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Goji berry effects on hamburger quality during refrigerated display time

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Abstract

Research on natural additives to replace or reduce synthetic ones in meat products is still being highlighted. The effect of goji berry (GB) (extract, powder and incorporated in an edible coating) in hamburgers during 10 days of refrigerated (2 °C) and illuminated (fluorescent lamp, 1200 lux, 12 h day^{-1}) display were evaluated. Four treatments were studied: control (CONT) – hamburger without GB; GBEX – hamburger with GB extract, GBPW – hamburger with GB powder and GBEC – hamburger with GB edible coating. pH, color, water losses, shear force, total phenolic compounds, antioxidant activity (DPPH and ABTS assays) and lipid oxidation (TBARS) were evaluated. The use of GB positively affected the quality of hamburger during display and the coated samples presented better results, with reduced weight and color losses, lower pH, and shear force values. The inclusion of GB in hamburgers increased the antioxidant activity and inhibited lipid oxidation. GB has potential application in hamburgers to maintain or improve their characteristics during the shelf-life.

Keywords: natural antioxidant; additives; oxidation; bioactive compounds; food quality.

Practical Application: Goji berry has potential application in hamburgers to maintain or improve their characteristics during the shelf-life.

1 Introduction

The search for new products similar to *in natura* ones and with high quality still brings challenges for the meat industry (Vital et al., 2018a; Vital et al., 2018b; Monteschio et al., 2020; Ornaghi et al., 2020). Meat and meat products with a high fat content are normally affected by lipid oxidation (Vital et al., 2021). However, various factors, such as oxygen, light, temperature, the presence of metals and others can accelerate the oxidation process (Domínguez et al., 2019). Lipid oxidation is one of the main significant causes of quality loss in meat products, leading to the appearance of undesirable compounds resulting in quality deterioration, especially with sensorial changes (odor, flavor, and texture), and loss of nutritional value, reducing product shelf life (Ortuño et al., 2014). Oxidative processes are often more intense in processed products associated with the larger surface area in contact with oxygen, and with to the processing itself, as in the case of the hamburger where the meat is ground, which anticipates lipid oxidation and reduces the quality of the product (Cleveland et al., 2014; Özvural et al., 2016).

Aiming to reduce oxidative process in food industry, synthetic antioxidants have already been used. However, due to an increase in demand for natural, healthier, and safe food by consumers', the replacement of synthetic antioxidants by natural products has been evaluated in different studies (Vital et al., 2016, 2021; Kempinski et al., 2017; Fachinello et al., 2018). Among the natural sources of bioactive compounds, the fruits have received considerable attention, in special the berries, which are consumed often by its attractive color and taste; but are also considered as one of the richest natural sources of bioactive compounds with antioxidant activity (Cardoso et al., 2021; Lorenzo et al., 2018). The goji berry (GB) for example has different active compounds such as caffeic acid, chlorogenic acid, coumaric acid, ferulic acid), hyperoxide, gallic acid, catechin, epicatechin, phellandrene, sabinene, γ-terpinene, citric acid, malic acid, oxalic acid, quinic acid and tartaric acid, and vitamin C (Donno et al., 2015). Their consumption was also associated with the prevention of degenerative and chronic diseases (Manganaris et al., 2014). These natural compounds can be used directly in the formulation of foods, processed, or added to the packaging/edible coatings and although these fruits have been widely studied as antioxidants, few studies have shown the effects of the addition of goji berry on meat product quality during its shelf life (Cardoso et al., 2022).

This study was conducted to verify the effect of goji berry on hamburger quality (pH, color, water losses, shear force, antioxidant activity and lipid oxidation) during 10 days of refrigerated display.

2 Materials and methods

2.1 Material

All reagents used were of analytical grade. 200 g of the ripe Goji berry fruit (*Lycium barbarum L.*) was purchased at a local market (Maringá, Paraná, Brazil) and they were used in full.

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2.2 Preparation of hamburger and treatments

Meat - semimembranosus muscle (SM) was obtained from *Longissimus dorsi* of young bulls (½ Angus vs. ½ Nellore; with 443.5 ± 26.2 kg) finished in a feedlot and slaughtered at 12 months old. After that, was vacuum-packaged and frozen at -20 °C until analysis (1 month). Before analysis, SM were thawed (4 °C/24 h), minced, used for hamburger production, and randomly distributed for treatment and analysis.

The GB was dried in a 55 °C greenhouse with air circulation for 48 h, crushed in a grain crusher (80393BZ, Hamilton Beach) with regulation. Different treatments were elaborated: control (CONT) – hamburger without GB extract; GBEX – hamburger with GB extract, GBPW – hamburger with GB powder and GBEC – hamburger with GB + edible coating. For GBPW, GB powder was added directly in minced meat (3% w/w). For the GBEX, 30 g of the GB were stirred with 1 L of water (70 °C) for 30 min. and the mixture was chilled to room temperature, added to minced meat and homogenized. For GBEC, 20 g of alginate was dissolved in 1 L of the so-obtained GB extract (at 70 °C). The hamburgers were, then, submerged in alginate solution for 1 min, allowed to drain (to remove coating excess) for 1 min, submerged in calcium chloride solution (2% w/v) used as a crosslinking for 30 s (Vital et al., 2016, p. 3) to result in the GBEC samples with ~3% GB w/w. Each hamburger was packaged (polystyrene tray), covered with a retractile film and stored with an illuminated display (2° C) (fluorescent lamp, 1200 lux, 12 h day^{-1}). Samples (four replicates per treatment for each analyze/day) were analyzed at 1, 3, 7 and 10 days of display. All samples were analyzed in triplicate.

2.3 pH measurements

The pH was determined at 1, 3, 7 and 10 days of storage time, using a digital pH meter with a penetration electrode as describe by Vital et al. (2016).

2.4 Water losses

The individual weights of hamburgers were recorded each day of analyses. Results were expressed as a percentage relative to hamburger's initial weight (day 0).

2.5 Shear force

Shear force (N) was analyzed using TA.XT Plus (texturometer - Texture Technologies 15 Corp., UK) with a Warner–Bratzler blade. The parameters used were a 5 kg load cell and a speed of 1 mm/s. Four samples were grilled at 200 °C on an electric grill (Grill Philco Jumbo Inox, Philco SA, Brazil) until 72 °C. Then, samples were cooled (25 °C), cut and analyzed in the center.

2.6 Color

Color was evaluated using a Minolta CR-400 (10° view angle and a D65 illuminant) as describe by Vital et al. (2016). Four measurements were recorded in each hamburger. Lightness (L*), redness (a*) and yellowness (b*) were obtained and Chroma and hue values were calculated in the Equations 1 and 2 bellow:

$$Chroma = \sqrt{a^2 + b^2} \quad (1)$$

and

$$Hue = \arctan \frac{b*}{a*} \quad (2)$$

2.7 Lipid oxidation

Malonaldehyde (MDA) content was quantified using TBARS assay (Vital et al., 2016). 5 g of each hamburger was mixed with TCA solution (0.1% EDTA, 0.1% gallic acid and 7.5% TCA) (10 mL), homogenized with an Ultra Turrax, and centrifuged (4° C/15 min/4.000 rpm). The supernatant was filtered and mixed (1:1 v/v) with TBARS solution (562.5 μM HCl, 15% TCA and 1% thiobarbituric acid). The mixture was boiled (100° C/15 min), then cooled, and measured against an MDA standard (535 nm). Results were expressed as mg MDA kg^{-1} of hamburger.

2.8 Total phenolic compound content (TPC) by Folin–Ciocalteu assay

The TPC was determined with modifications (Singleton & Rossi, 1965). The samples of hamburgers on 1 day of display were placed in the proportion of 1:1 (w/v) in methanol. The extracts (supernatant) were obtained by homogenization, centrifugation (15 min/4.000 rpm) and filtration. An aliquot of the supernatant (125 μL) was mixed with Folin– Ciocalteu (1:1 deionized water, 125 μL) and sodium carbonate (28 g/L, 2250 μL). Samples were incubated in the dark (25 °C/30 min) and measured at 725 nm (EvolutionTM 300 spectrophotometer; Thermo Scientific, Madison, USA). Results were expressed as mg gallic acid equivalent (GAE)/g of hamburger.

2.9 ABTS radical scavenging assay

ABTS was analyzed as demonstrated by Re et al. (1999). ABTS·+ was produced by the interaction of 5 mL (7 mM ABTS) with 88 μL potassium persulfate (140 mM), incubated in the dark (25 °C/16 h). Then, ABTS radical was diluted with ethanol (absorbance of 0.70 ± 0.02). The samples of hamburgers on 1 day of display were placed in the proportion of 1:1 w/v in methanol. The extracts (supernatant) were obtained by homogenization, centrifugation (15 min/4.000 rpm) and filtration. An aliquot of the supernatant (40 μL) was mixed with ABTS·+ radical (1960 μL) and absorbance was recorded after 6 min at 734 nm. The radical scavenging activity (%) was calculated as (Equation 3):

$$ABTS\ radical\ scavening\ activity\ (\%) = \left(1 - \left(\frac{A_{sample,t=0}}{A_{sample,t}}\right)\right) * 100 \quad (3)$$

where: $A_{sample,\ t=0}$: sample absorbance at time zero and $A_{sample,\ t}$: sample absorbance at 6 min.

2.10 DPPH radical scavenging assay

DPPH scavenging activity was analyzed as demonstrated by Li et al. (2009), with modifications. The samples of hamburgers on 1 day of display were placed in the proportion of 1:1 w/v in methanol. The extracts (supernatant) were obtained by homogenization, centrifugation (15 min/4.000 rpm) and filtration. An aliquot of the supernatant (150 μL) was mixed with s methanolic solution of DPPH (2850 μL; 60 μM), reacted during 30 min and absorbance was read at 515 nm. Antioxidant activity was calculated as (Equation 4):

$$DPPH\ radical\ scavening\ activity\ (\%) = \left(1 - \left(\frac{A_{sample,t=0}}{A_{sample,t}}\right)\right) * 100 \quad (4)$$

where: $A_{sample,\ t=0}$: sample absorbance at time zero and $A_{sample,\ t}$: sample absorbance at 30 min.

2.11 Statistical analyses

Data obtained from hamburgers analyzes were evaluated by analysis of variance using the GLM - general linear model (SPSS, v.20.0) (IBM SPSS Statistics, SPSS Inc., Chicago, USA). Means and standard error were calculated for each variable. Display time and type of goji berry application were considered fixed factors (factorial design) with four replicates per treatment. The experiment was repeated two times. When differences were significant, Tukey test was applied ($P < 0.05$). All samples were analyzed in triplicate.

3 Results and discussion

3.1 pH measurement, water losses and shear force of hamburger with goji berry during display

The values found for pH of hamburger are presented in Table 1. Generally, GBEC presented a lower pH value ($P < 0.05$), followed by GBEX, GBPW and CONT. The lower value observed in the GBEC treatments may be due to the coating pH (Approximate pH 6) as observed by Vital et al. (2016) in a study with edible coatings. Still, the lower value for treatment with GB addition may be associated with the lower pH of the fruit (around 3). During storage, pH increased for CONT, GBEX and GBPW treatments, while a decrease was observed to GBEC treatment (Table 1).

The increase in pH at the end of display can be caused by the production of volatile basic components such as ammonia and trimethylamine by endogenous or microbial enzymes (Herrera-Mendez et al., 2006; Zarei et al., 2015). Coating decreased water losses ($P < 0.001$), specially related to GBPW treatment, and in general, no differences were found for the other treatments (Table 2). The grater difference between samples was observed at 10 days of display, when the GBEC retained a significant quantity of water ($P < 0.016$). The weight losses increased for all treatments during display, as observed by Vital et al. (2016).

Regarding shear force, no interaction between display time and treatments were observed ($P > 0.083$). In this way, the data are not presented in tables. The shear force reduced with time ($P < 0.001$), ranging from 1.69 to 1.15 kgf, and the coating made the hamburgers tender (1.11 kgf). The higher shear force for samples without coating, 1.66, 1.43 and 1.42 respectively for CONT, GBEC and GBPW, may be related to the higher weight loss during display time. Water was maintained in the samples with a coating, providing a tender hamburger. This behavior was also observed by Vital et al. (2016), with coated beef.

3.2 Hamburger color

The use of different ingredients and an edible coating can change the appearance of hamburger since the additive color can be different related to its constituents. The color of hamburgers (L*, a*, b*, Hue and Chroma) is provided in Table 3. The lightness values (L*), was stable during time display ($P > 0.05$) for all treatments, except for GBEC. GBEC presented the lower L* value, probably associated with the lower oxidation (Table 4). Łopacka et al. (2016) also observed an increase in L* value when comparing packaging systems with high content of oxygen compared to lower oxygen. Related to the hamburgers with coating, the maintenance of exudates, as observed by Vital et al. (2016), darkens the color in this study. For GBEX and GBPW, no differences ($P > 0.05$) were observed during display time. About the redness values (a*), GBEC presented the highest values ($P < 0.05$) until the 7th day, at the 10th day, no differences were observed between the treatments. Meat pigment, without oxygen (deoxyMb) has a purple-red color. With oxygen (MbO_2), has a bright red (Insausti et al., 1999), the highest value for GBEC may be associated with the exudate that remains attached to the system, intensifying the red color.

Regarding b* value, a little variation was observed during display, and GBEC presented a higher value ($P < 0.05$), associated with the coating color (yellow).

Table 1. pH measurements of hamburgers with goji berry (GB) during refrigerated an illuminated display.

Treatments	Days				SEM[1]	P < Value
	1	3	7	10		
CONT	6.05[aB]	6.04[aB]	5.97[aB]	6.60[aA]	0.0423	< 0.001
GBEX	5.99[aB]	5.91[bBC]	5.83[cC]	6.13[bA]	0.0196	< 0.001
GBPW	5.99[aB]	6.02[aB]	5.87[bC]	6.48[aA]	0.0355	< 0.001
GBEC	5.97[bA]	5.92[bB]	5.79[dD]	5.85[cC]	0.0115	< 0.001
SEM[2]	0.0025	0.0104	0.0105	0.0498		
P < Value	< 0.001	< 0.001	< 0.001	< 0.001		

Note: [a-c] Means followed by the same lowercase letter in the same column do not differ statistically among themselves by Tukey test ($P < 0.05$). [A-D]Means with different uppercase letters in the same line are significantly different ($P < 0.05$). CONT: hamburger without GB extract, GBEX: hamburger with GB extract, GBPW: hamburger with GB + powder and GBEC: hamburger with GB + edible coating. SEM[1]: Standard error of means from the treatments. SEM[2]: Standard error of means from storage time.

Table 2. Water losses of hamburgers with goji berry (GB) during refrigerated an illuminated display.

Treatments	Days				SEM[1]	P < Value
	1	3	7	10		
CONT	1.26^{A}	1.63^{A}	2.62^{abB}	3.01^{abB}	0.16	< 0.001
GBEX	1.10^{D}	1.82^{C}	2.66^{abB}	3.60^{aA}	0.26	< 0.001
GBPW	0.97^{C}	1.51^{C}	3.04^{aB}	4.01^{aA}	0.20	< 0.001
GBEC	1.23^{B}	1.64^{AB}	2.09^{bAB}	2.49^{bA}	0.15	0.016
SEM[2]	0.04	0.06	0.12	0.17		
P < Value	0.050	0.416	0.038	0.005		

Note: $^{a\text{-}c}$ Means followed by the same lowercase letter in the same column do not differ statistically among themselves by Tukey test (P < 0.05). $^{A\text{-}D}$Means with different uppercase letters in the same line are significantly different (P < 0.05). CONT: hamburger without GB extract, GBEX: hamburger with GB extract, GBPW: hamburger with GB + powder and GBEC: hamburger with GB + edible coating. SEM[1]: Standard error of means from the treatments. SEM[2]: Standard error of means from storage time.

Table 3. Color of hamburgers with goji berry during display refrigerated an illuminated time.

Treatments	Storage days					
Lightness, L*	1	3	7	10	SEM[1]	P < Value
CONT	47.81^{a}	47.81^{a}	49.13^{a}	47.95	0.48	0.704
GBEX	46.63^{a}	47.53^{a}	48.03^{a}	47.71	0.42	0.680
GBPW	46.05^{ab}	48.95^{a}	47.01^{a}	45.88	0.51	0.201
GBEC	43.41^{bAB}	40.19^{bB}	39.74^{bB}	44.61^{A}	0.59	0.005
SEM[2]	0.46	0.67	0.64	0.59		
P < Value	0.006	< 0.001	< 0.001	0.153		
Redness, a*						
CONT	15.14^{bA}	12.96^{abB}	7.69^{bD}	9.60^{C}	0.47	< 0.001
GBEX	15.83^{abA}	9.87^{cB}	7.48^{bC}	9.04^{B}	0.45	< 0.001
GBPW	17.40^{aA}	11.15^{bcB}	7.62^{bC}	10.35^{B}	0.53	< 0.001
GBEC	17.36^{aA}	14.67^{aB}	13.02^{aB}	9.95^{C}	0.44	< 0.001
SEM2	0.27	0.38	0.33	0.27		
P < Value	0.004	< 0.001	< 0.001	0.400		
Yellowness, b*						
CONT	16.34^{cA}	16.14^{bcA}	13.74^{bB}	16.28^{abA}	0.44	< 0.001
GBEX	16.88^{cA}	14.30^{cBC}	13.68^{bC}	15.62^{bB}	0.21	< 0.001
GBPW	18.77^{bA}	17.09^{bAB}	14.83^{bC}	16.90^{aB}	0.30	< 0.001
GBEC	21.08^{aA}	19.40^{aAB}	18.69^{aBC}	17.08^{aD}	0.34	< 0.001
SEM2	0.32	0.39	0.30	0.22		
P < Value	< 0.001	< 0.001	< 0.001	0.015		
Chroma						
CONT	22.23^{bA}	20.74^{bAB}	15.79^{bC}	18.97^{abB}	0.42	<0.001
GBEX	23.17^{bA}	17.41^{cB}	15.61^{bC}	17.78^{bB}	0.41	<0.001
GBPW	25.63^{aA}	20.42^{bB}	16.71^{bC}	19.90^{aB}	0.51	<0.001
GBEC	27.37^{aA}	24.36^{aB}	22.83^{aB}	19.79^{abC}	0.62	<0.001
SEM2	0.36	0.51	0.42	0.28		
P < Value	< 0.001	< 0.001	< 0.001	0.027		
Hue						
CONT	47.18^{abB}	51.31^{cB}	60.92^{aA}	59.81^{A}	1.01	< 0.001
GBEX	46.87^{bC}	55.42^{abB}	61.32^{aA}	59.56^{A}	0.85	< 0.001
GBPW	47.21^{abC}	56.96^{aB}	62.70^{aA}	58.57^{B}	0.91	< 0.001
GBEC	50.57^{aC}	52.99^{bcBC}	55.29^{bB}	59.90^{A}	0.50	< 0.001
SEM2	0.49	0.54	0.54	0.66		
P < Value	0.019	0.001	< 0.001	0.895		

Note: $^{a\text{-}c}$ Means followed by the same lowercase letter in the same column do not differ statistically among themselves by Tukey test (P < 0.05). $^{A\text{-}D}$Means with different uppercase letters in the same line are significantly different (P < 0.05). CONT: hamburger without GB extract, GBEX: hamburger with GB extract, GBPW: hamburger with GB + powder and GBEC: hamburger with GB + edible coating. SEM[1]: Standard error of means from the treatments. SEM[2]: Standard error of means from storage time.

Samples that present low Chroma are considered pale (Cardoso et al., 2016) and in this study, CONT and GBEX showed lower values than GBEC until the 7th day, which may not be desirables to consumers at purchase time. Generally, GBEC had higher values during display time. Fresh meat normally becomes less light and red during display. Regarding Hue, the values increased with display time, and on the 10th day no differences between treatments were observed (P > 0.05). GBEC presented less variation in Hue value until the 7th day.

Thus, an additive or technology, as a powder, an extract, or an edible coating, that can intensify or maintain meat color, especially the redness, could lead to an extension in meat color display-life (Vital et al., 2016), favoring consumer choice at the time of purchase. Hue value was not different between treatments and increased with display time.

Fresh hamburgers are susceptible to fast deterioration especially due to the high level of moisture, protein, lipid, and processing. Thus, food industry wish/search new alternatives to extend the shelf-life of meat products and maintain their quality, especially the color, which is one of the principal attributes for the consumers on the purchase moment (Vital et al., 2016).

3.3 Lipid oxidation

The oxidation leads to degradation of lipids, pigments, proteins, and is one of the major mechanisms of quality for deterioration in meat products (Liu et al., 2010). The inclusion of GB in different ways significantly reduced TBARS values (Table 4). Lipid oxidation increased significantly (P < 0.001) during display only for CONT, while the other treatments maintained the oxidation stabilized. At 10 days, the TBARS values reached approximately 1.48, 0.99, 0.95 and 1.02 mg MDA kg^{-1} for CONT, GBEX, GBPW and GBEC, respectively. Oxidation is one of the major factors responsible deteriorations in foods leading to consumer rejection (Pouzo et al., 2016).

Thus, this study shows that the use of goji berry could be effective in reduce/inhibit the lipid oxidation in meat products during refrigerated display. Besides, other studies have also demonstrated the effectiveness of using natural compounds with antioxidant activity in coatings or films to prevent the lipid oxidation, as also in the isolated form. Bulambaeva et al. (2014) observed that GB powder effectively in inhibits the lipid oxidation of sausages. Amiri et al. (2019) evaluated the corn starch films with nanoemulsion of *Zataria multiflora* essential oil with cinnamaldehyde on fresh beef patties and observed that TBARs' values in samples containing EO and cinnamaldehyde were significantly lower than that in the control. Vital et al. (2021) observed that the lipid oxidation of lamb patties was reduced by the use of essential oil in coating and modified atmosphere. Cardoso et al. (2016) showed that a coating of chitosan and gelatin could reduce TBARS values, related to the chitosan antioxidant activity. Borella et al. (2019) evaluated the effect of rosemary antioxidant in hamburgers during shelf life and the natural antioxidants used were efficient in maintaining the oxidative stability of the product during the frozen storage time. In this way, natural compounds isolated or incorporated in a coating, such as the GB, can improve the quality and shelf-life of meat products by preventing its lipid oxidation.

3.4 Polyphenol compounds and antioxidant activity

Related to total phenolic compounds (TPC), treatments with GB had higher values (P < 0.001; Table 5), as expect, due to the bioactive compounds of the fruit. The antioxidant activity was measured using the DPPH and ABTS assays, and also hamburger with GB had a higher radical scavenging activity (P < 0.001).

Table 4. Lipid oxidation (TBARs) of hamburgers with goji berry during refrigerated an illuminated display time.

Treatments	Days				SEM[1]	P < Value
	1	3	7	10		
CONT	0.79^{C}	1.07^{aB}	1.43^{aA}	1.48^{aA}	0.30	< 0.001
GBEX	0.86	0.83^{b}	0.93^{b}	0.99^{b}	0.08	0.050
GBPW	0.80	0.80^{b}	0.96^{b}	0.95^{b}	0.11	0.073
GBEC	0.86	0.89^{b}	1.01^{b}	1.02^{b}	0.13	0.096
SEM[2]	0.07	0.13	0.23	0.24		
P < Value	0.316	0.002	< 0.001	< 0.001		

Note: $^{a-c}$ Means followed by the same lowercase letter in the same column do not differ statistically among themselves by Tukey test (P < 0.05). $^{A-D}$Means with different uppercase letters in the same line are significantly different (P < 0.05). CONT: hamburger without GB extract, GBEX: hamburger with GB extract, GBPW: hamburger with GB + powder and GBEC: hamburger with GB + edible coating. SEM[1]: Standard error of means from the treatments. SEM[2]: Standard error of means from storage time.

Table 5. Total phenolic compounds (TPC) and antioxidant activity (ABTS and DPPH assays) of hamburger with goji berry.

Analyses	Treatments				P < Value
	CONT	GBEX	GBPW	GBEC	
TPC (mg EAG/ kg hamburger)	0.24 ± 0.003^{c}	0.28 ± 0.004^{ab}	0.26 ± 0.005^{b}	0.29 ± 0.006^{a}	< 0.001
ABTS radical scavenging (%)	69.52 ± 0.56^{c}	78.39 ± 0.72^{b}	85.05 ± 0.90^{a}	84.62 ± 0.24^{a}	< 0.001
DPPH radical scavenging (%)	30.98 ± 1.21^{c}	49.66 ± 0.30^{a}	37.95 ± 1.50^{b}	42.89 ± 1.70^{b}	< 0.001

Note: $^{a-c}$ Means followed by the same lowercase letter in the same line do not differ statistically among themselves by Tukey test (P < 0.05). CONT: hamburger without GB extract, GBEX: hamburger with GB extract, GBPW: hamburger with GB + powder and GBEC: hamburger with GB + edible coating.

Samples with GB presented little differences between analyses (mythology employed), and these differences were because the bioactive compounds can act by different mechanisms with different radicals, such as reactions with electron transfer processes (ABTS), or by hydrogen atom transfer (DPPH) (Gülçin, 2010). Nevertheless, natural compounds with antioxidant activity as TPC can be used in the meat industry to minimize the degradation during display time (Kumar et al., 2015; Zhang et al., 2016).

4 Conclusion

The use of goji berry had positive effects on hamburger quality during display time. Generally, samples with coating presented better results, with less weight and color losses, lower pH values, and greater tenderness. Also, the use of goji berry in hamburgers increased the product antioxidant activity and inhibited its lipid oxidation. Thus, GB has potential application in the meat industry to maintain/improve final product characteristics during the shelf-life.

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