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Influence of different production systems on the sensory attributes, fatty acid composition and vitamin E concentration in meat from intact male lambs

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Sensory attributes, fatty acid composition and vitamin E concentration of meat from intact male lambs reared in four different production systems were analysed. The production systems were: I) indoor feeding with silage and concentrate; II) cultivated pasture; III) cultivated pasture with concentrate supplement; and IV) semi-natural pasture. Meat from lambs reared on semi-natural pasture tended to have stronger hay odour (p= 0.052) and leafy flavour (p= 0.078) than lamb meat from the production systems involving cultivated pasture and indoor feeding. Resistance to cutting was lower (p= 0.032) for meat from lambs reared on cultivated pasture without supplementary concentrate compared to cultivated pasture with supplemented concentrate. Production system resulted in a tendency for difference in the ratio between saturated and unsaturated fatty acids. The ratio between n-6 and n-3 was affected by production system (p< 0.0001) where the indoor feeding with silage and concentrate had a higher ratio (2.64) than the other groups (cultivated pasture plus concentrate=1.96, cultivated pasture=1.45 and semi-natural pasture=1.41). No other differences were found regarding fatty acid composition. Vitamin E concentration was higher (p< 0.0001) in all three pasture groups compared to the indoor feeding with silage and concentrate.

Key words: odour, flavour, tenderness, pasture, silage, concentrate

Introduction

Consumers usually determine meat quality by its eating quality with tenderness, juiciness and flavourbeing the most important attributes for beef (McIlveen and Buchanan 2001) and flavour, tenderness and juiciness the most important for lamb (Young et al. 1997, Pethick et al. 2006). The reason why flavour is the most important sensory attribute for lamb could be due to the characteristic flavour and odour associated with lamb and sheep meat (Young et al. 1994). It is important to identify whether the flavour of lamb can be affected by the production system. Many different factors from farm to fork, such as breed, feed components, slaughter method and cooking method, affect the eating quality of lamb meat (Sañudo et al. 1998). The eating quality of Swedish lamb meat is reported to vary (Carlsson and Arvidsson Segerkvist 2018), which might be due to the use of different production systems, breeds, gender, age at slaughter and slaughter weights, all of which can affect the sensory attributes of the meat. Differences between castrated and intact male lambs have been reported, with intact male lambs receiving higher scores for undesirable flavour and aroma attributes that may become more pronounced with increasing age (Gkarane et al. 2017). As only a small proportion of Swedish male lambs are castrated (castrated lambs are companion animals rather than production animals) it is critical to determine the sensory profile of meat from intact male lambs. Different feeding strategies involving pasture and grain can affect the quality of lamb meat of e.g. flavour (Watkins et al. 2013), so it is important to investigate the influence of rearing system on the sensory profile of the meat. The fatty acid composition of meat highly influences the nutritive aspects and sensory profile of meat. Wang et al. (2015) reported that lambs that spent more time grazing and consumed less concentrate exhibited higher levels of beneficial fatty acids, including conjugated linoleic acid (CLA) and n-3 polyunsaturated fatty acids (PUFAs), resulting in improved n-6/n-3 ratios. When considering the fatty acid composition of meat, storage stability is crucial for the sensory profile. Lauzurica et al. (2005) reported the importance of vitamin E in reducing lipid and protein oxidation. An indirect effect of vitamin E is to influence the aroma profile of meat by reducing oxidation of the fatty acids present (Bellés et al. 2019). The aim of this study wasto determine the effect of different feeding regimes on the sensory properties, fatty acid composition and vitamin E concentration of meat from intact male lambs.

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Materials and methods

Animals and experimental design

A detailed description of the experimental design, including animals, chemical composition and feeding values of experimental feeds, slaughter procedure, carcass characteristics, meat sample treatment and technological meat quality assessments is provided in the first paper in the current series (Stenberg et al. 2020). A total of 32 cross-bred weaned intact ram lambs (Dorset × Fine Wool; 75:25; mean age = 95 days) were assigned at random into four groups of eight animals and assigned to one of four production systems: indoor feeding cultivated pasture with concentrate supplementation or only cultivated pasture without concentrate supplementation, and semi-natural pasture . All animals in the study had *ad libitum* access to water, salt (99.8% sodium chloride whereof 39.3% was sodium and < 0.05 % water) and minerals (Table 1).

Table 1. Mineral composition of mineral block and granulated minerals

Composition	Mineral block[1]	Granulated minerals
Calcium (g kg^{-1} DM)	130	150
Phosphorus (g kg^{-1} DM)	45	45
Ca/P (g kg^{-1} DM)	2.9	3.3
Magnesium (g kg^{-1} DM)	80	80
Sodium (g kg^{-1} DM)	100	90
Sulphur 8 g kg^{-1} DM)	-	5
Vitamin A (IU)	-	3 500 000
Vitamin D (IU)	-	800 000
Vitamin E (mg kg^{-1} DM)	-	55 000[2]
Zinc (mg kg^{-1} DM)	50 000	50 000
Manganese (mg kg^{-1} DM)	40 000	40 000
Iodine (mg kg^{-1} DM)	2000	2000
Cobalt (mg kg^{-1} DM)	400	800
Selenium (mg kg^{-1} DM)	450	60[3]

[1]Mineral block=pasture groups. Granulated minerals=indoor group; [2]of which 1500 mg vitamin E was in natural form; [3]of which 15 mg was selenium yeast

Indoor treatment lambs were offered a total mixed ration (TMR) ad libitum consisting of grass-clover silage and 0.8 kg pelleted concentrate per lamb and day. The TMR was mixed daily in a large tub before feeding the animals to ensure equal mixing. Both cultivated pasture treatment lambs grazed two different enclosed pasture leys of 1.0 ha each divided into three sub-paddocks. In addition to grass, one group on cultivated pasture were given 0.3 kg of pelleted concentrate per lamb and day in feed troughs out on the pasture, on one occasion per day. Semi-natural pasture treatment (lambs were kept on semi-natural pasture. The metabolizable energy content of silage and pasture offered to lambs in groups indoors, cultivated pasture plus concentrate, cultivated pasture and semi-natural pasture was 11±0·3, 12±0.4, 10±0.5 and 12±0.3 MJ kg^{-1} DM, respectively, and the digestible protein content was 126±15·0, 140±27·6, 127±15.8 and 180±69.6 g kg^{-1} DM, respectively. The metabolizable energy and protein concentration of the concentrate was 13 MJ kg^{-1} DM and 185 g kg^{-1} DM, respectively. Lambs were weighed once weekly to determine when each animal was drafted for slaughter at a live weight of approximately 50 kg. Lambs in the cultivated pasture groups were moved to new grazing paddocks in connection to weighing once a week. The slaughter process mimicked the commercial slaughter process of lamb in Sweden as described by Stenberg et al. (2020). Age at slaughter and live weight gain (LWG) per day are shown in Table 2. After slaughter, all carcasses were put in +4 °C until cutting after six days aging time. The indoor and cultivated pasture groups were all reared at SLU Götala Beef and Lamb Research, Swedish University of Agricultural Sciences (SLU), Skara, Sweden (58°42’N, 13°21’E) and the group on semi-natural pasture was kept at a private farm outside Skara, Sweden (58°20’N, 13°26’E). The experiment was approved by the Ethics Committee on Animal Experiments, Gothenburg, Sweden (Registration No. 53-2016).

Table 2. Age at slaughter and live weight gain (LWG) of lambs in the different treatment groups

Parameter	Indoors[1]	Cultivated pasture plus concentrate[2]	Cultivated pasture[3]	Semi-natural pasture[4]	SEM	Significance
Age at slaughter, days	146[a]	163[b]	172[c]	193[d]	3.51	<0.0001
Live weight at slaughter, kg	51.8	50.3	49.2	50.9	0.71	0.096
Days in experiment	62[a]	77[b]	85[c]	108[d]	2.52	<0.0001
Carcass weight, kg	21.6[a]	21.3[a]	20.9[a]	18.8[b]	0.58	0.004
LWG, g day^{-1}	406[a]	315[b]	256[c]	224[d]	12.48	<0.0001

[1]Indoor lambs were reared indoors on silage and concentrate (0.8 kg/lamb/day); [2]Cultivated pasture plus concentrate lambs on cultivated pasture with concentrate (0.3 kg/lamb/day); [3]cultivated pasture lambs on only cultivated pasture; [4]Semi-natural pasture lambs on only semi-natural pasture; SEM = standard error of the mean; [a-d]Mean values within rows with different superscripts differ significantly (p< 0.05)

Meat sample handling and preparation

After six days of ageing at +4 °C, samples of *Musculus longissimus thoracis et lumborum* (LTL) were excised and immediately frozen and stored at –20 °C until sensory analysis. A sample of approximately 40–60 grams were cut off from the cranial end of the LTL and immediately frozen and stored at –20 °C until analysis of fatty acid composition and vitamin E concentration. For the sensory analysis, the samples were thawed at +4 °C overnight and cooked vacuum-packed in a circulating water bath at 70°C (PolyScience®, Sous Vide Professional™) to an internal temperature of 65.5 ± 1.2 °C, with an average cooking loss of 20.1 ± 2.0%. The cooked samples were chilled at +4 °C overnight and cut into 5-mm slices cut perpendicular to the muscle fibers, using a commercial meat slicer, on the day of sensory evaluation. Two slices per sample were placed in petri dishes labelled with a three-digit code and held at 70°C (ASCO, Hot Banquet Trolley) for 10 minutes before being served to the panellists in a randomised serving order.

Sensory evaluation

Sensory evaluation was performed using descriptive analysis (Stone and Sidel, 2004). Sample evaluation was carried out by an external panel of six assessors, who were selected and trained according to ISO 3972:2011(E) and SS-EN ISO 8586:2014(E) in a sensory laboratory at Kristianstad University equipped according to SS-EN ISO 8589:2010(E). In four training sessions lasting two hours each, the panel developed descriptions of the appearance and of key sensory attributes (flavour, odour, texture) of the lamb meat samples and reached consensus in evaluation of the selected attributes (Table 3). For initial training, lamb meat from different sources (New Zealand, Ireland and Sweden) was used in order to expose the panellists to different types of lamb meat. Reference materials were used as a help to associate the attribute to what to be assessed, these reference materials were used in training for attributes related to e.g. colour, odour and flavour.

After completion of the training, the 32 samples (n=8 lambs from each of the four treatment groups) were evaluated on five occasions. All samples were evaluated in triplicate and the assessors indicated the intensity of each attribute on a scale ranging from 0 to 100, anchored with 5=low intensity and 95=high intensity, using the software EyeQuestion® (Logic8 BV, The Netherlands). Between sample tests, the panellists cleansed their palate using water, wheat crackers and cucumber.

Ethical considerations

In Sweden, any research involving the processing of sensitive personal data falls under the jurisdiction of the Swedish Ethics Review Act. The present study, which explores perceptions of food, does not involve sensitive personal data as defined by the Data Protection Ordinance. All participants received written and oral information about the test and the contents of the assessed products and gave their informed consent to participate. No information from the questionnaire can be traced to or used to identify any individual participant, in accordance with the General Data Protection Regulation (GDPR).

Table 3. Definitions of the sensory attributes tested in sensory evaluation

Category/type	Attribute	Scale (0–100)	Assessment technique and definition	Reference materials*
Appearance	Pinkness	Low || High	Assessed at the core of the slice, as degree of pinkness	Myoglobin solution heated to 50–80 °C
Appearance	Fibre structure	Fine || Coarse	Determination of structure after ocular examination	Meat cuts with varying fibre structure
Odour	Lamb meat odour	Weak || Strong	Intensity when smelling sample	
Odour	Acidic odour	Weak || Strong	Intensity when smelling sample	
Odour	Hay odour	Weak || Strong	Intensity when smelling sample	Hay, silage and fresh grass, green tea
Texture - hand	Resistance to cutting	Low || High	Assessed on a plate by cutting through the sample at a right angles to the fibres using a knife and fork	
Texture - hand	Softness by compression	Soft || Hard	Assessed on a plate by compressing the meat using the back of a fork	
Texture - mouth	Tenderness	Low || Pronounced	Assessed by chewing three times using molar teeth and rating degree of tenderness	
Texture - mouth	Crumbliness	Low|| High	Crumbly/grainy texture assessed after chewing using molar teeth	
Flavour	Lamb meat flavour	Low || High	Intensity of total lamb meat flavour	
Flavour	Metal flavour	Low || High	Intensity of flavour perception related to iron and blood	
Flavour	Leafy flavour	Low|| High	Intensity of flavour perception related to tea, dried grass	Black tea, green tea
After flavour	Oiliness	Little || Much	Fatty perception, oily film on the palate	

* References served to the panellists as a clear association to the attributes to be assessed

Analysis of fatty acid composition and vitamin E concentration

Lipid extraction was performed by homogenizing the sample with a chloroform and methanol mixture following the method of Bligh and Dyer (1959). Fatty acid composition was analysed using an improved technique, in which fatty acids were esterified with methanol in the presence of sodium hydroxide and catalysed by boron trifluoride. Analysis of the methyl esters was conducted via gas chromatography with a flame ionization detector (GC-FID) using helium as the carrier gas (HP 6890) on a CP-sil 88 column (50 m, ID 0.25 mm, 0.20 lm Chrompack), as described by Jensen (2008). Fatty acid methyl esters (FAMEs) were identified by comparing retention times of FAME standards, and the fatty acids were classified into three major categories: saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs), and polyunsaturated fatty acids (PUFAs).

Statistical analysis

The sensory data obtained were analysed using Proc Mixed in Statistical Analysis Software (SAS) (SAS 9.4), with production system as fixed factor and assessor as random factor, in the model:

$$Y_{ijk} = \mu + P_i + a_j + e_{ijk}$$

Fatty acid and vitamin E data were analysed using a model which included production system (with four sub-classes) included as a fixed effect:

$$Y_{ij} = \mu + P_i + e_{ij}$$

where Yijk and Yij is the dependent variable, μ is the grand mean, Pi is fixed effect of production system, aj is random effect of assessor, and eij and eijk are the residual error (~ N(0, σ2)). A general Satterthwaite approximation for the denominator degrees of freedom was performed, using the SATTERTH option in SAS. Differences were considered significant at $p< 0.05$ and indicative of a tendency at $0.05 \leq p < 0.10$.

Results

Sensory evaluation

The effects of treatments on sensory scores are presented in Table 4. Meat from lambs offered the cultivated pasture treatment had lower resistance to cutting ($p= 0.032$) than meat from cultivated pasture with concentrate treatment. There was a tendency for lambs from the semi-natural pasture to produce meat with a higher leafy flavour ($p= 0.078$) and hay odour ($p= 0.052$). Otherwise treatment had no effect ($p> 0.05$) on sensory scores.

Table 4. Sensory scores obtained in sensory evaluation of meat from the four different production system tested (n=8 for each group)

Parameters	Indoors[1]	Cultivated pasture plus concentrate[2]	Cultivated pasture[3]	Semi-natural pasture[4]	SEM[5]	Significance
Pinkness	46[6]	47	45	46	2.34	NS
Fibre structure	37	35	35	33	1.57	NS
Lamb meat odour	48	48	49	49	1.07	NS
Acidic odour	32	30	31	33	0.97	NS
Hay odour	30	29	29	33	1.07	0.052
Resistance to cutting	37^{ab}	43^{b}	34^{a}	39^{ab}	1.91	0.032
Softness by compressing	55	50	55	54	1.90	NS
Tenderness	60	52	65	61	3.47	NS
Crumbliness	45	41	49	50	3.31	NS
Lamb meat flavour	54	53	54	56	1.16	NS
Metal flavour	39	42	41	43	1.57	NS
Leafy flavour	31	32	33	35	1.17	0.078
Oiliness	34	35	34	36	1.16	NS

[1]Indoor lambs were reared indoors on silage and concentrate (0.8 kg/lamb/day); [2]Cultivated pasture plus concentrate lambs on cultivated pasture with concentrate (0.3 kg/lamb/day); [3]cultivated pasture lambs on only cultivated pasture; [4]Semi-natural pasture lambs on only semi-natural pasture; [5]SEM = standard error of the mean; [6]Scores are on a scale of 1–100 anchored with 5=low intensity and 95=high intensity; [a-b]Mean values within rows with different superscripts differ significantly ($p< 0.05$) or show a tendency for significance at $0.05<p\leq 0.10$; NS: non-significant ($p> 0.10$)

Fatty acid composition and vitamin E concentration

The effect of treatments on intramuscular fat (IMF) content, fatty acid composition and vitamin E concentration are presented in Table 5. Meat from semi-natural pasture treatment had lower IMF content (p= 0.008), C16:0 (p= 0.0014) and the sum of n-6 fatty acids (p< 0.0001) than meat from the other three treatments. Both treatments including concentrate had higher levels of C18:1 n-9 (p< 0.0001) and sum of n-3 fatty acids (p< 0.0001) compared to treatments without concentrate supplementation, semi-natural pasture had lower amount than cultivated pasture treatment. Semi-natural pasture and cultivated pasture treatments all had higher composition of t-11 18:1 (trans vaccenic acid) (p= 0.022) and content of vitamin E (p< 0.0001) in meat compared to the indoor group. Semi-natural pasture treatment had higher content of C18:2 n-6 (p< 0.0001), C18:3 n-3 (p< 0.0001) and sum of other identified fatty acids (see table 4) compared to the other three groups. Indoor treatment had higher ratio between n-6 and n-3 acids (p< 0.0001) than the other three treatments, cultivated pasture with concentrate treatment had higher ratio than both cultivated pasture and semi-natural pasture treatments. Semi-natural pasture had lower concentration of the sum of saturated fatty acids (p= 0.048) compared to cultivated pasture with concentrate and cultivated pasture treatments. Semi-natural pasture treatment tended to have higher sum of unsaturated fatty acids and lowerratio between saturated and unsaturated fatty acids than the other three treatments. Otherwise, treatment had no effect (p> 0.05) on C18:0 and cis-9, t-11 18:2 (CLA).

Table 5. Intramuscular fat (IMF%), fatty acid composition (g FA/100g FA) and vitamin E (µg/g) concentration of meat from the four different production system tested (n=8 for each of group)

Parameters	Indoors[1]	Cultivated pasture plus concentrate[2]	Cultivated pasture[3]	Semi-natural pasture[4]	SEM[5]	Significance
IMF (%)	2.92a	3.53a	2.98a	1.87b	0.32	0.008
C16:0	24.4a	24.6a	23.8a	22.1b	0.45	0.001
C18:0	18.0	18.7	19.0	18.5	0.49	NS
C18:1 n-9	40.7a	40.0a	38.2b	35.0c	0.59	<0.0001
t-1118:1,	2.50a	3.02b	3.14b	3.56b	0.23	0.022
C18:2 n-6	4.22a	3.28b	3.68a	5.40c	0.25	<0.0001
C18:3 n-3	0.92a	1.18b	1.86c	2.60d	0.09	<0.0001
Cis-9, t-11 (CLA)	0.52	0.57	0.60	0.68	0.05	NS
Other FA[6]	8.76ab	8.70a	9.70b	12.2c	0.34	<0.0001
Sum n-6 FA	6.3a	5.30a	5.95a	8.83b	0.42	<0.0001
Sum n-3 FA	2.39a	2.73a	4.12b	6.31c	0.28	<0.0001
n-6/n-3 ratio[7]	2.64a	1.96b	1.45c	1.41c	0.04	<0.0001
Sum SFA	45.2ab	46.2a	45.8a	43.3b	0.74	0.048
Sum UFA	54.6	53.6	54.0	56.4	0.73	0.056
SFA/UFA ratio[8]	0.83	0.87	0.85	0.77	0.03	0.061
Vitamin E	1.51a	2.78b	2.87b	2.91b	0.18	<0.0001

[1]Indoor lambs were reared indoors on silage and concentrate (0.8 kg/lamb/day); [2]Cultivated pasture plus concentrate lambs on cultivated pasture with concentrate (0.3 kg/lamb/day); [3]cultivated pasture lambs on only cultivated pasture; [4]Semi-natural pasture lambs on only semi-natural pasture; [5]SEM = standard error of the mean; [6]Other fatty acids include sum of: C8:0+C10:0+C12:0+C13:0+C14:0+C14:1+C15:0+C16:1n-9+C16:1n-7+C17:1+C18:1n-7+trans10,cis12+C20:0+C20:1n-9+C20:2n-6+C20:3n-3+C20:3n-6+C30:4n-6+C20:5n-3+C22:0+C22:5n-6+C22:5n-3+C22:6n-3; [7]Quotient of the sum of *n*-6 and *n*-3 fatty acids; [8]Quotient of the sum of saturated fatty acids and unsaturated fatty acids; [a-b]Mean values within rows with different superscripts differ significantly (p<0.05) or show a tendency for significance at 0.05 < p≤ 0.10; NS: non-significant (p> 0.10)

Discussion

As lamb meat may be characterised by typical off-flavours (Young et al. 1994), it is a positive finding that the different production systems tested in the present study did not give rise to many differences in lamb meat odour or lamb meat flavour. Previous research has shown that consumers can be broadly divided into two different categories, based on whether they like a milk- or concentrate-related flavour (milk- or grain-fed lamb) or a grass-related flavour (pasture-fed lamb), although a minority of consumers can accept both types of flavour attributes (Sañudo et al. 2007). This finding is interesting since it indicates that lamb meat can be produced in different systems, depending on specific conditions on each individual farm, to suit different consumer preferences. The pastoral flavour associated with meat from lambs grazed on pasture may be unfamiliar to some consumers who are accustomed to eating meat from lambs reared on a diet based on grain, which is characterised by a more neutral flavour profile than meat from pasture-fed lambs (Watkins et al. 2013). In the present study, this was evident as a tendency for a difference in the attributes hay odour and leafy flavour between the groups. For both these attributes, meat from semi-natural pasture lambs was scored as having higher intensities than meat from lambs in the other three groups. Even though the difference was quite small, it was still detectable to the trained panellists. The higher intensities for these attributes may be related to the semi-natural pasture itself, indicating that the flavour of the meat can be affected by the feed through direct transfer of compounds from the digested feed components into the meat (Watkins et al. 2013). The compounds responsible for the specific flavours and odours in lamb meat are often methyl-branched-chain-fatty acids (BCFA), e.g. 4-methyloctanoic acid and 4-methylnonanoic acid (Wong et al. 1975), which are present in large quantities in lamb meat (Mottram 1998). These fatty acids are not included in the fatty acid results in the present study but their effect on sensory properties of lamb meat is however still very important to discuss when considering sensory aspects of lamb meat. In a recent study, 4-methyloctanoic acid was found to be positively correlated with intensity of lamb flavour and intensity of lamb aftertaste, while 4-methylnonanoic was found to be positively correlated with fatty aftertaste (Gkarane et al. 2020). An earlier study found that intact male lambs slaughtered at about 210 days of age, compared with a slaughter age of 80 days, had higher levels of BCFA and elevated levels of 4-methyloctanoic and 4-methylnonanoic acids (Sutherland and Ames 1996). The slaughter age of lambs in the present study ranged from 146 to 193 days on average, which corresponds to between 62 to 108 days in experiment (Stenberg et al. 2020), a range for which no differences in the species-specific lamb flavour/odour attributes have been reported. Based on this, it can be concluded that differences between the groups may not have been primarily caused by fatty acids correlated to more species-specific attributes. It would be interesting to investigate the effect of age differences at slaughter under controlled conditions, in order to identify when/if age affects differences in sensory attributes of lamb reared in different production systems, so that lamb producers can consider this factor and potentially control the presence or intensity of species-specific attributes in meat.

The differences found for the attributes hay odour and leafy flavour may instead be linked to more pastoral grassy flavours, rather than species-specific flavours. Alfa-linolenic acid (C18:3 n-3) has been identified as a lipid that can intensify the pastoral flavours of meat, through its oxidation products, and it is one of the dominant fatty acids in pasture foliage (Young and Baumeister 1999). Meat from lambs reared on pasture has been shown to have higher concentrations of α-linolenic acid than meat from lambs offered higher rations of concentrate, which contains low α-linolenic concentrations (Díaz et al. 2002, Font i Furnols et al. 2009). Which is also supported by the present study where the pasture groups had higher concentrations of α-linolenic acid compared to the silage group. Another interesting aspect of the results is that the inclusion of concentrate in the diet, as for cultivated pasture with a daily concentrate ration in the diet did decrease the α-linolenic acid concentration in meat compared to lambs that were only grazing cultivated pasture. The difference in α-linolenic acid may be one explanation for the observed tendency for differences in the sensory attributes hay odour and leafy flavour in meat from lambs reared on semi-natural pasture compared with lambs from the other three rearing systems. The exact species composition of the semi-natural pasture grazed by semi-natural pasture treatment was not determined, but it contained herbs and other plant species not present in the cultivated pasture/silage offered to lambs in the other groups, which may have caused the increase in sensory intensity for the pastoral-specific odour and flavour observed for the semi-natural pasture treatment.

From a consumer point of view, the nutritive value of meat could be an important factor to discuss. In the present study, the results of conjugated linoleic acid (CLA: cis-9, t-11 18:2), and the ratio between n-6/n-3 and saturated/unsaturated fatty acids can be used to talk about healthy or less healthy fatty acid composition in meat between the treatments tested. A quite recent meta-analysis publication states that a diet based on pasture exclusively results in higher CLA concentration compared to diets with inclusion of other feedstuffs (Hampel et al. 2019). This was however not supported by the results from the current study, where there were no differences between treatments. One explanation for this may be that the inclusion of concentrate in the diets was too small to induce such a difference in CLA between treatments.

The content of vitamin E in meat can influence the storage stability in terms of its ability to delay lipid oxidation of the meat and thereby increase the storage ability (Hampel et al. 2019, Álvarez-Rodríguez et al. 2022). Results from Guidera et al. (1997) did present an increased stability in colour in both fresh and frozen meat as an effect of supplementation of vitamin E. The increased concentration of vitamin E in meat from the pasture groups of the present study are explained by diet, which can be supported by (Luciano et al. 2011), who reported that vitamin E concentration of beef meat decreased when the inclusion of concentrate increased within different diets. Based on information from the previously published papers cited above it is valid to propose that meat from the pasture groups within the current study, with higher concentration of vitamin E, could experience less lipid oxidation and be more colour stable compared to the indoor/silage group which had a lower concentration of vitamin E in the meat.

The relationship between Warner-Bratzler shear force (WBSF) and sensory evaluation of meat texture can be used for comparing the results from texture measurements by instruments with findings from sensory texture analysis. In the present study, comparison of WBSF values reported in Stenberg et al. (2020) against the results obtained for the sensory attribute resistance to cutting revealed similar ranking of the four different groups in both approaches.

Conclusions

The four different feeding regimes tested in this study did not result in species-specific odour and flavour differences in the meat from intact male lambs. Further, the meat samples did not show any differences in species-specific odour and flavour attributes related to differences in slaughter age between the groups. The sensory differences detected were related to pastoral odour and flavour. The meat from lambs grazed on only cultivated pasture exhibited lower resistance to cutting than meat from lambs on cultivated pasture plus concentrate. The differences in fatty acid composition were mainly due to differences within the diets where pasture and concentrate inclusion of the diet have had a significant role. Vitamin E concentration was higher in the pasture groups compared to the indoor/silage group, as an effect of diet.

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