Impact of juçara (*Euterpe edulis*) fruit waste extracts on the quality of conventional and antibiotic-free broiler meat

Beatriz da Silva Frasao,[*] Anisio Iuri Lima dos Santos Rosario,[†,‡,¶] Bruna Leal Rodrigues,[*] Hariadyne Abreu Bitti,[*] Jéssica Diogo Baltar,[§] Regina Isabel Nogueira,[|] Marion Pereira da Costa,[†,1] and Carlos Adam Conte-Junior[*,‡,§,¶,#,**,††]

[*]*Centro Laboratorial Analítico, Faculty of Veterinary Medicine, Fluminense Federal University (UFF), Vital Brazil Filho, Niterói, RJ, 24230-340, Brazil;* [†]*Laboratório de Inspeção e Tecnologia de Leite e Derivados (LAITLACTEOS), Federal University of Bahia (UFBA), Salvador, BA, 40170-110, Brazil;* [‡]*Graduate Program in Veterinary Hygiene (PPGHV), Faculty of Veterinary Medicine, Fluminense Federal University (UFF), Vital Brazil Filho, Niterói, RJ, 24220-000, Brazil;* [§]*Graduate Program in Food Science (PPGCAL), Institute of Chemistry (IQ), Federal University of Rio de Janeiro (UFRJ), Cidade Universitária, Rio de Janeiro, RJ, 21941-909, Brazil;* [|]*Embrapa Food Technology, Brazilian Agricultural Research Corporation, Rio de Janeiro, Brazil;* [¶]*Center for Food Analysis (NAL), Technological Development Support Laboratory (LADETEC), Federal University of Rio de Janeiro (UFRJ), Cidade Universitária, Rio de Janeiro, RJ, 21941-598, Brazil;* [#]*Laboratory of Advanced Analysis in Biochemistry and Molecular Biology (LAABBM), Department of Biochemistry, Federal University of Rio de Janeiro (UFRJ), Cidade Universitária, Rio de Janeiro, RJ, 21941-909, Brazil;* [**]*Graduate Program in Sanitary Surveillance (PPGVS), National Institute of Health Quality Control (INCQS), Oswaldo Cruz Foundation (FIOCRUZ), Rio de Janeiro, RJ, 21040-900, Brazil; and* [††]*Graduate Program in Chemistry (PGQu), Institute of Chemistry (IQ), Federal University of Rio de Janeiro (UFRJ), Cidade Universitária, Rio de Janeiro, RJ, 21941-909, Brazil*

ABSTRACT Juçara (*Euterpe edulis*) is a native Brazilian palm tree from the Atlantic Forest, whose fruit-processing waste can present high concentration of antioxidant compounds. This research was assessed to determine the antioxidant potential of juçara waste extracts aiming to reduce the lipid and protein oxidation processes on conventional and antibiotic-free broiler meat throughout 9 d during refrigerated storage. The juçara waste extracts were obtained by microwave-assisted extraction. Two different extracts were tested based on the optimum point obtained when checking total phenolic (**TPC**) contents (Extract P) and antioxidant activity (Extract A) based on a previous study. The treatments using conventional and antibiotic-free broiler meat included: chicken patties without antioxidant addition (AFBNC and CBNC), with synthetic antioxidant (BHT) (AFBPC and CBPC), with Extract P (AFBEP and CBEP) and with Extract A (AFBEA and CBEA), totaling 8 treatments. Antioxidant activity of extracts along with TPC, flavonoid, anthocyanin, and tannin contents of extracts and patties were assessed. Proximate composition, fatty acid profile, lipid and protein oxidation process, and instrumental color were analyzed in patty treatments. Although both extracts had similar content of TPC and tannin, extract A presented the highest anthocyanin, while extract P exhibited the highest flavonoid. While extract A exhibited the highest antioxidant activity, extract P was highly influential in the stability of lipid oxidative degradation in both types of broiler meat (AFBEP and CBEP), and as successful as BHT (AFBPC and CBPC). In addition, extract P was also able to stabilize protein oxidation in conventional broiler meat (CBEP) from the third day, until the end of the storage period. Therefore, the fruit waste extract P of juçara can be a promising source of natural antioxidants to prevent the oxidative process in conventional and antibiotic-free broiler meat.

Key words: chicken meat, lipid oxidation, protein oxidation, phenolic compounds, oxidation stability

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[1]Corresponding author: marioncosta@ufba.br

INTRODUCTION

From a nutritional perspective, broiler meat has a desirable fatty acid profile consisting of low content of saturated fatty acids (**SFA**) and relatively high concentrations of polyunsaturated fatty acids (**PUFAs**),

whose dietary intake is related to reducing the risk of cardiovascular diseases, cancer, and other conditions (Milićević et al., 2014). However, because PUFAs are chemically unstable and highly oxidizable molecules (Wang et al., 2017a), their predominance in muscle membranes may favor the oxidation process, thus reducing meat shelf-life. Oxidation is the primary cause of meat deterioration involving lipid and protein nonmicrobial degradation, including the generation of health-damaging components related to pathologies, inflammation, carcinogenesis, aging, among others (Domínguez et al., 2019). The susceptibility of lipids to peroxidation in muscle tissue depends on the proportion of PUFAs in lipid bilayers, the presence of reactive oxygen species and nutritional oxidants (Brenes et al., 2008). Covalent modification of proteins induced either directly, by the action of reactive species, or indirectly, by a reaction with secondary oxidative stress by-products was observed in protein oxidation (Salles et al., 2019). Also, redox imbalance and early protein oxidation have been related to meat quality (Carvalho et al., 2017). Furthermore, lipid oxidation reduces the sensory and nutritional values of meat products by forming undesirable odors and flavors (Amaral et al., 2018), leading to consumer rejection. To minimize the effects of lipid oxidation, synthetic antioxidants such as butylated hydroxytoluene (**BHT**) have been used in the poultry industry, although its use is discouraged due to the probability of causing toxigenic and carcinogenic effects (Karre et al., 2013). In this context, there is a need to develop a strategy to safely increase the antioxidant capacity of broiler meat, which can be achieved by adding natural compounds to it.

Public demand regarding animal welfare has changing livestock production systems over the years (de Jonge and van Trijp, 2013), including the broiler sector. In this context, these production systems need to be flexible as consumers may claim different allegations, such as sustainable rearing, antibiotic-free production, nontransgenic feeding, among others (Cervantes, 2015; Gocsik et al., 2016). For instance, in conventional systems, broilers are raised in controlled environments with no outdoor access, fed with processed food made from animal by-products, and supplemented with synthetic antioxidants (Salami et al., 2015). By contrast, in traditional-backyard systems, broilers are maintained outdoors and may have access to different food sources, such as vegetables and plants, much of them containing natural antioxidant compounds (Castellini et al., 2002; Pal et al., 2020). Increasing attention in recent years, the organic system consists of rearing broilers in free-range areas, feeding with a special diet of certified organic grains, without using antibiotics for therapy or growth promotion (Diaz-Sanchez et al., 2015). This information is important because modifications to the broiler diet and environment are believed to influence meat quality, fatty acid profile and sensory attributes (Kalakuntla et al., 2017; Galli et al., 2020). While this is true, because there exist a great variety of rearing methods, there is no consensus on the influence of different production systems on broiler meat quality parameters. However, commercial rearing systems are strictly related to oxidative stress in chickens (Surai et al., 2019).

Due to the aforementioned toxigenic effect caused by synthetic antioxidants, natural antioxidants such as biopreservatives derived from plant extracts can be used as alternatives to minimize the oxidative deterioration in meat products. Juçara (*Euterpe edulis*) is a native Brazilian palm tree from the Brazilian Atlantic Forest that produces small globose and violet berries that resemble *Euterpe oleracea's* and *Euterpe precatoria's* berries, mostly known as açai (Schulz et al., 2017). The intense purplish color observed in juçara fruits can be potentially attributed to anthocyanins' presence, belonging to the group of flavonoids, whereas cyanidin-3-glucoside and cyanidin-3-rutinoside are the most abundant anthocyanins in this fruit (Schulz et al., 2016). In addition, other bioactive molecules such as phenolic acids: protocatechuic, p-coumaric, gallic, ferulic, cinnamic, and synaptic; and flavonoids: quercetin, aromadendrin, and rutin, have also been identified in juçara fruit, providing high antioxidant capacity to it (Schulz et al., 2019). Besides attenuating oxidative reactions, published data on juçara fruit extracts revealed good bioavailability, non-hepatotoxicity and neuroprotective effect (Schulz et al., 2017, 2019; Garcia et al., 2019). However, studies reporting the phenolic composition and antioxidant capacity of juçara waste extracts are still scarce. In its industrial processing, after passing by a de-pulping machine that separates the mesocarp and the epicarp from the seeds, juçara berries are usually marketed as juice or frozen pulp, producing wastes (epicarp, endocarp, seed) that can also present important antioxidants compounds (Bicudo et al., 2014; Garcia et al., 2019). In a previous study carried out by our group, juçara waste extract reduced lipid and protein oxidation in antibiotic-free broiler meat previously oxidized by UV-C (Frasao et al., 2018).

For these reasons, this study's objective was to evaluate the efficiency of *Euterpe edulis* fruit waste extracts on antioxidant compounds and activity, aiming to verify the lipid and protein oxidation's inhibition potential in conventional and antibiotic-free broiler meat during refrigerated storage.

MATERIALS AND METHODS

Juçara Fruit Waste Extracts Preparation

Juçara (*Euterpe edulis*) fruit wastes (epicarp and endocarp) were supplied by Juçaí Industry (Juçaí, Rio de Janeiro, Brazil, 22° 240 4400 S, 42° 570 5600 W). The wastes were air-dried at 24°C until constant weight (48 h) and then ground utilizing a manual burr grinder MSS-1B (Hario, Tokyo, Japan) (Frasao et al., 2017). Ground samples were sieved through a 250 Mesh screen to standardize the particle sizes and stored at −20 °C until use.

The compounds from juçara fruit wastes were extracted by microwave-assisted extraction

(Cunha et al., 2021) using a DGT 100 Plus system (Provecto Analytics Ltd., Jundiai, SP, Brazil) under 2 optimized conditions, whereas 500 mg waste powder was added to 25 mL of an aqueous ethanol solution under specific microwave power and time. According to a previous study (Frasao et al., 2017), 2 different extractions were performed based on the optimum point obtained when targeting total phenolic contents (Extract P - microwave power at 668.17 W, ethanol concentration at 93.65%, and 65.60 s) and antioxidant activity (Extract A - microwave power at 668.17 W, ethanol concentration at 64.41%, and 110.45 s). After, the extracts were concentrated by removing all ethanol in a lyophilizer Edwards Pirani 501 (São Paulo, Brazil) and stored in amber vials at 4°C until use.

Content of Antioxidant Compounds in Juçara Fruit Waste Extracts

The antioxidant compounds of the extracts P and A were verified at d 0, using a Spectrophotometer UV-1800 (Shimadzu Corporation, Kyoto, Japan), according to Frasao et al. (2017). First, total phenolic content (**TPC**) was assessed based on the Folin-Ciocalteu method (Ainsworth and Gillespie, 2007) measured at 765 nm, based on the standard curve prepared with gallic acid (0.00-1,25 mg L^{-1}). Second, total flavonoid content (**TFC**) was estimated by a colorimetric method (Chang et al., 2002) measured at 415 and 700 nm (the latter wavelength was used to correct the haze influence) in a quercetin standard curve (0-50 mg L^{-1}). Third, total monomeric anthocyanin content (**TAC**) was calculated using the pH differential method (Lee et al., 2005) measured at 520 and 700 nm, at pH 1.00 and pH 4.5 (the latter wavelength was used to correct the haze influence). Finally, total tannin content (**TTC**) was achieved based on condensed tannins' precipitation using PVPP based on a tannic acid standard curve (0−14 μg mL^{-1}). Finally, the results were calculated and expressed as mg gallic acid equivalent (**GAE**) per mL of extract (for TPC), mg of quercetin equivalents (**QE**) per mL of extract (for TFC), mg cyanidin-3-glucoside equivalents per liter of extract (for TAC), and μg of tannic acid equivalents (**TAE**) per 100 mL of extract (for TTC). TPC values were used to determine the quantity of each extract added to the meat treatments (100 $mg.kg^{-1}$).

Antioxidant Activity of Juçara Fruit Waste Extracts

The antioxidant activity of the extracts was evaluated using a β-carotene-linoleic acid model system at d 0 (Frasao et al., 2017). Briefly, 2 emulsions were prepared using 20 mL of linoleic acid, 200 mg Tween 40 and 50 mL of distilled water, whereas 1 mL of β-carotene was added into one of the emulsions. Aliquots of both emulsions were transferred to tubes containing 0.2 mL of extracts P and A and set in a 50°C water bath for 2 h. The absorbance of each sample was measured using a Spectrophotometer UV-1800 (Shimadzu Corporation, Kyoto, Japan) set at 470 and 700 nm immediately after sample preparation (t = 0 min) and at 30-min intervals until the end (t = 120 min) of the experiment. Water and BHT (3 mg/mL) were used were the negative and positive controls, respectively. The antioxidant activity of the extracts was calculated and expressed in percentage.

Chicken Patties Preparation

Six kilograms of conventional (Rica - conventional rearing) and 6 kilograms of antibiotic-free (Korin sustainable rearing − animal welfare certified, no antibiotic or anticoccidial administration, animal feeding without using transgenic grains or ingredients of animal origin) broiler thighs and drumsticks were obtained. The samples were transported in refrigerated conditions. After deboning, the meat and skin of both conventional and antibiotic-free broilers were separately minced into 8- and 6-mm pieces. After mincing, 20% (w/w) of broiler abdominal fat was mixed with the minced pieces for standardization. Subsequently, the samples were assigned to the following treatments with juçara fruit waste extracts: Extract P (**AFBEP** - antibiotic-free broiler meat with extract P; **CBEP** − conventional broiler meat with extract P), and Extract A (**AFBEA** - antibiotic-free broiler meat with extract A; **CBEA** - conventional broiler meat with extract A). In addition, treatments with BHT were used as the positive controls (**AFBPCC** - antibiotic-free broiler meat positive-control; **CBPC** - conventional broiler meat positive-control), and treatments with no added antioxidant were used as the negative controls (**AFBNC** - antibiotic-free broiler meat negative-control; **CBNC** - conventional broiler meat negative-control).

The samples were mixed for 1 min with a food mixer, and 30 g patties were made, totalizing approximately 100 kg of patties for each treatment. All samples were packaged under aerobic conditions in polyethylene bags, sealed with a vacuum-packaging machine (TECMAQ, Vacuum sealer, AP 450), and stored at 4 ± 1°C for 9 d. The antioxidant content of patties was carried out on d 0 and 9. Proximate analysis and fatty acid profile were achieved on d 0. Lipid and protein oxidation and color analysis were performed on d 0, 3, 6 and 9. The experiment was carried out in triplicate (n = 3), and all analyses were carried out in triplicate.

Content of Antioxidant Compounds in Chicken Patties

The antioxidant compounds of the chicken patties treatments were carried out on d 0 and 9, using a Spectrophotometer UV-1800 (Shimadzu Corporation, Kyoto, Japan), according to Frasao et al. (2017), as previously cited. However, a previous extraction of the antioxidant compounds was performed on the patties before analysis. Briefly, 1 gram of each treatment was added to a vessel with 10 mL of 95% (vol/

vol) methanol and allowed to stand under darkness for 48 h. TPC, TFC, TAC and TTC were calculated and estimated as aforementioned. Again, the results were expressed as mg GAE per mL of extract, mg of QE per mL of extract, mg cyanidin-3-glucoside equivalents per liter of extract, and μg of TAE per 100 mL of extract.

Proximate Composition

The proximate composition of chicken patties was determined for characterization at d 0. Moisture was determined by the stove method at 105°C, the protein content was carried out by the micro-Kjeldahl method, and the ash content was achieved by total sample carbonization as recommended by AOAC (2012) methods 940.05, 954.01, and 942.02, respectively. Lipid content was extracted and measured by cold-extraction, according to Bligh and Dyer (1959).

Fatty Acid Profile

The fatty acid profile was determined for the characterization of the chicken patties on d 0. Total lipids were obtained by cold-extraction Bligh and Dyer (1959) in quadruplicate. For methylation, a solution (10% HCl in methanol) with hexane was used (Chin et al., 1992; Kishino et al, 2002).

A gas chromatograph equipped with a flame ionization detector (Perkin Elmer, Waltham, MA) was used to analyze fatty acid methyl esters. An OmegawaxTM 320 column (30 m length, 0.32 mm internal diameter, and 0.25 μm particle size) (Supelco Inc., Bellefonte, PA) was used for separation. 2 μL of sample size and 1:20 split were used. The injector and detector temperatures were set at 260 and 280°C, respectively. The initial temperature of the oven was set at 110°C, and the temperature ramp was obtained by: increasing temperature from 110 to 233°C at 40°C/min, holding at 233°C for 2 min, increasing from 233 to 240°C at 1°C/min, and finally holding at 240°C for 21 min. Helium was used as the carrier gas at a flow rate of 1.8 mL/min (10 psi). fatty acid methyl esters were identified comparing the retention time of a commercial standard comprising methyl esters of 28 individual fatty acids (Supelco Inc., Bellefonte, PA). The results were expressed as a relative percentage of the area (Memon et al., 2011).

Lipid Oxidation Analysis

Lipid oxidation was carried out during storage (d 0, 3, 6, and 9) of conventional and antibiotic-free chicken patties samples. The substances reactive to thiobarbituric acid (**TBARS**) were quantified by a spectrophotometer UV-1800 (Shimadzu Corporation, Kyoto, Japan) at 532 nm during several points of storage (Alcântara et al., 2015). The results were expressed as mg of malonaldehyde (**MDA**) per kilogram of meat, based on a calibration curve.

Protein Oxidation Analysis

Protein oxidation was also carried out during storage (d 0, 3, 6, and 9) of conventional and antibiotic-free chicken patties. A 2,4-Dinitrophenylhydrazine (DNPH) derivatization-based assay was used to estimate total carbonyl content (Armenteros et al., 2009). The absorbance was read at 280 nm against a bovine serum albumin standard curve. In contrast, carbonyl content was calculated utilizing absorption at 370 nm and an absorptivity coefficient for protein hydrazones of 21.0 mM-1 cm-1. The results were expressed as nmol of carbonyl per mg of protein.

Instrumental Color

A Minolta CM-600D spectrophotometer (Minolta Camera Co., Osaka, Japan) was used to determine the color characteristics of the patty samples on d 0, 3, 6, and 9 of storage at 4°C. Samples were exposed to oxygen for 5 min, and the sensor was mounted directly on the patty surfaces to prevent ambient light noise (Zhuang and Bowker, 2016). The following color coordinates were determined: lightness (L^*, 100 = white, 0 = black), redness (a^*, + red, −green), and yellowness (b^*, + yellow, −blue). In addition, chroma (C*), hue angle (h°), and total color change (ΔE^*) were also calculated (Incedayi et al., 2016).

Statistical Analysis

Results were reported as means ± standard deviation. All data were analyzed using XLSTAT version 2013.2.03 (Addinsoft, Paris, France). All parameters were analyzed using one-way ANOVA. Tukey's test was applied to verify the differences between treatments when a significant value ($P < 0.05$) was observed.

RESULTS AND DISCUSSION

Antioxidant Content and Activity of Juçara Fruit Waste Extracts

The antioxidant content and activity of juçara fruit waste extracts (P and A) are presented in Table 1. Both extracts presented similar content of TPC and TTC. However, extract P presented the highest ($P < 0.05$) TFC, whereas extract A exhibited the highest ($P < 0.05$) TAC. In this way, extract P's antioxidant activity can be related to the sum of the different antioxidant compounds (TFC, TAC, and TTC), while in extract A, it is probably related to the content of anthocyanins (TAC). According to Fang (2015), fruits containing anthocyanins can be grouped into 3 groups based on the corresponding type of anthocyanin aglycones: the pelargonidin, the cyanidin/peonidin where juçara waste extract is included, and the multiple anthocyanin groups. Considering the position and the number of hydroxyl and methyl groups, the anthocyanin structure is crucial for the radical scavenging activities of these

Table 1. Antioxidant content and antioxidant activity of juçara (*Euterpe edulis*) fruit wastes extracts.

					Antioxidant activity[5]				
Extracts	TPC[1]	TFC[2]	TAC[3]	TTC[4]	0 min	30 min	60 min	90 min	120 min
Extract P	$2.39 \pm 0.07^{A,a}$	$2.68 \pm 0.01^{A,a}$	$0.84 \pm 0.01^{C,b}$	$0.62 \pm 0.08^{C,a}$	$100.00 \pm 0.10^{A,a}$	$82.13 \pm 0.02^{B,b}$	$68.46 \pm 0.07^{C,b}$	$58.06 \pm 0.11^{D,b}$	$49.80 \pm 0.10^{E,b}$
Extract A	$2.16 \pm 0.06^{A,a}$	$1.11 \pm 0.08^{B,b}$	$0.91 \pm 0.01^{C,a}$	$0.61 \pm 0.04^{C,a}$	$100.00 \pm 0.05^{A,a}$	$94.26 \pm 0.12^{B,a}$	$89.90 \pm 0.13^{BC,a}$	$85.94 \pm 0.10^{CD,a}$	$81.31 \pm 0.11^{D,a}$
BHT	-	-	-	-	$100.00 \pm 0.02^{A,a}$	$91.57 \pm 0.12^{B,a}$	$87.31 \pm 0.10^{C,a}$	$84.05 \pm 0.13^{CD,a}$	$80.27 \pm 0.12^{E,a}$

All results are the means ± SD (n = 3).
[a-b]Same letters prescribe no difference between the lines results; different letters determine the difference.
[A-E]Same letters prescribe no difference between the columns results; different letters determine the difference.
Extract P is *Euterpe edulis* fruit waste extract obtained with the optimal extraction of TPC yield.
Extract A is *Euterpe edulis* fruit waste extract obtained with the optimal extraction of antioxidant activity yield.
BHT is a positive control used to determine antioxidant activity.
[1]Total phenolic content expressed as mgGAE.mL^{-1}.
[2]Total flavonoid content expressed as mgQE. mL^{-1}.
[3]Total monomeric anthocyanin content expressed as mgC3QE. L^{-1}.
[4]Total tannin content expressed as μgTAE.100mL^{-1}.
[5]AA%.

molecules, whereas Kähkönen, 2003 reported great antioxidant activity of cyanidins, compared to other groups of anthocyanins. To corroborate, regarding the antioxidant activity of juçara extracts, extract A confirmed optimal antioxidant extraction presenting the highest ($P < 0.05$) antioxidant activity values compared to extract P, indicating that the higher content of anthocyanin, the higher the antioxidant potential of juçara fruit waste extracts. Furthermore, extract A obtained a similar antioxidant activity compared to the synthetic antioxidant (BHT) (positive control), which infers that extract A may have the potential to be used as a natural antioxidant.

Proximate Composition and Fatty Acid Profile of Chicken Patties

There was no difference ($P > 0.05$) in moisture and lipid content among treatments, indicating a successful fat standardization from the addition of skin and abdominal fat (Table 2). Similarly, Frasao et al. (2018) also observed no difference in these parameters. In contrast, the conventional broiler meat presented higher ($P < 0.05$) values for protein and ash contents than the antibiotic-free broiler meat. It is well known that feeding constituents can affect broiler meat composition. To accelerate the growth and weight-gain, conventional broiler feed has been reported to contain cereals, vegetable oils, vitamins supplements, animal protein, enzymes, amino acids, and even some additives like antibiotics, steroids, and toxic elements such as roxarsone and melamine (Ahmad et al., 2018). Although we did not specifically have the dietary components of the broilers feed used in this study, we believe it played a role in samples' protein composition. However, as the addition of the extracts did not influence any of the parameters, the patties' proximate composition cannot be considered a biasing factor.

Table 2. Proximate composition of broiler meat treatments.

Treatments	Moisture	Lipid	Ash	Protein
AFBNC	71.87 ± 0.40^{a}	8.31 ± 0.50^{a}	0.79 ± 0.04^{b}	0.79 ± 0.04^{b}
AFBPC	72.19 ± 0.31^{a}	8.71 ± 0.28^{a}	0.76 ± 0.05^{b}	0.76 ± 0.05^{b}
AFBEP	69.73 ± 0.34^{a}	8.26 ± 0.62^{a}	0.81 ± 0.03^{b}	0.81 ± 0.03^{b}
AFBEA	69.73 ± 0.87^{a}	8.66 ± 0.40^{a}	0.80 ± 0.05^{b}	0.80 ± 0.05^{b}
CBNC	71.87 ± 0.03^{a}	7.82 ± 0.18^{a}	1.20 ± 0.15^{a}	1.20 ± 0.15^{a}
CBPC	71.87 ± 0.54^{a}	8.35 ± 0.30^{a}	1.15 ± 0.09^{a}	1.15 ± 0.09^{a}
CBEP	69.26 ± 0.66^{a}	7.77 ± 0.86^{a}	1.15 ± 0.10^{a}	1.15 ± 0.10^{a}
CBEA	69.44 ± 0.41^{a}	8.43 ± 0.64^{a}	1.10 ± 0.04^{a}	1.10 ± 0.04^{a}

All results are the means ± SD (n = 3).
Means that do not share a superscript letter are significantly different.
Abbreviations: AFBEA, antibiotic-free broiler meat with extract A; AFBNC, antibiotic-free broiler meat negative-control;AFBPC, antibiotic-free broiler meat positive-control (with BHT); AFBEP, antibiotic-free broiler meat with extract P; CBPC, conventional broiler meat positive-control (with BHT); CBNC, conventional broiler meat negative-control; CBEP, conventional broiler meat with extract P; CBEA, conventional broiler meat with extract A.
Results are expressed in percentage.

The fatty acid profile of the patties obtained from antibiotic-free broilers is in g/100 g, as it follows: C6:0 (2.35 ± 0.09), C8:0 (0.26 ± 0.01), C10:0 (0.63 ± 0.01), C11:0 (0.30 ± 0.01), C14:0 (42.20 ± 2.42), C16:0 (13.55 ± 1.34), C16:1 (1.83 ± 0.29), C17:0 (1.57 ± 0.10), C18:0 (0.65 ± 0.12), C18:1n7 (7.35 ± 0.76), C18:1n9 (9.59 ± 0.67), C18:2n6 (12.83 ± 1.54), C18:3n6 (0.75 ± 0.12), C18:3n3 (0.28 ± 0.12), C20:1 (0.37 ± 0.09), C20:2 (0.23 ± 0.01), C20:3n6 (2.99 ± 0.50), C20:4n6 (1.67 ± 0.53), C22:2 (0.36 ± 0.01), docosahexaenoic acid (DHA − C22:6n3 - 0.24 ± 0.03). In this way, the meat of antibiotic-free broilers presented a higher proportion of SFA (61.51%) when compared to monounsaturated fatty acids (**MUFA**) (19.14%) and PUFA (19.35%).

The profile of conventional broiler meat obtained from patties was C6:0 (2.31 ± 0.19), C8:0 (0.26 ± 0.03), C10:0 (0.74 ± 0.02), C11:0 (0.31 ± 0.04), C14:0 (54.99 ± 2.54), C16:0 (9.57 ± 1.43), C16:1 (0.70 ± 0.19), C17:0 (1.40 ± 0.12), C18:0 (0.11 ± 0.02), C18:1n7 (5.12 ± 0.35), C18:1n9 (7.87 ± 0.47), C18:2n6 (9.62 ± 1.50), C18:3n6 (0.70 ± 0.02), C18:3n3 (0.16 ± 0.02), C20:1 (0.17 ± 0.03), C20:2 (0.14 ± 0.01), C20:3n6 (2.16 ± 0.43), C20:4n6 (3.21 ± 0.33), C22:2 (0.31 ± 0.03), docosahexaenoic acid (DHA − C22:6n3 - 0.14 ± 0.02). Thus, SFA (69.69%) are in higher proportion when compared to MUFA (13.86%) and PUFA (16.45%).

The fatty acid profile values are in agreement with the ones observed by (Dalziel et al., 2015). To compare, (Castellini et al., 2002) demonstrated that the breast

Table 3. Antioxidant compounds content in antibiotic-free and conventional broiler patties at d 0 and 9 storage at 4 ± .

		Antibiotic Free				Conventional			
Analysis	Day	AFBNC	AFBPC	AFBEP	AFBEA	CBNC	CBPC	CBEP	CBEA
TPC[1]	0	$22.22 \pm 1.04^{A,a}$	$22.26 \pm 3.38^{A,b}$	$24.16 \pm 1.61^{A,a}$	$23.25 \pm 3.18^{A,a}$	$18.82 \pm 1.95^{A,a}$	$18.74 \pm 1.85^{A,b}$	$23.32 \pm 2.30^{A,a}$	$20.72 \pm 2.94^{A,a}$
	9	$36.91 \pm 1.94^{AB,a}$	$43.00 \pm 1.21^{A,a}$	$26.54 \pm 1.54^{B,a}$	$28.13 \pm 4.32^{B,a}$	$25.07 \pm 1.24^{B,a}$	$35.30 \pm 1.14^{AB,a}$	$25.00 \pm 3.99^{B,a}$	$29.66 \pm 1.75^{B,a}$
TFC[2]	0	$36.76 \pm 3.46^{A,a}$	$35.24 \pm 3.30^{A,a}$	$34.88 \pm 6.01^{A,b}$	$29.63 \pm 3.65^{A,b}$	$30.22 \pm 2.05^{A,a}$	$35.05 \pm 3.19^{A,a}$	$31.66 \pm 6.56^{A,b}$	$34.54 \pm 6.21^{A,b}$
	9	$36.12 \pm 1.19^{B,a}$	$42.78 \pm 1.29^{B,a}$	$59.92 \pm 3.59^{A,a}$	$50.89 \pm 6.30^{A,a}$	$35.99 \pm 4.11^{B,a}$	$42.17 \pm 6.87^{B,a}$	$56.70 \pm 6.32^{A,a}$	$54.48 \pm 1.98^{AB,a}$
TAC[3]	0	$3.42 \pm 0.17^{C,a}$	$4.36 \pm 0.41^{BC,a}$	$11.86 \pm 1.96^{A,a}$	$13.19 \pm 1.77^{A,a}$	$3.74 \pm 0.89^{C,a}$	$5.36 \pm 0.75^{B,a}$	$7.29 \pm 1.89^{B,a}$	$5.11 \pm 1.36^{B,a}$
	9	$1.04 \pm 0.15^{B,a}$	$0.95 \pm 0.08^{B,b}$	$2.55 \pm 0.03^{A,b}$	$2.69 \pm 0.12^{A,b}$	$1.66 \pm 0.01^{AB,a}$	$1.06 \pm 0.01^{B,b}$	$2.76 \pm 0.07^{A,b}$	$2.02 \pm 0.09^{A,b}$
TTC[4]	0	$0.33 \pm 0.00^{B,b}$	$0.48 \pm 0.00^{A,a}$	$0.49 \pm 0.00^{A,a}$	$0.51 \pm 0.00^{A,a}$	$0.28 \pm 0.00^{B,b}$	$0.45 \pm 0.00^{A,a}$	$0.60 \pm 0.00^{A,a}$	$0.46 \pm 0.00^{A,a}$
	9	$0.34 \pm 0.00^{B,b}$	$0.45 \pm 0.00^{B,a}$	$0.50 \pm 0.00^{A,a}$	$0.63 \pm 0.00^{A,a}$	$0.27 \pm 0.00^{B,b}$	$0.24 \pm 0.00^{B,b}$	$0.21 \pm 0.00^{B,b}$	$0.21 \pm 0.00^{B,b}$

All results are the means ± SD (n = 3).

[a-b] Same letters prescribe no difference between the lines results; different letters determine the difference.

[A-B] Same letters prescribe no difference between the columns results; different letters determine the difference.

Abbreviations: AFBNC, antibiotic-free broiler meat negative-control;AFBPC antibiotic-free broiler meat positive-control (with BHT); AFBEP, antibiotic-free broiler meat with extract P; ACBPC, conventional broiler meat positive-control (with BHT); CBNC, conventional broiler meat negative-control; CBEP, conventional broiler meat with extract P; AFBEA, antibiotic-free broiler meat with extract A; CBEA, conventional broiler meat with extract.

[1]Total phenolic content expressed as mgGAE.mL^{-1}.

[2]Total flavonoid content expressed as mgQE. mL^{-1}.

[3]Total monomeric anthocyanin content expressed as mgC3QE. L^{-1}.

[4]Total tannin content expressed as μgTAE.100mL^{-1}.

and drumstick muscles of the organic broiler (raised indoors with outdoor access) had a higher content of SFA and PUFA compared to conventional broiler (raised indoors), probably due to the grass intake that happened when the organic broiler went outdoors. The authors also reported higher TBARS values in organic meat than conventional meat, plus a posterior increase in TBARS values after cooking, which did not influence sensory acceptance. By contrast, Castromán et al. (2013) reported a lower content of PUFA and lower values of TBARS in organic broiler meat compared to conventional broiler meat. In fact, the content of MUFA and PUFA in a meat matrix can interfere with its lipid oxidation potential (Domínguez et al., 2019).

Antioxidant Compounds Content of Chicken Patties

Polyphenol content in chicken patties treatments is shown in Table 3. Regarding the first day of storage (d 0), TPC and TFC values were similar ($P > 0,05$) for all treatments. However, the treatments with juçara fruit waste extract addition (AFBEP, AFBEA, CBEP, CBEA) presented the highest ($P < 0.05$) TAC and TTC values, certainly related to juçara high content of anthocyanins and tannins (Frasao et al., 2017, 2018). Moreover, although TTC was also high in treatments with BHT (AFBPC, CBPC), we cannot precisely explain these values. Since BHI is a synthetic antioxidant, we believe it may be composed of molecules misidentified as tannins. Furthermore, on day 9 of storage, AFBPC presented the highest ($P < 0.05$) TPC value, while the treatments with the addition of juçara fruit waste extracts (AFBEP, AFBEA, CBEP, CBEA) showed the highest ($P < 0.05$) values of TFC and TAC. Regarding TTC, AFBEP, and AFBEA presented the highest ($P < 0.05$) values. Again, these values are related to juçara fruit being considered a source of these compounds (Frasao et al., 2017, 2018).

During storage, AFBPC and CBPC showed an increase ($P < 0.05$) in TPC values. These treatments were added of BHT, a synthetic antioxidant that is possibly less stable than the natural antioxidants from juçara (Cheynier, 2005), whereas the BHI compounds of lower complexity were broken down into smaller molecules, being quantified as phenolic compounds.

In general, all treatments numerically increased TFC values during storage, but the juçara waste extract treatments (AFBEP, ADBEA, CBEP, and CBEA) presented the highest ($P < 0.05$) values when comparing d 0 to d 9. During the storage time, the muscle tissue suffers natural processes leading to the formation of bioactive peptides (Fukada et al., 2016), which could be detected as flavonoids, explaining the increase.

On the other hand, TAC values of treatments with BHT and with juçara waste extract addition (AFBPC, CBNC, AFBEP, AFBEA, CBEP, CBEA) show a decrease ($P < 0.05$) during storage. This fact can be explained by the fact that anthocyanins can be consumed in the antioxidant reaction, reducing this compound's concentration (Martín et al., 2017).

Moreover, CBPC, CBEP, and CBEA presented a decrease ($P < 0.05$) of TTC values. Tannins are polyphenols that have a special interaction with enzymes, proteins and other macromolecules: they can bind and aggregate with these particles, which results in the formation of a precipitate (Adamczyk et al., 2017). Since the conventional chicken treatments presented higher protein and ashes contents, tannin compounds might have been consumed in reactions by forming protein aggregates.

Concerning the similar values of TPC, TFC, TAC, and TTC in the negative-control treatments (AFBNC and CBNC) compared to the other treatments, it may be related to the fact that the chicken's dark musculature already presents molecules with antioxidant properties (Fukada et al., 2016), which can be

detected in these analyses. The same behavior was observed by Frasao et al. (2018) in antibiotic-free broiler meat treated by UV-C with pequi and juçara waste extracts.

Lipid Oxidation of Chicken Patties

The lipid oxidation of the treatments was verified using TBARS, and results were expressed as mg of MDA per kg of meat. As TBARS values are related to the formation of secondary lipid products, such as aldehydes and carbonyls of hydrocarbons (Chinprahast et al., 2020), the rancidity process is characterized by lipid oxidation during meat storage, whereas the reaction occurs in the double bond sites of triacylglycerol molecules in meat, leading to sensorial and nutritional deterioration (Sohaib et al., 2017). All treatments showed an increase in lipid oxidation during storage (Figure 1A). AFBNC presented values ranging from 1.40 to 7.77, AFBPC 0.86 to 4.22, AFBEP 1.02 to 2.20, AFBEA 0.82 to 3.82, CBNC 0.69 to 2.92, CBPC 0.71 to 1.95, CBEP 1.25 to 2.34, CBEA 0.85 to 3.01 mgMDA.g^{-1} on d 0 and 9, respectively.

Considering the treatments with no addition of antioxidants, AFBNC presented the highest ($P < 0.05$) TBARS values of all treatments during all the storage time, being 1.40, 4.14, 5.68, 7.77 mgMDA.kg^{-1}, on d 0, 3, 6, and 9, respectively. Contrasting, CBNC presented similar TBARS values to the antioxidant-treated samples, being 0.69, 1.93, 1.91, 2.91 mgMDA.kg^{-1} on d 0, 3, 6, and 9, respectively. Indeed, Średnicka-Tober et al. (2016) have pointed to higher oxidation in organic broiler meat than in conventional chicken because of higher values of PUFA in organic meat that predispose to lipid oxidation (Penko et al., 2015). Although we did not use organic broiler meat in this study, the antibiotic-free broiler, which has a similar rearing system compared to organic, showed higher PUFA values (19.35%) than conventional (16.45%) meat, explaining the observed lipid oxidation values (Figure 1). Besides that, the antibiotic-free broilers used in this study were created exclusively indoors but with reduced stocking densities and more free-space. Broilers that present a higher degree of physical fitness are prone to have higher amounts of heme-iron in muscles and increased muscle oxidative capacity, favoring

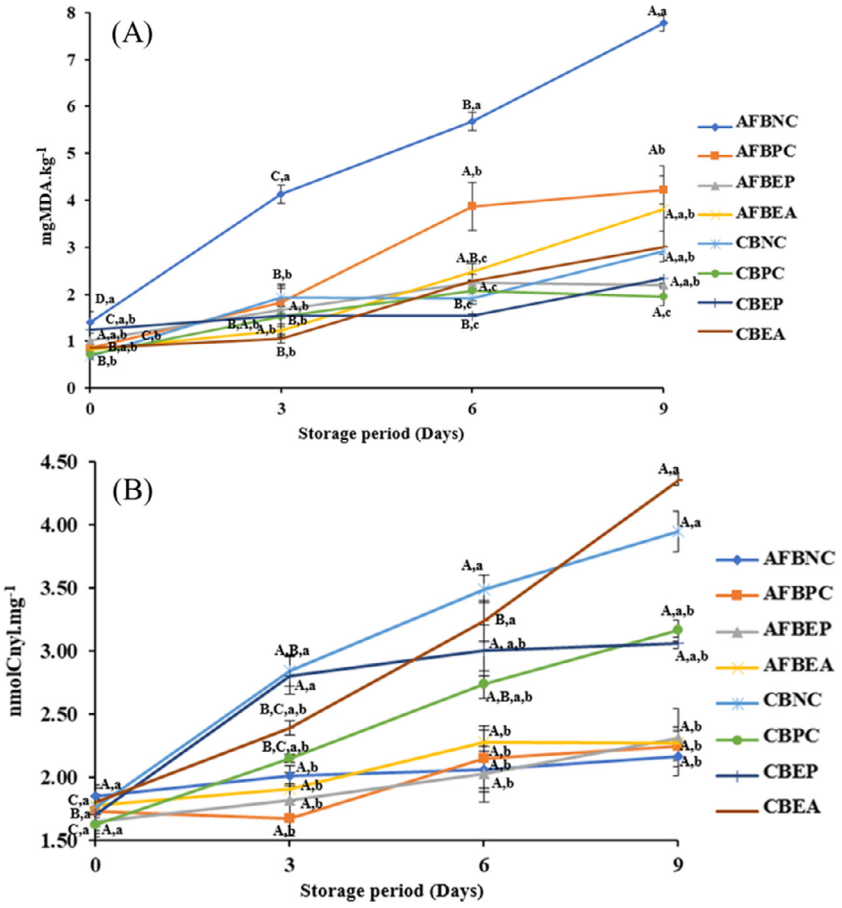

Figure 1. Oxidation of broiler meat treatments during storage at 4°C for 10 days. (A) Lipid oxidation. (B) Protein oxidation. All results are the means with standard deviation (n = 3). [a-b]Same letters prescribe that there was no difference between the treatments in the same day results within the analysis; different letters determine the difference. [A-D]Same letters prescribe that there was no difference between the days results within the analysis; different letters determine the difference. Abbreviations: AFBEA, antibiotic-free broiler meat with extract A; AFBEP, antibiotic-free broiler meat with extract P; AFBNC, antibiotic-free broiler meat negative-control; AFBPC, antibiotic-free broiler meat positive-control (with BHT); CBNC, conventional broiler meat negative-control; CBPC, conventional broiler meat positive-control (with BHT); CBEP, conventional broiler meat with extract P; CBEA, conventional broiler meat with extract A; mgMDA.kg^{-1}, miligrams of malonaldeyde per kilograms of broiler meat; nmolCnyl.mg^{-1}, nano mols of carbonyl per miligrams of broiler meat protein.

postmortem lipid peroxidative processes (Castellini et al., 2002). By contrast, Viana et al. (2016) compared organic and nonorganic broiler meat and reported similar ($P > 0.05$) TBARS values until d 9 of refrigerated storage, where nonorganic broiler exhibited higher ($P > 0.05$) TBARS values. Contrasting results suggest further studies need to be conducted to prove the rearing system affects lipid oxidation.

Moreover, all treatments with antioxidant addition (AFBPC, AFBEP, AFBEA, CBPC, CBEP, and CBEA) presented the lowest ($P < 0.05$) TBARS value on d 3 of the storage period, while only CBNC presented the lowest ($P < 0.05$) TBARS value on d 6. As low TBARS values refer to the formation of fewer secondary oxidation compounds, this result suggests that the presence of antioxidants in chicken patties postponed lipid oxidation in these samples.

Among the conventional broiler meat samples, broiler meat with BHT (CBPC) and extract P (CBEP) showed to be more efficient ($P < 0.05$) in the reduction of lipid oxidation at the end of storage (d 9). Similarly, the treatment with extract P of antibiotic-free broiler meat (AFBEP) presented more consistent TBARS values during storage and lower ($P < 0.05$) lipid oxidation on d 9, compared to the other antibiotic-free treatments (AFBNC, AFBPC, and AFBEA). In this context, we can suggest that juçara fruit waste extract P delivered greater antioxidant activities for both conventional and antibiotic-free broiler meat, being even better than BHT concerning antibiotic-free meat. Therefore, extract P has the potential to be used as a natural antioxidant in chicken meat, especially in antibiotic-free chicken patties.

The lipid oxidation process modifies particles' chemical properties and brings forth the loss of function of producing peroxides and aldehydes (Sohaib et al., 2017). Nevertheless, the concentration of reaction substrates, prooxidant and antioxidant compounds, and the matrix composition interfere with the oxidative stability principle in complex food matrices such as meat (Ramana et al., 2017). The TBARS values in which rancid off-flavors become remarkable range from 0.5 to 1.0 mg MDA.kg^{-1} meat (given by trained panelists) and 0.6 to 2.0 mg MDA.kg^{-1} meat (given by untrained panelists) (Chinprahast et al., 2020). In this study, after nine days of storage, only CBPC was not considered rancid since its TBARS value was below 2.0 mgMDA.kg^{-1}. However, AFBEP just started to become rancid, with TBARS values of 2.2 mgMDA.kg^{-1}. This value was much lower ($P < 0.05$) than the negative-control sample (AFBNC) that showed rancidity values throughout all the storage period. Therefore, the extract P from juçara fruit waste might be a technological alternative to promote lipid oxidation stability and benefit consumers' health.

Protein Oxidation of Chicken Patties

The degree of protein oxidation in the treatments was verified by determining nmol of carbonyl per mg of protein. The treatments showed an increase ($P < 0.05$) in protein oxidation during storage (Figure 1B). Carbonyl generation is the most common damage from protein oxidation. These compounds are mainly generated by the oxidative deterioration of amino acids (lysine, proline, histidine and arginine) and interfere with the function of meat proteins, leading to decreased texture, aroma and flavor (Soladoye et al., 2015). The addition of antioxidants to meat and meat products is credited to decrease protein oxidation rates (Serpen et al., 2012).

On d 0 of storage, all treatments presented similar ($P > 0.05$) protein oxidation values (Figure 1B). However, since day 3 of storage, all antibiotic-free chicken patties, AFBNC (2.01, 2.06, 2.16, respectively), AFBPC (1.67, 2.14, 2.24, respectively), AFBEP (1.82, 2.02, 2.31, respectively), and AFBEA (1.90, 2.27, 2.27, respectively) showed the lowest carbonyl values, remaining stable ($P > 0.05$) until d 9. This fact may be related to the poultry breeding system. The broiler's physiological response to stress stimuli such as different rearing systems, high stocking densities, heat exposure, handling/shipping, and nutritional deprivation can disrupt homeostasis (Wein et al., 2017), leading to oxidative processes in muscle proteins. The imbalance caused by these factors can induce oxidative stress by creating highly reactive oxygen/nitrogen/chlorine species capable of modifying molecules, such as amino acids and proteins (Akbarian et al., 2016). First, the antibiotic-free broilers used in this study were created under the allegation of following a strict welfare protocol including balanced nutrition, comfortable shelters, resting areas and adequate space for the manifestation of natural behaviors, which are technology strategies credited to reduce poultry stress (Grandin, 2015), and consequently, reduce protein oxidation. Furthermore, the antibiotic-free broilers used in this study received a diet containing phytogenic compounds, essential oils, prebiotics, and probiotics that could diminish the effects of protein oxidative stress, as published data show the incorporation of such natural additives to broiler feed can improve its antioxidant capacities (Zhai et al., 2018; Adeyemi et al., 2021; Long et al., 2021). Contrasting, conventional broilers feed usually involves mixing various ingredients such as fat and metal ions, which are highly oxidizable, aiming for fast growth. In this context, dietary oxidation can lead to biochemical changes in broiler muscles, including increased susceptibility to post-mortem protein oxidation (Zhang et al., 2011). However, more studies aiming at identifying the molecules responsible for post-mortem protein stability and action, regarding different rearing systems, still need to be performed to confirm these characteristics.

By contrast, CBNC (conventional broiler meat negative-control) presented the highest ($P < 0.05$) carbonyl values, showing the high protein oxidation level of conventional broiler meat. CBPC and CBEP, from d 3 until the end (d 9) of storage, presented protein oxidation stability ($P > 0.05$). Interestingly, CBEA showed an increase ($P < 0.05$) of the levels of protein oxidation during storage, becoming similar ($P > 0.05$) to the negative-

control treatment (CBNC) at the end of the storage period. Even though CBPC and CBEP treatments did not statistically differ from the other treatments, they presented lower carbonyl values than CBNC and CBEA treatments. Hence, as the extract P demonstrated similar effectiveness in the stabilizing protein oxidation compared to the synthetic antioxidant (BHT), we suggest that extract P has the potential to be a substitute for BHT in stabilizing the oxidative process in food, as this procedure is normally achieved by the utilization of synthetic antioxidants by the food industry (Sohaib et al., 2017). In this case, the extract P of juçara fruit waste can improve meat products' conservation by promoting protein oxidation stability.

Frasao et al., 2018 is a preliminary research using juçara and pequi (*Caryocar brasiliense*) waste extracts as preservatives to stabilize the oxidation processes applied directly to pre-oxidized poultry meat. Other studies regarding the application of natural antioxidants in chicken meat during refrigerated storage reported promising results using rosemary extract (*Rosmarinus officinalis*), acorn extract (*Quercus ilex* L. subsp. *Ballota*), oregano (*Origanum vulgare*), and sage (*Salvia officinalis*) (Sampaio et al., 2012; Feng et al., 2016; Ferreira et al., 2017). Therefore, this study is innovative, although more research related to the application must be carried out, including a sensory analysis. Although the sensory analysis is fundamental in developing new products, this study aimed to assess the real potential of juçara fruit waste extract in reducing oxidative degradation in conventional and antibiotic-free chicken meat. In the future, our research group might further run a sensory evaluation to measure the effects of this extract addition on the characteristics of the chicken meat under different forms of preparation.

Color Characterization of Chicken Patties

Color in meat is an attribute directly related to the product's quality, interfering with consumer choice. Different factors can influence food color, as the physical, chemical, biochemical and microbial characteristics, which can vary according to post-mortem process, maturation, microorganism growth, and storage (Feng et al., 2016). The color characteristics of the treatments are shown in Figure 2.

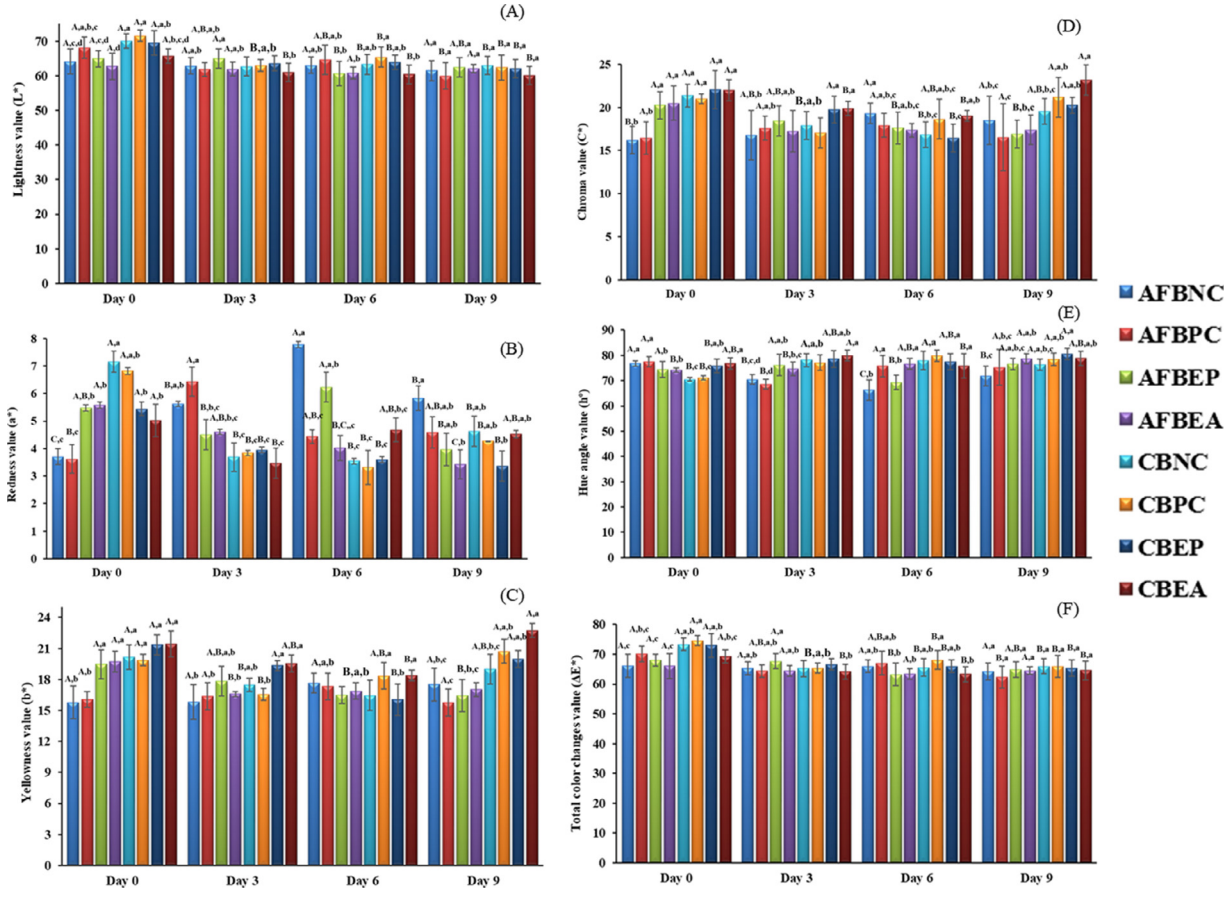

Figure 2. Color characterization of broiler treatments during 10 days storage at 4 °C. (A) Lightness value (L*). (B) Redness value (a*). (C) Yellowness value (b*). (D) Chroma values (C*). (E) Hue Angle values (h°). (F) Total Color Change values (ΔE*). All results are the means ± SD (n = 3). [a-d]Same letters prescribe that there was no difference between the treatments in the same day results within the analysis; different letters determine the difference. [A-C]Same letters prescribe that there was no difference between the days results within the analysis; different letters determine the difference. Abbreviations: AFBEA, antibiotic-free broiler meat with extract A; AFBEP, antibiotic-free broiler meat with extract P; AFBNC, antibiotic-free broiler meat negative-control; AFBPC antibiotic-free broiler meat positive-control (with BHT); CBNC, conventional broiler meat negative-control; CBPC, conventional broiler meat positive-control (with BHT); CBEP, conventional broiler meat with extract P; CBEA, conventional broiler meat with extract A.

During storage, the lightness value (L^*) of AFBNC and AFBEA did not differ ($P > 0.05$). The other treatments presented a reduction ($P < 0.05$) on these values from the beginning to the end of the storage period. L^* reduction in AFBEP, CBEP, and CBEA can be explained by the extract presence, once juçara fruit waste extract shows high levels of anthocyanins, a purple pigment (Frasao et al., 2017). Published data demonstrated that inclusion of anthocyanin in meat products decreases ($P < 0.05$) L^* values, meaning the color and the composition of the extract influence the darkening of the meat (Naveena et al., 2008; Gong et al., 2021). At the end of the storage period (d 9), no difference ($P > 0.05$) was observed between the treatments.

Redness values (a^*) on d 0 presented differences ($P < 0.05$) between treatments. CBNC and CBPC showed the highest values, whereas AFBNC and AFBPC the lowest. Moreover, AFBEP, AFBEA, CBEP, and CBEA did not differ ($P > 0.05$) between them or the other treatments. The similarity between juçara treatments can be related to the extract compounds, like flavonoids and anthocyanins, whose color ranges from pink to magenta (Iwashina, 2015). At the end of storage (d 9), AFBNC showed the highest ($P < 0.05$) a^* values and AFBEA and CBEP the lowest ($P < 0.05$). During storage, an increase ($P < 0.05$) of this parameter was observed on AFBNC and a decrease ($P < 0.05$) on AFBEP, AFBEA, CBNC, CBPC, CBEP and CBEA treatments from d 0 and 9. This behavior can be related to meat discoloration during the storage period, potentially due to the myoglobin molecule's oxidation (Joseph et al., 2012).

Yellowness values (b^*) remained stable ($P > 0.05$) in all treatments, except ($P < 0.05$) AFBEP and AFBEA, during the storage period. This decrease in b^* values can be related to dark pigments distant from yellow but approaching blue, such as purple from anthocyanins (Rufino et al., 2010). On d 0, AFBNC and AFBPC ($P < 0.05$) showed lower b^* values than the other treatments. At the end of storage (d 9), AFBPC still showed the lowest ($P < 0.05$) b* value and CBEA showed the highest ($P < 0.05$). In conventional broiler production systems, pigments are usually added to poultry feeds, which may increase the yellowness perception (b^*) of their products (Wang et al., 2017b).

Regarding the chroma (C*), the observed increase ($P < 0.05$) in AFBNC values during storage is related to the fact that it presents the same behavior as a^* value. Furthermore, a C* decrease in AFBEP and AFBEA treatments is related to the same behavior of a^* and b^* values, which showed a decrease ($P < 0.05$). When comparing treatments on day zero of storage, AFBNC and AFBPC showed the lowest ($P < 0.05$) C* values, whereas on d 9 of storage, AFBPC presented the lowest ($P < 0.05$) and CBEA show the highest ($P < 0.05$) value. So, this parameter behavior was related to the value observed in a^* and b^* at this point.

Hue angle values (h°) are expressed in degrees starting in red (0°), with a gradual increase to yellow (90°), green (180°) and blue (270°) colors (Incedayi et al., 2016). During the storage period, AFBNC showed a decrease ($P < 0.05$), while AFBEA, CBNC, CBPC, and CBEP showed an increase in h° values. On d 0, AFBNC, AFBPC and CBEA presented the highest values, whereas CBNC and CBPC show the lowest. On d 9 of storage, AFBNC presented the lowest value, while CBEP presented the highest. Despite this variation, all treatments presented values near 90° (yellow), in accordance with the color of the chicken meat, which has low concentrations of myoglobin (Joseph et al., 2012; Carvalho et al., 2017), being classified as white meat instead of red meat.

The ΔE* value is obtained after a calculation using the L^*, a^* and b^* values (Incedayi et al., 2016). On d 0 of storage, CBPC presented the highest ($P < 0.05$) value of total color changes, whereas AFBNC, AFBEP, AFBEA shows the lowest values, which can be related to the results observed in a^* and b^* since they are used to obtain the values of ΔE*. On d 9 of storage, no difference ($P > 0.05$) was observed between the treatments. This same behavior was also observed in L^* since this variable is used to calculate the parameter. During storage time (9 d), AFBPC, CBNC, CBPC, CBEP, and CBEA showed a decrease in total color changes. This parameter behavior is related to the value observed in a^* parameter of these treatments.

The muscle structure and pigment concentration interfere with color changes in meat and meat products (Feng et al., 2016; Ferreira et al., 2017). In this study, the variations observed in treatments with juçara fruit extract can be attributed to the presence of some pigments such as anthocyanin. Furthermore, variations in color parameters in the negative-control treatment of antibiotic-free broiler meat can be related to the high oxidation processes observed, changing the muscle structure.

The addition of juçara waste extract with the optimal extraction of phenolic compounds (extract P) in conventional and antibiotic-free broiler meat was useful in the stability of lipid oxidation. Besides, this extract was efficient in reducing protein oxidation damage in conventional chicken meat. In this way, we can conclude that the *Euterpe edulis* fruit waste extract exhibits a high impact on broiler meat's oxidative stability by reducing the degradation caused by lipid and protein oxidation, compared to the control samples. Therefore, juçara fruit waste can be used as a source of natural antioxidants to be applied in chicken meat to prevent oxidative stress increasing meat quality.

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DISCLOSURES

The authors declare no conflict of interest.

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