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A consumer study of the effect of castration and slaughter age of lambs on the sensory quality of meat

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Highlights

- Rams have superior production performance than castrates.
- Small sensory differences exist between meat from rams and castrates.
- Consumers prefer castrate meat but do not dislike ram meat.
- More intense flavour and off-flavours are found in meat from older lambs.

Abstract

Meat from ram lambs is often considered inferior to meat from castrated lambs, especially in older or heavier animals. This study aimed to determine if differences exist in the sensory quality and acceptability of meat from rams and castrates, slaughtered at mean ages of 196 or 385 days. Rams had higher average daily gain, feed conversion efficiency, total weight gain and lower carcass fatness than castrates. A triangle test (n= 81 consumers) showed a difference ($P < 0.05$) in the sensory quality of meat from rams vs castrates. A 9-point hedonic test involving 100 consumers showed that, although meat from both rams and castrates was 'liked', meat from castrates scored higher ($P < 0.05$) in Overall Liking, Flavour Liking and Tenderness Liking. Meat from castrates was also rated lower ($P < 0.05$) in Unpleasant Taste/Off-Flavour Intensity. Flavour Intensity and Unpleasant Taste/Off-Flavour Intensity increased ($P < 0.05$) with age at slaughter. This consumer study revealed that while meat from castrates was higher in Overall Liking, Flavour Liking and Tenderness Liking and lower in Unpleasant Taste/Off-Flavour Intensity than meat from rams, both meats were 'liked' by consumers.

Keywords: Acceptability, Castrate, Off-flavour, Ram, Triangle Test

1. Introduction

Rams (intact males) are superior to wethers (castrated males) with respect to average daily gain, feed conversion ratio, weight at slaughter and production of leaner carcasses (Claffey et al., 2018). However, meat from rams has been associated with a more intense and undesirable odour and flavour and a lower tenderness, in comparison to meat from castrates, which has a milder aroma and flavour, is less greasy and more tender (Misock et al., 1976; Crouse et al., 1981; Ames and Sutherland, 1999). Slaughter weight or age also affects the sensory quality of lamb (Jeremiah et al., 1998; Young et al., 2006), with meat from younger animals generally preferred over meat from older animals (Schönfeldt et al., 1993; Young et al., 1994).

Recently, using quantitative descriptive analysis, Gkarane et al. (2017) showed that there was a small but significant sensory differences due to sex of lambs, with ram meat having higher scores for 'intensity of lamb aroma', 'animal smell/farm smell', 'woolly aroma', 'rancid aroma', 'manure/faecal aroma', 'sweaty aroma' and 'off-flavours' than castrate meat. On the other hand, the same authors (Gkarane et al., 2017) reported that effects of age of lambs on sensory attributes of meat were not linear. While many sensory studies on the effects of lamb sex and age at slaughter on meat quality used a small number of trained panelists (Misock et al., 1976; Jeremiah et al., 1998) the effects on consumer acceptability remain inconclusive (Batcher et al., 1969; Field, 1984). Consequently, the current study was undertaken to determine the relevance of the findings of a trained panel's assessment of meat from ram lambs compared to castrated lambs (Gkarane et al., 2017) for consumer perception and acceptability of meat from the same animals, which in turn will affect consumer decision to purchase. Specifically, the objectives of the current study were to determine: (1) using a triangle test, if consumers

could detect any differences in the overall sensory characteristics of meat from rams and castrates slaughtered at two ages; (2) whether overall acceptability was affected by any sensory differences due to castration or age at slaughter and (3) the nature of any differences between meat from rams and castrates that might affect overall acceptability.

2. Materials and methods

2.1. Animal management

Forty Texel × Scottish Blackface Spring-born lambs, of which 20 were castrated (castrates) and 20 were left intact (rams), were used in the study. The lambs formed part of a larger study involving 200 lambs ([Gkarane et al., 2017](#); [Claffey et al., 2018](#)). Lambs were raised at pasture from birth, housed individually in slatted pens and, following a 12 d adaptation period during which the lambs were gradually introduced to a barley/maize-based concentrate ration and grass silage, they received *ad libitum* a finishing diet consisting of the barley/maize-based concentrate ration (95% dietary dry matter (DM) intake) and grass silage (5% DM intake) for 36 d pre-slaughter. The concentrate diet was composed of 300 g maize, 300 g barley, 165 g soya hulls, 155 g soya bean meal, 50 g molasses and 30 g vitamin/mineral pre-mix per kg. The details of the animal management, production traits and proximate composition of the animal feeds are available in [Claffey et al. \(2018\)](#).

At the end of the finishing period, lambs were transported ~83 km (travel time, ~1 h) to a commercial abattoir (Gillivan's, Moate, Co. Westmeath) for slaughter. Groups of 10 rams and 10 castrates were slaughtered at age 196 days (6.7 months) and at age 385 days (12.8 months). After slaughter, carcasses were chilled overnight (reaching a mean internal temperature of 6.2°C in the *M. longissimus thoracis et lumborum* (LTL) within 25h

of slaughter) and transported in a refrigerated container to Teagasc Food Research Centre, Ashtown (Dublin 15, Ireland) for dissection. Within 48 h *post-mortem* the muscles *M. semimembranosus* and *M. biceps femoris* were excised from each carcass, vacuum packed, aged for 8 days at 4°C and frozen at -20°C until required for analyses. All animal procedures used in this study were conducted under experimental license from the Irish Health Products Regulatory Authority (HPRA) in accordance with the European Union protection of animals used for scientific purposes regulations 2012 (S.I. No. 543 of 2012).

2.2. Sensory evaluation

The conduct of the sensory study was approved by the Human Research Ethics Committee for Sciences at UCD (LS-15-76-Monahan). Lamb meat consumers (panelists) recruited in this study were staff and students at University College Dublin (UCD), Ireland (Table 1). Two separate panels were recruited, 12 months apart, the first for a triangle test and the second for a hedonic and attribute intensity test. The consumers evaluated samples in individual sensory booths and under red lighting to mask any differences in sample appearance. Data were collected using paper-based score sheets. The *M. semimembranosus* was used for the triangle test and the *M. biceps femoris* was used for the hedonic and attribute intensity test. Muscles were defrosted overnight at 4°C, trimmed of external visible fat and connective tissue, minced and formed into meatballs. Meatballs (15 g), without seasonings or additives, prepared from muscle from each of the 40 animals, were cooked to an internal temperature of 75°C (Superfast Thermapen™ Thermometer serial no: B14351885) in a domestic oven set at 200°C. Meatballs were chosen to minimize potential texture differences between intact un-minced samples and to permit panelists to focus more on other sensory attributes, particularly flavour (Batcher

et al., 1969). Cooked meatballs were wrapped individually in tinfoil, labeled with random three-digit codes and served warm to the panelists, in a completely balanced serving order. Palate cleansing was done before tasting each sample using unsalted crackers and deionized distilled water.

2.2.1. Triangle test

The triangle test (ISO, 2004) was performed in three sessions per day, once per week for four consecutive weeks, with a total of 81 consumers (Table 1). Each consumer received two plates consecutively (one for each slaughter age: 196 day or 385 day samples) and each plate contained three meatballs (one castrate and two ram or two castrate and one ram samples). On receipt of each plate, consumers were instructed to choose the odd one among the three meatballs and they were also permitted to record comments about the samples.

2.2.2. Hedonic and attribute intensity test

The hedonic and attribute intensity test was performed in two sessions per day, twice per week for four consecutive weeks, with a total of 100 consumers (Table 1). Each consumer received four samples individually, one from each treatment (196 day castrate, 196 day ram, 385 day castrate and 385 day ram). The assignment of the 40 samples and the serving order were completely balanced across 100 consumers, with each sample being assessed by 10 consumers. For each sample, consumers were asked to rate Overall Liking, followed by Aroma Liking, Aroma Intensity, Flavour Liking, Flavour Intensity, Juiciness Liking, Juiciness, Tenderness Liking and Tenderness on 9-point

hedonic (1 = dislike extremely to 9 = like extremely) or intensity scales (1 = extremely weak/dry/tough to 9 = extremely strong/juicy/tender). In addition, panelists were asked if any Unpleasant Aroma/Off-Odour or Unpleasant Taste/Off-Flavour was detectable and, if present, to rate the intensity on a 9-point intensity scale (1 = extremely weak to 9 = extremely strong), otherwise a score of 0 (not detected) was assigned. Optional comments for each sample were invited.

2.3. Proximate composition

The composition of *M. biceps femoris* was determined as described in [Gkarane et al. \(2017\)](#). The moisture and intramuscular fat (IMF) contents were measured on a 2-4 g sample using a SMART Trac Rapid Fat Analyzer (CEM Corporation, NC, USA) while the crude protein concentration was determined on a 0.20-0.30 g sample using a LECO FP328 (LECO Corp., MI, USA) protein analyzer. Ash content was determined on a 3-5 g sample following incineration of samples overnight in a furnace at 540°C. All measurements were performed in duplicate.

2.4. Statistical analysis

The Critical Number of Correct Responses for a Triangle Test ([ISO, 2004](#)) was used to determine if there were significant differences between the overall sensory attributes (aroma, flavour etc.) between meat from rams and castrates at $\alpha = 0.05$. The experimental unit for this analysis was the lamb. For the hedonic and attribute intensity test, 10 consumers sampled meat from each lamb (n=40) and the mean value for each lamb was considered as the experimental unit. All data were analysed using SAS v.9.4.

Data diagnostics for normality was performed on all hedonic and attribute intensity data (sensory scores), proximate and animal performance and carcass characteristics data and, for data where the residuals were not normally distributed, a Box-Cox transformation in PROC TRANSREG was used to determine the appropriate lambda value for the transformation (Fahey et al., 2007). A multivariate analysis of variance (MANOVA in PROC GLM) using lamb as the experimental unit was conducted using the proximate composition and sensory scores to estimate partial correlations and to determine if sensory scores were different considering sex (ram vs castrate), slaughter age (196 day vs 385 day) and their interactions in the model with lamb as a random effect. ANOVA, using lamb as the experimental unit, was performed on proximate, animal performance and carcass characteristic data and sensory scores using a mixed model (PROC MIXED) where sex, slaughter age and their interactions were considered as fixed effects and individual lamb as a random effect.

3. Results

3.1. Animal performance, carcass characteristics and proximate composition of muscle

Slaughter weights increased with age of lambs as expected ($P < 0.001$) (Table 2). Average daily gain was higher ($P = 0.002$) in rams than in castrates and age effects approached significance ($P = 0.08$). A significant interaction between sex \times age ($P = 0.025$) of lambs for average daily intake (ADI) showed that ADI increased with age in rams ($P = 0.002$) but not in castrates. There was a significant increase in cold weight ($P = 0.004$) with lamb age. For feed conversion efficiency (FCE) there was a significant sex \times age interaction ($P = 0.009$), whereby at 196 days, but not at 385 days, rams had higher ($P <$

0.001) FCE (lower FCE value) than castrates, and castrates (but not rams) showed an increase in FCE with age ($P = 0.019$). Overall, rams had higher total weight gain ($P = 0.002$) and lower carcass fatness ($P = 0.01$) than castrates.

The moisture, protein, IMF and ash contents of *M. biceps femoris* were not different between sexes and there were no sex \times slaughter age interactions ($P > 0.05$; Table 2). The mean protein content of muscle from the 196 day old lambs (21.9%) was higher than the 385 day old lambs (21.2%) ($P = 0.011$) and the mean moisture values of muscle from younger lambs (74.1%) was slightly lower ($P = 0.051$) than older lambs (74.9%).

3.2. Triangle test

Of the 81 consumers who participated in the triangle test, 41 correctly identified the different sample among the three meat samples tasted from the 196 day or the 385 day groups (data not presented) ($P < 0.05$). Both male and female consumers could identify the odd sample among the 196 day samples ($P < 0.05$) and among the 385 day samples ($P < 0.01$ for male and $P < 0.05$ for female consumers). Optional comments left by the panelists, who correctly identified ($P < 0.05$) the different sample, more often described meat from rams as having 'stronger', 'gamier', 'iron' and 'liver' flavours than meat from castrates.

3.3. Hedonic and attribute intensity test

Results of the MANOVA using the hedonic and attribute intensity data showed no overall effects of lamb sex (*Wilk's lambda* = 0.07) or slaughter age (*Wilk's lambda* = 0.15), and no sex \times slaughter age interactions (*Wilk's lambda* = 0.34). However, ANOVA showed

significant effects of sex and age on individual hedonic and intensity scores. There were no significant interactions between sex and slaughter age ($P > 0.05$; Table 3) and, consequently, the following discussion focusses on the individual effects of sex and slaughter age.

3.3.1. Overall liking

The Overall Liking scores were lower in meat from rams (5.8) than in meat from castrates (6.3) ($P = 0.002$) (Table 3). The difference in Overall Liking between meat from rams and castrates approached significance at 196 days ($P = 0.06$) and was significant at 385 days ($P = 0.007$). There was no difference in Overall Liking due to age at slaughter (scores of 6.2 and 5.9 for 196 day and 385 day samples, respectively; $P = 0.16$).

3.3.2. Aroma and flavour

Neither lamb sex nor slaughter age affected Aroma Liking ($P = 0.18$, $P = 0.10$, respectively) and Aroma Intensity ($P = 0.46$, $P = 0.36$, respectively) (Table 3). For Flavour Liking, overall, there was a significant effect of sex ($P = 0.03$) with meat from castrates preferred over meat from rams (6.2 vs 5.8), although Flavour Liking did not differ between sex at 196 days ($P = 0.20$) and differences in mean values approached significance at 385 days ($P = 0.07$) (Table 3). In contrast to the findings on Flavour Liking, there was no difference in Flavour Intensity due to sex ($P = 0.90$) (Table 3). With regard to age effects on Flavour Liking, scores were not different ($P = 0.12$) between younger (6.1) and older (5.8) animals while Flavour Intensity increased ($P = 0.04$) from 196 day (5.4) to 385 day (5.7) old lambs (Table 3).

3.3.3. Juiciness and tenderness

Juiciness Liking and Juiciness scores were unaffected by the sex of lambs ($P = 0.99$ and $P = 0.51$, respectively) and slaughter age ($P = 0.81$ and $P = 0.66$, respectively; Table 3). The relationship between Juiciness and moisture content ($r = 0.15$) or IMF ($r = -0.18$) was low and not significant ($P > 0.05$). Tenderness Liking scores were lower for ram meat (6.3) than castrate meat (6.7) ($P = 0.04$; Table 3). The differences between rams and castrates in Tenderness Liking at 196 days old approached significance ($P = 0.10$) and effects of sex disappeared at 385 days old samples ($P = 0.19$). The effect of sex on Tenderness was insignificant ($P = 0.16$; Table 3). Furthermore, no effect of slaughter age on Tenderness Liking ($P = 0.93$) or Tenderness ($P = 0.92$) was found in this study. There was no correlation found between Tenderness and IMF ($r = -0.02$; $P = 0.92$).

3.3.4. Unpleasant aroma/off-odour and unpleasant taste/off-flavour

Unpleasant Aroma/Off-Odour Intensity was not affected by sex ($P = 0.43$) or slaughter age ($P = 0.10$) (Table 3). Considering each sex separately, Unpleasant Aroma/Off-Odour Intensity in ram meat increased ($P = 0.05$) with slaughter age (scores of 1.1 and 1.7 for animals slaughtered at 196 and 385 days, respectively) but there was no difference ($P = 0.73$) in castrate meat (scores of 1.2 and 1.3 for animals slaughtered at 196 and 385 days, respectively). An Unpleasant Taste/Off-Flavour Intensity was detected in ram meat by 36% of the consumers and in castrate meat by 31% of the panelists, with a higher intensity in meat from rams (1.7) than from castrates (1.1) ($P = 0.01$; Table 3). Taking each slaughter age separately, the Unpleasant Taste/Off-Flavour

Intensity in meat was numerically higher in rams than castrates and approached significance (196 days, $P = 0.10$; 385 days, $P = 0.06$). With regard to a slaughter age effect, Unpleasant Taste/Off-Flavour was detected in meat from 385 day old lambs by 35% of the consumers and from 196 day old lambs by 32% of the consumers and the Unpleasant Taste/Off-Flavour Intensity was higher ($P = 0.04$) in older lambs (1.6 vs 1.2).

4. Discussion

4.1. Animal performance, carcass characteristics and proximate composition of muscle

Consistent with the current results, Mazon et al. (2017) observed that lambs fed for a longer time had heavier final live weight and cold carcass weight than younger animals. Rams had higher average daily gain, feed efficiency and lower carcass fatness than castrates in agreement with other reports (Seideman et al., 1982; de Araujo et al., 2017). The superiority of rams over castrates in terms of production parameters is associated with testicular hormones particularly testosterone (Seideman et al., 1982). Previous studies have reported significant effects of sex on muscle composition (Kemp et al., 1972; Solomon et al., 1990) while others have not (Dransfield et al., 1990; Tejeda et al., 2008; de Araujo et al., 2017). Protein deposition is reduced in older ruminants (Annison et al., 1993) and this may partly explain the lower protein content of the older animals reported here. However, the difference in protein content was small and is supported by the lack of a significant effect on the IMF or ash constituents, although the mean moisture values of muscle from younger lambs was slightly lower than older lambs.

4.2. Triangle test

The triangle test results indicate a difference in the overall sensory characteristics of ram meat from castrate meat, and agree with previous studies showing that there were sex differences in the sensory perception of lamb (Misock et al., 1976; Jeremiah et al., 1998; Gkarane et al., 2017). The description of meat from ram lambs, in optional comments from panelists, to have stronger, 'gamier' flavours than meat from castrates, is consistent with the findings of Crouse et al. (1981; 1983) and iron and liver flavours associated with the ram meat were previously found in very old ewes (Rousset-Akrim et al., 1997). Panelists comments on tenderness showed no consistent trend, which suggests that serving the samples minced was successful in minimizing the texture differences, which could otherwise lead to a halo effect (*i.e.* consumers are more likely to rate flavour as desirable if tenderness is desirable) (Corbin et al., 2015).

While the results of the triangle test confirmed a difference in the sensory characteristics of meat between rams and castrates, whether or not consumer acceptability would be affected remained to be established. A hedonic and attribute intensity test was undertaken to determine, firstly, if the differences between meat from rams and castrates detected using the triangle test would affect Overall Liking of lamb by consumers and, secondly, what the nature of the differences between meat from rams and castrates was.

4.3. Overall liking

As animals get older or become heavier differences in sensory quality due to sex have been shown to increase (Kemp et al., 1972; Misock et al., 1976; Ames and

Sutherland, 1999). The results of the current study are in general agreement with these previous studies whereby the difference in Overall Liking between meat from rams and castrates approached significance in younger animals and was significant in older animals. An important point to note is that both ram and castrate meat had hedonic ratings for Overall Liking of greater than '5' (equivalent to 'neither like nor dislike'), indicating that consumers did not 'dislike' any of the samples (rather they 'liked' the meat from castrates more than meat from rams) and that meat from both sex was acceptable. Pethick et al. (2005) also reported no difference in Overall Liking of grilled *M. biceps femoris* from animals with a greater age range (from 8.5 up to 32.5 months at slaughter) than ours (6.1 – 7.4 months vs 12.1 – 13.3 months at slaughter). Kemp et al. (1972) observed an increase in overall satisfaction of meat from rams or castrates with increase in slaughter weight (36, 45 and 54 kg) but all scores were within the acceptable range.

4.4. Aroma and flavour

The differences found in scores for Flavour Liking but not for Aroma Liking may reflect the additional contribution of taste, with aroma, to flavour (Lind et al., 2011) and the detection, by way of the retro-nasal passage at the back of the oral cavity, of odours released from meat during chewing (Young et al., 2003). The current results on Flavour Liking differences due to sex of lambs were in general agreement with the findings of several other sensory studies using trained or experienced panelists. Meat from intact males was inferior to castrated males in odour and flavour (Kemp et al., 1972; Misock et al., 1976; Ames and Sutherland, 1999); the flavour of meat from female was preferred more than that of male lambs (Arsenos et al., 2002); meat from rams had gamier flavours

than meat from female lambs (Crouse et al., 1983; Lind et al., 2011); and ram meat had a stronger flavour than castrate meat (Crouse et al., 1981). In a larger study with the same lambs as those used in the current study, quantitative descriptive analysis (QDA) of grilled LTL showed that castrates scored higher for 'intensity of roast meat aroma' and 'roast meat flavour' (Gkarane et al., 2017).

No difference in Flavour Intensity due to sex was found in this study. Lind et al. (2011) found that meat flavour intensity (the sum of metallic, cloying, ryegrass, concentrate, gamey and rancid) was stronger in male than female lambs and Crouse et al. (1981) and Field (1984) found meat flavour intensity to be stronger in rams than castrates. However, others like Tejeda et al. (2008), Butler-Hogg et al. (1984) and Batcher et al. (1969) found that lamb flavour intensity did not differ between sex, in agreement with the current results. In lambs weighing <50 kg the differences in flavour between rams and castrates were small (Kemp et al., 1972; Vesely, 1973; Dransfield et al., 1990). On the other hand, at slaughter weights >60 kg rams had a more intense flavour (Crouse et al., 1981; Field, 1984). The small but significant sex effects on Flavour Liking and the non-significant effect on Flavour Intensity obtained in our study may be due to the similarity in slaughter weight ranges between rams (44.7 – 62.0 kg) and castrates (46.8 – 59.4 kg) and to the similarity in the IMF between ram meat and castrate meat. Indeed, both ram and castrate meat had Flavour Liking scores greater than '5' (equivalent to 'neither like nor dislike'), indicating flavour acceptability of meat from both sex to consumers.

Slaughter age affected the Flavour Intensity of lamb meat. The results of the present study are in agreement with a review by Sink and Caporaso (1977), where it was concluded that there seemed to be an age effect on sheep meat flavour, with older animals yielding a more intense odour and flavour (Young et al., 1994). In contrast to our findings

on flavour liking, a trained descriptive attribute panel found the flavour of *M. semimembranosus* from lambs with no permanent incisors more acceptable than that from animals with 1-6 or 7-8 permanent incisors, and authors attributed the difference to a more intense meat flavour in the older animals (Schönfeldt et al., 1993). Furthermore, Jeremiah et al. (1998) found that lambs slaughtered at 6 – 9 months had a more favorable flavour profile than lambs slaughtered at 12 – 15 months. The age and weight range of animals used in our study (6.1 – 7.4 months and 44.7 – 58.6 kg for the 196 day animals; 12.1 – 13.3 months and 47.6 – 62.0 kg for the 385 day animals) may have been insufficient to elicit a significant response in Flavour Liking. This assumption is further supported by the similar results obtained by Pethick et al. (2005), who did not find an effect of age of lambs (8.5 – 20.0 month old) on consumer flavour liking scores of grilled *M. biceps femoris*. The authors suggested that the absence of subcutaneous and intermuscular fat in the grilled or roasted meat could minimize the effects of age on flavour. The *M. biceps femoris* used in our study was trimmed of visible fat prior to mincing and cooking, which could explain the comparable results found. Batcher et al. (1969) found significant flavour intensity differences when minced lamb contained 20% fat, but no differences when lamb contained 3-9% IMF content. Likewise, no differences were detected, by an experienced panel, in meat flavour liking of lambs slaughtered at 32, 41 or 50 kg (Kemp et al., 1980) or, by an untrained panel, of lambs slaughtered at 54 or 64 kg (Lloyd et al., 1980). On the other hand, Misock et al. (1976) did not find a consistent effect of age (185 – 295 days) on flavour liking of *longissimus* muscle of rams.

4.5. Juiciness and tenderness

The initial juiciness of the meat is believed to derive from the release of constitutive water, which is related to the moisture content of the meat, while the secondary or sustained juiciness is related to the infiltrated fat content (Tejeda et al., 2008; della Malva et al., 2016). The absence of effect of sex or slaughter age on either moisture or IMF content most likely explains the lack of an effect on juiciness, in addition to the low and insignificant correlation between Juiciness and moisture content or IMF. Despite the differences in Tenderness Liking between ram meat and castrate meat with meat from castrates being more 'liked' than that from rams, both exceeded the hedonic score of '5' for 'neither like nor dislike'. Other authors (Kemp et al., 1972) also found that ram meat had lower tenderness liking scores than castrate meat (at slaughter weights 30 – 54 kg), although values were within an acceptable range. Furthermore, muscle from rams had higher collagen than castrates or ewes when compared at 20 weeks of age (Dransfield et al., 1990) and this may in part explain the differences in Tenderness Liking observed in the current study. However, although significant, the differences we observed were numerically small and may not have practical importance as reflected by the lack of a significant effect of sex on Tenderness. Similarly, Kemp et al. (1980), Lloyd et al. (1980) and Mazon et al. (2017) did not find differences in meat toughness between rams, castrates and ewes.

Although meat tenderness in lamb was observed to decrease with age, attributed to an increase in insoluble collagen content (Schönfeldt et al., 1993), in the current study, slaughter age did not affect either Tenderness Liking or Tenderness. Our results agree with the results of QDA on intact LTL, where there was no difference due to age in lamb meat 'tenderness' and 'stringiness/fibrousness', although meat from older lambs was

chewier than that from younger lambs (Gkarane et al., 2017). The absence of an effect of slaughter age on tenderness may have been because the age difference between lambs used in the study was not large enough to affect sensorial tenderness or because meat samples used in the study were minced. Furthermore, the IMF content, which is known to affect perception of tenderness (Hopkins and Mortimer, 2014) did not differ between rams and castrates or between 196-day and 385-day old lambs, and there was no correlation between Tenderness and IMF.

4.6. Unpleasant aroma/off-odour and unpleasant taste/off-flavour

Previous studies showed contrasting evidence of sex and slaughter age (or weight) effects on the presence of undesirable odours. There was no evidence of undesirable sexual odour or flavour in meat from rams slaughtered at either <17 or >17 kg (Butler-Hogg et al., 1984), similar to the findings of a study with rams, castrates and ewes slaughtered at 20 weeks (Dransfield et al., 1990). Rancid smell and sheep smell in meat did not differ between rams and castrates slaughtered at 52.3 kg and 46.6 kg, respectively (Mazon et al., 2017). Despite the differences in the Unpleasant Aroma/Off-Odour Intensity in the current study, the values for all treatments were low (1 = extremely weak to 9 = extremely strong). Ames and Sutherland (1999) concluded that sexually mature rams (30 weeks old) had more undesirable 'sweaty', 'goaty-mutttony' and 'farmyard' odours in fat tissue than castrated lambs at a similar age, and this was also the case for 12 weeks old rams or castrates. The authors attributed the difference to high amounts of indoles, branched chain fatty acids and phenols in the older samples. Ammonia or "staggy" odour

was more noticeable in meat from older (237 and 295 days old) and heavier (39.0 and 43.1 kg) rams than in younger (183 days) or lighter (23.9 kg) rams (Misock et al., 1976).

In agreement with the results for Unpleasant Taste/Off-Flavour Intensity, using QDA Gkarane et al. (2017) found that the LTL of rams scored higher for undesirable 'rancid', 'farmyard' and 'off' flavours and the subcutaneous adipose tissue higher levels of branched chain fatty acids, which are associated with off-flavours. As lambs become older, the differences in Unpleasant Taste/Off-Flavour Intensity between ram meat and castrate meat become larger. Meat from ram lambs slaughtered at over 200 days of age had more undesirable 'sheep meat', 'animal', and 'rancid' sensory attributes than younger animals and this was attributed not only to the age of the lambs but also to the sexual maturity of the rams (Rousset-Akrim et al., 1997). In a comparison of male and female lambs Tejeda et al. (2008) noted higher unpleasant flavour (defined as an undesirable sensation with 'rancid', 'wooly', 'ammonia', 'sulfur' and 'liver' notes) in meat from male in comparison to female lambs. Likewise, Lind et al. (2011) suggested that cloying flavour (suggested to be linked to male sexual maturation) was more intense in meat from male lambs than from female lambs. Conversely, others did not find effects of sex on 'barnyard' and 'sheep meat' odours and flavours (Young et al., 2006), sheep flavour and rancid flavour (Mazon et al., 2017) and other sex-related and foreign flavours in sheep (Butler-Hogg et al., 1984; Dransfield et al., 1990).

Although the increase in slaughter age resulted in an increase in Unpleasant Taste/Off-Flavour Intensity scores in lamb meat, scores were low considering the scale used (1 = extremely weak to 9 = extremely strong). Tejeda et al. (2008) reported an increase in unpleasant flavour with lamb slaughter weights (24 vs 29 kg), while Crouse et al. (1981) did not find slaughter weight effects on lamb flavour scores (62.45 vs 75.83 kg).

The intensities of 'barnyard' and 'sheepmeat' flavours in lean meat were affected by age of lambs (4 months to 2 years), but no clear trend was observed by Young et al. (2006). Furthermore, Crouse et al. (1983) reported that for animals slaughtered at 50.0 kg and 68.6 kg, 'gamey' and 'sweet' flavour notes were higher in lamb chops from the rams at the higher slaughter weight, while 'muttony' and 'musty' flavour notes were higher in chops from ewes at the higher slaughter weights.

Overall, using meat from the same lambs, the small but significant differences in sensory characteristics between rams and castrates detected by a trained sensory panel (Gkarane et al., 2017), were also detected by an untrained consumer panel in the current study, whereby castrate meat was preferred more than ram meat and older lambs had more intense flavour and unpleasant taste/off-flavour. Despite the differences detected by the consumers, all meats scored above '5', indicating that consumers did not dislike any of the meat samples.

5. Conclusion

Rams have superior production performances and lower carcass fat than castrates. The evaluation of the sensory quality of Irish lamb meat by consumers shows that meat from castrated lambs scores higher for Overall Liking, Flavour Liking and Tenderness Liking and lower for Unpleasant Taste/Off-Flavour Intensity compared to rams. However, importantly, lamb from rams is not "disliked", rather its level of "liking" is lower than that of lamb from castrates. The Flavour Intensity and Unpleasant Taste/Off-Flavour Intensity of lamb meat from older animals is higher than that of younger animals. However, scores for Unpleasant Taste/Off-Flavour Intensity in general are low.

Conflict of interest

There are no conflicts of interest associated with the work presented here.

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Table 1 Sex and age profile of lamb meat consumer panels used for the triangle test and the hedonic and attribute intensity test.

Characteristic	Triangle test	Hedonic and attribute intensity test
Sex		
Female	38	60
Male	43	40
Age		
<30	63	72
31-50	13	21
>50	4	7
No Answer	1	
Total	81	100

Table 2 Animal performance, carcass characteristic and proximate composition of *M. biceps femoris* of lambs from rams or castrates slaughtered at different ages.

	196 days		385 days		SEM	P-values [†]	
	Ram	Castrate	Ram	Castrate		Sex	Age
Animal performance, carcass characteristic							
Slaughter weight, kg	51.8 ^{Ba}	48.2 ^{Bb}	55.7 ^A	55.0 ^A	0.88	0.11	<0.001
Average daily gain (ADG), kg/day	0.40 ^a	0.29 ^{Bb}	0.41	0.36 ^A	0.017	0.002	0.08
Average daily intake (ADI), kg/day	1.7 ^B	1.8	2.0 ^A	1.8	0.04	0.16	0.02
Feed conversion efficiency (FCE)	4.5 ^b	6.3 ^{Aa}	5.1	5.0 ^B	0.23	0.008	0.44
Total weight gain, kg	14.3 ^a	10.3 ^{Bb}	14.8	12.9 ^A	0.62	0.002	0.08
Cold weight, kg	23.7	23.4 ^B	25.4	26.5 ^A	0.05	0.50	0.004
Carcass fatness, mm	3.0 ^c	3.5 ^d	2.9 ^b	3.4 ^a	0.01	0.01	0.55
Composition (%)							
Moisture	74.2	74.0	75.0	74.8	2.84	0.61	0.051
Protein	21.9	21.9 ^A	21.3	21.1 ^B	1.80	0.65	0.01
Intramuscular fat	2.6	2.6	2.9	2.9	1.65	0.94	0.20
Ash	1.1	1.2	1.1	1.2	0.12	0.14	0.81

Within sex, means bearing different letters were significantly different due to age, $P < 0.05^{A,B}$ or approached significance $P < 0.1^{C,D}$

Within age, means bearing different letters are significantly different due to sex, $P < 0.01^{a,b}$ or approached significance $P < 0.1^{c,d}$

[†]There were significant sex by age interaction for ADI ($P = 0.025$) and FCE ($P = 0.009$)

Table 3 Hedonic and attribute intensity scores of *M. biceps femoris* of lambs from rams or castrates slaughtered at different ages.

Attribute	196 days		385 days		SEM	P-values†	
	Ram	Castrate	Ram	Castrate		Sex	Age
Overall Liking ¹	5.9 ^d	6.4 ^c	5.6 ^b	6.3 ^a	0.13	0.002	0.16
Aroma Liking ¹	5.7	6.0	5.4	5.7	0.14	0.18	0.10
Aroma Intensity ²	5.1	4.9	5.2	5.1	0.13	0.46	0.36
Flavour Liking ¹	6.0	6.3	5.6 ^d	6.1 ^c	0.14	0.03	0.12
Flavour Intensity ²	5.4	5.4	5.7	5.7	0.11	0.90	0.04
Juiciness Liking ¹	6.0	5.8	5.9	6.0	0.12	0.99	0.81
Juiciness ³	5.5	5.2	5.4	5.5	0.11	0.51	0.66
Tenderness Liking ¹	6.3 ^d	6.7 ^c	6.4	6.6	0.11	0.04	0.93
Tenderness ⁴	5.9	6.2	5.9	6.2	0.16	0.16	0.92
Unpleasant Aroma/Off-Odour Intensity ⁵	1.1 ^B	1.2	1.7 ^A	1.3	0.14	0.43	0.10
Unpleasant Taste/Off-Flavour Intensity ⁵	1.4 ^{Dc}	0.9 ^d	1.9 ^{Cc}	1.3 ^d	0.15	0.01	0.04

Within sex, means bearing different letters were significantly different due to age, $P < 0.05^{A,B}$ or approached significance $P < 0.1^{C,D}$

Within age, means bearing different letters are significantly different due to sex, $P < 0.01^{a,b}$ or approached significance $P < 0.1^{c,d}$

Category/Intensity scale: ¹1 = dislike extremely, 9 = like extremely; ²1 = extremely weak, 9 = extremely strong; ³1 = extremely dry, 9 = extremely juicy; ⁴1 = extremely tough, 9 = extremely tender; ⁵0 = not detected, 1 = extremely weak, 9 = extremely strong.

†There were no significant sex by age interactions, ($P > 0.05$).