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Vida útil da carne de sol pelo uso de atmosfera modificada

Shelf life of sun-dried meat through the use of modified atmosphere

Vida útil de la carne solar mediante el uso de atmósfera modificada

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Maria Carla da Silva Campêlo
ORCID: https://orcid.org/0000-0002-6365-1519
Universidade Federal Rural do Semi-Árido, Brasil
E-mail: carlacampelo2@hotmail.com
Jovilma Maria Soares de Medeiros
ORCID: https://orcid.org/0000-0001-6774-8433
Universidade Federal Rural do Semi-Árido, Brasil
E-mail: jovilmasoares@outlook.com
Lucas de Oliveira Soares Rebouças
ORCID: https://orcid.org/0000-0003-3279-7029
Universidade Federal Rural do Semi-Árido, Brasil
E-mail: lucaslosr@gmail.com
Luciana Veras Aquino Figueiroa
ORCID: https://orcid.org/0000-0002-9039-5557
Universidade Federal Rural do Semi-Árido, Brasil
E-mail: lucianaveras_1@yahoo.com.br
Manuella de Oliveira Cabral Rocha
ORCID: https://orcid.org/0000-0002-6966-3414
Universidade Federal Rural do Semi-Árido, Brasil
E-mail: manucabralrocha@hotmail.com
Palloma Vitória Carlos de Oliveira
ORCID: https://orcid.org/0000-0002-8855-6008
Universidade Federal Rural do Semi-Árido, Brasil
E-mail: pallomavictoria@hotmail.com.br
Patrícia de Oliveira Lima
ORCID: https://orcid.org/0000-0002-1887-3446
Universidade Federal Rural do Semi-Árido, Brasil
E-mail: pattlima@ufersa.edu.br

Jean Berg Alves da Silva
ORCID: https://orcid.org/0000-0001-8414-4316
Universidade Federal Rural do Semi-Árido, Brasil
E-mail: jeanberg@ufersa.edu.br

Resumo

Objetivou-se avaliar os efeitos de diferentes atmosferas modificadas nas embalagens de carne de sol e sua influência na vida útil. Para isso, bifes de carne bovina tipo coxão duro (*Bíceps femoris*) foram cortados, salgadas com 2,5% de NaCl e embaladas nas seguintes atmosferas: ar atmosférico (CE-Ar); vácuo (CE-V); 100% de CO_2 (CE-ATM1); 50% de CO_2 + 50% de N_2 (CE-ATM2); 70% de CO_2 + 30% de N_2 (CE-ATM3); 30% de CO_2 + 70% de N_2 (CE-ATM4). As amostras foram avaliadas quanto à qualidade microbiológica e físico-química. As carnes embaladas em atmosferas com diferentes razões de CO_2 e N_2 apresentaram vida útil de até 12 dias, sem variações significativas entre tratamentos, quanto à qualidade microbiológica. Em relação às características físico-químicas, apesar de aumentar a oxidação lipídica na carne, as atmosferas com diferentes misturas de CO_2 e N_2 utilizadas para embalagem as carnes apresentaram as melhores características da qualidade. Portanto, de acordo com este estudo, as atmosferas modificadas com CO_2 e N_2 podem ser recomendadas como melhores alternativas para prolongar a vida útil da carne de sol.

Palavras-chave: Carne; Validade; Embalagem; Qualidade; Modificação de gases.

Abstract

The objective was to evaluate the effects of different modified atmospheres on the packaging of sun-dried meat and their influence on the useful life. To this end, beef steaks of the hard topside type (*Bíceps femoris*) were cut, salted with 2.5% NaCl and packed in the following atmospheres: atmospheric air (CE-Ar); vacuum (CE-V); 100% CO_2 (CE-ATM1); 50% CO_2+ 50% N_2 (CE-ATM2); 70% CO_2+ 30% N_2 (CE-ATM3); 30% CO_2 + 70% N_2 (CE-ATM4). The samples were evaluated for microbiological and physico-chemical quality. Meat packed in atmospheres with different $CO_2$and N_2 ratios had a useful life of up to 12 days, without significant variations between treatments, as to microbiological quality. Regarding the physicochemical characteristics, despite increasing the lipid oxidation in the meat, the atmospheres with different mixtures of CO_2 and N_2 used for packaging the meats presented the best quality characteristics. Therefore, according to this study, atmospheres modified with CO_2 and N_2 can be recommended as better alternatives to prolong the life of sun-dried meat.

Keywords: Meat; Shelf life; Packaging; Quality; Gas modification.

Resumen

El objetivo fue evaluar los efectos de diferentes atmósferas modificadas sobre el envasado de carnes solares y su influencia en la vida útil. Para ello, se cortaron filetes de ternera (*Biceps femoris*), se salaron con NaCl al 2,5% y se envasaron en las siguientes atmósferas: aire atmosférico (CE-Ar); vacío (CE-V); 100% CO_2 (CE-ATM1); 50% CO_2 + 50% N_2 (CE-ATM2); 70% CO_2+ 30% N_2 (CE-ATM3); 30% CO_2 + 70% N_2 (CE-ATM4). Las muestras fueron evaluadas por su calidad microbiológica y físico-química. Las carnes envasadas en atmósferas con diferentes proporciones de CO2 y N_2 tenían una vida útil de hasta 12 días, sin variaciones significativas entre tratamientos, en cuanto a la calidad microbiológica. Mientras a las características físico-químicas, a pesar de aumentar la oxidación lipídica en la carne, las atmósferas con diferentes mezclas de CO_2 y N_2 utilizadas para envasar la carne presentaron las mejores características de calidad. Por tanto, según este estudio, las atmósferas modificadas con CO_2 y N_2 pueden recomendarse como mejores alternativas para prolongar la vida útil de la carne solar.

Palabras clave: Carne de vaca; Duracion; Embalaje; Calidad; Modificación de gas.

1. Introduction

Preserved only by its salt content, sun-dried meat has characteristics more similar to those of fresh, chilled meat than those of salted products, such as charc and jerked beef. The production of sun-dried meat is typically artisanal, on a small scale and without standardized technological processing. Due to its low sodium chloride content, the water activity of jerked beef is not reduced in large quantities, remaining around 0.90 and 0.92, which does not characterize this product as a salted meat of intermediate humidity, unstable at room temperature. Besides, it does not have legislation that establishes production, packaging and storage criteria, preventing product standardization, quality and safety. Thus, the shelf life of sun-dried meat, at room temperature, may vary from 2 to 4 days and may be extended with refrigeration (Costa & Silva, 2001, Ishihara et al., 2013; Bolognesi et al., 2015).

The deterioration of meat starts when microorganisms grow during storage, causing the release of volatile compounds and the oxidation of lipids present in the product, which makes the meat unacceptable for human consumption (Gram et al., 2002). Associations of different conservation methods, such as the use of refrigeration, salting and packaging, are viable alternatives to increase the shelf life of highly perishable foods, such as sun-dried meat, as they cause a delay in the metabolic activities of deteriorating microorganisms and in undesirable chemical reactions (Storia et al., 2012).

Chilling meat products, even under different packaging conditions, prolongs the shelf life of these foods. However, this method of preservation does not prevent the growth and survival of psychrotrophic micro-organisms. Therefore, additional methods are needed to ensure the safety of such chilled products, such as modified atmosphere packaging (Mohan et al., 2016).

Packaging technology has been a viable alternative for extending the shelf life of meat and dairy products. Modified atmosphere packaging (MAP) allows the substitution of gases from the ambient atmosphere, such as O2, creating an effective barrier against microorganisms and chemical and enzymatic reactions. In addition, gases with antimicrobial properties can be distributed more evenly in the packaging container compared to antimicrobials in liquid or solid form (Chen & Brody, 2013).

Previously, meat MAPs were only found with high concentrations of O2, considered traditional MAPs, which contained 70-80% O2 and 20-30% CO2, which maintained the color of fresh meat, the main attraction for consumers. However, it was found that the large amount of O2 also starts the early oxidative deterioration, leaving the meat less tender and juicy with a taste of rancidity and prolonged premature darkening, resulting in a decrease in food quality (Lagerstedt, Lundström & Lindahl, 2011; Torngren et al., 2018).

The effectiveness of MAP in extending the life of meat can be attributed to the antimicrobial activity of CO2. When meat is in contact with CO2 inside the package, changes in the dominant microflora are caused and consequently inhibition of microbial growth, also preserving the meat from deterioration (Limbo et al., 2010). CO2 has been used in concentrations of 20 to 40% to suppress microbial growth (Stoops et al., 2015).

Due to the lack of fundamental standards for the determination of quality parameters in sun-dried meat and the lack of adequate packaging to help prolong the shelf life of these foods, the aim was to evaluate the effects of different modified atmospheres on the packaging of sun-dried meat.

2. Methodology

For the production of sun-dried meat, a hard topside piece of meat (Bíceps femoris) from a slaughterhouse with the federal inspection seal was used. All the processing and preparation of the meat was performed with good food handling practices standards. The meat was cut into portions of approximately 200g and measuring about 4cm thick.

The 2.5% sodium chloride concentration was used for the production of sun- dried meat, since this NaCl concentration for the preparation of sun-dried meat had better physical-chemical and sensory characteristics of meat quality, it was felt the need for an increase in the theory of barriers to enable the extension of the commercial life of meat.

After salting, the meat remained immersed in brine for 24 hours before being packed in the treatments. Thus, the meat samples were classified into six groups, five treatments and one control group. The samples were packed with a Sulpack® packer (Supervac 500-Gas model) coupled to a compressor and gas mixing module, creating the following experimental groups: CE-Ar: air packed samples (control group); CE-V: vacuum packed samples; CE-ATM1: samples packed in the modified atmosphere with 100% CO2; CE-ATM2: samples packed in the modified atmosphere with 50% CO2 and 50% N2; CE- ATM3: samples packed in the modified atmosphere with 70% CO2 and 30% N2; and, CE- ATM4: samples packed in the modified atmosphere with 30% CO2 and 70% N2. The meats packed in the different experimental groups were stored under refrigeration (4 ± 1ºC).

2.1. Microbiological analyses

Microbiological tests on sun-dried meat samples were performed on day zero, 24 hours after salting, and again after 3, 6, 9, 12 and 15 days of refrigerated storage at 4ºC ± 1ºC. The samples of sun-dried meat were weighed (25g) aseptically transferred to sterile plastic bags, where 225 mL of sterile buffered peptone water was added for subsequent homogenization in Stomacher for 2 minutes, thus obtaining the dilution 10-1, from which the remaining decimal dilutions up to 10-4 were obtained. After the dilutions, the samples of sun-dried meat were submitted to techniques to determine the Most Probable Number (MPN) of coliforms at 35ºC and 45ºC, the total counts of psychrotrophic bacteria, halophilic and aerobic mesophilic bacteria, and the presence of Salmonella sp. using the methodology recommended by the American Public Health Association (Downes & Ito, 2001).

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2.2. Physico-chemical tests

The physicochemical tests were performed in triplicate, at zero storage time, 24 hours after the salting process (0) and again after 3, 6, 9, 12 and 15 days of refrigerated storage at 4ºC ± 1ºC.

2.2.1. pH

The pH of the samples was determined according to the methodology established by AOAC, 2005, where the HANNA® digital pHmeter model HI 99163 was used, coupled to a penetration electrode. The pH was measured directly on the muscle (AOAC, 2005).

2.2.2. Color

The color was evaluated by the Konica Minolta colorimeter, CM-700d/600d (CIE System L*a*b*), whose system considers the coordinates L* luminosity (black/white), a* red content (green/red) and b* yellow content (blue/yellow).

2.2.3. Water Retention Capacity

The determination of water retention capacity (WRC) was based on the measurement of released water when pressure was applied to muscle tissue. Through the difference of weights (initial - final) the water retention capacity was determined, expressed as a percentage of weight lost from the initial sample (Hamm, 1960).

2.2.4. Shearing Force

The shear force was measured by means of a TEXTURE ANALYZER TA-XT- 125, coupled to the Warner-Bratzler device, which expresses the force in kgf/cm2 (Hamm, 1960).

2.2.5. Weight Loss by Cooking

For the analysis of weight loss by cooking (PPC), the sample was weighted and then cooked in a grill, where the internal temperature of the muscle reached 71 to 75 °C. Subsequently, the samples were taken from the grill and weighed again to calculate the percentage of water loss during the thermal process (Osory & Osory, 1998).

2.2.6. Thiobarbituric Acid Reactive Substances (TBARS)

For the thiobarbituric acid (TBARS) reactive substances test, 0.5g of sun-dried meat was used, with the addition of the stock solution (0.375% thiobarbituric acid, 15% trichloroacetic acid and 0.25M HCL), in which the positive samples develop pink color during heating. The absorbance of the solution was determined at 532nm against white. The amount of TBARS was expressed as milligrams of malonaldehyde per kg of sun- dried meat (Amsa, 2012).

2.3. Statistical analysis

The homoscedasticity and normality of the data were verified, and no outlier was recorded. The data were then submitted to analysis of variance (ANOVA) and the Tukey test at 5% significance was used to verify significant differences. All analyses were performed with the statistical software SISVAR 5.6.

3. Results and Discussion

Analyzing the microbiological quality of sun-dried meat stored in different modified atmospheres, the absence of coliforms at 35ºC and 45ºC was verified, as well as *Salmonella* sp. in all samples throughout the experimental period.

There was an increase in the growth rate during the storage period in the count of psychrotrophic, halophilic, mesophilic aerobic bacteria (Figure 1), with values above 8 logarithmic cycles on day 15. All treatments presented values above 4 logUFC / g on day zero and according to Hong et al. (2012), the maximum acceptable microbiological growth value is 7 logUFC / g.

Therefore, the samples packed in different concentrations of N_2 and CO_2 had a microbiologically acceptable shelf life of up to 12 days, considering the growth of mesophilic aerobic bacteria, and up to 9 days for psychrotrophic and halophilic bacteria.

According to Jakobsen & Bertelsen (2004), the antimicrobial effect of N_2 and CO_2 commonly used in modified atmosphere packaging, is dependent, among other factors, on solubility, partial pressure, pH, temperature, fat content and total volume ratio of the product inside the packaging (Nair et al., 2014). In addition, the cooling temperature at which meat is stored can directly influence the growth of microorganisms in food, regardless of their atmosphere (Lan et al., 2016).

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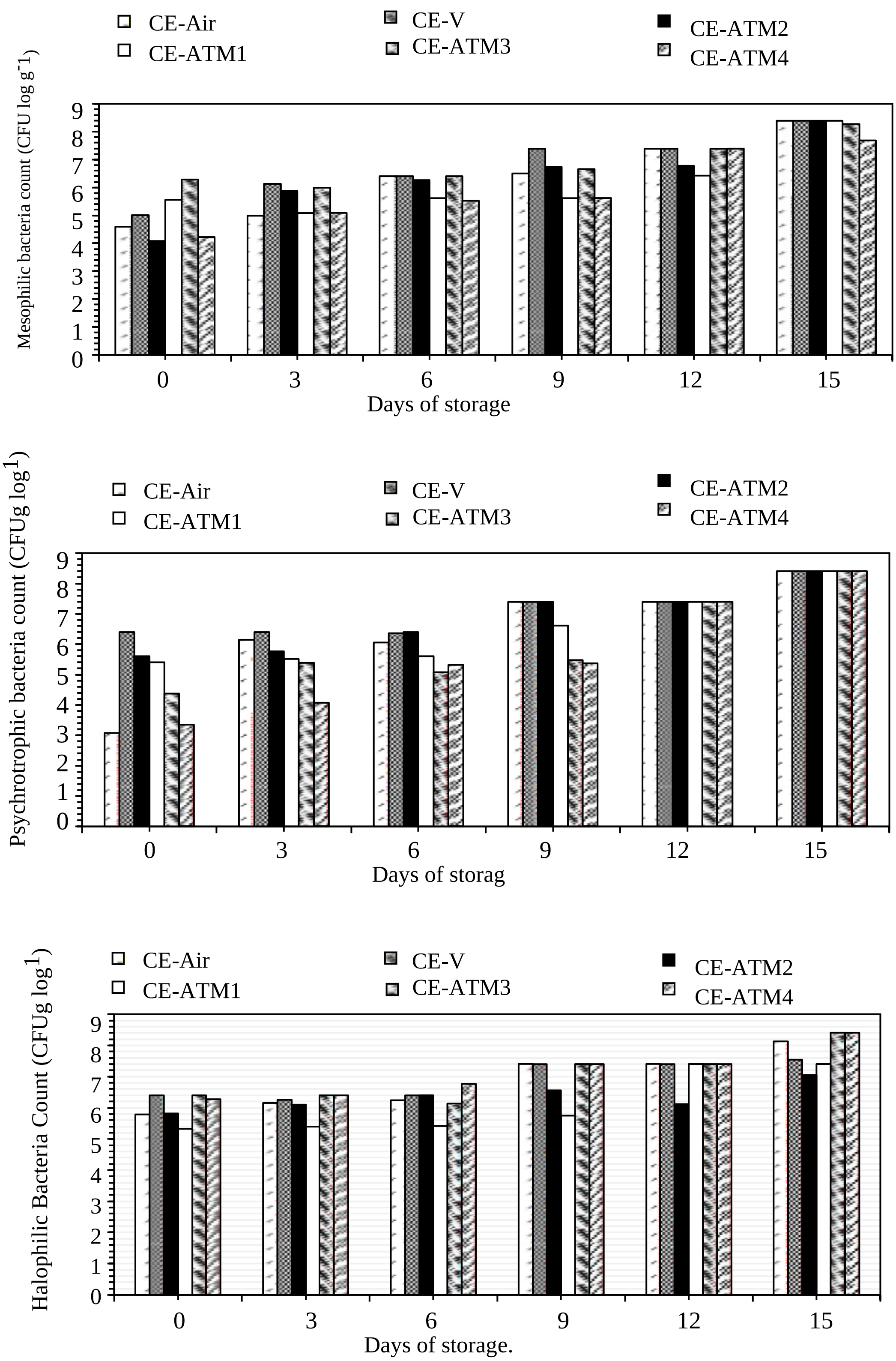
Figure 1. Results of aerobic, psychrotrophic and halophilic mesophilic bacteria counts in sun-dried meat packed in different atmospheres.



Source: Authors.

The colour of sun-dried meat samples, packed in different atmospheres and measured one hour after opening the packages, remained constant during the days of storage in all treatments. The variation of gases in the atmosphere of the package used to store the sun-dried meat samples was not able to change their color significantly (Table 1). The presence of CO_2 in meat packaging can cause color stability, unlike O_2, which allows accelerated oxidation of myoglobin into metmioglobin (Vergara & Gallego, 2001; Salviano et al., 2015).

Table 1: Color analysis of packed sun-dried meat in different atmospheres over 15 days of refrigerated storage.

Days of storage	Color	Treatments						CV (%)
		EC-Air	**CE-V**	**EC- ATM1**	**EC- ATM2**	**EC-ATM3**	**EC- ATM4**	
0	L*	65.85 Aa	66.58 Aa	68.40 Aa	67.77 Aa	66.11 Aa	66.82 Aa	9.6
3		65.95 Aa	67.05 Aa	67.56 Aa	67.29 Aa	67.27 Aa	66.38 Aa	
6		65.55 Aa	66.98 Aa	66.97 Aa	67.31 Aa	67.48 Aa	67.12 Aa	
9		68.20 Aa	67.62 Aa	67.12 Aa	67.01 Aa	67.35 Aa	66.06 Aa	
12		66.09 Aa	67.18 Aa	66.39 Aa	67.05 Aa	66.17 Aa	68.11 Aa	
15		66.58 Aa	66.41 Aa	67.58 Aa	66.92 Aa	66.36 Aa	67.66 Aa	
0	a*	3.79 Aa	2.89 Aa	4.21 Aa	4.03 Aa	3.15 Aa	3.29 Aa	20.28
3		2.96 Aa	3.06 Aa	3.26 Aa	3.47 Aa	2.81 Aa	3.62 Aa	
6		2.75 Aa	2.83 Aa	3.04 Aa	3.31 Aa	3.26 Aa	2.51 Aa	
9		3.11 Aa	3.16 Aa	3.16 Aa	2.85 Aa	2.78 Aa	2.45 Aa	
12		2.78 Aa	3.35 Aa	2.79 Aa	3.79 Aa	3.27 Aa	2.74 Aa	
15		3.16 Aa	3.73 Aa	3.91 Aa	3.47 Aa	2.77 Aa	3.11 Aa	
0	b*	7.81 Aa	6.41 Aa	8.73 Aa	8.41 Aa	7.04 Aa	7.17 Aa	18.24
3		6.96 Aa	7.91 Aa	7.49 Aa	7.81 Aa	7.68 Aa	7.63 Aa	
6		6.81 Aa	7.21 Aa	7.77 Aa	7.57 Aa	7.95 Aa	7.61 Aa	
9		7.89 Aa	7.78 Aa	7.94 Aa	6.98 Aa	7.65 Aa	6.69 Aa	
12		6.85 Aa	7.71 Aa	7.73 Aa	7.86 Aa	7.28 Aa	7.92 Aa	
15		7.41 Aa	7.09 Aa	8.55 Aa	7.86 Aa	7.28 Aa	7.67 Aa	

[A, B, C] Different capital letters in the same column indicate differences between storage times according to Tukey's 5% test. [a, b, c] Different lower case letters in the same line indicate differences between treatments according to Tukey's 5% test. Source: Authors.

During storage, there were significant differences in the pH of packed sun-dried meat in different atmospheres (Table 2). It was noted that the samples packed in atmospheric air had higher pH values when compared with the other sample groups, on all days of storage, with the meat being controlled, with atmospheric air, having presented the highest value on the 15th day of refrigerated storage or among all samples.

The water retention capacity maintained a standard, with values above 80%, until the 9th day of storage in the samples of CE-Air, CE-V, CE-ATM1, CE-ATM3 and CE-ATM4, with significant differences between the treatments. From the 12th day of storage, the sample packed with 50% of N_2 and 50% of CO_2 (CE-ATM2) presented lower water retention capacity, when compared to other treatments. It was also observed that in all sample groups there was a decrease in the percentage of water retention capacity of packed meats in different atmospheres.

According to Vergara and Gallego (2001), high microbial counts cause deterioration of meat, which can contribute negatively to the loss of protein stability and, consequently, decrease water retention capacity. The reduction in water retention capacity of the samples evaluated in this study, throughout the days of storage, may have been influenced by the high microbial counts found.

Table 2. pH tests, water retention capacity, cooking loss and shear strength in sun-dried meat packed in different atmospheres.

Days of storage	Variables	Treatments						CV (%)
		EC-Air	CE-V	EC- ATM1	EC- ATM2	EC-ATM3	EC- ATM4	
0	pH	5.60Aa	5.57 Ba	5.60Aa	5.61Ba	5.59 Ba	5.58 Ba	0.93
3		5.83Aa	5.49 Bb	5.45Bb	5.54Bb	5.51 Bb	5.53 Bb	
6		5.79Aa	5.58 Bb	5.56Bb	5.63Bb	5.64 Ab	5.58 Bb	
9		5.84 Aa	5.76 Aa	5.72Aa	5.71Aa	5.69 Ab	5.68Ab	
12		5.84 Aa	5.66 Bab	5.69Ab	5.68Ab	5.70 Aa	5.67Aab	
15		6.08 Aa	5.73 Ab	5.62Ab	5.70Ab	5.78 Ab	5.75Ab	
0	Water holding capacity (%)	88.41 Aa	89.56 Aa	88.76 Aa	86.12 Aa	86.17 Aa	86.23 Aa	6.28
3		84.53Ba	83.27 Aa	82.65 Ab	81.82 Ab	84.91 Aa	82.93 Ab	
6		83.73 Bb	88.38 Aa	89.96 Aa	69.73 Bc	86.99 Aa	83.71 Ab	
9		87.29 Aa	80.33 Bb	89.22 Aa	69.01 Bc	77.67 Bb	85.47Aab	
12		74.83 Ba	74.34BCa	70.05Bbc	65.18 Bb	67.94 Cb	73.52 Ba	
15		70.23 Ba	65.31Cb	77.83 Ba	57.54 Cc	61.45 Cb	71.59 Ba	
0	Loss of weight per cooking (%)	39.19 Aa	36.33 Ab	36.25 Ab	39.58 Aa	39.25 Aa	37.77Aa	4.67
3		36.35 Bb	34.03Aab	33.63BCc	38.39 Aa	35.49 Ab	35.9 Ab	
6		35.32Bb	32.79Bc	33.33BCb	39.58 Aa	33.58 Bb	30.62 Bc	
9		29.36 Cc	31.08 Bb	35.66Aaa	36.91 Aa	31.57 BCb	31.58 Bb	
12		29.07 Cc	31.95Bb	35.68Aa	33.78 Bb	32.73 BCb	30.61 Bc	
15		29.15 Cb	26.19 Cc	30.7 Cb	33.06 Ba	29.36 Cc	30.1 Bb	
0	Shearing force (kgf/cm²)	7.34 Aa	4.5 Ab	3.64Bc	4.55Ab	6.04 Aa	4.74Ab	7.98
3		5.56 Ba	4.59 Ab	3.71 Ac	4.19 Ab	4.37 Bb	4.67Ab	
6		4.22 Ba	4.39 Aa	3.87 Ab	4.39 Aa	4.54 Ba	4.45 Ba	
9		4.24 Ba	4.23 Aa	3.99 Ab	4.81 Aa	4.8 Ba	4.38 Ba	
12		3.46 Ca	1.99 Bb	3.54 Ba	3.55 Ba	2.11 Cb	3.99 Ba	
15		3.46 Ca	2.93 Bb	3.46 Ba	2.78 Bb	1.46 Cb	1.97 Cc	

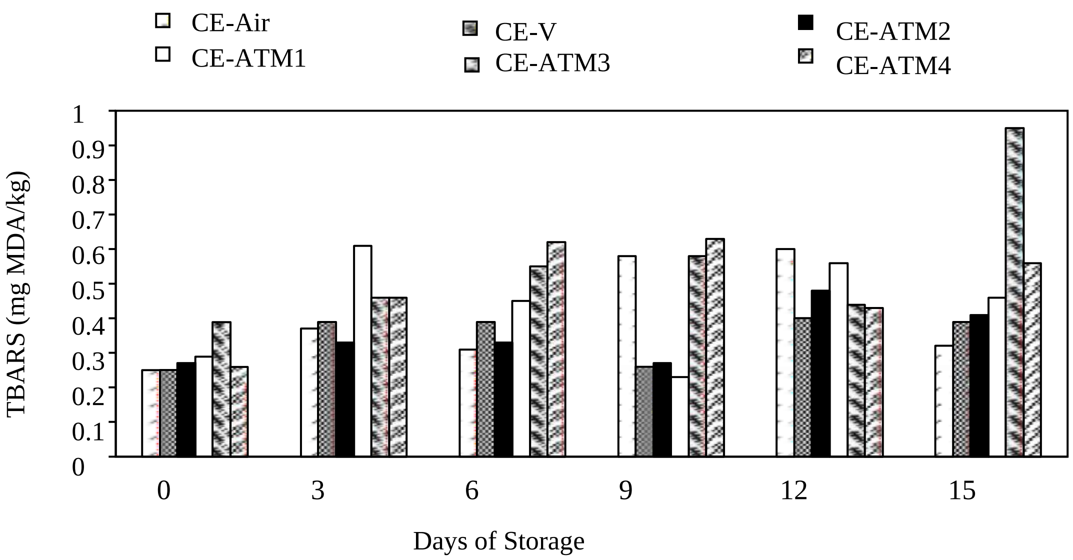
[A, B, C] Different capital letters in the same column indicate differences between storage times according to Tukey's 5% test. [a, b, c] Different lower case letters in the same line indicate differences between treatments according to Tukey's 5% test. Source: Authors.

When analyzing the weight loss by cooking, it was found that there was a gradual decrease in weight loss of meat after cooking, during the days of storage. Storage time and treatments showed significant differences ($P < 0.05$) in the weight loss after cooking, thus having lower losses in meat yield over the days. The highest PPC values were recorded in the packed samples in 50% of N_2 and 50% of CO_2 (CE-ATM1), while the lowest values were found in vacuum packed meats (Table 2).

Throughout the storage period, there was a decrease in the shear force values in all sunflower samples packed in different modified atmospheres, considering them very soft (values below 3.2 kgf) or intermediate softness (values between 3.9 and 4.6 kgf) (Bellew et al., 2003) at 15 days of storage sampling. From the results, it is possible to infer that the samples packed with changes in gaseous atmospheres, on all sample days, had less force necessary to shear, making them softer, when compared with the other sample groups.

Regarding lipid oxidation, the lowest TBARS values (Figure 2) were found in vacuum packed samples and in 100% CO_2. The highest amount of malonaldehyde was found in samples packed with CO_2 and N_2 in the proportions of 70% and 30%. However, throughout the days of storage, all samples presented values below the maximum limit of 2 mg / kg, from which the food started to present distinct odors and rancid taste, becoming undesirable to consumers. Besides the rancid taste and odors, lipid oxidation can lead to changes in the structure of proteins, causing undesirable changes in the quality characteristics of meat (Spanos et al., 2016). Such effect can be verified in the shear force, where it is possible to verify that the meats that presented less necessary force to shear were also the ones that exhibited greater values of malonaldehyde, demonstrating greater lipidic oxidation present in the samples. Therefore, the softness of sun-dried meats found during storage may be associated mainly with swelling of the filamentary structure and extraction/solubilization of myofibrillar proteins (Xiong, 2005).

Figure 2. Thiobarbituric acid reactive substance tests - TBARS in sun-dried meat packed in different atmospheres.



Source: Authors.

Sun-dried meat has no specific legislation that guarantees product identity standards. Moreover, in general, it is not properly packaged to guarantee its quality and ensure food safety for the consumer. Today, in the face of progressive social changes in the food chain, more often than not, consumers are seeking information about the safety and quality of a product. Therefore, the use of modified atmosphere for packaging meat can not only ensure food quality, but also contribute to providing essential information that can significantly influence consumer opinion about the product.

4. Conclusion

Therefore, the insertion of different proportions of CO_2 and N_2 in the packaging of sun-dried meat provided a shelf life of 9 to 12 days of storage, with no significant differences between the treatments. In addition, such gases stood out because they provided better meat quality characteristics. Therefore, according to this study, coating sun-dried meat with changes in the atmosphere, including CO_2 and N_2 gases, may be recommended as alternatives to extend the useful life of this product.

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Porcentagem de contribuição de cada autor no manuscrito

Maria Carla da Silva Campêlo – 30%

Jovilma Maria Soares de Medeiros – 6%

Lucas de Oliveira Soares Rebouças – 6%

Luciana Veras Aquino Figueiroa – 6%

Manuella de Oliveira Cabral Rocha – 6%

Palloma Vitória Carlos de Oliveira – 6%

Patrícia de Oliveira Lima – 20%

Jean Berg Alves da Silva – 20%