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Feeding systems and tocopherol level in the diet and their effects on the quality of lamb meat: a meta-analysis

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ABSTRACT - The objective of the present study was to evaluate, through a meta-analysis, the effects of feeding systems and tocopherol levels found in the diet of lambs on qualitative characteristics of their meat. A search of the computerised literature in Science Direct databases, PubMed, Scopus, and SciELO virtual library was carried out to select works that evaluated the quality of lamb meat. As a first requirement for inclusion in the meta-analysis, articles were selected with the keywords "tocopherol", "meat", and "lamb". The variables extracted from the articles were classified according to the type of feeding system and tocopherol level in the diet of lambs. Production systems alter the qualitative characteristics of meat. Lambs raised exclusively on pasture present a higher tocopherol concentration in their meat, a lower omega 6:omega 3 ratio, a lower omega 6 concentration, and a higher conjugated linoleic acid concentration. Regardless of the dietary systems, when we classify the tocopherol levels of lamb diet, the tocopherol concentration and fatty acid level are altered by tocopherol levels in the diet. The lower tocopherol level in the diet results in meat with lower tocopherol concentration and with greater propensity to lipid oxidation.

Keywords: antioxidant, concentrated, omega 3, oxidative stress, pasture

Introduction

The search for healthier foods with a longer shelf life has attracted the interest of both consumers and the food industry. Due to the behavioural modifications of the consumer population, the offer of products considered as healthy has led several researchers to try to manipulate the composition of foods, especially those related to cardiac problems (Ítavo et al., 2016). Extending the shelf life of meat by delaying oxidative deterioration is an important goal in the meat supply chain (Luciano et al., 2009).

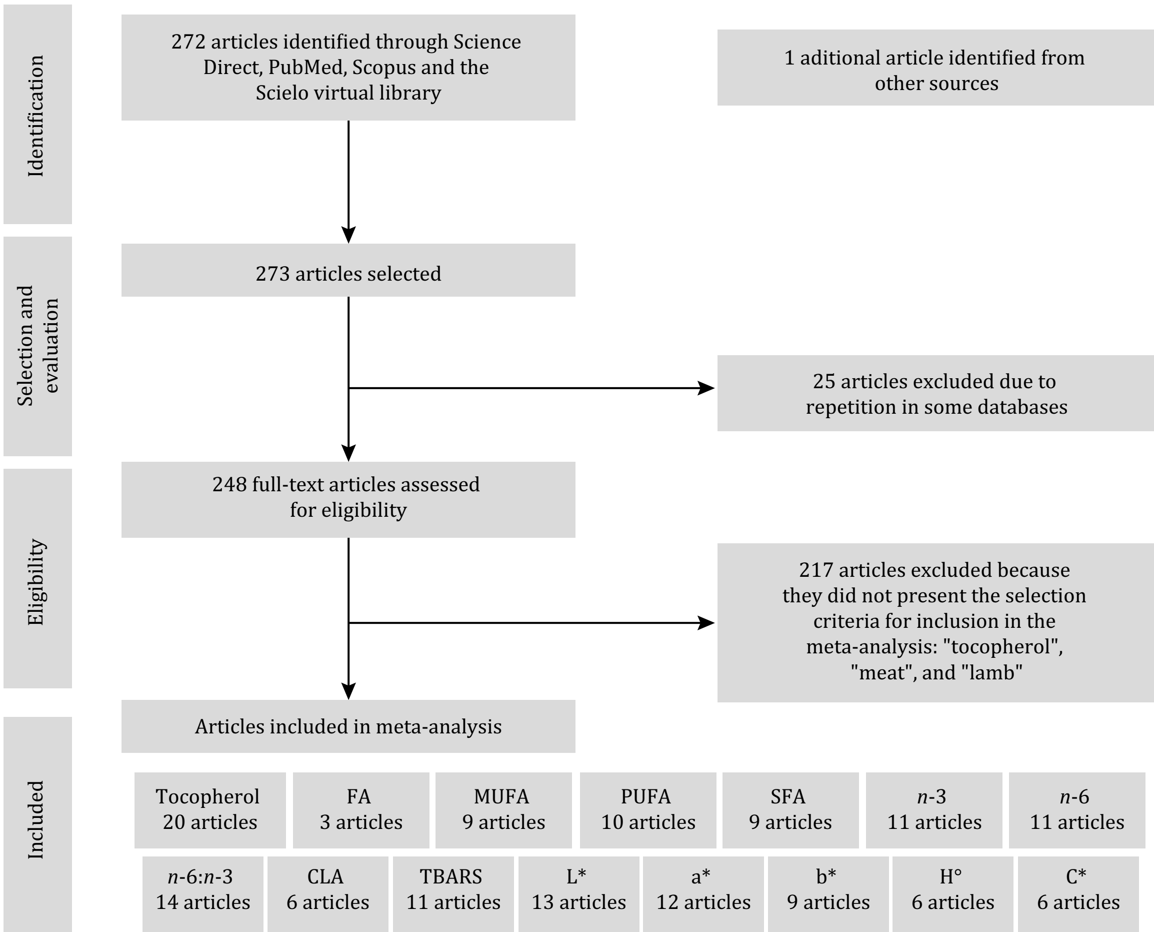
The search for healthier foods has led researchers in meat science to characterise the lipid profile of these foods. Shelf life attributes, such as colour stability and oxidation of meat fatty acids, are influenced by the composition of muscle tissues, which, in turn, are governed by antioxidant capacity, haem pigment (haem iron) concentration, and lipid concentration and composition found in muscles. All these characteristics are linked to the feed given to animals (Papuc et al., 2017; Luciano et al., 2009).

Tocopherol is an antioxidant that plays an important role as an inhibitor of the oxidation of free radicals and makes it retarding to convert unsaturated fatty acids into aldehydes (Lobo et al., 2010). These reactions result in changes in colour and loss of taste and nutritional value, thus limiting the shelf life of the meat (Luzia and Jorge, 2009). The addition of tocopherol to diet of lambs, via either pasture or supplementation, may maintain the desirable red colour of the meat in nature on display at a retail store. The protective effect of tocopherol is exerted by retarding the oxidation of the oxymyoglobin pigment and inhibiting the oxidation of polyunsaturated fatty acids (PUFA) (González-Calvo et al., 2015).

Previous studies have reported the benefits of tocopherol in the quality and maintenance of lamb meat quality. However, not all studies evaluate the variables associated with meat quality within the scope of tocopherol level in the diet and types of diet. Therefore, it is important to carry out a study to assess the effects that compiles several studies to obtain novel information concerning the effects of tocopherol level and type of diet on various aspects of meat quality. In such cases, meta-analysis is a valuable tool. Thus, the objective of the present study was to evaluate the effects of feeding systems as well as tocopherol levels in the diet on qualitative characteristics of lamb meat using a meta-analysis.

Material and Methods

A literature search was conducted in multiple databases, including Science Direct, PubMed, Scopus, and SciELO virtual library, to select studies that evaluated the quality of lamb meat regarding the tocopherol content in the diet of lambs and type of feeding offered to them. This review was conducted in four stages: identification, selection, evaluation of eligibility, and inclusion, as recommended in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009) (Figure 1).



FA - total fatty acid content; MUFA - monounsaturated fatty acid content; PUFA - polyunsaturated fatty acid content; SFA - saturated fatty acid content; *n*-3 - fatty acid content of omega 3; *n*-6- fatty acid content of omega 6; CLA - conjugated linoleic acid content; TBARS - thiobarbituric acid reactive substances, six days of storage; L* - brightness; a* - redness; b* - yellowness; H° - hue angle; C* - chroma.

Figure 1 - PRISMA flowchart.

Combinations of the search terms “tocopherol”, “meat”, and “lamb” were used in the research. The selected articles were published between 2007 and February, 2018. After the search, 272 articles were found, and the work of Turner et al. (2002), which aided in the classification of levels, described below, was also added to the database. The 25 articles were repeated in some database. After this first selection, the abstracts of these 248 articles were read, in which the first requirement for inclusion in the meta-analysis was to find the keywords “tocopherol”, “meat”, and “lamb”. The selected papers were read in full for a second stage of selection, according to pre-defined eligibility criteria, and after this stage, 31 studies were selected for the meta-analysis.

The information extracted from articles was organised in a spreadsheet. The tocopherol concentration in the diet and types of feed offered to lambs were included in the analysis. We used variable responses extracted from the articles in the meta-analysis (Table 1). Among them are the tocopherol and fatty acid concentrations, as well as characteristics of lamb, including meat tocopherol content (Tocopherol), total fatty acid (FA) content, monounsaturated fatty acid (MUFA) content, polyunsaturated fatty acid (PUFA) content, saturated fatty acid (SFA) content, fatty acid content of omega 3 (*n*-3) and omega 6 (*n*-6) groups, *n*-6:*n*-3 ratio, conjugated linoleic acid (CLA) content, thiobarbituric acid reactive substances (TBARS) – six days of storage, brightness (L*), redness (a*), yellowness (b*), hue angle (H°), and chroma (C*).

Data from the different articles were classified according to the feeding system used and tocopherol level found in the diet. In the first classification, data were grouped according to one of three types of feeding system: pasture (animals kept exclusively on pasture); concentrated (animals kept exclusively receiving some type of concentrate with a small addition of roughages); and pasture + concentrated (animals kept in the pasture or silage receiving some type of concentrate). In the second classification, data were grouped according to tocopherol levels found in the diet of lambs: level 1 (animals receiving up to 200 mg kg^{-1} DM in the diet), level 2 (animals receiving 201 to 400 mg kg^{-1} DM), and level 3 (animals receiving above 400 mg kg^{-1} DM tocopherol in their diet). The classification of tocopherol levels in lamb diet was based on the work of Turner et al. (2002), who reported that tocopherol levels above 400 mg kg^{-1} reach a plateau, and more tocopherol is not accumulated in the meat. Therefore, we used levels up to 400 mg kg^{-1} as an intermediate level and included a level above (more than 400 mg kg^{-1}) and another below (up to 200 mg kg^{-1}).

The analyses were made according to the following general mathematical model:

$$\gamma ijk = \mu + Ti + aj + \varepsilon ijk,$$

in which γijk = dependent variables, μ = mean of all observations, Ti = fixed effect of feeding systems or tocopherol levels, aj = random effect of articles, and εijk = random residual error.

After the normality test of the residues, a variance analysis was performed using the MIXED procedure in the SAS program (Statistical Analysis System, version 9.4). A test of selection of structures was made using the Bayesian information criterion, from which the structure “variance component” (VC) was selected. When differences were observed, the means were compared using the LSmeans. The significance was established at P-value = 0.05, whereas probability values between 0.05 and 0.10 were considered as tendency. In addition, Pearson correlation analysis as well as multiple regression using the STEPWISE procedure (Forward = 0.05) were also conducted. The variables CLA and omega *n*-6:omega *n*-3 ratio were transformed via $\log^{10}$, because they did not show normality. For the variables b*, H°, and C* of colour, we only performed the comparison between pasture and concentrate, by the absence of values for the mixed classification (concentrate + pasture). For the variable b* of colour, when compared with tocopherol levels, we only performed the comparison between level 1 and level 3, due to the absence of values for the intermediate level (level 2).

Results

Grazing, as an option for increasing α-tocopherol of muscle of lambs kept exclusively on pasture, is 38.04% higher compared with the other feeding systems (2.54 mg kg^{-1}; Table 2; $P<0.05$). The proportion

Table 1 - Description of the primary studies included in the meta-analysis

Study[1]	Country	Feeding system	Observed variable
Álvarez et al., 2014	Spain	Concentrated Pasture	L*, a*, b*, C*
Bellés et al., 2018	Spain	Concentrated -	Tocopherol, MUFA, PUFA, SFA, *n*-6, *n*-3, *n*-6:*n*-3
Berthelot et al., 2014	France	Concentrated -	FA, MUFA, SFA, *n*-6, *n*-3, *n*-6:*n*-3, CLA
Bhatt et al., 2015	India	Concentrated Pasture	MUFA, PUFA, SFA, *n*-6:*n*-3, CLA, TBARS
Brito et al., 2017	Australia	- Pasture	Tocopherol, *n*-6:*n*-3, TBARS
González-Calvo et al., 2014	Spain	Concentrated -	Tocopherol, MUFA, PUFA, SFA, *n*-6, *n*-3, *n*-6:*n*-3, TBARS, CLA, L*, a*, b*
D'Alessandroa et al., 2012	Italy	Concentrated Pasture	Tocopherol, TBARS
Hopkins et al., 2013	Australia	- Pasture	Tocopherol
Jose et al., 2016	Australia	Concentrated Pasture	Tocopherol
Kasapidou et al., 2012	United Kingdon	Concentrated Pasture	Tocopherol, *n*-6, *n*-3, *n*-6:*n*-3, TBARS, CLA
Lee et al., 2007	United States	Concentrated -	Tocopherol
Liu et al., 2013	China	Concentrated -	Tocopherol, MUFA, PUFA, SFA, *n*-6, *n*-3, *n*-6:*n*-3
Lobón et al., 2017	Spain	Concentrated Pasture	Tocopherol, L*, a*, b*, H°, C*
Milewski et al., 2014	Poland	- Pasture	Tocopherol, FA, MUFA, PUFA, SFA, *n*-6, *n*-3, *n*-6:*n*-3, CLA
Morán et al., 2012a	Spain	Concentrated -	L*, a*, b*
Morán et al., 2012b	Spain	Concentrated -	TBARS
Morán et al., 2013	Spain	Concentrated -	MUFA, PUFA, SFA, *n*-6, *n*-3, *n*-6:*n*-3, CLA
Muela et al., 2014	Spain	Concentrated -	TBARS, L*, H°, C*
Muíño et al., 2014	Spain	Concentrated -	Tocopherol, MUFA, PUFA, SFA, *n*-6, *n*-3, *n*-6:*n*-3, TBARS
Ortuño et al., 2015	Spain	Concentrated -	TBARS, L*, a*, H°, C*
Petron et al., 2007	Belgium	- Pasture	Tocopherol, TBARS, L*, a*, b*
Ponnampalam et al., 2012a	Australia	- Pasture	Tocopherol, FA, PUFA, *n*-6, *n*-3, *n*-6:*n*-3, TBARS

Continues...

Table 1 (Continued)

Ponnampalam et al., 2012b	Australia	Concentrated Pasture	Tocopherol, PUFA, *n*-6, *n*-3, *n*-6:*n*-3, a*
Ponnampalama et al., 2016	Australia	Concentrated Pasture	Tocopherol, *n*-6:*n*-3
Ripoll et al., 2011	Spain	Concentrated Pasture	TBARS, L*, H°
Ripoll et al., 2013	Spain	Concentrated Pasture	Tocopherol, TBARS, L*, a*, b*, H°, C*
Sales et al., 2013	Brazil	Concentrated -	L*, a*, b*
Simitzis et al., 2013	Greece	Concentrated -	FA, L*, a*
Turner et al., 2002	United States	Concentrated Pasture	Tocopherol
Vieira et al., 2012	Spain	Concentrated -	Tocopherol, MUFA, PUFA, SFA, *n*-6, *n*-3, *n*-6:*n*-3, TBARS, L*, a*, b*
Yagoubia et al., 2018	Tunisia	Concentrated -	Tocopherol, *n*-6:*n*-3, TBARS, L*, a*, b*, H°, C*

FA - total fatty acid content; MUFA - monounsaturated fatty acid content; PUFA - polyunsaturated fatty acid content; SFA - saturated fatty acid content; *n*-3 - fatty acid content of omega 3; *n*-6 - fatty acid content of omega 6; CLA - conjugated linoleic acid content; TBARS - thiobarbituric acid reactive substances, six days of storage; L* - brightness; a* - redness; b* - yellowness; H° - hue angle; C* - chroma.
[1] List of references used for the meta-analysis and the variable responses extracted from the articles.

of forage in the diet of lambs receiving concentrate + pasture was not sufficient to alter the deposition of tocopherol in their meat (Table 2; P>0.05).

There were no significant differences (P>0.05) among type of feeding systems on the groups of FA according to saturation degree (Table 2). Type of feeding systems only affected MUFA, *n*-6, and *n*-6:*n*-3 (P<0.05; Table 2). Lambs from the pasture feeding systems had meat with less *n*-6 and lower *n*-6:*n*-3 ratio (Table 2). Lambs from the pasture + concentrated feeding systems had meat with greater MUFA (P<0.05; Table 2).

The inclusion of pasture in the diet of lambs influences the CLA concentration in the meat (Table 2). Lambs of pasture or pasture + concentrated systems showed a proportion of CLA that was three times higher (P<0.05; Table 2) than lambs consuming exclusively concentrated.

Lipid peroxidation of meat is measured by the content of TBARS. There were no significant differences (P>0.05) among type of feeding systems on TBARS, with a mean of 0.48 mg of malonaldehyde kg^{-1} (Table 2). The lambs of pasture feeding systems presented greater L* and b* values (P<0.05), and a tendency of greater of C* value (P = 0.0840) in the meat, when compared with the other feeding systems (Table 2).

Meta-analysis showed that the tocopherol content of the feeding has an influence on the tocopherol content in lamb. This influence may be affected by the different tocopherol levels found in the feeding systems. As expected, the tocopherol content in lamb meat is lower when the dietary content is less than 200 mg kg^{-1} DM (level 1; Table 3). However, when tocopherol levels in the feed are above 400 mg kg^{-1} DM, there is no significant increase in the concentration of alpha-tocopherol in the meat. The highest tocopherol concentration in the diet was observed at level 2 (200 to 400 mg kg^{-1} DM; Table 3).

Most of the FA groups according to the degree of saturation were not affected by tocopherol level in the diet (Table 3). The tocopherol level only affected the FA and MUFA (P<0.05; Table 3). The FA content

Table 2 - Attributes of meat of lambs from different feeding systems

Variable	Feeding system			P[1]	SE	n[2]
	Pasture	Concentrated	Pasture + concentrated			
Alpha-tocopherol (mg kg^{-1})	4.10a	2.45b	2.63b	0.0003	0.25	67
FA (%)	43.85	37.88	44.17	0.6828	4.47	14
SFA (%)	51.98	46.27	42.01	0.4400	4.53	31
MUFA (%)	41.33b	41.55b	48.34a	0.0260	2.95	31
PUFA (%)	5.70	6.23	7.65	0.5040	1.35	34
n-6 (%)	2.52b	6.14a	4.02ab	0.0431	1.15	41
n-3 (%)	1.23	1.52	0.83	0.2904	0.35	41
n-6:*n*-3	1.88b	5.71a	4.84a	0.0003	0.74	53
CLA	0.85a	0.24b	0.76a	0.0118	0.15	22
TBARS (mg of malonaldehyde kg^{-1})	0.23	0.94	0.29	0.1241	0.35	51
L*	58.77a	43.16b	31.32c	0.0005	4.65	38
a*	10.33	9.34	12.40	0.1553	1.54	30
b*	15.04a	10.90b	-	0.0001	0.51	21
H°	51.70	35.18	-	0.3666	12.31	18
C*	15.63	13.13	-	0.0840	0.91	16

FA - total fatty acid content; MUFA - monounsaturated fatty acid content; PUFA - polyunsaturated fatty acid content; SFA - saturated fatty acid content; *n*-3 - fatty acid content of omega 3; *n*-6 - fatty acid content of omega 6; CLA - conjugated linoleic acid content; TBARS - thiobarbituric acid reactive substances, six days of storage; L* - brightness; a* - redness; b* - yellowness; H° - hue angle; C* - chroma; SE - standard error.
[1] Probability.
[2] Number of repetitions.
a,b - Values within a row with different letters differ significantly at P<0.05.
For the variables yellowness (b*), hue angle (H°), and chroma (C*) of colour, when compared to feeds, we only have the comparison between pasture and concentrate, by absence of values for the mixed classification (concentrate + pasture).

Table 3 - Attributes of lamb meat for three tocopherol levels in the diet

Variable	Level			P[1]	SE	n[2]
	Level 1 0-200 mg kg^{-1} DM	Level 2 201-400 mg kg^{-1} DM	Level 3 > 400 mg kg^{-1} DM			
Alpha-tocopherol (mg kg^{-1})	1.97b	4.35a	2.85c	0.0003	0.27	67
FA (%)	27.38b	35.13ab	68.38a	0.0446	8.49	14
SFA (%)	48.01	47.39	44.52	0.8312	5.05	31
MUFA (%)	42.38ab	47.83a	41.02b	0.1196	2.06	31
PUFA (%)	6.05	6.10	7.43	0.6538	1.44	34
n-6 (%)	4.50	4.56	3.62	0.7926	1.23	41
n-3 (%)	1.31	1.53	0.73	0.2736	0.34	41
n-6:*n*-3	4.04	2.69	5.70	0.0905	0.85	53
CLA	0.52	0.66	0.66	0.7447	0.16	22
TBARS (mg of malonaldehyde kg^{-1})	1.26a	0.54ab	0.27b	0.0018	0.38	51
L*	45.05	41.79	46.41	0.7641	3.91	38
a*	10.14	12.24	9.70	0.7306	1.69	30
b*	9.22	-	8.83	0.5777	0.47	21
H°	40.11	34.41	55.85	0.1948	13.04	18
C*	14.69	13.05	15.76	0.2779	1.07	16

FA - total fatty acid content; MUFA - monounsaturated fatty acid content; PUFA - polyunsaturated fatty acid content; SFA - saturated fatty acid content; *n*-3 - fatty acid content of omega 3; *n*-6 - fatty acid content of omega 6; CLA - conjugated linoleic acid content; TBARS - thiobarbituric acid reactive substances, six days of storage; L* - brightness; a* - redness; b* - yellowness; H° - hue angle; C* - chroma; SE - standard error.
[1] Probability.
[2] Number of repetitions.
a,b - Values within a row with different letters differ significantly at P<0.05.
For the variable yellowness (b*) of colour, when compared to tocopherol levels, we only have the classification between level 1 and level 3, due to the absence of values for the intermediate level (level 2).

in lamb meat increases as the tocopherol levels ingested by lambs in the diet increase; the highest FA content was observed when the animals received supplementation with more than 400 mg kg^{-1} DM (level 3; Table 3). The lambs from the level 2 (201-400 mg kg^{-1} DM) had greater MUFA ($P<0.05$; Table 3). That could be related to the higher tocopherol concentration of meat (Table 3), which could prevent oxidation of two MUFA.

The lipid oxidation, measured as TBARS, was significantly altered by the tocopherol level in the diet ($P<0.05$; Table 3). We observed a correlation between decreasing TBARS and increasing tocopherol dose in the diet ($P = 0.0022$; $r = -0.41$). The tocopherol level in diet did not affect the colour variables of meat ($P>0.05$; Table 3).

Discussion

Grazing is an option for increasing alpha-tocopherol muscle content, as green forages are rich in this compound (Ripoll et al., 2013; Jose et al., 2016). The type of tocopherol that the feeding system made available may have been related to the tocopherol concentration in lamb meat because, according to Ponnampalam et al. (2012a), who kept the lambs in a perennial pasture or in an annual pasture and fed a concentrated diet, a higher alpha-tocopherol concentration was found in the muscle of lambs kept in the perennial pasture. This result is because animals in perennial pastures ingested greater amounts of alpha-tocopherol and lambs kept in the annual pasture in senescence and received the concentrated diet ingested more gamma-tocopherol. The alpha-tocopherol form is most prevalent in different tissues of animals and humans. In fact, there is a preference for the absorption of alpha-tocopherol in relation to gamma-tocopherol in the peripheral system of the body (Ponnampalam et al., 2012a).

The pasture + concentrated feeding systems resulted in lamb meat with greater MUFA concentration, because there may have been a higher rate of passage of these fatty acids through the rumen with the mixed feed, and also because they are less prone to lipid oxidation (Díaz et al., 2011).

The lower values of n-6 fatty acids in the meat of lambs fed in pasture systems may be related to a lower concentration of this lipid in plants, and consequently, a lower accumulation of intramuscular lipids in animals (Popova et al., 2015). The ability of PUFA to be incorporated into phospholipids is limited, and *n*-6 fatty acids compete more efficiently than *n*-3 fatty acids (Wood et al., 2008). The *n*-6:*n*-3 ratio in the meat of lambs raised exclusively on pasture (1.88) is within the limits recommended by Simopoulos (2002), 4:1, to be beneficial to human health.

The inclusion of pasture in the feeding of lambs improves the proportion of CLA in meat. Boughalmi and Araba (2016), working with three feeding systems, also found that grazing animals, with or without supplementation, showed a higher CLA concentration (0.88 g 100 g^{-1}) than animals receiving concentrate exclusively (0.51 g 100 g^{-1}). This result can be explained by the fact that when ruminants consume pasture, it includes PUFA, which are later biohydrogenated in the rumen and transformed into vaccenic acids, which are later the precursor to CLA (Hajji et al., 2016). The CLA concentration provides benefits to human health (Salter and Tapper, 2013).

In this meta-analysis, it was found that the *n*-6 concentration in the diet was the main cause of the variation of *n*-6:*n*-3 ratio in lamb meat. There was no effect of dietary systems on the concentration of omega-3 (n-3) family of fatty acids (Table 2), which contradicts trends that have been reported in the literature and indicates that there is a higher *n*-3 concentration in meat of ruminant animals when they are fed exclusively on pasture (Cividini et al., 2014). This disagrees with previous reports that indicate that there is a higher *n*-3 concentration in meat of ruminant animals fed exclusively on grazing-based systems.

The stability of fatty acid oxidation of meat is influenced by the composition of muscle tissues, which is tightly related to feed offered (Daley et al., 2010). Hajji et al. (2016) found an important effect of feeding system on lipid oxidation. Animals kept on pasture showed lower TBARS concentrations. Popova et al.

(2015) worked with data from a meta-analysis and also did not find a significant effect of feeding system on the total lipid content.

Pasture systems change the colouring of lamb meat. Atti et al. (2013), working with lambs, also found higher values of b* in the colouration of meat of lambs grazing vs. those fed concentrate. Grazing animals consume a greater proportion of antioxidants that contribute to increases in the haeminic pigments, changing the colour and brightness of lamb meat (Costa et al., 2011). The darker colouration of the meat of grazing animals can be related to the increase of myoglobin in the muscle, justified by the greater physical activity of these animals (Perlo et al., 2008).

The tocopherol content of meat may have an absorption limit to the inclusion of tocopherol in the diet with an effect on the tocopherol concentration in the muscle. This result was also found by Turner et al. (2002) who, working with different alpha-tocopherol levels in the diet, found a quadratic equation regarding dose and muscle concentration. They reported that a plateau occurs where the highest tocopherol concentration in the diet occurred when the animals received 403 mg kg^{-1} DM. However, the duration of dietary supplementation may influence the deposition of alpha-tocopherol. In general, higher tocopherol content in the diet or longer supplementation time are associated with higher tocopherol concentrations in the meat (Ripoll et al., 2013).

The higher tocopherol level in the diet resulted in higher FA concentration in the meat. Berthelot et al. (2014), working with levels similar to those found in this analysis, reported that when lambs received the highest tocopherol levels in the diet, they tended to have a higher FA concentration in the muscle.

The level 2 of tocopherol in diet resulted in a meat with greater MUFA. Liu et al. (2013), working with different tocopherol supplementation levels in the diet, stated that there is an effect of tocopherol levels in the diet of lambs in MUFA, PUFA, and SFA concentrations in the meat. In our review, the meta-analysis shows that dietary tocopherol levels do not influence PUFA and SFA concentrations.

The meta-analysis shows that there is no significant effect of tocopherol levels on omega-6 and omega-3 concentrations, and on the *n*-6:*n*-3 ratio in meat (P>0.05; Table 3). Because tocopherol is mainly present in green pastures and that grass-fed animals have a lower *n*-6:*n*-3 ratio than animals fed concentrate, it was expected that the tocopherol in the diet could influence the omega-6 and omega-3 levels (Mapiye et al., 2012). However, this variation of the unsaturated fatty acids is influenced by different factors, among them the finishing of the animal. Due to the different variations that occurred between the studies, it was not possible to determine the differences between tocopherol levels.

Although the CLA content was influenced by feeding system to which the lambs were subjected (Table 2), the CLA content is not associated with the tocopherol concentration in the diet (P>0.05; Table 3). Although there was a higher tocopherol concentration in the pasture, this did not influence in an effective manner to improve the amount of CLA in the meat. Even though CLA is primarily a product of ruminant animals, produced from bacteria present in their ruminal environment, and since the tocopherol level does not alter ruminal bacteria, the CLA content was similar between levels (Table 3).

The lipid oxidation decreases with increasing tocopherol dose (Kasapidou et al., 2009). Even though the level of lipid oxidation at level 1 showed the highest TBARS concentration, this value only exceeded slightly the accepted threshold value of 1 mg MDA kg^{-1} in meat (Ripoll et al., 2011).

The tocopherol level in the diet did not affect meat colour. Ripoll et al. (2013) used different doses on different days with 500 mg tocopherol day^{-1} and found no difference in colour. This result shows that tocopherol in the diet does not affect the colouring of the meat. All lambs displayed average L* values of 40, indicating a light-coloured and acceptable meat (Hajji et al., 2016).

Conclusions

Feeding systems alter the qualitative characteristics of meat. Lambs exclusively raised on pasture present higher tocopherol concentrations, lower omega-6:omega-3 ratio, lower omega 6, and higher conjugated linoleic acid concentration in their meat. Regardless of dietary systems, tocopherol levels alter the tocopherol concentration in meat. The lower tocopherol level in the diet results in a meat with lower tocopherol concentration and with greater propensity to lipid oxidation.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

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