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Pink pepper extract as a natural antioxidant in chicken burger: Effects on oxidative stability and dynamic sensory profile using Temporal Dominance of Sensations

Beatriz Schmidt Menegali[a], Miriam Mabel Selani[b], Erick Saldaña[c], Iliani Patinho[a], Julia Pereira Diniz[b], Priscilla Siqueira Melo[a], Natan de Jesus Pimentel Filho[b], Carmen J. Contreras-Castillo[a,*]

[a] *Departamento de Agroindústria, Alimentos e Nutrição, Escola Superior de Agricultura "Luiz de Queiroz" (ESALQ), Universidade de São Paulo (USP), Piracicaba, SP, Brazil*

[b] *Centro de Ciências da Natureza, Universidade Federal de São Carlos (UFSCAR) - Campus Lagoa do Sino, Buri, SP, Brazil*

[c] *Facultad de Ingeniería Agroindustrial, Universidad Nacional de Moquegua (UNAM), Moquegua, Peru*

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ABSTRACT

This study aimed to elucidate the effect of pink pepper extract and different types of packaging on the physicochemical characteristics, oxidative stability and dynamic sensory profile of chicken burger. Pink pepper extract was incorporated into chicken burgers, which were stored in aerobic and vacuum packaging for 7 days at 2 °C. A formulation with synthetic antioxidant (butylated hydroxytoluene - BHT) and a control (without antioxidants) were also analysed. Pink pepper extract was as effective as BHT to delay the lipid oxidation of chicken burger after 7 days of refrigeration. Vacuum packaging was effective in preventing myoglobin oxidation, avoiding sample discoloration during storage. Burgers manufactured with pink pepper extract stored under vacuum packaging showed sensory properties similar to those manufactured with synthetic antioxidant.

1. Introduction

The presence of polyunsaturated fats in meat products, as well as some unit operations (e.g., size reduction, cooking and salt addition) promote the breakdown of the oxidative balance in the food matrix, making them susceptible to lipid oxidation. To control this deteriorative process in meat products, the use of natural antioxidants and vacuum packaging has recently been studied by both industry and academia (Devatkal, Thorat, & Manjunatha, 2014; Packer et al., 2015).

Pink pepper (*Schinus terebinthifolius* Raddi) has been reported for having important bioactive compounds, such as ascorbic acid, phenolic compounds and carotenoids (Pagani et al., 2014). Due to its composition, the incorporation of these compounds may represent a suitable alternative as natural antioxidants in foods. However, few studies have evaluated the application of pink pepper in meat and fish products. For instance, an active chitosan film with pink pepper residue extract was studied for the packaging of restructured chicken products (Serrano-León et al., 2018) and salmon fillets (Merlo et al., 2019), showing important results in delaying lipid oxidation. However, in both studies the temporal consumer's sensory perception of the products was not addressed.

In the context to assess the changes in the intensity of a sensory attribute during a certain period of time, the Time-Intensity (TI) methodology has been used. However, as any other sensory method, TI has limitations, such as the long training periods and the evaluation of one sensory attribute at a time, which does not reflect the multidimensionality of perception. Considering these drawbacks, a new "multi-attribute" method, called Temporal Dominance of Sensations (TDS) was developed to evaluate the sequence of dominant sensory attributes of a product in a given period of time (Pineau et al., 2009). TDS has already been used to characterize wine (Galmarini, Visalli, & Schlich, 2017), chocolate (Rodrigues et al., 2016) and smoked bacon (Saldaña et al., 2019).

The TDS method, as most sensory methods, originally used trained assessors and intensity scales (Pineau et al., 2009). However, the difficulty of scoring intensity led to the use of dominance rather than intensity, making it a much simpler task of choice (Pineau et al., 2009). This fact facilitated the use of consumers as a sensory panel in the TDS task, as observed in studies with flavored fresh cheese ((Meyners & Castura, 2019)), smoked bacon (Saldaña et al., 2019), and prato cheese

* Corresponding author.
E-mail address: ccastill@usp.br (C.J. Contreras-Castillo).

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(Rodrigues, Souza, Lima, Cruz, & Pinheiro, 2018). In this regard, the creators of the method concluded that TDS can be done by consumers and argued that it is easier than scoring (Schlich, 2017). Even when consumers perform the TDS task, hedonic measures and different intakes can be coupled, as in the present study and in previous studies with dairy products (Thomas et al., 2015, 2016). Thus, the use of regular consumers of the product seems promising as the sensory profile will be taken directly from the end consumer.

Although TDS can be performed by consumers (Albert, Salvador, Schlich, & Fiszman, 2012), there are no applications in chicken burger. Therefore, this study aimed to investigate the effect of pink pepper extract and different types of packaging on the oxidative stability, color, pH and temporal and hedonic sensory perception of chicken burger.

2. Materials and methods

2.1. Pink pepper extract

2.1.1. Preparation of the raw material

Pink pepper (*Shinus terenbithifolius* Raddi) was obtained in the local commerce (São Paulo, SP, Brazil), ground in a knife mill and stored for up to 4 months at −18 °C in the dark.

2.2. Preparation of the extract

Samples (5 g) were added to 50 mL of 80% ethanol-water (v/v), maintained in a water bath (20 min, 90 °C) and then in an ultrasonic bath (15 min, at room temperature). The mixture was centrifuged (15 min, 5000 *g*), filtered (qualitative filter paper) and the supernatant (ethanolic extract of pink pepper) was collected for the analysis of total phenolic content and antioxidant activity. For further technological application, the ethanolic extracts were concentrated in a vacuum rotary evaporator at 50 °C until the solvent was removed and then dissolved in water to the volume of 12 mL.

2.2.1. Total phenolic content (TPC)

TPC was determined in triplicate as described by Singleton, Orthofer, and Lamuela-Raventós (1999), using the Folin-Ciocalteu reagent. The results were expressed as mg of gallic acid equivalents (GAE)/mL extract. This quantification was also used to determine the volume of aqueous extract to be added to the burger.

2.2.2. Antioxidant activity (AA)

The AA of the pink pepper extract was evaluated in triplicate by the DPPH and ABTS assays, following the method described by Al-Duais, Muller, Bohm, and Jetschke (2009). In both assays Trolox was used as standard and the results were reported as μmol of Trolox equivalents/g sample.

2.3. Chicken burger

2.3.1. Manufacture

Boneless and skinless chicken thighs and drumsticks were obtained from a local slaughterhouse (Rio Claro, SP, Brazil) and transported in ice boxes to the processing plant of the Escola Superior de Agricultura "Luiz de Queiroz" (ESALQ), Universidade de São Paulo (USP), Brazil. Meat was ground in a meat grinder (0.8-cm diameter die plate) and divided into 3 parts, which received 3 different formulations: 1) PP: addition of the volume of pink pepper extract equivalent to 90 mg GAE/kg meat; 2) BHT: addition of 90 mg BHT/kg meat; and 3) C: control, without antioxidants.

The concentration of pink pepper extract was based on a previous study of Serrano-León et al. (2018). The same concentration of BHT (dissolved in soybean oil without antioxidant) was used. Water (in the same volume of pink pepper extract) and soybean oil (in the same volume used to dissolve BHT) were added to the other formulations for standardization. Sodium chloride (1%), monosodium glutamate (0.2%), onion powder (2%) and garlic powder (0.2%) were added in all samples (w/w). Each formulation was homogenized in meat blender for 5 min, and then 100 g portions were manually shaped (10 cm diameter and 1 cm thick). Burgers were packaged in either aerobic (polystyrene tray overwrapped with polyvinyl chloride (PVC) film) and vacuum bags (Cryovac BB2620, oxygen permeability rate: 25 cm ^{3}/m^2 24 h at 23 °C/0% relative humidity (RH) and water vapor permeability rate: 9 g H_2O/m^2 24 h at 38 °C/90% RH).

Considering 3 formulations and 2 types of packaging, 6 treatments were manufactured: burgers with pink pepper extract, and packaged under either aerobic (PP_PVC) or vacuum (PP_V) conditions; burgers manufactured with BHT, packaged under either aerobic (BHT_PVC) or vacuum (BHT_V) conditions; and the control, burgers packaged under either vacuum (C_V) or aerobic (C_PVC) conditions. Samples were stored at 2 °C with white light incidence (fluorescent lamp, 800 lm light flux) and evaluated for consecutive 7 days.

2.3.2. Thiobarbituric acid reactive substances (TBARS)

TBARS levels were determined in triplicate as described by AOCS (Cd 19–90, 1990), with modifications. Each sample (7 g) was added to 0.015 g of ethylenediamine tetra-acetic acid, 0.015 g of propyl gallate and 15 mL of a 7.5% trichloroacetic acid solution. The solution was vortexed (1800 rpm, 1 min) and 15 mL of a 7.5% trichloracetic acid solution were added. The mixture was filtered (qualitative filter paper), and 2.5 mL of the filtrate were added to 2.5 mL of an aqueous solution of thiobarbituric acid (TBA) at 46 mmol/L. Samples were incubated in water bath with boiling water (approximately 97 °C, 35 min) and then cooled in an ice bath. Absorbance was measured in a spectrophotometer at 532 nm. TBARS values were calculated from a standard curve of 1,1,3,3 tetraethoxypropane and expressed as mg malonaldehyde (MDA)/kg sample. The analyzes were performed on days 1, 3, 5 and 7 of storage.

2.3.3. Color and pH

Color was determined using a CR-400 Minolta colorimeter with a measurement area of 8 mm in diameter, observation angle of 10° and illuminant D65. Lightness (L*), redness (a*), and yelowness (b*) were determined. The pH was determined using a potentiometer with automatic temperature compensation (Oakton pH300, 35,618) and glass penetration electrode (Digimed). Both measurements were performed in 3 samples of each treatment, in triplicate, on days 1, 3, 5 and 7 of storage.

2.3.4. Sensory analysis

This study was approved by the Ethics Committee for Human Research of ESALQ/USP (protocol 2.235.735).

2.3.4.1. Microbiological analysis. In order to guarantee safety to the consumers, determination of thermotolerant coliforms, coagulase-positive staphylococci and sulfite-reducing clostridia and evaluation of the presence/absence of *Salmonella* were conducted according to methodologies described by the Compendium of Methods for the Microbiological Examination of Foods (APHA, 2001). Analysis were performed immediately prior to the application of sensory tests.

2.3.4.2. Consumers. Eighty-seven regular consumers of chicken burger (18–52 years, 53% male) were recruited at ESALQ-USP. Participants declared having a frequency of burger consumption at least once a month, as well as being healthy, non-smokers and over 18 years old.

2.3.4.3. Procedure. Samples were cooked in a hot plate until the internal temperature reached 75 °C, cut into 10 g cubes and served monadically in disposable plastic plates coded with 3-digit random numbers, following a balanced design.

Firstly, a 30-min single session familiarization was conducted, with

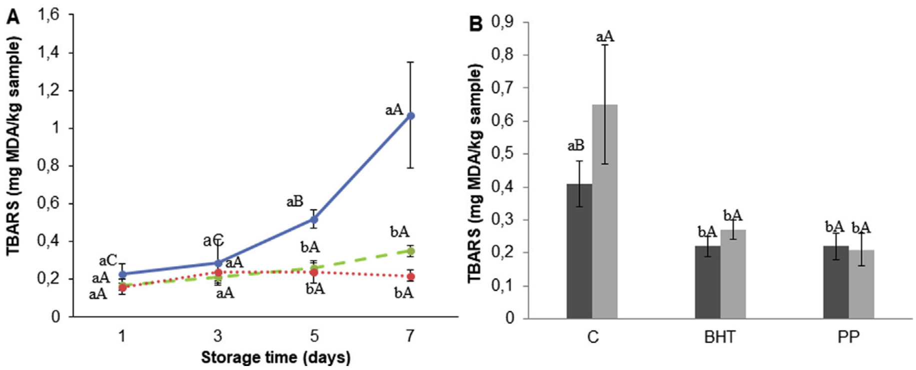

Fig. 1. Effects of antioxidants and storage time (A) and antioxidants and packaging type (B) on TBARS values (mg malonaldehyde/kg meat) of chicken burgers.
A: Different lowercase letters between treatments and different capital letters between days indicate significant difference according to the Tukey test ($p < 0.05$). C-control (—◆—); PP- Pink pepper (··●··), BHT-butylated hydroxytoluene (– ● –) B: Different lowercase letters between treatments and different capital letters between packages (Vacuum packaging (■); aerobic packaging (■)) indicate significant difference according to the Tukey test ($p < 0.05$). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

an introduction to the TDS method and definition of the dominant sensation (the sensation that catches the attention at a given moment, not necessarily being the most intense) (Pineau et al., 2009). Then, chicken burgers (at 1 and 7 days of storage) were characterized by TDS. Data collection was performed using Compusense Cloud (Compusense Inc., Guelph, Ontario, Canada) using tablets (Samsung Tab E/SM-T560/ 9.6) with android system.

2.3.4.4. Temporal Dominance of Sensations. The attributes list was defined based on previous studies (Rios-Mera et al., 2019; Serrano-Leon, 2015) and pre-tests with trained assessors. For each consumer, the attributes were presented in a balanced way. However, for the same consumer, the attributes were presented in the same order for all samples. To start the test, participants were instructed to click on the "start" button when the sample was in the mouth. During chewing, the selection of dominant attributes was recorded. The maximum time per evaluation was 180 s, defined in pre-tests. However, the consumers were free to click the "stop" button when they did not notice any more dominant sensation. Consumers were not required to use all terms of the attribute list, and an attribute could be selected more than once during the test. Water and crackers were provided to clean the palate between samples. After sample ingestion, consumers were asked to evaluate the overall liking, using a 9-point structured hedonic scale, ranging from "dislike extremely" (1) to "like extremely" (9).

2.4. Data analysis

Burgers were prepared following a randomized block design (two independent processing), with factorial arrangement 3 x 2 x 4, considering as factors the treatments, packaging type, and storage time. For the physicochemical analyzes, the results were submitted to analysis of variance (ANOVA), considering treatment, packaging, and storage time and their interactions as sources of variation. The pairwise comparisons were performed by the Tukey test at 5% significance, using the R software, version 3.5.1.

For TDS results, dominance rates considering standardized time were calculated and plotted by bandplot per attribute (Galmarini et al., 2017; Merlo et al., 2019b). This graphic representation of the dominance rate is adequate since in this study we worked with 12 samples, which represent 12 traditional plots (Galmarini et al., 2017). Then, the standardized duration of dominant attributes was calculated (Galmarini et al., 2017) and submitted to ANOVA (samples and consumers as factors), followed by the Tukey test considering 5% significance. A multidimensional representation of the standardized duration of dominant sensations was obtained through Canonical Variate Analysis (CVA) (Peltier, Visalli, & Schlich, 2015). Sensory data were analyzed using TimeSens © software (INRA, Dijon, France).

3. Results and discussion

3.1. Total phenolic content and antioxidant activity

TPC of pink pepper extract was 12.17 mg GAE/g. Merlo et al., 2019 and Serrano-León et al. (2018) reported higher values, 29.20 and 45.01 mg GAE/g, respectively, while a similar content (12.03 mg GAE/g) was found by Romani, Hermández, and Martins (2018). The phenolic content of pink pepper stands out compared to that of green (approximately 1.8 mg GAE/g sample) (Vega-Gálvez et al., 2009) and black pepper (2.27 mg GAE/g sample) (Vadivel et al., 2018).

For the DPPH and ABTS assays, the results were lower than that found by Serrano-León (2018), who reported 535.74 and 931.0 μmol Trolox/g for DPPH and ABTS, respectively. Variations in TPC and, consequently, in the antioxidant activity, may be due to differences in the production, such as maturation degree, stage of growth and harvest conditions (Kim, Jeong, & Lee, 2003) and extracting conditions (method, solvent, time, temperature, solid/liquid ratio) (Feng, Luo, Tao, & Chen, 2015). (+)-Catechin, *p*-coumaric acid, miricetin and (−)-epicatechin are some of the phenolics found in pink pepper extract that can be responsible for its antioxidant activity (Bergamaschi, 2016).

3.2. Chicken burger

3.2.1. Oxidative stability

TBARS values were affected by treatments, packaging, storage time and interactions between "treatments and time" and "treatments and packaging". From the fifth day of storage, PP-samples had significantly lower TBARS value (Fig. 1A) than the control and showed similar oxidative stability to BHT-samples. At the end of the storage time, BHT and PP had significantly lower TBARS values, which demonstrate the protection of both antioxidants against the lipid oxidation process. This protection can be represented by the reduction of TBARS in 79.44% for PP and 67.29% for BHT compared to control.

Regarding the storage time, only the control showed a significant increase in TBARS (Fig. 1A). According to Kanner (1994), lipid-free radicals are stable at low temperature, allowing the diffusion to longer distances which may dissiminate the oxidation. Thus, storing samples at refrigeration temperature is not enough to significantly delay the oxidative process, showing that the use of antioxidants is essential. On the other hand, pink pepper extract and BHT were efficient in maintaining the oxidative stability of chicken burgers during 7 days of storage. Antioxidant effects of pink pepper extract were also reported in salmon fillet (Merlo et al., 2019) and chicken burger (Serrano-León et al., 2018).

According to the interaction between packaging and treatments, the control sample showed significantly higher TBARS values than BHT and PP in both aerobic and vacuum packaged conditions (Fig. 1B). As previously mentioned, this result is a consequence of the absence of antioxidants in this formulation. Comparing the two types of packaging, burgers aerobically packaged showed higher TBARS values than vacuum-packaged samples only for the control. The lower stability of aerobically-packaged samples is related to the presence of oxygen, since the two main mechanisms of lipid oxidation depend on its presence. In auto-oxidation, triplet oxygen is responsible for the free radical chain reaction, whereas in photo-oxidation singlet oxygen rapidly promotes lipid oxidation in foods containing photosensitizers (Mariutti & Bragagnolo, 2017).

However, for BHT and PP no significant packaging effect was observed. This result shows important information about the effectiveness of the antioxidants, since even with the presence of oxygen in the aerobic packaging, they were able to retard lipid oxidation in a comparable way to vacuum-packaged burgers. According to Lucarini and Pedulli (2007), antioxidants suppress lipid oxidation and when all of them are consumed in the inhibition process, this food deteriotation proceeds as rapidly as in the absence of an antioxidant. Thus, it is possible that the storage time of up to 7 days was too short for the total antioxidant consumption and, therefore, to visualize a significant effect of vacuum packaging in the prevention of lipid oxidation in the model used herein.

3.2.2. Physicochemical properties

The pH had significant effect of treatments and storage time, but there was no effect of interaction. PP-samples showed the lowest pH value, which is probably associated to the slightly acidic character of the pink pepper extract (pH = 5.10). Although a pH difference between samples was found, a variation of only 0.11 can be considered marginal and not significant at a practical level. A significant decrease in pH values during 7 days (Table 1) was also verified, which may be attributed to lactic acid bateria that are the dominant microflora in vacuum-packaged meats (Lin et al., 2004).

Among the color parameters, lightness was affected by treatments, storage time and type of packaging. No interaction effects were observed. PP-burgers were significantly darker than BHT and control. This is certainly related to the presence of pink pepper extract, which affected the natural color of the burger formulations. Similarly, Selani et al. (2011) reported darker chicken products manufactured with grape peel extracts. Regarding the type of packaging, aerobically-packaged samples were slightly lighter than vacuum-packaged burgers. This may be related to the protective effect of vacuum packaging against lipid oxidation, which not only negatively affects odor and flavor, but also causes meat discoloration. According to Carvalho, Shimokomaki, and Estévez (2017), poultry discoloration is related to oxidative damage and may cause defects in various stages of meat processing. Regarding storage time, although significant differences in lightness between days were observed, they were marginal (ranging from 58.49 to 60.50) and did not show a clear trend.

Yellowness was significantly affected by treatments and storage time. PP-samples showed the lowest b* value, which was different from the control. These results may be related to the interference of the extract color and the protection of PP extract against the color alterations caused by lipid oxidation. Regarding storage time, small variations in yellowness were observed during 7 days, but there was no difference at the beginning and end of the storage period. According to Hernández-Salueña, Sáenz-Gamasa, Diñeiro-Rubial, & Alberdi-Odriozola (2019), redness and yellowness decrease during storage have been related to metmyoglobin formation and meat discoloration. The present study showed the opposite behavior - an increase in a* values and maintenance of the b* values - which may indicate that oxymioglobin was present and remained stable during the storage period.

Redness showed significant effect of treatment, storage time, type of packaging and interaction between storage time and packaging ($p < 0.05$). For the treatment effect, PP-burgers were redder than control and BHT. Again, this result is possibly related to the color of the pink pepper extract. Regarding the interaction effect between packaging and storage time (Fig. 2), vacuum packaging samples resulted in redder samples than burgers aerobically packaged during all the storage period. This fact, as previously mentioned, could be due to the interdependence between myoglobin oxidation and lipid oxidation in meats. Since TBARS values (pooled over the storage time and treatments) of aerobically-packaged burgers (1.13 mg MDA/kg sample) were higher than those of vacuum-packaged samples (0.85 mg mDA/kg sample), products of lipid oxidation may have entered into the cytoplasm to react with oxymyoglobin and accelerate metmyoglobin accumulation (Faustman, Sun, Mancini, & Suman, 2010), decreasing the redness of the aerobically-packaged burgers.

During the storage period, samples stored under aerobic and vacuum packaging showed opposite behaviours regarding the a* value. While redness of vacuum-packaged samples significantly increased from the 1st to the 7th day of storage, the a* value of the aerobically-packaged samples decreased. This effect may be also related to the relationship between lipid and myoglobin oxidation, in which the protection of the vacuum packaging against the lipid oxidation helped to maintain the redness of the burger during storage.

3.2.3. Microbiological analysis

Microbiological analysis, performed prior to sensory evaluation, revealed absence of thermotolerant coliforms, sulfite-reducing clostridia and *Salmonella*. Only one sample presented *S. aureus* counts of 3.8×10^2 CFU/mL. Thus, all samples were within the limits stablished

Table 1
Effects of antioxidants, packaging type and storage time on the color and pH of chicken burgers.

Source of variation	L*	a*	b*	pH
Treatment				
C	60.37 ± 0.80 [a]	7.45 ± 0.55 [b]	13.35 ± 0.55[a]	6.22 ± 0.02 [a]
BHT	60.45 ± 1.71[a]	7.11 ± 0.75 [b]	13.34 ± 1.21 [a]	6.17 ± 0.01 [ab]
PP	58.10 ± 0.90 [b]	8.10 ± 0.78 [a]	13.13 ± 0.85 [a]	6.11 ± 0.01 [b]
p-value	$p < 0.001$	$p < 0.001$	$p > 0.05$	$p < 0.01$
Packaging				
Aerobic	59.96 ± 0.80 [a]	6.99 ± 0.56[b]	14,89 ± 0.66 [a]	6.16 ± 0.01 [a]
Vacuum	59.33 ± 1.46 [b]	9.00 ± 0.76[a]	11,66 ± 1.03 [b]	6.18 ± 0.02 [a]
p-value	$p < 0.05$	$p < 0.001$	$p < 0.001$	$p > 0.05$
Storage time (days)				
1	60.50 ± 1.38 [a]	9.00 ± 0.62[b]	13.63 ± 0.92[ab]	6.24 ± 0.02 [a]
3	58.49 ± 0.78 [b]	8.22 ± 0.40[c]	12.41 ± 0.72[c]	6.15 ± 0.01 [ab]
5	58.80 ± 0.52 [b]	8.94 ± 0.76[b]	13.00 ± 0.58[bc]	6.17 ± 0.01[ab]
7	60.78 ± 1.83 [a]	9.81 ± 1.12[a]	14.07 ± 1.12[a]	6.11 ± 0.02 [b]
p-value	$p < 0.001$	$p < 0.001$	$p < 0.001$	$p < 0.01$

Mean ± standard deviation.
Means followed by different letters in the same column for the same source of variation are significantly different according to the Tukey test ($p < 0.05$).
C-control; PP- Pink pepper, BHT-butylated hydroxytoluene.

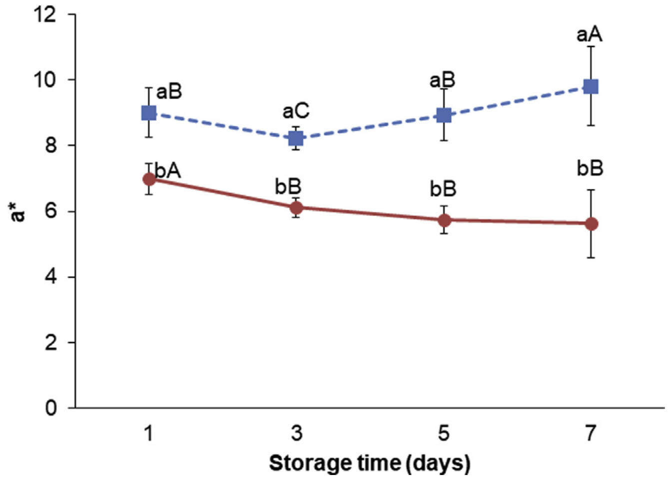

Fig. 2. Effects of packaging type and storage time on the a* value of chicken burgersDifferent
lowercase letters between packages and different capital letters between days indicate significant difference according to the Tukey test ($p < 0.05$). Vacuum packaging ( ); aerobic packaging ( ).

by Brazilian law (Brasil, 2001), ie, they were suitable for human consumption.

3.3. Sensory analysis

3.3.1. Dominance

The bandplot (Fig. 3) shows the different rates and sequences of dominant attributes during tasting. The attributes “tender” and “juicy” were perceived at the beginning of the tasting in all samples. The attributes with higher dominance rate in aerobic packaging samples were similar, indicating that the dominant terms were more related with the characteristics of the burger itself than to the addition of PPE or the advance of lipid oxidation. The “rancid” attribute was observed only in the control after 7 days of storage, which is certainly related to oxidation reactions. Oxidation in this sample was expected as it was manufactured without antioxidants and an oxygen-permeable packaging was used. BHT-samples had the “characteristic taste” for a longer time (related to the efficacy of BHT in inhibiting the lipid oxidation), followed by “characteristic taste”, “juicy”, “tender” and “grilled".

Control samples packaged in PVC after 1 and 7 days of refrigerated storage were characterized as “juicy”, “tender”, “characteristic taste” and “salty”. However, on the first day of storage, the dominance of the attribute “characteristic taste” was longer, which is clearly related to the absence of the oxidation. The vacuum-packaged samples were characterized by the attributes “juicy”, “tender”, “characteristic taste”, “salty” and “grilled”. On the 7th day of storage these attributes were cited throughout the chewing period, but with a lower dominance rate. In addition, the rancid attribute was perceived as dominant, which is indicative of lipid oxidation.

According to Saldaña et al. (2019), the perception of attributes related to flavor and texture depends on the chewing stage, since initially the physical structure of the food must be broken to facilitate the release of flavor compounds. This was noticed during the chewing of all samples, since texture attributes (tenderness and juiciness) were initially perceived, and flavor attributes were generally perceived from the middle to the end of chewing.

Fig. 4A shows the path of the burgers in the sensory space over the course of consumption. At the beginning, treatments were distributed along the second dimension of the PCA, being associated with the attributes “juicy” and “tender”. As the test continued, samples moved to

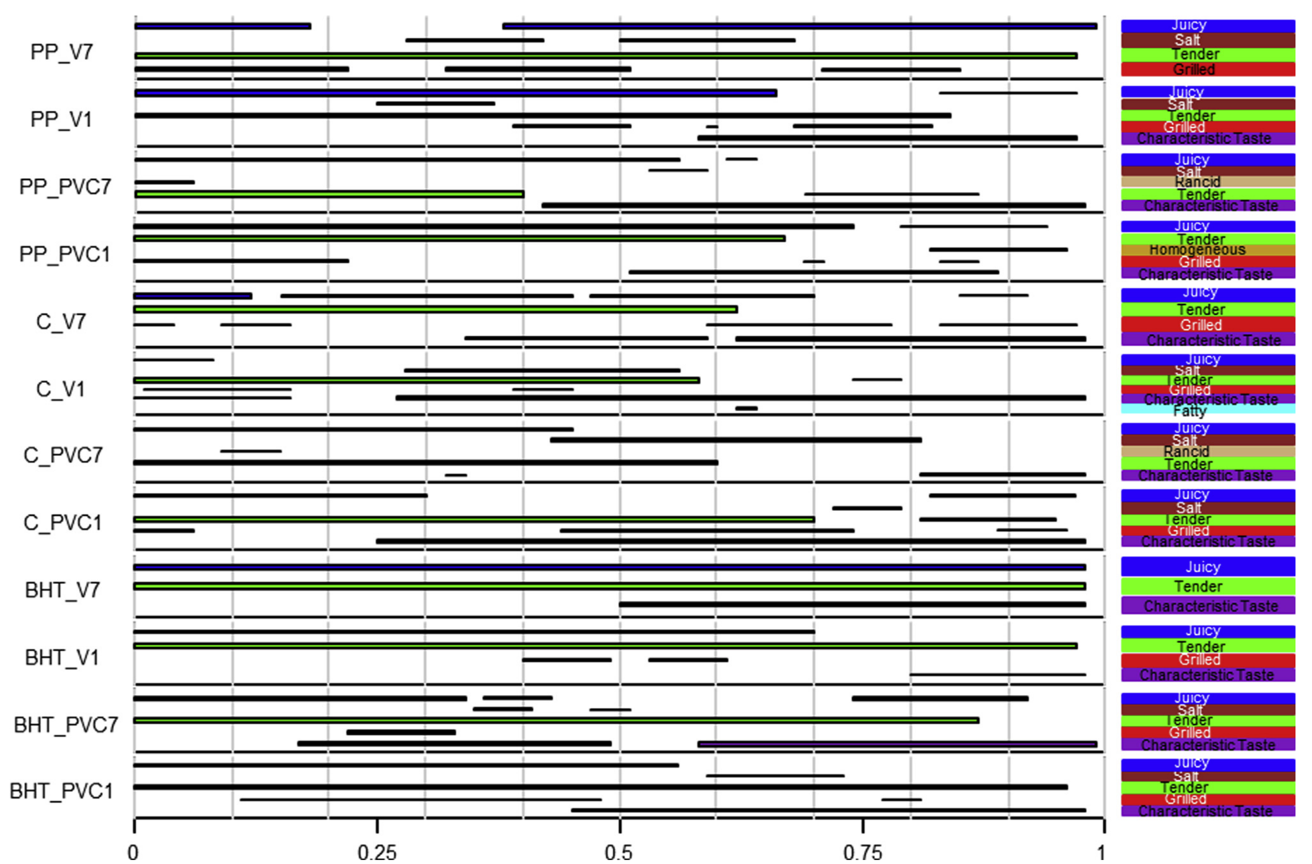

Fig. 3. TDS bandplot by descriptor for chicken burgers. PP-Pink Pepper, C-Control, BHT-butylated hydroxytoluene, V-Vacuum packaging, PVC-Aerobic packaging, 1 and 7 days of storage. . (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

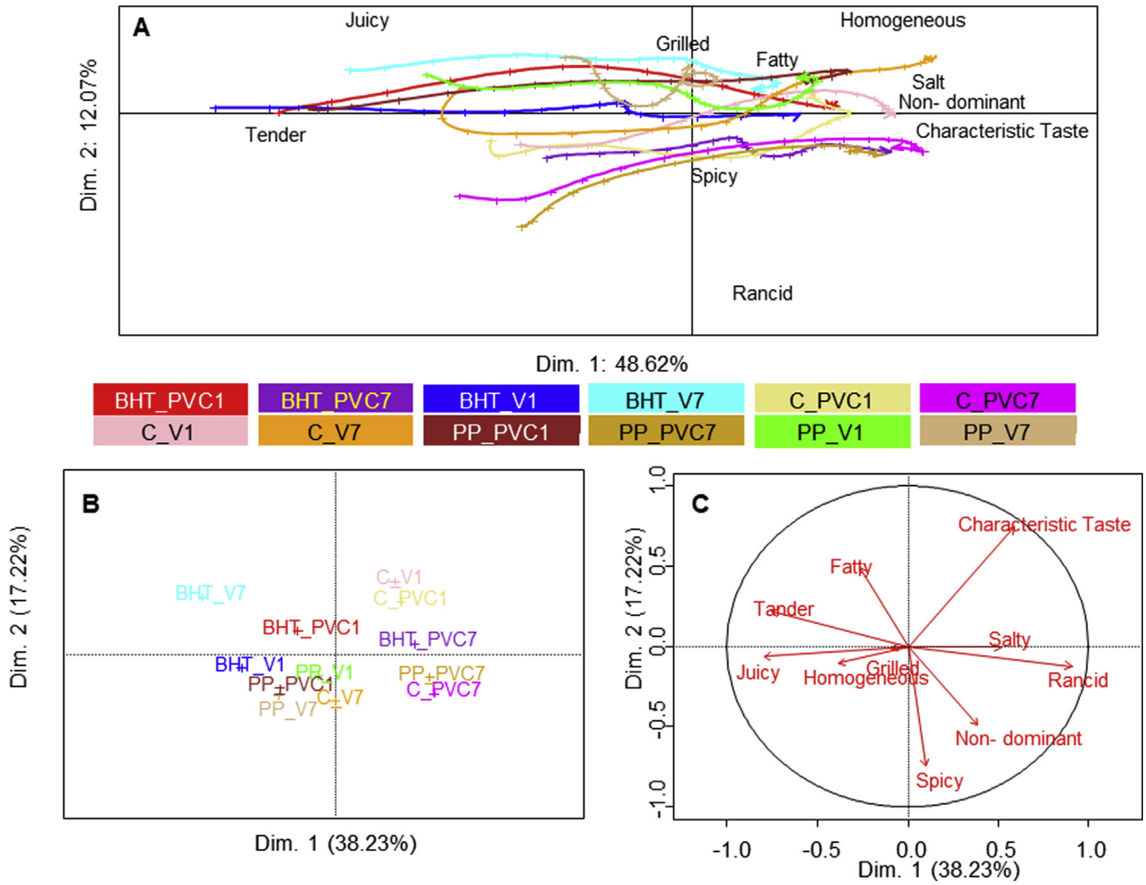

Fig. 4. Trajectory of the treatments in the dynamic sensory space (A) and multidimensional representation of dominance duration for treatments (B) and attributes (C) . PP-Pink Pepper, C-Control, BHT-butylated hydroxytoluene, V-Vacuum packaging, PVC-Aerobic packaging, 1 and 7 days of storage. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

the positive part of the first dimension, characterized by the attributes "grilled", "spicy", "fatty" and "rancid". At the end of the tasting, the attributes "homogeneous", "salty", "non-dominant", and "characteristic taste" were dominants. The samples closest to the "rancid" attribute were PP_PVC7, C_PVC7 and BHT_PVC7, which had in common the aerobic packaging and 7 days of storage. This result confirms what was previously discussed, i.e., in longer storage times with the presence of oxygen, oxidation levels were higher. The trajectory plot corroborates with the bandplot results, since at the beginning of the ingestion the consumer's description was related to texture due to the force necessary to disintegrate the food during chewing.

It is important to mention that the rancid attribute was not strongly associated with any sample, confirming that TBARS values (Fig. 1) were below the limit of sensory quality loss (2 mg malonaldehyde/kg meat) (Heck et al., 2019; Trindade, Mancini-Filho, & Villavicencio, 2009).

3.3.2. Duration of dominance

In addition to the sequence, rate and trajectory of the attributes, the duration of dominant attributes can be explored through ANOVA, which is one of the most important parametric methods in sensory science (Næs, Brockhoff, & Tomic, 2010). According to Table 2, only 3 attributes were different between treatments: "rancid", "homogeneous" and "spicy". Samples packaged in PVC for 7 days showed longer duration of the "rancid" attribute; however, as previously indicated, the oxidation level was low. Burgers characterized as "spicy' were those with the addition of pink pepper extract. One hypothesis for the "homogeneous" attribute would be its relation to the visual homogeneity of the product.

The multidimensional representation of the duration of the dominant attributes and treatments is shown in Fig. 4B and C. The "rancid" and "salty" attributes were related to the C_PVC7, BHT_PVC7 and PP_, PVC7 showing that the aerobically-packaged samples stored for 7 days were more susceptible to lipid oxidation.

3.4. Overall liking

All burgers showed a good overvall liking, with scores above 5 on a 9-point hedonic scale (Fig. 5). The control packaged in PVC film after 7 days of refrigeration was the least liked sample. The lowest scores were given to the aerobically-packaged treatments at the end of the storage time. These samples had liking scores significantly lower than PP vacuum-packaged samples after 1 day of refrigeration. These data show that liking was negativelly affected by the lipid oxidation, since the results are consistent with the physicochemical analyzes.

4. Conclusion

Pink pepper extract proved to be as effective as BHT to retard the lipid oxidation while preserving the sensory characteristics of chicken burger. Regarding TDS, differences in sensory perception and dominant attributes during chewing were more related to product characteristics than to the antioxidants studied. Thus, pink pepper extract can be a source of natural antioxidants and possibly replace synthetic antioxidants in burger formulations without affecting their sensory liking.

CRediT authorship contribution statement

Beatriz Schmidt Menegali: Writing - original draft. **Miriam Mabel**

Table 2
ANOVA of dominant attributes.

Treatment	Rancid	Homogeneous	Spicy	Non-dominant	Tender	Characteristic taste	Fatty	Juicy	Grilled	Salty
BHT_PVC1	0.03 ± 0.02[ab]	0.05 ± 0.02[ab]	0.04 ± 0.02[a]	0.04 ± 0.01	0.21 ± 0.03	0.13 ± 0.03	0.08 ± 0.02	0.15 ± 0.03	0.12 ± 0.02	0.10 ± 0.02
BHT_PVC7	0.08 ± 0.02[ab]	0.02 ± 0.02[a]	0.08 ± 0.02[a]	0.02 ± 0.01	0.17 ± 0.03	0.16 ± 0.03	0.07 ± 0.02	0.15 ± 0.03	0.11 ± 0.02	0.10 ± 0.02
BHT_V1	0.04 ± 0.02[ab]	0.05 ± 0.02[ab]	0.08 ± 0.02[a]	0.03 ± 0.01	0.25 ± 0.03	0.10 ± 0.03	0.09 ± 0.02	0.16 ± 0.03	0.11 ± 0.02	0.08 ± 0.02
BHT_V7	0.00 ± 0.02[a]	0.08 ± 0.02[ab]	0.03 ± 0.02[a]	0.01 ± 0.01	0.22 ± 0.03	0.14 ± 0.03	0.08 ± 0.02	0.21 ± 0.03	0.08 ± 0.02	0.07 ± 0.02
C_PVC1	0.09 ± 0.02[b]	0.05 ± 0.02[ab]	0.02 ± 0.02[a]	0.04 ± 0.01	0.19 ± 0.03	0.17 ± 0.03	0.06 ± 0.02	0.15 ± 0.03	0.13 ± 0.02	0.10 ± 0.02
C_PVC7	0.10 ± 0.02[b]	0.07 ± 0.02[ab]	0.05 ± 0.02[a]	0.07 ± 0.01	0.16 ± 0.03	0.12 ± 0.03	0.04 ± 0.02	0.12 ± 0.03	0.08 ± 0.02	0.11 ± 0.02
C_V1	0.05 ± 0.02[ab]	0.06 ± 0.02[ab]	0.03 ± 0.02[a]	0.04 ± 0.01	0.17 ± 0.03	0.18 ± 0.03	0.10 ± 0.02	0.12 ± 0.03	0.13 ± 0.02	0.10 ± 0.02
C_V7	0.04 ± 0.02[ab]	0.06 ± 0.02[ab]	0.08 ± 0.02[a]	0.07 ± 0.01	0.17 ± 0.03	0.12 ± 0.03	0.05 ± 0.02	0.16 ± 0.03	0.13 ± 0.02	0.10 ± 0.02
PR_PVC1	0.04 ± 0.02[ab]	0.10 ± 0.02[b]	0.07 ± 0.02[a]	0.04 ± 0.01	0.19 ± 0.03	0.11 ± 0.03	0.06 ± 0.02	0.18 ± 0.03	0.12 ± 0.02	0.06 ± 0.02
PR_PVC7	0.11 ± 0.02[b]	0.04 ± 0.02[ab]	0.10 ± 0.02[a]	0.03 ± 0.01	0.16 ± 0.03	0.15 ± 0.03	0.09 ± 0.02	0.15 ± 0.03	0.08 ± 0.02	0.09 ± 0.02
PR_V1	0.04 ± 0.02[ab]	0.02 ± 0.02[a]	0.07 ± 0.02[a]	0.02 ± 0.01	0.16 ± 0.03	0.11 ± 0.03	0.07 ± 0.02	0.18 ± 0.03	0.12 ± 0.02	0.09 ± 0.02
PR_V7	0.03 ± 0.02[ab]	0.06 ± 0.02[ab]	0.06 ± 0.02[a]	0.04 ± 0.01	0.19 ± 0.03	0.09 ± 0.03	0.07 ± 0.02	0.17 ± 0.03	0.13 ± 0.02	0.12 ± 0.02

Mean ± standard deviation.
Means followed by different letters in the same column are significantly different according to Tukey test ($p < 0.05$).
PP-Pink Pepper, C-Control, BHT-butylated hydroxytoluene, V-Vacuum packaging, PVC-Aerobic packaging, 1 and 7 of days storage.

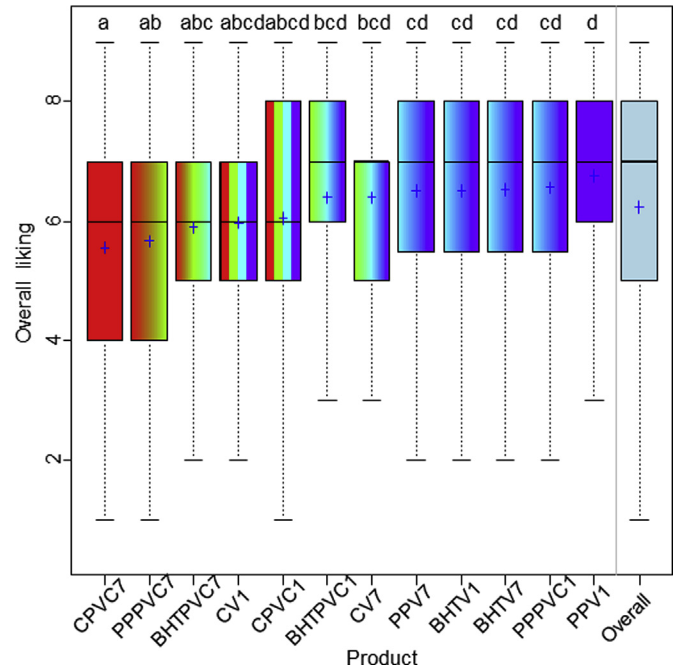

Fig. 5. Overall liking of chicken burgers. Treatments with different letters are significantly different according to Tukey test ($p < 0.05$). P P-Pink Pepper, C-Control, BHT-butylated hydroxytoluene, V-Vacuum packaging, PVC-Aerobic packaging, 1 and 7 days of storage. . (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Selani: Writing - original draft. **Erick Saldaña:** Writing - original draft. **Iliani Patinho:** Formal analysis. **Julia Pereira Diniz:** Formal analysis. **Priscilla Siqueira Melo:** Formal analysis. **Natan de Jesus Pimentel Filho:** Formal analysis. **Carmen J. Contreras-Castillo:** Supervision, Writing - original draft.

Declaration of competing interest

The author(s) declare(s) that they have no competing interests.

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