	0.274
L-Lysine HCl	0.300	0.248	0.246
L-threonine 98%	0.113	0.078	0.069
Starch	0.500	0.500	0.500
Vitamin Suplement[1]	0.100	0.100	0.100
Mineral Suplement[2]	0.050	0.050	0.050
Calculated Values			
Metabolizable energy (kcal/kg)	2,960	3,050	3,150
Crude Protein (%)	22.40	21.20	19.80
Digestible Lysine (%)	1.324	1.217	1.131
Digestible Arginine (%)	1.417	1.337	1.235
Digestible Methionine (%)	0.658	0.591	0.555
Digestible Threonine (%)	0.861	0.791	0.735
Digestible Tryptophan (%)	0.257	0.241	0.222
Calcium (%)	0.920	0.841	0.758
Available Phosphorus (%)	0.470	0.401	0.354
Chlorine (%)	0.309	0.298	0.758
Sodium (%)	0.220	0.210	0.200

[1]Amount per kg of supplement: 3,125,000 IU Vitamin A; 550,000 IU Vitamin D3; 3,750 mg Vitamin E; 625 mg Vitamin K3; 250 mg Vitamin B1; 1125 mg Vitamin B2; 250 mg Vitamin B6; 3750mg Vitamin B12; 9,500 mg niacin; 3750 mg calcium pantothenate; 125 mg folic acid; 350,000 mg DL-methionine; 150,000 mg choline chloride 50%; 50 mg selenium.

[2]Amount per kg of supplement: manganese 150,000mg; zinc 100,000mg; iron 100,000mg; copper 16,000mg; iodine 1,500mg.

The dietary treatments consisted of the basal diet with no addition of antioxidants (negative control; CONT), and diets supplemented with200, 400 or 600 ppm of *barbatimão* or *pacari* extracts at the expense of starch. Treatments were applied in a completely randomized experimental design in a 2x3 factorial arrangement (2 plants x 3 concentrations) plus CONT. No synthetic antioxidants were added to the vitamin and mineral premix; only a basal amount of 20 mg of alpha-tocopheryl acetate/kg of diet was supplied to meet the physiological requirements of the birds.

All experimental procedures were previously by the Committee of Ethics on the Use of Animals – CEUA/UFG (protocol 030/2012).

Meat sampling and analyses

At 41 days of age, 10 birds per treatment were slaughtered in a commercial processing plant, according to the Brazilian legislation (Brasil, 2000). Raw deboned and skinless breast and thigh meat

samples were stored chilled (4°C) for 24 h, after which meat pH and color (CIELAB System: L*=lightness, a*=redness and b*=yellowness) were recorded in triplicate using a portable pH meter (AG 205, Testo do Brasil®, Campinas, SP) and chroma meter (CR-400, Konica-Minolta Inc., Japan).

Samples were then vacuum packed and stored chilled until meat composition analyses (humidity HU, crude protein CP, total lipid content TLC and ash AS) were performed in quadruplicate. Meat tenderness was evaluated by cooking weight loss (CWL) and shear force (SF) in breast meat samples only. Duplicates of 2.5x2.5x2.5cm meat cubes were collected from the right portion of *Pectoralis major* muscle, weighed and cooked in electric oven (170°C) until reaching 70°C internal temperature, monitored using a thermocouple thermometer (Type K, Testo® do Brasil, Campinas, SP) inserted in the center of a cube with the average weight of the replicate. After cooling, meat cubes were again weighed to calculate CWL (%) and used to evaluate SF (kgF), as described by Froning & Uijttenboogaart (1988). Briefly, cylindrical samples with 1.27-cm diameter were cut from each cube parallel to the muscle fibers and sheared in a Warner-Bratzler® meat shear apparatus (Model 235 6X, GR Manufacturing Co., Manhattan, KS) with a V-type of blade (1.016-cm thickness and fixed speed of 20 cm/min).

Storage trials

Breast and thigh meat samples were minced separately, 0.5% food-grade salt was added, and shaped into meatballs (30 g ± 0.5 g). Breast and thigh meatballs were vacuum packed and cooked in water bath at 100°C for 10 minutes, according to Racanicci *et al*. (2004). Pre-cooked meatballs were repacked in oxygen-permeable bags and kept chilled at 4°C in the dark for 8 days.

Secondary lipid oxidation products were evaluated on days 0, 2, 4, 6 and 8 of storage by malondialdehyde quantification using TBARS (thiobarbituric acid reactive substances). TBARS was determined in duplicate in two meatballs per treatment, according to Madsen *et al*. (1998). Absorbance was measured at 532 and 600 nm with spectrophotometer (UV-340G, Gehaka do Brasil, São Paulo, SP) and results were expressed in µmol of malondialdehyde (MDA) per kilogram of meat, using a 1,1,3,3-tetraethoxypropane (TEP) standard curve.

Statistical Analysis

The experiment was analyzed as a completely randomized experimental design in a 2x3 factorial arrangement (2 plants: BAR and PAC; 3 concentrations: 200, 400 and 600 ppm) plus negative control (CONT). Results were analyzed using PROC GLM (meat tenderness) and PROC MIXED procedures (repeated measurements: color, pH, TBARS) of the software SAS® (v.9.3, Statistical Analysis System, NC, USA). Means were compared by Tukey's test at 5% significance level. The statistical model used for the analysis of variance was: $Y_{ijk} = \mu + P_i + C_j + PxC_{ij} + e_{ijk}$, where: Y_{ijk} = dependent variables; μ = general mean; P_i = effect of the i^{th} plant; C_j = effect of the j^{th} concentration; PxC_{ij} = interaction between the i^{th} and the j^{th} factors ; e_{ijk} = random residual error.

RESULTS

Meat composition

The HU (73.78±0.49 and 73.98±0.52), CP (25.3±0.84 and 20.40±0.44), TLC (1.80±0.23 and 5.79±0.32) and AS (1.52±0.11 and 1.46±0.03) contents determined in the breast and thigh meat samples, respectively, were similar to those found in the Brazilian (NEPA, 2011) and American (USDA, 2012) composition tables and were not affected (p>0.05) by dietary treatments.

Table 2 – Average pH, color (L*, a*, b*), cooking weight loss (CWL, %), shear force (SF, KgF) values obtained in breast meat samples.

		Color				
Treatment*	pH	L*	a*	b*	CWL	SF
CONT	5.97	47.49^{ab}	3.02	8.33^{ab}	15.88^{b}	2.85^{a}
BAR200	5.87	47.73^{ab}	3.48	7.82^{b}	14.04^{b}	2.17^{ab}
BAR400	5.92	46.58^{b}	3.52	7.59^{b}	10.27^{c}	1.40^{b}
BAR600	5.83	48.19^{ab}	3.10	7.99^{ab}	13.71^{b}	1.71^{b}
PAC200	5.86	49.64^{a}	3.30	9.71^{a}	20.70^{a}	1.63^{b}
PAC400	5.89	49.13^{ab}	3.22	8.73^{ab}	15.62^{b}	1.82^{b}
PAC600	5.87	47.45^{ab}	2.98	8.35^{ab}	12.47^{b}	1.65^{b}
Stand. Dev.	0.50	0.69	0.31	0.60	1.09	0.41

^{a,b,c} Means with different letters in the same row are statistically different (p<0.05).

*Treatments: negative control diet with no antioxidants (CONT) and diets supplemented with of 200, 400, or 600 ppm of *barbatimão* (BAR) or *pacari* (PAC) alcoholic extracts.

Meat pH and color

The addition of BAR and PAC did not affect breast meat pH or a* color (Table 2). The diets containing BAR400 promoted the lowest (46.58 and 7.59) and PAC200 the highest (49.64 and 9.71) L* and b* values, respectively. Likewise, the pH of the thigh meat samples (Table 3) were not different when BAC and PAC were compared with the CONT treatment. Thigh meat a* values were not different among treatments; however, the birds fed the PAC200 diet presented higher thigh meat (p<0.05) L* (48.86) and b* (11.27) values compared with those fed the CONT diet.

Table 3 – Average pH and color (L*, a*, b*) values obtained in thigh meat samples.

		Color		
Treatment*	pH	L*	a*	b*
CONT	6.11^{ab}	46.68^{b}	13.81	9.54^{b}
BAR200	6.12^{ab}	47.56^{ab}	15.49	10.71^{ab}
BAR400	6.17^{a}	47.31^{ab}	15.01	10.33^{ab}
BAR600	5.98^{b}	47.48^{ab}	15.03	10.06^{ab}
PAC200	6.06^{ab}	48.86^{a}	13.59	11.27^{a}
PAC400	6.08^{ab}	47.64^{ab}	14.45	10.67^{ab}
PAC600	6.02^{ab}	46.64^{b}	14.78	10.35^{ab}
Stand.Dev.	0.06	0.74	0.97	0.59

^{a,b,c} Means with different letters in the same row are statistically different (p<0.05).

*Treatments: negative control diet with no antioxidants (CONT) and diets supplemented with of 200, 400, or 600 ppm of *barbatimão* (BAR) or *pacari* (PAC) alcoholic extracts.

Meat tenderness

CWL and SF values were significantly affected (p<0.05) by the dietary treatments (Table 2). The meat of the birds fed the BAR400 diets presented the lowest CWL value (10.27%; p<0.05) whereas the opposite was observed in the meat of PAC200-fed birds (20.70%). The inclusion of the evaluated plant extracts to broiler diets significantly reduced (p<0.05) breast meat SF relative to the CONT diet, except for BAR200.

Meat oxidation

Statistical differences (p<0.07) among treatments regarding malondialdehyde (MDA) accumulation in precooked breast meat were detected during the entire storage period (Figure 1). On day zero, broilers fed the diets with BAR and PAC inclusion presented similar oxidation levels compared with the CONT diet, except for BAR200, which pro-oxidant effect was detected immediately after cooking. From day2 to 6 of chilled storage, dietary PAC400 inclusion effectively (p<0.06) prevented lipid peroxidation compared with the CONT diet, while the oxidation levels determined with the other dietary BAR and PAC levels was similar to that of the CONT diet. Up to day 8, the dietary addition of BAR600 and PAC600 significantly reduced (p<0.06) MDA levels in cooked breast meatballs, efficiently delaying oxidation compared with the CONT diet.

In thigh meatballs (Figure 2), the dietary inclusion of BAR400 and PAC200 was able to protect lipids from oxidation (p<0.02) during cooking (day zero) compared with the CONT diet, whereas the treatment PAC600 increased (p<0.0002) TBARS levels. Between days 2 and 6 of storage, the dietary supplementation of BAR and PAC was not effective to prevent the formation of TBARS compared with the CONT diet. However, at the end of storage (day 8), the dietary inclusion of BAR and PAC showed (p<0.03) significant antioxidant activity, preventing lipid oxidation relative to the CONT diet, except for BAR200.

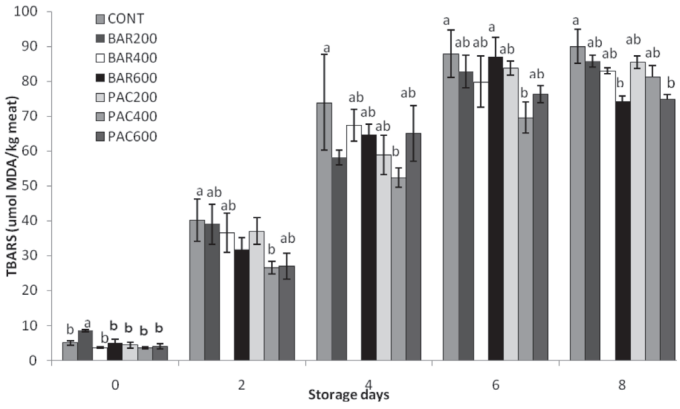

Figure 1 – Secondary compounds of lipid oxidation (TBARS, µmol MDA/kg meat) in precooked chicken breast meatballs during chilled storage. *Treatments: negative control diet with no antioxidants (CONT) and diets supplemented with of 200, 400, or 600 ppm of barbatimão (BAR) or pacari (PAC) alcoholic extracts. ^{a,b,c} Means with different letters on the same day are statistically different (p<0.1).

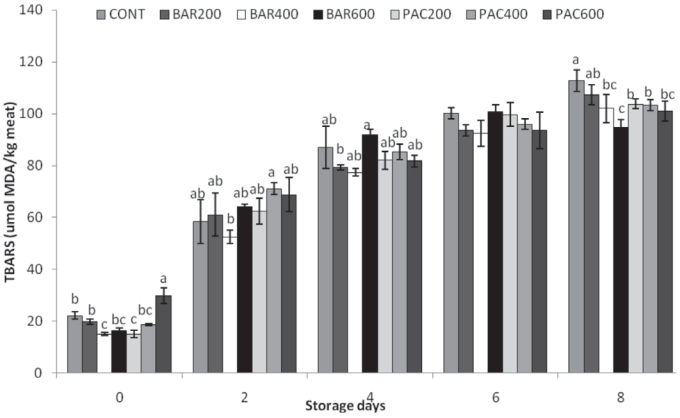

Figure 2 – Secondary compounds of lipid oxidation (TBARS, µmol MDA/kg meat) in precooked chicken thigh meatballs during chilled storage. *Treatments: negative control diet with no antioxidants (CONT) and diets supplemented with of 200, 400, or 600 ppm of barbatimão (BAR) or pacari (PAC) alcoholic extracts. ^{a,b,c} Means with different letters on the same day are statistically different (p<0.1).

DISCUSSION

Meat pH and color

Average breast meat pH values within the range expected for this type of meat 24 hours *post mortem*, according to Lesiow *et al*. (2009) and Glamoclija *et al*. (2015). As expected, higher pH values were determined in thigh meat (dark meat) than in breast meat (white meat) due to the different types of their

muscle fibers. The dark color of thigh meat is given by its high amount of type I muscle fibers, which are aerobic, and therefore, have low glycolytic potential. The metabolism of muscle I fibers results in low glycogen and lactic acid production, which are involved in the transformation of muscle into meat (Dransfield & Sosnicki, 1999; Joo *et al*., 2013).

According to Beraquet (2000), normal chicken meat pH ranges between 5.8-6.2. In this experiment, the meat pH values obtained with all treatments were within this range. However, there was no effect of the tested antioxidants on pH, as observed by Lee *et al*. (2012), who detected an increase in meat pH values in the meat of broilers fed garlic and linoleic acid with those fed a control diet. Those authors concluded that the dietary supplementation of those natural antioxidants was able to slow down pH decline *post-mortem*, possibly due to the antioxidant effect of the phenolic compounds deposited in the meat. Lima *et al*. (2015) concluded that the inclusion of 500ppm of the Cerrado plants *copaiba* (*Stryphnodendron adstringens*) and *sucupira* (*Lafoensia pacari*) oil resins in broiler diets delayed thigh meat lipid oxidation compared with a control diet, but did not detect any pH differences.

Barbut *et al*. (1997) classified chicken breast meat as normal, DFD (dark, firm and dry), or PSE (pale, soft and exudative) according to the pH and L* (luminosity) values evaluated 24 hours *post-mortem* in chilled *pectoralis major* muscle. DFD meat is characterized by L* values lower than 46 and pH values higher than 6.1, whereas PSE meat presents L* values higher than 53 and pH lower than 5.7. According to these values, all treatments applied in the present study produced breast meat that can be classified as normal. Breast meat color was not affected by natural extracts supplementation when compared with the CONT treatment, as previously reported by Leonel *et al*. (2007) evaluating different levels of vitamin E.

Overall, the higher redness (a*) value detected in thigh meat compared with breast meat is related to the tissue concentrations of hemoglobin, and specially, of myoglobin (Hedrick *et al*., 1994; Muhlisin *et al*., 2016). These heme proteins are responsible for meat pigmentation and their concentration in meat is related to several factors, such as tissue muscular activity, blood supply, oxygen availability, and age (Kranen *et al*., 1999; Min *et al*., 2008). As observed in other studies with natural antioxidants (Chouliara *et al*., 2007; Simitzis *et al*., 2008), the supplementation of PAC200 was capable of delaying deterioration of yellowness (b*) in thigh meat, suggesting improvement in myoglobin stability.

Meat tenderness

In general, the average CWL values observed in this study (10.27-20.70%) were lower than those reported by Almeida *et al*. (2002) and Shafey *et al*. (2014) in normal breast meat (23.0-31.69%). On the other hand, Barbut *et al*. (2005) considered normal meat when CWL average values were close to 11.25%. Shear force results (1.40-2.85) were within the expected range for chicken breast meat (Souza *et al*., 2011; An *et al*., 2015).

Cooking loss and shear force are related with meat tenderness and water holding capacity, i.e., with the capacity of retaining water associated with the intramuscular fibers (Müller *et al*., 2012). The results of the present study showed that the breast meat of broilers fed 400 ppm of *barbatimão* was capable of retaining water inside the muscle fibers and, therefore, being more tender than the meat of those fed the control diet. These results are in agreement with other studies evaluating plant extract supplementation in broiler diets (Lahucky *et al*., 2010; Luna *et al*., 2010).

Lipid oxidation

The inclusion of plant extracts in broiler diets, such as BAR and PAC, led to the incorporation of antioxidant compounds in the cell membrane and muscle tissue (breast meat, Figure 1 and thigh meat, Figure 2) after these compounds were metabolized by the birds. The uniform distribution of the antioxidant substances derived from the plant extracts is directly correlated with their antioxidant efficiency after the muscle is converted into meat, because these compounds are available close to the damaged sites (Sies & Stahl, 1995; Cui & Decker, 2016).

Although the dietary inclusion of *pacari* at 400 ppm delayed breast meat lipid oxidation up to day 6 of storage, only the highest dose (600 ppm) effectively prevented lipid oxidation on day 8 (Figure 1). This result probably is related to the depletion of most of the antioxidant compounds accumulated in the muscle at lower supplementation levels, as the supplementation of both evaluated plant extracts at 600 ppm was able to maintain higher antioxidant levels available to prevent lipid oxidation until the end of the storage period.

On the other hand, the dietary inclusion of BAR and PAC at any level delayed thigh meat lipid oxidation until the day 6 (except on day zero) (Figure 2). Nevertheless, on day 8, the dietary inclusion of all levels of BAR and PAC, with except for BAR200, significantly ($p<0.03$) delayed thigh meat oxidation compared with the CONT diet.

Therefore, the results observed in this study are consistent with those reported by Botsoglou *et al*. (2002), who detected antioxidant activity of the dietary supplementation of oregano essential oil (50 and 100 ppm) on both breast and thigh meat compared with a control diet, obtaining the best results with the highest dosage. Moreover, Narciso-Gaytán *et al*. (2011) found that DL-α-tocopheryl acetate supplemented at 200 ppm in broiler diets was effective in preventing both breast and thigh meat oxidation. However, Mariutti *et al*. (2011) obtained different results when evaluating 0.1% inclusion of dried garlic directly in minced breast meat before cooking. The authors did not detect antioxidant activity of garlic when compared to a control without the use of antioxidants.

The antioxidant efficacy of BAR and PAC natural extracts, as well as of other plant extracts, is influenced by several plant-related factors, including the geological region where the plants are grown, harvesting season, climate, and part of the plant used (Fernandez-Panchon *et al*., 2008). Most part of the essential oils compounds present in plant extracts is rapidly absorbed in the gut after oral administration, metabolized, and excreted by the kidneys. Only a small amount of these compounds is deposited in the body, especially on cellular membranes (Mitsumoto, 2000; Cui & Decker, 2016). However, the balance between the amount of compounds stored and excreted can vary according to the composition of these essential oils (Igmi *et al*., 1974; Lee, 2004).

The *in-vitro* antioxidant potential of *barbatimão* extract was previously reported by Lopes *et al*. (2005), who demonstrated the antioxidant activity of this plant by DPPH (1,1-diphenyl-2-picryl-hydrazyl) radical scavenging. Solon *et al*. (2000) also showed that *pacari* extract has antioxidant activity *in vitro*. Therefore, the results of the present study confirm those previous findings, as shown by the effective lipid oxidation control at the end of the storage period of the breast and thigh meat of broilers fed BAR and PAC compared with the CONT diet.

CONCLUSIONS

The dietary supplementation of broilers with alcoholic extracts of *barbatimão* and *pacari* seems to improve breast meat quality and preserve yellowness in thigh meat. Low dietary supplementation levels of these extract maybe used to prevent early lipid oxidation in chicken breast meatballs; however, higher levels are needed to protect breast meat lipids for longer periods, whereas the antioxidant effect of *barbatimão* and *pacari* in chicken thigh meatballs was detected at the end of chilled storage period.

REFERENCES

Adams SM. Ecological Role of Lipids in the Health and Success of Fish Populations. In: Arts MT, Wainman BC, editors. Lipids in freshwater ecosystems. New York: Springer; 1999.

Almeida SP, Proença CEB, Sano SM, Ribeiro JF. Cerrado: espécies vegetais úteis. Planaltina: EMBRAPA-CPAC; 1998.

An BK, Kim JY, Oh ST, Kang CW, Cho S, Kim SK. Effects of onion extracts on growth performance, carcass characteristics and blood profiles of white mini broilers. Asian-Australasian Journal of Animal Science 2015;28:247–251.

Ander BP, Dupasquier CMC, Prociuk MA, Pierce GN. Polyunsaturated fatty acids and their effects on cardiovascular disease. Experimental and Clinical Cardiology 2003;8:164-172.

Araújo JA, Silva JHV, Amâncio ALL, Lima MR, Lima CB.Uso de aditivos na alimentação de aves. Acta Veterinaria Brasílica 2007;1:69-77.

Barbut S. Problem of pale soft exudative meat in broiler chickens. British Poultry Science 1997;38: 355-358.

Barbut S, Zhang L, Marcone M. Effects of pale, normal and dark chicken breast meat on microstructure, extractable proteins, and cooking of marinated filets. Journal Poultry Science 2005;84:797-802.

Barroeta AC. Nutritive value of poultry meat - relationship between vitamin E and PUFA. Worlds Poultry Science Journal 2007;63:277-284.

Beraquet NJ. Influência de fatores ante e post mortem na qualidade da carne de aves. Revista Brasileira de Ciência Avícola 2000;1:155-166.

Botsoglou NA, Christaki E, Fletouris DJ, Florou-Paneri, P, Spais, AB. The effect of dietary oregano essential oil in lipid oxidation in raw and cooked chicken during refrigerated storage. Meat Science 2002;62:259-265.

BRASIL. Ministério da Agricultura e Abastecimento. Instrução Noramativa nº 3, de 17 de janeiro de 2000. Regulamento técnico de métodos de insensibilização para o abate humanitário de animais de açougue. Brasília, DF: Secretaria de Defesa Agropecuária, 2000.

Chouliara E, Karatapanis A, Savvaidis IN, Kontominas MG. Combined effect of oregano essential oil and modified atmosphere packaging on shelf-life extension of fresh chicken breast meat stored at 41C. Food Microbiology 2007;24:607-617.

Cui L, Decker EA. Phospholipids in foods: prooxidants or antioxidants? Journal of The Science of Food And Agriculture 2016,96:18–31.

Delles RM, Xiong YL, True AD, Ao T, Dawson KA. Dietary antioxidant supplementation enhances lipid and protein oxidative stability of chicken broiler meat through promotion of antioxidant enzyme activity. Journal of Poultry Science 2014;94:1368-1378.

Dransfield E, Sosnicki A. Relationship between muscle growth and poultry meat quality. Journal of Poultry Science 1999;78:743-746.

Fernandez-Panchon MS, Villano D, Troncoso AM, Garcia-Parrilla MC. Antioxidant activity of Phenolic compounds: From in vitro results to in vivo evidence. Food Science and Nutrition 2008;48:649-671.

Froning GW, Uijttenboogaar TG. Effect of post mortem electrical stimulation on colour, texture, pH and cooking loses of hot and cold deboned chicken broiler breast meat. Journal of Poultry Science 1988;67:1535-1544.

Galdino PM, Nascimento MVM, Sampaio BL, Ferreira RN, Paula JR, Costa EA. Antidepressant-like effect of *Lafoensia pacari*A. St.-Hil. ethanolic extract and fractions in mice. Journal of Ethnopharmacology 2009;124:581-585.

Glamoclija N, Starcevic M, Janjic J, Ivanovic J, Boskovic M, Djordjevic J, et al.. The effect of breed line and age on measurements of pH-value as meat quality parameter in breast muscles (m. pectoralis major) of broiler chickens. Procedia Food Science 2015;5:89-92.

Grashorn MA. Functionality of poultry meat. Journal Applied Poultry Research 2007;16:99-106.

Harris WS, Mozaffarian D, Rimm E, Kris-Etherton P, Rudel LL, Appel LJ, et al. Omega-6 fatty acids and risk for cardiovascular disease. Journal of the American Heart Association 2009;119:902-907.

Hedrick HB, Aberle E, Forrest JC, Judge MD, Merkel RA. Principles of meat science. 3rd ed. Dubuque: Hunt Publishing, Dubuque; 1994. p.354.

Igmi H, Nishimura M, Kodama R, Ide H. Studies on the metabolism of d-limonene (p-mentha-1,8-diene): The absorption, distribution and excretion of d-limonene in rats. Xenobiotica 1974;4:77-84.

Joo ST, Kim GD, Hwang YH, Ryu YC. Control of fresh meat quality through manipulation ofmuscle fiber characteristics. Meat Science 2013;95:828-836.

Kranen RW, Van Kuppevelt TH, Goedhard HA, Veerkamp CH, Lambooy E, Veerkamp JH. Hemoglobin and myoglobin content in muscles of broiler chickens. Journal of Poultry Science 1999;78:467-496.

Lahucky R, Nuernberg K, Kovac L, Bucko O, Nuernberg G. Assessment of the antioxidant potential of selected plant extracts--in vitro and in vivo experiments on pork. Meat Science 2010;85:779-784.

Lee KH, Jung S, Kim HJ, Kim IS, Lee JH, Jo C. Effect of dietary supplementation of the combination of gallic and linoleic acid in thigh meat of broilers. Asian-Australasian Journal of Animal Science 2012;25:1641-1648.

Lee KW, Everts H, Beynen AC. Essential oils in broiler nutrition. International Journal of Poultry Science 2004;3:38-752.

Leonel FR, Oba A, Pelicano ERL, Zeola NMBL, Boiago MM, Scatolini AM, et al. Performance, carcass yield, and qualitative characteristics of breast and leg muscles of broilers fed diets supplemented with vitamin E at different ages. Brazilian Journal of Poultry Science 2007;9:91-97.

Lesiow T, Szmanko T, Korzeniowska M, Bobak L, Oziemblowski M. Influence of the season of theyear on some technological parameters and ultrastructureof PSE, normal and DFD chicken breast muscles. Proceedings of the 19º European Symposium on the Quality of Poultry Meat; 2009; Turku. Finlândia: WPSA; 2009. p.21-25.

Lima CB de, Racanicci AMC, Oliveira GR, Migotto DL, Amador AS, Souza TC de, et al. Effects of the dietary supplementation of sucupira (*Pterodon Emarginatus* Vog.) and copaiba *(Copaifera Langsdorffii*) resinoils on chicken breast and thigh meat quality and oxidative stability. Brazilian Journal of Poultry Science 2015;17:47-56.

Lopes GC, Sanches ACC, Nakamura CV, Dias-Filho BP, Hernandes L, De Mello JCP. Influence of extracts of Stryphnodendron polyphyllum Mart. and Stryphnodendron obovatum Benth, on the cicatrisation of cutaneous wounds in rats. Journal of Ethnopharmacology 2005;99:265-272.

Lorenzi H. Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas nativas do Brasil. 3rd ed. Nova Odessa: Plantarum; 2000.

Luna A, Labaque MC, Zygadlo JA, Marin RH. Effects of thymol and carvacrol feed supplementation on lipid oxidation in broiler meat. Journal of Poultry Science 2010;89:366-370.

Madsen HL, Sørensen B, Skibsted LH, Bertelsen G. The antioxidative activity of summer savory (Satureja hortensis L) and rosemary (Rosmarinus officinalis L) in dressing stored exposed to light or in darkness. Food Chemmisty 1998;63:173-180.

Mariutti LRB, Nogueira GC, Bragagnolo N. Lipid and cholesterol oxidation in chicken meat are inhibited by sage but not by garlic. Journal of Food Science 2011;76:909-915.

Milani LIG, Terra NN, Fries LLM, Rezer APS. Effect of persimmon (Diospyros kaki, L.) extracts on the lipid oxidation, sensory characteristics and colour of heat treated chicken meat. Brazilian Journal of Food Technology 2010;13:242-250.

Min BR, Nam KC, Cordray JC, Ahn DU. Factors affecting oxidative stability of pork, beef, and chicken meat [Animal Industry Report]. 2008. Available from: http://lib. dr.iastate.edu/ans_air/vol654/iss1/6.

Mitsumoto M. Dietary delivery versus exogenous addition of antioxidants. In: Decker E, Faustman C, Lopezbote CJ, editors. Antioxidants in muscle foods. New York: Wiley-Interscience; 2000. p.315–328

Muhlisin, Utama DT, Lee JH, Choi JH, Lee SK. Antioxidant enzyme activity, iron content and lipid oxidation of raw and cooked meat of korean native chickens and other poultry. Asian - Australasian Journal of Animal Science 2016;29:695-701.

Müller AT, Paschoal EC, Santos JMG. Impacto do manejo pré-abate na qualidade da carne de frango. Revista em Agronegócios e Meio Ambiente 2012;5:61-80.

Narciso-Gaytán C, Shin D, Sams AR, Keeton JT, Miller RK, Smith SB, et al. Lipid oxidation stability of omega-3- and conjugated linoleic acid-enriched sous vide chicken meat. Poultry Science 2011;90:473-480.

NEPA - Núcleo de Estudos e Pesquisas em Alimentação. Tabela brasileira de composição de alimentos. 4ª ed. Campinas: Editora UNICAMP; 2011. p.16-104.

Oliveira SS, Vanzeler MLA. Evaluation of effects of metabolic extract of Stryphnodendrom tightens (Mart) Coville for gavagem in the estral cicle of female rats. Elect J Pharm 2011;8:22-28.

Padilha ADG. Antioxidante natural de erva mate na conservação da carne de frango in vivo [dissertação]. Santa Maria (RS): Centro de Ciências Rurais da Universidade Federal de Santa Maria; 2007. 97p.

Panda AK, Cherian G. Role of vitamin E in counteracting oxidative stress in poultry. Journal of Poultry Science 2014;51:109-117.

Pereira PMCC, Vicente AFRB. Meat nutritional composition and nutritive role in the human diet. Meat Science 2013;93:586-592.

Qiao M, Fletcher DL, Northcutt JK, Smith. The relationship between raw broiler breast meat color and composition. Journal of Poultry Science 2002;81:422-427.

Racanicci AMC, Danielsen B, Menten JFM, Regitano-D´arce-Mab-Skibsted LK. Antioxidant effect of dittany (Origanum dictamnus) in pre-cooked chicken meat balls during chill storage in comparison to rosemary (Rosmarinus officinalis). European Food Research and Technology 2004;218:521-524.

Rostagno HS, Albino LFT, Donzele JL, Gomes PC, Oliveira RF, Lopes DC, et al. Tabelas brasileiras para aves e suínos: composição de alimentos e exigências nutricionais. 3ª ed. Viçosa: UFV; 2011.

Shafey TM, Mahmoud AH, Hussein ES, Suliman G. The performance and characteristics of carcass and breast meat of broiler chickens fed diets containing flaxseed meal. Italian Journal of Animal Science 2014;13:752-758.

Sies H, Stahl W. Vitamins E and C, a-carotene, and other carotenoids as antioxidants. The American Journal of Clinical Nutrition 1995;62:1315S-1321S.

Simitzis PE, Symeon GK, Charismiadou MA, Ayoutanti AG, Deligeorgis SG. The effects of dietary hesperidin supplementation on broiler performance and chicken meat characteristics. Canadian Journal of Animal Science 2011;91:275-282.

Solon S, Lopes L, Sousa-Junior PTDe, Schmeda-Hirschmann G. Free radical scavenging activity of *Lafoensia pacari*. Journal of Ethnopharmacology 2000;72:173-178.

Souza TM, Severi JA, Silva VYA, Santos E, Pietro RCLR. Bioprospecção de atividade antioxidante e antimicrobiana da casca de *Stryphnodendron adstringens* (Mart.) Coville (Leguminosae-Mimosoidae). Journal of Basic & Applied Pharmaucetical Science 2007;28:221-226.

USDA - United States Department of Agriculture. Composition of foods raw, processed, prepared USDA national nutrient database for standard reference. USDA: Washington; 2012. p.106-110.