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Lamb burgers made with low and high value cuts: Effect of the spice added and the packaging method on shelf life

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ABSTRACT

The use of low-value commercial pieces (breast and neck) of lamb carcass could be an opportunity to make processed-products, increase lamb-meat consumption and revalorize the whole carcass. The synergistic effect of adding spices [rosemary, thyme, sage, garlic or only salt (control group)] along with a packaging system [vacuum (VP), AA: 30%CO2 + 70%O2 or AB: 30%CO2 + 69.3%N2 + 0.7%CO] on microbiological quality, color (L*, a*, and b*) and lipid oxidation was analysed in burgers made with breast and neck minced meat (1/3; in equal parts) and leg (2/3) during 13 days. The added spice showed a low antimicrobial effect, garlic-burger (in all packaging) presented the highest microbial counts, except for Pseudomonas spp. The combination of rosemary, thyme or sage with VP, AA or AB stabilized the lipid oxidation throughout the study. However, the combination AA-garlic presented the highest discoloration and rancidity level. Packaging with VP or AB of samples-garlic decreased the values of lipid oxidation.

KEYWORDS

Lamb-burgers; shelf-life; spices; low-value-cuts; system-packaged

INTRODUCTION

Meat consumption, in developed countries, has decreased in the last year (OECD/FAO (Food and Agriculture Organization of the United Nations), 2017). According to Beriain, Gómez, Ibáñez, Sarríés, and Ordóñez (2018) this has been due to reasons related to health and safety food. This reduction is especially important in some types of meat, such as sheep meat, even considering it as a natural product of extraordinary organoleptic quality (Vergara & Gallego, 2001). Specifically in Spain, the lamb meat consumption has declined from 2.7 Kg/per capita in 2006 to 1.5 Kg/per capita in 2018 (MAPAMA, 2018). In addition, there are other factors (shortage of shepherds, low benefits that threaten the continuity of this sector (the second-biggest producer in EU). Moreover, lamb-consumers prefer legs, ribs or shoulders (high-value carcass pieces) meat to neck or breast (third class/low prices/intensive culinary treatment). Taking advantage of the consumption increase of processed meat, such as burgers [the most popular meat product consumed over the world (Hashemi Gahruie et al., 2017), along with patties (Alejandre, Passarini, Astiasarán, & Ansorena, 2017), the manufacture of these foodstuffs using low-value lamb carcass commercial pieces could be an excellent opportunity to (1) increase the lamb meat consumption and (2) revalorize the whole carcass.

These raw products are made with minced meat and have a limited shelf life due to their intrinsic composition (nutrients, water activity, pH . . .) and the processing technique and storage (Addis, 2015). In addition, the porous structure of matrix and mincing process favour the reduction of service-life by the action of microorganisms and the lipid oxidation (Esmer, Irkin, Degirmencioglu, & Degirmencioglu, 2011; Sun & Holley, 2012) with economic losses for meat industry (Falowo, Fayemi, & Muchenje, 2014). For this reason, it is necessary to apply some preservation systems (chemical or physical) that maintain and prolong the quality and shelf life of the food products.

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life of these foodstuffs (Vergara & Cózar, 2015). Among the chemical methods, the antioxidant, antimicrobial, and medicinal properties of spices (Jessica Elizabeth, Gassara, Kouassi, Brar, & Belkacemi, 2017) make them an alternative to synthetics preservatives. Regarding physical methods, the packaging systems such as vacuum or the modified atmospheres has become common preservation method in the last two decades (Esmer et al., 2011) with the aim to prolong the shelf life of food (Sun & Holley, 2012).

There are few scientific documents that study the possible synergy in the application of both methods (spices and packaging systems) on the quality and safety of these meat processed manufactures with low-value cuts. Our previous paper (Cózar, Rubio, & Vergara, 2018) analysed the combination of spices and packaging systems in lamb burgers elaborated only with high commercial value pieces (leg meat). However, according to Beriaín et al. (2018) the different chemical composition of meat (such as retail cuts) could affect to the quality of meat products (Al-Mrazeeq, Al-Abdullah, & Al-Ismail, 2010). Therefore, the objective of this work was to determine the shelf-life (assessed by coordinates chromatics, microbiology, and rancidity) of these lamb meat products and the synergy of the powdered spice (rosemary, thyme, sage or garlic) and a non-spiced group combined with a packaging system [vacuum, or a gases mixture (AA: 30%CO₂; AB: 30%CO₂ + 69.3%N₂ + 0.7%CO)] during 13 days at 2°C.

Material and methods

Burgers preparation and packaging

Lamb burgers were manufactured using a proportion of 2/3 minced leg meat and 1/3 of neck and breast ground meat (in equal parts). Meat was obtained from Spanish Manchega breed male lambs (25 kg live weight, 70 days old) carcass (chilled at 4°C for 24 h). Animals were slaughtered and dressed using standard commercial procedures. Minced meat matrix was divided into five batches after mixing by hand for 5 min with salt (1% w/w) along with one powdered spice [0.1% w/w; purchased at supermarket and ground in our laboratory: rosemary, thyme, sage or garlic] and a non-spiced group combined with a packaging system [vacuum, or a gases mixture (AA: 30%CO₂ + 70%O₂; AB: 30%CO₂ + 69.3%N₂ + 0.7%CO)] during 13 days at 2°C.

Analysis of lamb burgers quality

Shelf life was assessed by colour coordinates, microbiology, and lipid oxidation at 0, 6, 9, and 13 days post-packaging. In samples under AA or AB packaging, the gas composition was checked by a CheckMate PBI Dansensor (Ringsted, Denmark) gas analyser, before to open the trays.

Colour coordinates

Fifteen minutes after opening the packages, lightness (L*), redness (a*) and yellowness (b*) was recorded using a Minolta CR400 chromimeter (Osaka, Japan) with a D65 illuminate and a 10º standard observer angle, calibrated against a standard white tile. The final value was the mean of three determinations on the surface of raw burgers.

Microbiological analysis

Five grams (approximately) from each burger were collected aseptically and transferred to a sterile stomacher bag, then 45 mL of buffered peptone water (Scharlau Chemie, Barcelona, Spain) was added, homogenized for 1 min in a Stomacher (Masticator, IUL Instruments, Barcelona, Spain). After that, serial decimal dilutions were prepared and spread in duplicate in the corresponding media, expressing the results as log CFU/g:

- For total viable count (TVC) or Enterobacteriaceae were used Petrifilm™ (3M™, Madrid, Spain), incubated at 32°C/48 h and 32°C/24 h, respectively. Microbial count was made manually.
- Plate Petri, with Pseudomonas Agar Base with a cetriolic activity; Coopbox Hispania S.L.U., Lorca, Murcia, Spain) covered with barrier film (Aertop, 60 µm of thickness; Ind. Pargon, José Bernad S. L., Albacete, Spain) was used to form the burgers (100 g and 10 cm diameter).

After manufacturing, burgers of each batch were preserved under different packaging conditions; the packaging materials are described in more detail in Cózar et al. (2018):

- In vacuum packaging (VP): A vacuum machine Selecta Vacuum saler (model "Sealcom-V", Abrera, Barcelona; magnitude of vacuum was ~0.1 MPa) was used. Burgers were placed into a vacuum bags (150 µm of thickness; Ind. Pargon, José Bernad S.L., Albacete, Spain).
- In modified atmosphere packaging (MAP): An ILPRA packaging machine (model FB Basic, Vigenano, Italy) was used. Samples were introduced into trays (Aerpack, model B3-55; Coopbox Hispania S.L.U., Lorca, Murcia, Spain) covered with barrier film (Aerop, 60 µm of thickness; Coopbox Hispania S.L.U., Lorca, Murcia, Spain). The gases mixtures used were AA: 30%CO₂ + 70%O₂ and AB:

Lipid oxidation (LO)

Lipid oxidation (LO) (as mg malondialdehyde (MDA)/kg of meat) were assessed according to Tarladgis, Pearson, and Dugan (1964). A sample of 5 g raw burger with 25 mL of distilled water, was homogenized for 2 min at 10,000 rpm to room temperature, using a homogenizer Ultraturrax T25 digital (Ika Works, Inc.). Absorbance at 532 nm of 2-thiobarbituric acid reactive substances (TBARS) was measured in duplicate with a Helios α-spectrophotometer (THERMO, Electron Corporation, England).
**Statistical analysis**

A Shapiro–Wilk test was determined for checking the normality and homogeneity of variance of all variables. Then, a two-way ANOVA was performed, using the SPSS Statistics General Lineal Model (GLM) procedure, to evaluate the effect of the spice (control, rosemary, thyme, sage or garlic), the system of packaging (VP, AA or AB) and the interaction between both factors on the parameters analysed, at 6, 9, and 13 days post-manufacture. In addition, an ANOVA was carried out to check the effect of time (0, 6, 9, and 13 days) on parameters studied in each batch. When the differences were significant \((p < 0.05)\) a Tukey’s test at a significance level of \(p < 0.05\) verified the differences between pairs of groups. The statistical analysis of data was made with the SPSS Statistics 22.0 version (IBM Corp., 2013).

**Results**

**Colour coordinates**

The influence of packaged method (VP, AA or AB), powdered spice added (control, rosemary, thyme, sage or garlic) and the interaction of both factors on the chromatic coordinates \((L^*, a^*\) and \(b^*\)) of lamb burgers are summarized in Table 1. A significant effect \((p < 0.001)\) of the packaging system on \(a^*\) and \(b^*\) coordinates was observed in all times of study. The added spice affected the colour coordinates in all times analysed \((p < 0.001;\) except in \(b^*\) at 6 days storage \(p < 0.05\)). A significant interaction of factors studied (packaging and spice) was shown on \(L^*\) (at 13 days; \(p < 0.05\), \(a^*\) (in all times; \(p < 0.001\)) and \(b^*\) (at 6 and 13 days; \(p < 0.05\)).

- In VP-burgers, the chromatic coordinates remained stable during the study (Table 1) regardless of the added spice.
- In burgers under AB method, \(a^*\) and \(L^*\) coordinates were stable after 6 and 9 days, respectively. \(b^*\)values remained without changes in control samples or with rosemary or sage during all study, and from 6 days post-packaging in thyme and garlic-ones.
- By contrast, in AA-burgers the values of chromatic coordinates presented the greatest changes during storage: Redness significantly decreased in all burgers \((p < 0.001)\) with the highest and lowest values in sage and garlic samples, respectively. Yellowness (except in products with sage) and lightness (except in control/rosemary/or garlic- burgers) increased over time.

**Microbiology**

The packaging method did not show statistical differences on microbial count (Table 2), except for LAB \((p < 0.01\) and \(p < 0.001,\) at 9 and 13 days, respectively). However, the effect of the spice added to burgers on microorganisms count was significant (except on Enterobacteriaceae and Pseudomonas spp., at 13 days, and on LAB at 9 days of storage). In general, at the end of storage, the samples with garlic, regardless of the packaging system used, presented the highest TVC, Enterobacteriaceae and LAB counts. With respect to Pseudomonas spp., the highest values were found in sage-hamburgers and packed with VP or AA. Nevertheless, there was no interaction between the analysed factors (packaging and spice) in any batch. A significant increase in the counts of bacteria in all analysed samples (Figure 1–3) was observed during the period of storage, except on Enterobacteriaceae counts, which only increased with time in spiced AA-burgers with rosemary and in AB-samples with garlic or non-spiced.

**Lipid oxidation**

Both the specie added and the packaging affected \((p < 0.001)\) the lipid stability of the hamburgers, in all times of study (Table 3):

- LO values in VP or AB samples spiced with rosemary, thyme or sage remained lower than 2 mgMDA/Kg meat during storage.
- By contrast, samples with garlic or control reached at the end of storage the highest TBARS values, which were close to 2, 3 or 5 mgMDA/Kg meat, depending on the type of packaging (VP, AB or AA; respectively).
- Burgers packaged under AA method had the highest LO values, especially in the samples with garlic or control, over 5 mgMDA/Kg meat at the end of storage.
- Samples with rosemary showed a high oxidative stability afterwards 13 days of study, even in the samples under AA packaging.

**Discussion**

**Colour coordinates**

The minced process to manufacture of ground meat products (such as burgers) provokes the discolouration of meat due to the oxymyoglobin oxidation (O’Grady, Monahan, Burke, & Allen, 2000). This fact affects to visual appearance (colour), which is related to acceptance of meat and meat products by consumers. In this sense, the packaging-methods and the addition of natural substances have shown a fundamental role in the maintenance of colour of these products.

Colour of lamb burgers showed a different evolution depending on packaging method, added spice and the interaction of both factors:

- The most drastic changes were found in the redness, especially in the AA-garlic and AA-control samples, with values below 9.5. According to Khliji, van de Ven, Lamb, Lanza, and Hopkins (2010) values equal or over to 9.5 of \(a^*\) are required to the average consumers consider acceptable the lamb meat colour. The combined effect of a high oxygen content in AA and a pro-oxidant activity of the garlic could explain these unfavourable values. However, in agreement with Sánchez-Escalante et al. (2011) this discolouration could be avoided using natural substances. In this case, the addition of rosemary, sage or thyme delayed the variations of the \(a^*\) value in AA-packaging. The antioxidant activity attributed to the chemical composition (rosmarinic acid, caffeic acid, ferulic acid, carnosol...) of these spices could be responsible of these results (Embuscado, 2015), avoiding the formation of met-myooglobin (Velasco & Williams, 2011). A great stability in \(a^*\) was found after 6 days of storage in the systems VP and AB, independently of the used spice. This fact could be explained by the absence of \(O_2\) [in AB and VP; Jeong and Claus (2011)] and the high stability of
### Table 1. Influence of packaging method (VP, AA or AB) and spice used (control, rosemary, thyme, sage or garlic) on colour coordinates (L*, a*, and b*; Mean ± S.E.) of lamb burgers.

| Colour coordinates | Type of packaging | Type of spice | Time of storage (days) | Effect of storage |
|--------------------|-------------------|---------------|------------------------|-----------------|
| L*                | VP                | Control       | 0, 6, 9, 13            | n.s.            |
|                   |                   | Rosemary      | 0: 9.84 ± 0.40, 9.45 ± 0.36   | 9.34 ± 0.29, 9.48 ± 0.32 |
|                   |                   | Thyme         | 9.17 ± 0.35, 9.15 ± 0.35   | 9.48 ± 0.26, 9.56 ± 0.30 |
|                   |                   | Sage          | 9.63 ± 0.35, 9.62 ± 0.35   | 9.67 ± 0.35, 9.68 ± 0.36 |
|                   |                   | Garlic        | 9.88 ± 0.40, 9.86 ± 0.40   | 9.88 ± 0.40, 9.88 ± 0.40 |
|                   |                   | AA            | 9.90 ± 0.40, 9.90 ± 0.40   | 9.92 ± 0.40, 9.92 ± 0.40 |
|                   |                   | AB            | 9.90 ± 0.40, 9.90 ± 0.40   | 9.92 ± 0.40, 9.92 ± 0.40 |
|                   |                   | A             | 9.90 ± 0.40, 9.90 ± 0.40   | 9.92 ± 0.40, 9.92 ± 0.40 |
|                   |                   | Sage          | 9.63 ± 0.35, 9.62 ± 0.35   | 9.67 ± 0.35, 9.68 ± 0.36 |
|                   |                   | Garlic        | 9.88 ± 0.40, 9.86 ± 0.40   | 9.88 ± 0.40, 9.88 ± 0.40 |
|                   |                   | AA            | 9.90 ± 0.40, 9.90 ± 0.40   | 9.92 ± 0.40, 9.92 ± 0.40 |
|                   |                   | AB            | 9.90 ± 0.40, 9.90 ± 0.40   | 9.92 ± 0.40, 9.92 ± 0.40 |
|                   |                   | A             | 9.90 ± 0.40, 9.90 ± 0.40   | 9.92 ± 0.40, 9.92 ± 0.40 |
|                   |                   | Sage          | 9.63 ± 0.35, 9.62 ± 0.35   | 9.67 ± 0.35, 9.68 ± 0.36 |
|                   |                   | Garlic        | 9.88 ± 0.40, 9.86 ± 0.40   | 9.88 ± 0.40, 9.88 ± 0.40 |
|                   |                   | AA            | 9.90 ± 0.40, 9.90 ± 0.40   | 9.92 ± 0.40, 9.92 ± 0.40 |
|                   |                   | AB            | 9.90 ± 0.40, 9.90 ± 0.40   | 9.92 ± 0.40, 9.92 ± 0.40 |
|                   |                   | A             | 9.90 ± 0.40, 9.90 ± 0.40   | 9.92 ± 0.40, 9.92 ± 0.40 |

**Indicates significance levels at 0.05, 0.01, and 0.001, respectively.**

*a* Different letters in the same row indicate significant differences (p < 0.05) due to the effect of storage period.

*b* Different letters in the same column and type of packaging (VP or AA or AB) indicate significant differences (p < 0.05) due to the effect of powdered spice.

## Notes

- In addition, the variations presented in all colour coordinates of AA-burgers, mainly with garlic and in control samples, could be associated with the high content of O₂, since this gas could trigger the lipid and myoglobin oxidation of meat products, causing discoloration.

- carboxymioglobin [in AB; Sørheim, Nissen, and Nesbakken (1999)]. A similar tendency of a* coordinate during storage was found in beef steak, pork chops, and ground beef storage under vacuum and with CO (Jeong & Claus, 2011; Sørheim et al., 1999).
In general, the trend of the chromatic coordinates was similar to those found in our previous study (Cózar et al., 2018), in which only pieces of high commercial value (leg) were used in the burgers manufacture. Similar redness but slightly higher $L^*$ and $b^*$ index was observed in the present study, in spite of the different nutritional composition (data reported in Linares, Cózar, Garrido, and Vergara, 2012).

Microbiology

The effectiveness of preservation techniques used in meat and meat products is conditioned to different factors, such as initial count of microorganisms and method of packaged (gas mixture, film permeability). Process of manufacturing (minced, hygiene of used machines . . .) could even affect adversely to the shelf life of these foods (Singh, Wani, Saengerlaub, & Langowski, 2011).

In this study, some batches (depending on packaging and spice combination) exceeded the limit value of 6.69 log CFU/g (Regulation EC 2073/05, 2005) at 13 days of storage. The increase of TVC with time storage is associated with different causes, such as the level of oxygen in the gas mixture and the permeability of material packaged, due to an increase in $O_2$ content by the manipulation process to meat products (Martínez, Djenane, Cilla, Beltrán, & Roncalés, 2005; Newton & Rigg, 1979), which is related with the growth of some aerobic bacteria that need a lower content of $O_2$ (Nowak,

Table 2. Influence of packaging method (VP: Vacuum, AA: 30%CO$_2$ + 70%O$_2$ or AB: 30%CO$_2$ + 69.3%N$_2$ + 0.7%CO) and spice used (control, rosemary, thyme, sage or garlic) on microorganisms counts (TVC, Enterobacteriaceae, Pseudomonas spp. and LAB) of lamb burgers.

| Parameters                  | Time of Storage (days) | Packaging | Spice | Packaging x Spice |
|-----------------------------|------------------------|-----------|-------|-------------------|
| Total Viable Count (TVC)    | 6                      | NS        |       | NS                |
|                             | 9                      | NS        |       | NS                |
|                             | 13                     | NS        | ***   | NS                |
| Enterobacteriaceae          | 6                      | NS        |       | NS                |
|                             | 9                      | NS        | ***   | NS                |
|                             | 13                     | NS        | NS    | NS                |
| Pseudomonas spp.            | 6                      | NS        | ***   | NS                |
|                             | 9                      | NS        | NS    | NS                |
|                             | 13                     | NS        | NS    | NS                |
| Lactic acid bacteria (LAB)  | 6                      | NS        | **    | NS                |
|                             | 9                      | NS        |       | NS                |
|                             | 13                     | ***       | ***   | NS                |

NS: not significant.

* ** *** Indicates significance levels at 0.05, 0.01, and 0.001, respectively.

NS: no significante.

* ** *** Indica nivel de significancia de 0.05, 0.01 y 0.001, respectivamente.

Figure 1. Microbial growth (TVC, Enterobacteriaceae, Pseudomonas spp., LAB) of spiced lamb burgers under vacuum (Mean ± S.E.). Not significant. * ** *** Indicates significances levels at 0.05, 0.01, and 0.001, respectively. Different letters indicate significant differences ($p < 0.05$) due to the powderred spice added (control, rosemary, thyme, sage or garlic).
These facts along with the initial count of this bacteria conditioned the shelf life of products. Despite the increase in *Pseudomonas* spp., *Enterobacteriaceae* and LAB over time, the counts were below 7 log CFU/g. This value is associated with the onset of the meat spoilage (slime, unpleasant odour...) (Feiner, 2006). Only VP-sage or AA-sage exceeded this maximum value in *Pseudomonas* spp. at 13 days of storage.

According to Jessica Elizabeth et al. (2017) the antimicrobial effect of natural ingredients is related to several factors (such as the composition and the concentration added of substance, the microorganism counts, the storage conditions...). As regards the concentration of the substance, some authors (Jessica Elizabeth et al., 2017; Shelef, 1983) have reported that the amount of herbs and spices added to food is insufficient to control microbial growth. Therefore, to obtain this antimicrobial effect it would be necessary to add a high amount of natural substance, but this could affect negatively the sensory acceptance of the products (Negi, 2012). In general, in our study, the added concentration (0.1%) of spices showed a minimal antimicrobial effect. The garlic-burgers (regardless of the system of packaging) had the highest counts in all the bacteria studied, except for *Pseudomonas* spp., obtaining the highest counts in hamburgers with powdered sage. Other authors noticed a low inhibitory effect of sage essential oil (in vitro analysis) against *Pseudomonas aeruginosa* and *Pseudomonas putida* (Hammer, Carson, & Riley, 1999; Oussalah, Caillet, Saucier, & Lacroix, 2006; respectively). This fact could also explain the higher counts of *Pseudomonas* spp. during the period of the study found in VP and AA burgers spiced with sage.

The microbial count was slightly lower in all microorganism evaluated than those found in our previous paper (Cózar et al., 2018) for hamburgers made only with leg meat, except for *Pseudomonas* spp. In addition, during the period of study, the trend of all bacteria was similar in both studies, showing an increase over time of TVC, *Pseudomonas* spp., *Enterobacteriaceae* and LAB. By contrast, the variations due to the added spice were not observed in lamb burgers manufactured with high-commercial value cuts (leg). This fact could be explained by the different nutritional composition of both lamb burgers, since a high percentage of fat could difficult the growth of microorganisms (Kumar & Sharma, 2004).

**Lipid oxidation**

There are also several bibliography that have been proven the antioxidant effect of spices combined with methods of packaging (Martínez, Cilla, Beltrán, & Roncalés, 2006; Sánchez-Escalante, Djenane, Torrescano, Beltrán, & Roncalés, 2001).

In the current work, LO value ranged from 2.69 to 5.19 mg MDA/kg meat in control, 0.24 to 0.75 mg MDA/kg meat in rosemary, 0.45 to 2.30 mg MDA/kg meat in thyme,
0.90 to 2.03 mg MDA/kg meat in sage and 2.52 to 5.94 mg MDA/kg meat in garlic. These variations were caused by the combination of added spice and the packaging system:

- The combination of rosemary with VP, AA or AB caused the lowest LO values during the storage period. This fact proved the effectiveness of powdered rosemary in the control of the LO, the same that other authors found in beef patties (Sánchez-Escalante et al., 2001).
- Although, the burgers with thyme or sage, under VP or AB, showed low values of rancidity, these spices were not able to reduce the pro-oxidant effect of high O₂ level (O’Grady et al., 2000) in samples under AA method. These results were slightly higher than 2 mgMDA/kg of meat, perceptible by the lamb meat consumer (Camo, Beltrán, & Roncalés, 2008). Anyway, the values of AA-thyme and AA-sage were the half of those obtained in AA-garlic and AA-control.
- AA-garlic samples showed similar result to what found in our previous paper (Cózar et al., 2018). The bibliography showed effects contradictory related to antioxidant capacity of garlic in food products, some authors have found an antioxidant activity of this spice in pork meat (Kim et al., 2010) and in ground camel meat (Gheisari & Ranjabar, 2014), but other authors have pointed a pro-oxidant or a low antioxidant effect in chicken meat (Mariutti, Nogueira, & Bragagnolo, 2011), in pork patties (Park & Chin, 2014), in Chinese sausages (Sun, Ockerman, & Marriott, 1999) and in other food such as almond oil (Rabadán, Pardo, Gómez, & Álvarez-Ortí, 2018). In agreement with Mariutti and Braganolo (2009), the possible antioxidant or pro-oxidant effect of garlic is related to matrix used in study, concentration, and format of addition along with the method of packaging. These factors could explain the high LO values in samples with garlic [even higher than in the burgers control (only 1% salt)]. According to our results, the use of VP or AB was able to reduce this adverse activity and LO values were, at 13 days of storage, similar to that found in fresh lamb burgers at 6 days of study (Cózar, Rubio, & Vergara, 2017).

Jessica Elizabeth et al. (2017) asserted that the Lamiaceae (such as rosemary, thyme, sage...) are spices with higher antioxidant effect. According to Velasco and Williams (2011) this beneficial activity is associated to their phenolic composition (rosmarinic acid, carnosol, rosmanol, caffeic acid...) and their different mechanisms of action (free radical scavengers, oxygen scavenger and chelating agents) (Emboscado, 2015).

In agreement with the results of our studies, the antioxidant effectiveness of powdered spice decreased in this order: rosemary > thyme > sage > control (non-spiced) > garlic. Therefore, powdered rosemary was the best spice.
to control the LO [also in our previous paper; Cózar et al. (2018)] regardless of systems of packaging used. Other authors also found that the addition of rosemary decreased the LO in products under atmosphere packaging, in fresh pork sausages with powdered format (Martínez et al., 2011)) regarding the addition of garlic to lamb burgers, at the added concentration (0.1%), had a pro-oxidant effect that can be minimized by using VP or AB systems, regardless of the type of meat (high or low value) used to elaborate the hamburgers. In addition, from 9 days of storage the burgers elaborated with neck/ breast and leg meat had higher LO values than burgers manufactured only with leg, this fact could be explained by the different fat content of burgers [5% only leg and 10% with neck and breast in the formulation; Linares et al. (2012)].

Conclusions

From the results, it can be concluded that (1) there was a remarkable synergistic influence among packaging and spice on colour and LO of lamb burgers elaborated with low-value cuts. (2) The combination of AA and garlic presented the highest discoloration and rancidity; the use of VP or AB reduced these negative effects. (3) Besides, the addition of rosemary, thyme or sage in the manufacture, minimized the variations of colour and stabilized the rancidity during the storage period, regardless of the packaging tested. (4) On the other hand, the microbial quality was influenced only by the added spice, showing the garlic-burgers the highest counts (except for Pseudomonas spp.).

Disclosure statement

No potential conflict of interest was reported by the authors.

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