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Shelf life of meat from Boer-Saanen goats fed diets supplemented with vitamin E

Ana Paula S. Possamai[a,*], Claudete R. Alcalde[a], Andresa C. Feihrmann[b], Ana Cássia S. Possamai[c], Robson M. Rossi[d], Bruno Lala[e], Stefania C. Claudino-Silva[f], Francisco de Assis F. Macedo[g]

[a] Department of Animal Science, State University of Maringá, Av. Colombo, 5790, 87020–900 Maringá, Paraná, Brazil
[b] Department of Food Engineering, State University of Maringá, Paraná, Brazil
[c] Department of Agronomy, Universidade do Estado de Mato Grosso-UNEMAT, Av. das Arapongas, 1384N, 78450-000 Nova Mutum, Mato Grosso, Brazil
[d] Department of Statistics, State University of Maringá, Paraná, Brazil
[e] Department of Animal Science, UNESP – São Paulo State University, FMVZ – Botucatu, P.O. box 560, 18618-970 Botucatu, São Paulo, Brazil
[f] Department of Veterinary Sciences, University Center of Maringá, Av. Guedner, 1610, 87050-900 Maringá, Paraná, Brazil
[g] Department of Animal Science, Federal University of Sergipe, Av Mar Rondon S/N, 49100-000 São Cristóvão, Sergipe, Brazil

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ABSTRACT

This work aims at evaluating shelf life of meat from Boer-Saanen cross goats fed on diets containing vitamin E. Thirty-five feedlot-fed goats with an initial body weight of 21.6 ± 2.8 kg were subjected to four treatments in a completely randomized design: a control treatment with vitamin E plus others containing 50, 150, and 450 mg DL-α-tocopherol acetate/kg DM. Longissimus lumborum (LL) muscle samples were stored at temperatures between 4 and 6 °C during 15 days, and evaluated for lipid peroxidation using the thiobarbituric acid reactive substances (TBARS) method and for visual acceptance by consumers by different survival analysis techniques. The addition, vitamin E in diets influenced shelf life of LL muscle, indicating longer meat preservation as the levels of the vitamin in diet increased, as the results obtained in chemical and subjective visual assessments showed. TBARS analysis showed to be more accurate in predicting shelf life of meat than subjective visual assessment by consumers, which reached a saturation threshold of 2 mg malonaldehyde/kg of meat earlier at all tested levels of vitamin E inclusion.

1. Introduction

Muscle pigment and lipid oxidation are two major effects of deterioration of meat because they affect essential sensory qualities, producing undesirable flavors, colors, and textures (Estévez, Ventanas, & Cava, 2005). Shelf life is one of the greatest problems of meat sale. Expiration date of meats depends on oxidative processes caused by storage temperature, exposure to oxygen and light, as well as microbiological growth. The possibility of extending meat shelf life by delaying oxidative deterioration is of commercial importance for meat industry (Luciano et al., 2009).

In order to extend the meat's shelf life, antioxidants can be added to the meat, e.g. nitrites, but this preservation method has been rejected by consumers (Resconi, 2007) due to changes in their culture and lifestyle, their awareness of healthier eating habits and a preference for food with little or no synthetic preservatives (Gupta & Abu-Ghannam, 2011). Another way to improve the color aspect and lipid stability is to include antioxidants in animal diets. Antioxidants are incorporated into cell membranes and increase stability of meat (Kerry, Buckley, Morrissey, O'Sullivan, & Lynch, 1998).

Membranes of muscle cells are comprised of phospholipids which have a high concentration of polyunsaturated fatty acids more susceptible to peroxidation during storage at low temperatures (Kanner, 1994). Vitamin E is deposited in muscle cell membranes and lipid deposits, and it is widely used as an antioxidant in its isomeric form of α-tocopherol, reducing lipid oxidation and providing color stability (Liu, Lanari, & Schaefer, 1995; López-Bote, Daza, Soares, & Berges, 2001). Animals do not synthesize Vitamin E, but require a regular dietary supplement that will help in protection against peroxidation of highly oxidizable polyunsaturated fatty acids by reactive oxygen types produced by enzymes linked to adjacent membranes (McCay & King, 1980).

Meat color is the most important factor for buying decision by consumers (Mancini & Hunt, 2005). In this aspect, in it possible to gather information that would include integration of data relevant to critical points of shelf life and that will satisfy consumer. In this context,

* Corresponding author.
E-mail address: anapaula_possamai@hotmail.com (A.P.S. Possamai).

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acceptance by consumers based on visual attributes can be useful for evaluation of purchasing attitude for various products by consumers (Gacula & Singh, 1984), thus showing to be an appropriate method of estimating shelf life. Survival analysis methodology has been applied to estimate shelf life of foods (Gámbaro, Ares, & Gimenez, 2006; Giménez et al., 2007; Hough, Langohr, Gómez, & Curia, 2003), which makes it possible to determine the time, during which the product remains acceptable for consumption (Gómez, 2002).

Studies involving vitamin E in animal diets have shown an increase in shelf life (Juárez et al., 2012; Karami, Alimon, Sazili, Goh, & Ivan, 2011; Kasapidou et al., 2012; Ripoll, Joy, & Muñoz, 2011), due to less oxidation and the persistence of color that is more acceptable by consumers. Meats may have their quality and composition constantly modified providing them with a healthy aspect for longer periods of time (Fernández-Ginés, Fernández-López, Sayas-Barberá, & Pérez-Alvarez, 2005). Vitamin E is a natural compound highly accepted in food products and widely used to reduce lipid oxidation and maintain a stable color in meats (López-Bote et al., 2001). Thus, in this work we aim to evaluate the effect of the addition of vitamin E in diets of Boer-Saanen goats on shelf life of *Longissimus lumborum* (LL) muscle by laboratory assessment methods and subjective evaluation by consumers.

2. Material and methods

2.1. Animals, housing and diets

This experiment was approved by Department of Animal Production and Research Ethic Committee at the State University of Maringá. It meets the requirements of the guiding principles of biomedical research involving animals (CIOMS/OMS, 1985), and was conducted at the Goat Sector, State University of Maringá, Experimental Farm Station at Iguatemi city, Paraná State, Southern Brazil.

The experiment involved large control groups of animals receiving treatment with low (50 mg) and high (450 mg) levels of vitamin E, whereas a smaller number of kids was subjected to intermediate treatment (150 mg), so that if there are any problems during the experiment, the general data would not be lost, for we would still have the extreme treatments used on a number of kids that would be sufficient to allow the evaluation of the results. In addition, the Bayesian inference method used to treat the obtained data consists of using information regarding the sample data (likelihood function), previous knowledge about the parameters (a priori distribution) and the a posteriori calculation of distribution of the parameters resulting from the two previous types of data, based on which all decisions and inferences are made. Therefore, the number of animals in the intermediate treatment (150 mg) was not detrimental to the data evaluation.

Thirty-five Boer-Saanen goats, with an average age of 122.1 ± 3.6 days and an average initial body weight of 21.6 ± 2.9 kg, were distributed in a completely randomized manner among four treatment programs, including a control treatment without vitamin E and others containing 50, 150, and 450 mg DL-α-tocopherol acetate/kg. Diets were adjusted according to NRC (2007) to provide a daily weight gain of 0.150 kg for goats in growing stage. Diets had a roughage:concentrate ratio of 30:70 and were pelleted to prevent selection and wasting.

Vitamin E was added to diet in the form of DL-α-tocopherol acetate (ROVIMIX® E-50 Adsorbate). Ingredients and chemical composition (g/kg) of experimental diets are described in Table 1.

The feed was given to animals at 08 h00, in the proportion of 3.5% dry matter relative to their body weight, to allow for approximately 10% as leftovers. Before feed supply, leftovers were weighed daily at the beginning of the experiment and subsequently every 14 days, in order to adjust the diet and to monitor body weight until reaching final weight of approximately 32 kg. The kids were confined in a suspended facility on slatted floor, in individual stalls equipped with drinkers and feeders.

Table 1
Ingredients, in g/kg of dry matter, and chemical composition of the experimental diets.

Item	Diet (mg DL-α-tocopherol acetate/kg DM)			
	0	50	150	450
	n = 10	n = 10	n = 5	n = 10
Oat hay	300.00	300.00	300.00	300.00
Ground corn	498.30	498.30	498.30	498.30
Soybean meal	141.71	141.71	141.71	141.71
Common salt	17.63	17.63	17.63	17.63
Ammonium chloride	10.00	10.00	10.00	10.00
Mineral supplement[a]	32.35	32.34	32.33	32.30
DL-α-tocopherol acetate	0.00	0.005	0.015	0.045
Dry matter	894.84	890.54	892.50	892.12
Organic matter	917.74	912.88	916.23	918.08
Crude protein	147.06	144.73	154.72	150.14
Ether extract	10.52	11.98	10.90	11.39
Total carbohydrates	760.16	753.17	750.61	754.54
Non-fibrous carbohydrates	207.22	194.12	218.50	221.26
Neutral detergent fiber	552.94	559.04	551.17	553.27
Acid detergent fiber	143.97	142.22	146.53	141.97

[a] Product formulated without inclusion of vitamin E. Chemical composition (per kg of product): calcium 240 g; phosphorus 71 g; fluorine 710 mg (max); magnesium 20 g; potassium 28.20 g; iron 2500 mg; copper 400 mg; manganese 1350 mg; zinc 1700 mg; cobalt 30 mg; iodine 40 mg; selenium 15 mg; chromium 10 mg; vit. A 135,000 IU; vit. D3 68,000 IU.

2.2. Sample collection and analyses

At the end of the experimental period, upon reaching an average weight of approximately 32 kg, the goats were deprived of solid feed (16 h). Animals were stunned for slaughter by a 220 V electric shock for 8 s., followed by bleeding by sectioning jugular veins and carotid arteries, skinning, and had their internal organs removed in full accordance with the technical regulation for humane slaughter in Brazil (Brasil, 2000). All animals were slaughtered at the same day. Samples of *Longissimus lumborum* (LL) muscle from the left half of the carcass were collected for evaluation of lipid oxidation and shelf life by chemical method using thiobarbituric acid reactive substances (TBARS) and by visual method in which consumers declared their preference. The meats were packed in polyethylene packages and stored in freezer until they were evaluated. The panelists recruited for visual evaluation were selected according to their habit of consuming red meats. The panellists were not trained but they consumed meat frequently. Consumers who ate red meat at least 4 times a week were selected.

Lipid oxidation was determined according to Raharjo, Sofos, and Schmidt (1992) modified by Wang, Pace, Dessai, Bovell-Benjamin, and Phillips (2002) on control days 0, 3, 7, and 14. For each control day, a sample of LL muscle was separated, placed on an expanded polystyrene (EPS) white tray, wrapped in plastic wrap, and stored at temperatures between 4 and 6 °C.

On predefined days, samples were taken from refrigerator, ground, and 5 g of each sample were homogenized in 0.5 mL 0.15% BHT dissolved in ethanol (w/v) and 36 mL 5% trichloroacetic acid (w/v). Samples were left for approximately 10 min for TBARS to be extracted; afterwards, they were filtered and 2 mL of the filtrate were mixed with 2 mL 0.08 M thiobarbituric acid and kept in a water bath for 5 min at a temperature of 95 °C. A blank sample was prepared containing 36 mL of trichloroacetic acid solution, 0.5 mL of BHT solution, and 2 mL of thiobarbituric acid solution. Using an Agilent UV-8553 spectrophotometer, the rate of absorbance was established to be at 532 nm vs. blank sample.

TBARS was calculated using 1,1,3,3 tetraethoxypropane as standard (1×10^{-8} to 10×10^{-8} mol/mL) and expressed in milligrams of malonaldehyde (MDA) per kilogram of muscle. For evaluation purposes, the amount of 2 mg of MDA per kg was adopted as critical point of lipid oxidation (Campo et al., 2006), being the amount at which

anomalous rancid flavor overcomes meat flavor and produces a taste in red meat that is unacceptable for consumers.

For subjective evaluations of shelf life, daily observations were carried out by 18 consumers on portions of LL muscle, each approximately 3 cm thick. These steaks were placed on EPS trays, one sample of muscle from each animal per tray, covered with plastic wrap, and stored in a refrigerated display case with controlled temperature between 4 and 6 °C, and intermittent illumination, with 11 h of light and 13 h of dark each day.

During the 15 days of exposure, consumers evaluated attributes related to visual aspects, especially meat color, using a form, in which buying intention for each steak (yes or no) had to be inserted for each one of evaluation days. To prevent bias during visual assessment, trays were shuffled randomly every two days inside the refrigerated display case. For these assessments, the first day of rejection of any sample by a consumer was considered a critical point, i.e., the day when the consumer determined that, based on the visual aspects of the presented sample, it would no longer generate a positive purchase intention.

2.3. Statistical analysis

The results of body weight of kids and the TBARS method were submitted to analysis of variance (ANOVA) with Tukey's test ($P > 0.005$) using the PROC REG of SAS software, version 9.3.

To evaluate the occurrence of events (lipid oxidation via TBARS method and the moment of rejection by consumers) over time, data were analyzed using the Kaplan and Meier's (1958) (KM) non-parametric procedure for probability of non-oxidation and visual acceptance by the consumers (survival) at moment t (days) by *survfit* command from *survival* library of R computer software. Some probabilistic models (Exponential, Weibull's, and Log-Normal) were applied to data using *survreg* command also from *survival* library of R software (R Development Core Team, 2014). The best fitting model by logL criterion (lowest values - log likelihood) was used to evaluate survival function $S(t)$, percentile $t_p = 100p\%$ of distribution considered at 50%, i.e., the estimated median, by chi-squared test (Giolo & Colosimo, 2006), and once difference between treatments adjusted according to the best suited models was observed, data were evaluated by contrasts in Bayesian models. For this step, non-informative a priori distributions were considered for all model parameters, and two-by-two differences between a posteriori distributions of respective treatments were taken and considered different at 5% significance level when credibility intervals for mean differences did not include value 0. The procedure was performed using BRugs package of R software.

3. Results

There was no difference ($P > 0.05$) in the initial and final body weight between treatments (Table 2).

Fig. 1 suggests the existence of the effect of vitamin E in goat diets on deceleration of lipid oxidation in meat. This effect is caused by the longer free time of oxidation shown in graph, as levels of applied vitamin E in diets increase. It was observed that curves representing lower vitamin E inclusion levels have a more marked decline than those representing higher levels. Thus, samples of meat from animals supplemented with vitamin E reach a malonaldehyde concentration > 2 mg/kg, which was indicated by Campo et al. (2006) as a limit for perception of rancid taste in red meats by consumers/untrained panelists, who detected the taste after further increase of inclusion levels in animal diets.

Table 2
Productive performance of Boer-Saanen kids fed with dietary vitamin E levels.

Parameters	Levels of DL-α-tocopherol acetate (mg/kg)				SE
	0	50	150	450	
Initial body weight (kg)	21.49	21.81	21.31	21.98	0.537
Final body weight (kg)	31.45	32.59	31.85	32.49	0.737

Different letters on the line indicate significant differences ($P < 0.05$) by Tukey test. SE: standard error.

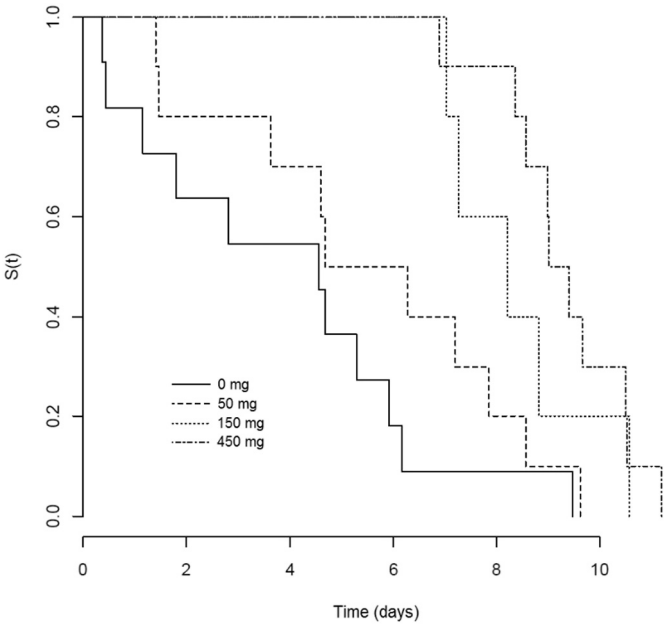

Fig. 1. KM survival S(t) curves adjusted for the time (days), by type of treatment (simultaneous), lipid oxidation - TBARS.

Fig. 2 shows that visual assessment performed by consumers demonstrated a similar behavior to that observed in chemical evaluation of meat shelf life, suggesting higher probability of meat preservation as vitamin E inclusion levels in goats' diet are increased. Consumers showed a preference for visual aspects of steaks from animals which received a diet supplemented with vitamin E for a longer period as compared with visual aspects of those from the control treatment batch.

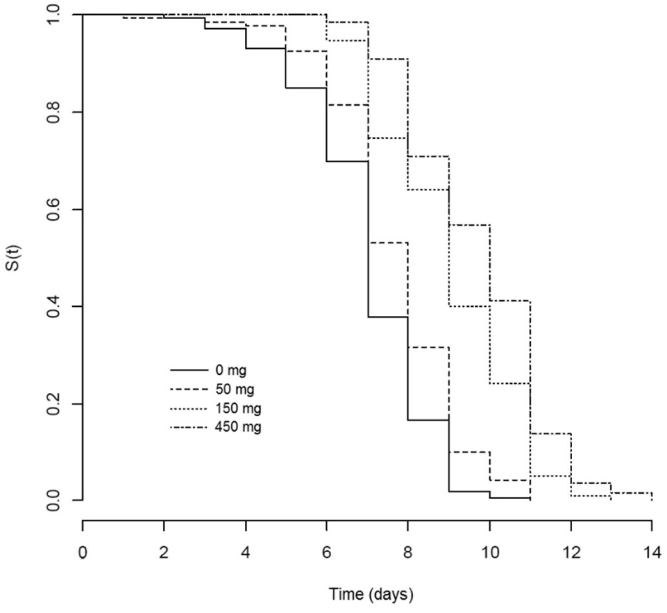

Fig. 2. KM survival S(t) curve adjusted for the time (days), by type of treatment (simultaneous), as evaluated by consumers.

Table 3
Adjustment criterion - log likelihood (− logL) for adopted models.

Evaluation	Model		
	Exponential	Weibull	Log-Normal
TBARS	101	88.8	96.4
Consumers	2121.1	1302.4	1385.8

Based on Figs. 1 and 2 of KM evaluation, which suggest the existence of differences in shelf life survival curves of evaluations based on lipid oxidation ($P = 0.000255$) and performed by the consumers ($P = 0.000$) for the vitamin E levels in diet, results were adequate for a parsimonious parametric model for adjustment of data. Based on log-likelihood criterion, distributions considered here showed an adjustment threshold according to data given in Table 3.

Weibull model was adopted given the logL values obtained for different proposed models, as it adjusted best to lowest value for evaluation of different levels of vitamin E in diet for both analyses. When using the chi-squared test, considering Weibull method, a significant difference was found between treatments in chemical ($P = 0.0007$) and visual ($P = 0.000$) assessments. Curves adjusted via Weibull model are presented in Figs. 3 and 4, showing an adequate adjustment to data.

The lipid oxidation measured in the form of TBARS contained in the *Longissimus* muscle was significantly altered according to the level of vitamin E provided in the animals' diet (Table 4). According to the obtained data, it was observed that even on day 0 of meat exhibition for the consumers, the treatments with higher levels of inclusion were shown to be more efficient in the slowdown of the lipid oxidation. This was repeated with 3 and 7 days of exposure, where treatments of 150 and 450 mg of DL-α-tocopherol acetate/kg DM were similar and had lower TBARS values. At 14 days, it was noted that regardless of the diet that the kids received, no effects of vitamin E supplement on TBARS levels were observed in the animals' meat.

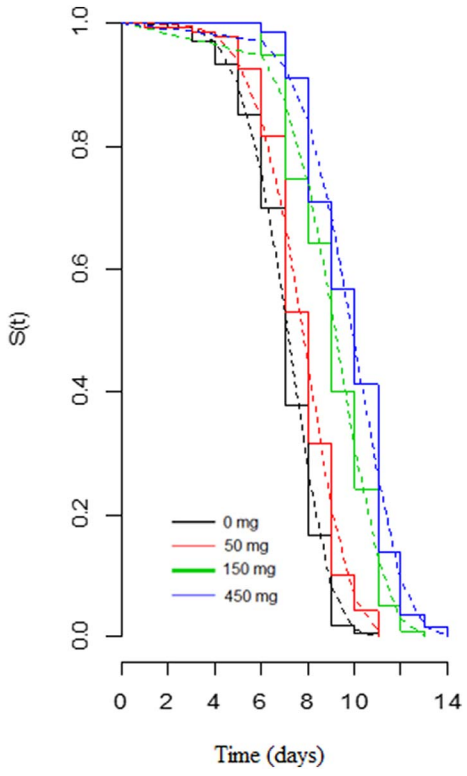

Fig. 3. KM and Weibull survival curve adjusted for the time (days), by type of treatment (evaluation by consumers).

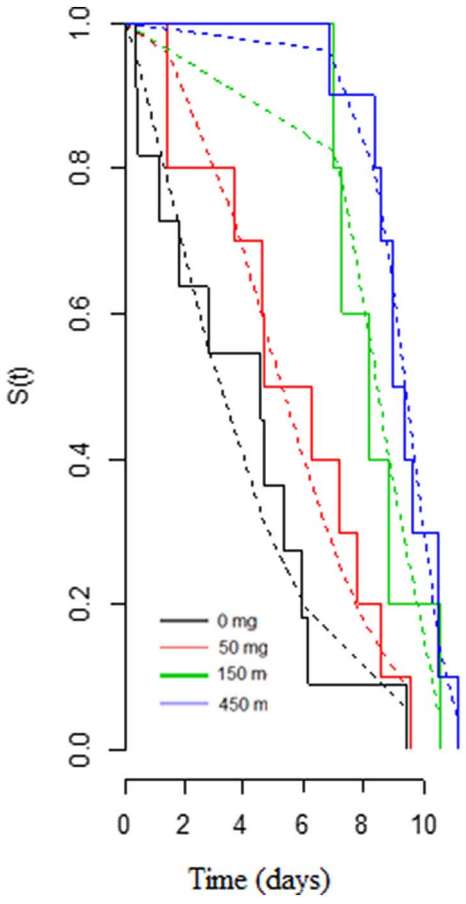

Fig. 4. KM and Weibull survival curve adjusted for the time (days), by type of treatment (chemical evaluation - TBARS).

Table 4
Lipid oxidation (TBARS mg/kg muscle) during simulated retail display.

Display day	Diet (mg DL-α-tocopherol acetate/kg DM)				SE
	0	50	150	450	
0	0.63 ^{Ca}	0.47 ^{Cb}	0.23 ^{Dc}	0.25 ^{Dc}	0.005
3	2.04 ^{Ba}	1.68 ^{Ba}	0.90 ^{Cb}	0.71 ^{Cb}	0.029
7	3.43 ^{Aa}	2.95 ^{Aa}	1.58 ^{Bb}	1.38 ^{Bb}	0.044
14	4.70 ^{Aa}	3.56 ^{Aa}	2.75 ^{Aa}	2.49 ^{Aa}	0.054

Lower case letters on the line indicate significant differences ($P < 0.05$) by Tukey test. Capital letters on the column indicate significant differences ($P < 0.05$) by Tukey test. SE: Standard error.

As for the effect of the number of exhibition days in each treatment, it was observed that for treatments with 0 and 50 mg of DL-α-tocopherol acetate/kg DM, day 0 of exhibition provided low level of TBARS, day 3 was intermediate, while days 7 and 14 were the days in which the highest rates of lipid oxidation occurred in the meats. Between 7 and 14 days no differences in TBARS levels were observed. For inclusion levels of 150 and 450 mg of DL-α-tocopherol acetate/kg DM, it was observed that there was a significant increase in TBARS as the number of exhibition days for the meat increased and thus, in stark difference from the treatments with lower supplementation of vitamin E in the diet (0 and 50 mg), at 7 days, it was still possible to observe vitamin E effect in delaying lipid oxidation in meats.

Table 5 presents the Frequentist estimates of parameters, using the Weibull model in different treatments. For both evaluations, shelf life of meat from animals consuming diets supplemented with vitamin E was longer than that of control treatment.

Table 5
Estimates of parameters, considering the Weibull model, per treatment (level of DL-α-tocopherol acetate) and per evaluation method.

DL-α-tocopherol acetate level	Parameter	Evaluation method			
		Visual - consumers		TBARS	
		Mean (SD)	CI (95%)[a]	Mean (SD)	CI (95%)
0	Scale (mean)	7.61^{Da} (0.10)	(7.41;7.81)	4.18^{Da} (1.01)	(2.20;6.16)
	Md = $t_{50\%}$ (days)	7.10^{Da} (0.11)	(6.90;7.32)[b]	3.20^{Cb} (0.95)	(2.80;6.52)
50	Scale (mean)	8.31^{Ca} (0.12)	(8.08;8.53)	6.24^{Ca} (0.95)	(4.36;8.12)
	Md = $t_{50\%}$ (days)	7.80^{Ca} (0.12)	(7.54;8.02)[b]	5.30^{Bb} (1.00)	(3.45;7.41)
150	Scale (mean)	9.74^{Ba} (0.18)	(9.40;10.09)	8.95^{Ba} (0.63)	(7.72;10.17)
	Md = $t_{50\%}$ (days)	9.10^{Ba} (0.18)	(3.06;12.58)[b]	8.50^{Aa} (0.81)	(7.00;10.09)
450	Scale (mean)	10.49^{Aa} (0.13)	(10.24;10.74)	9.82^{Ab} (0.36)	(9.12;10.52)
	Md = $t_{50\%}$ (days)	9.90^{Aa} (0.14)	(9.66;10.21)[b]	9.40^{Aa} (0.42)	(8.57;10.25)

Md = Median values; Different uppercase letters indicate significant differences between the treatments within the same evaluation, and different lowercase letters indicate significant differences between the treatments in the different evaluation methods by the Bayesian contrast at the credibility level of 95%.
[a] Interval with 95% reliability (Frequentist).
[b] Interval with 95% credibility (Bayesian).

Evaluation of shelf life by thiobarbituric acid reactive substances (TBARS) method showed that inclusion of 150 and 450 mg DL-α-tocopherol acetate/kg DM did not differ significantly by Bayesian contrast, revealing 8.5 and 9.4 days, respectively, to have malonaldehyde (MDA) levels above 2 mg/kg for 50% of evaluated samples, representing an approximately five to six days longer shelf life than steaks from animals not supplemented with vitamin E. Treatment with inclusion of 50 mg DL-α-tocopherol acetate/kg DM was at an intermediate level of efficiency in reduction of lipid oxidation, with 2.3 extra days of shelf life before levels of lipid oxidation could be considered perceptible in comparison with those of control treatment.

4. Discussion

The diets supplied to the animals consisted of the same chemical composition, being different only in relation to the levels of inclusion of vitamin E, which, in turn, did not correspond to changes in the performance of the animals. Kasapidou et al. (2012), working with supplementation of 50, 60, 120, 250 and 450 mg all-rac-α-tocopheryl acetate/day on lamb diet, also did not observe effects of vitamin E supplementation on animal performance.

Kaplan-Meier model was used as a non-parametric model to investigate the probability of occurrence of events (lipid oxidation in the TBARS analyses and moment of rejection by consumers) in the meats submitted for analysis. Through the data analyzed using this model it was possible to observe (Figs. 1 and 2) that there were some effects of treatments. However, the model does not distinguish the difference between treatments. Thus, the data were tested with the Exponential, Weibull and Log-Normal probabilistic models to find among these three what would be the best fit for the data to build the survival curve upon. In Table 2, it can be observed that of the three proposed models, the Weibull model presented the lowest values of − logL in both treatments (TBARS and consumer assessment). Therefore, this model (Weibull) was used to construct the survival curve of the evaluated data (Figs. 3 and 4).

The critical point that Campo et al. (2006) describes as the TBARS point where the rancid flavor becomes greater than the beef flavor was used as a base parameter to ascertain whether the meats visually analyzed by consumers would be accepted for the same period (days) that took the meats to reach 2 mg of MDA/kg. Additionally, since studies with the TBARS point where the rancid flavor becomes greater than the beef flavor have not yet been performed with goat meat, in order to perform survival analysis, data available for red meat was used as criteria.

Kasapidou et al. (2012) evaluated the effect of including vitamin E in diets for Suffolk-Charolais lambs and observed an increase in lipid oxidation (TBARS mg/kg muscle) during the simulated retail sale of meat from animals that received concentrate and diets with low vitamin E (30 and 60 mg), reporting 2.425 and 1.976 mg MDA/kg at six days of exposure, respectively, when compared with the meat from animals fed by diets with higher vitamin E levels — 120, 250, and 500 mg —, which showed 0.564, 0.186, and 0.072 mg MDA/kg at six days of simulated retail sale, respectively. Karami et al. (2011) reported decreased lipid oxidation in the meat from Kacang kids consuming diets supplemented with 400 mg DL-α-tocopherol acetate/kg DM, stored for 14 days, with values below 1.8 mg MDA/kg, whereas control diet showed MDA values near 2 mg/kg.

Although the available sources report results similar to those observed here, in which lipid peroxidation decreased while shelf life of meats from animals fed with diets with higher levels of vitamin E increased, MDA values for treatments with high vitamin E inclusion (above 400 mg/kg DM) obtained by Kasapidou et al. (2012), Karami et al. (2011), and Ripoll et al. (2011) during simulated retail sale periods of 6, 14, and 13 days, respectively, did not exceed 2 mg MDA/kg, with the maximum level of vitamin E inclusion (450 mg/kg DM) resulting in 9.4 days of storage and MDA amounts higher than the 2 mg/kg indicated as ideal for consumption (Campo et al., 2006). This discrepancy in oxidation time is mainly due to the adopted method of meat conditioning, as in these tests, modified atmosphere packaging was used, which provides greater control over the effects of O_2 in the color and oxidative reactions of the meat.

In Brazil, the use of modified atmosphere packaging in the sale of meats is not common yet, mainly because of its high cost; consequently, meat is sold in retail shops in EPS trays covered with plastic wrap. This fact justifies the adoption of this packaging method in the present study, which aimed to investigate the oxidation values during the storage of meats under similar conditions to those adopted in the sale of meats in Brazil. Likewise, evaluations performed visually by consumers demonstrate a longer shelf life for meats as the inclusion levels of vitamin E in diet are increased. Vitamin E inclusion level that provided the best and the highest visual appreciation was 450 mg/kg DM, followed by 150 and 50 mg/kg DM and the control diet.

The results showed that visual assessment performed by consumers indicated an approximately 8.97%, 21.98%, and 28.28% longer acceptance for meats from animals fed with diets supplemented with 50, 150, and 450 mg vitamin E, respectively, when compared with the shelf life of the meats from animals fed with the control diet. Visual appearance of fresh meat is the aspect of greatest relevance in the consumer's decision to purchase meat and meat products, since surface discoloration can be interpreted as indicative of a product unsuitable for consumption (Macit et al., 2003). Meat color is a characteristic that the consumer evaluates at the moment of purchase and that indirectly determines its shelf life, which makes it a basic criterion in one's choice (Pinheiro et al., 2009).

As the time passes and due to contact with air (O_2), the oxymyoglobin is gradually oxidized. This oxidation transforms myoglobin molecule into metmyoglobin, which has a brown color and a rancid flavor, which are both characteristics rejected by consumer at the time of purchase. According to this study, the presence of vitamin E in the meats was efficient in delaying oxymyoglobin oxidation, because it is a strong cell membrane antioxidant.

If we compare different evaluation methods, TBARS showed to be

more precise in evaluation of oxidation of goat meat. As the inclusion levels were increased, fewer discrepancies were observed between median values (days) of evaluation days. Only for treatment with the inclusion of 450 mg/kg DM there was some similarity between shelf lives of meats evaluated by both methods, while in the other treatments, TBARS showed lower values in days for the evaluation of shelf life: 6.59%, 32.05%, and 54.93% shorter shelf lives for the meats from animals fed with 150 and 50 mg vitamin E/kg DM and control diet, respectively.

Thus, it has been observed that meats resulting from treatments with lower inclusion of vitamin E in animal diets, still showed visually acceptable features that could lead to a positive purchase decision when evaluated by consumers, although laboratory test indicated that they had already reached 2 mg MDA/kg of lipid peroxide, which is recognizable to the taste. One of the possible reasons for lower perception of lipid oxidation during visual assessment based on the darkening of meat, may be due to the lower amount of intramuscular and subcutaneous fat in goat meat compared with meat from other ruminants (Lawrie, 2005) and also because meats from younger animals with lower proportion of fat were used (Lawrie, 2005; Zapata, Nogueira, & Seabra, 2003).

5. Conclusions

Inclusion of 450 mg vitamin E/kg DM in diets for Boer-Saanen goat kids slows the lipid oxidation of their meat according to both methods used for evaluation in this study, providing a 28.28% longer period of acceptance of meats.

TBARS method appears to be more accurate for the evaluation of lipid oxidation than the visual assessment performed by consumers, which allowed the saturation threshold of 2 mg malonaldehyde/kg of meat to be reached earlier under all off the tested vitamin E inclusion levels.

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