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Original study

Fatty acid composition and sensory analysis in Boer kids meat

Angela Cividini[1], Ana Kaić[2], Dragomir Kompan[1] and Klemen Potočnik[1]

[1]Department of Animal Science, Biotechnical Faculty, University of Ljubljana, Domžale, Slovenia, [2]Department of Animal Science and Technology, Faculty of Agriculture, University of Zagreb, Zagreb, Croatia

Abstract

This study was undertaken to characterize the fatty acid profile and sensory properties of *longissimus dorsi* (LD) muscle of Boer kids as affected by sex (17 male, 15 female) and slaughter weight (pre-weaned 20 kg, post-weaned 30 kg). Regarding sex differences, higher percentage amounts of lauric, myristic, pentadecanoic, linolenic and docosapentaenoic acids were found in LD muscle of male compared to female kids, whereas greater amounts of oleic acid were detected in LD muscle of female kids. Also, LD of male kids contained higher percentage amounts of saturated (SFA), polyunsaturated (PUFA) and n-3 polyunsaturated fatty acids (n-3 PUFA) while higher amounts of monounsaturated fatty acids (MUFA) were detected in LD of female kids. Regarding slaughter weight, percentage amounts of lauric, myristic, margaric, pentadecanoic, linolenic, linoleic, arachidonic and docosapentaenoic acids significantly decreased with age ($P \leq 0.001$), while percentage amounts of heptadecenoic and oleic acids significantly increased ($P \leq 0.001$). LD muscle from lighter kids contained higher percentage amounts of SFA and PUFA, while heavier kids had higher percentage amounts of MUFA and n-3/n-6 fatty acid ratio. Except meat colour, sensory traits (marbling, off-odour, flavour, juiciness and tenderness) were neither significantly affected by sex nor slaughter age.

Keywords: fatty acid composition, kids, sensory traits, sex

Abbreviations: LD: *longissimus dorsi*, MUFA: monosaturated fatty acids, ns: not significant, PUFA: polyunsaturated fatty acids, SFA: saturated fatty acids, UFA: unsaturated fatty acids

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Corresponding author:
Ana Kaić; email: akaic@agr.hr
Department of Animal Science and Technology, Faculty of Agriculture, University of Zagreb, Svetošimunska cesta 25, 10000 Zagreb, Croatia

Introduction

In comparison to other meats available on the market, goat meat has advantages such as low fat, high digestibility, high protein, iron and unsaturated fatty acid amounts (Madruga 2004). Although consumption of goat meat varies according to the demands of the societies, consumer demands are more often in search of low-fat, low-calorie, healthy and a new meat sources (De Smet 2012). Previous studies have shown that consumers' perception on meat healthiness is related to its fat content and fatty acid composition (Fisher *et al.* 2000). Meat quality and acceptability is also affected by its appearance (colour), tenderness and sensory properties (Krystallis & Arvanitoyannis 2006, Kor & Keskin 2011). The sensory quality of meat remains one of the primary factors influencing consumer satisfaction (Kor & Keskin 2011). Increasing consumer demands for goat meat has led to elevated consumers expectations towards goat meat quality and sensory characteristics. Due to fast grow rates and excellent carcass qualities of Boer goats, this study aimed at characterizing lipid profiles and sensory properties of Boer kids of different sex and slaughter weight.

Material and methods

Animals and rearing

The study was carried out at the Educational and Research Animal Husbandry Centre (Logatec) of Department of Animal Science at Biotechnical Faculty (University of Ljubljana, Slovenia). Thirty-two Boer genotype twin and triplet kids (17 male and 15 female kids) were used in the study. Kids were randomly assigned into two different groups based on target slaughter weight of 20 and 30 kg. Each group represent both sexes. Kids stayed with their mothers until weaning at around 20 kg of live weight (85 days of age). All kids were weaned at the same time, when they reached around 20 kg (80-90 days of age). The first group (G1) comprised of eight male and eight female kids represents weaned kids slaughtered on weaning day at an average slaughter weight of 20 kg (85 days of age). The remaining kids (nine male and seven female; G2) after weaning, were fed on with hay and commercial concentrate (18 % crude protein, 2.2 % crude fat, 7.9 % crude fibre, 7.8 % ash) until they reached 30 kg of slaughter weight (140 days of age). The kids were weighted once a week to follow the growth and slaughtered by the same procedure on consecutive dates when reached the predetermined slaughter weight. At slaughter, lambs were weighted on the farm before transportation to the experimental abattoir at the Zootechnical Department at Biotechnical Faculty (50 km). Carcasses were kept at 18 °C for 5 h to avoid the development of cold shortening, and then chilled at 4 °C for 24 h in a conventional chill cooler.

Sampling

The *longissimus dorsi* (LD) samples were taken 24 h post mortem from whole loin cuts. The LD samples for fatty acid analysis were cut between the last thoracic and first lumbar vertebrae and between the second and third lumbar vertebrae of each carcass (100 g) and were vacuum-packaged in polyamide – polyethylene bags and immediately stored at –20 °C. The other half of the loin (cut between the second and third lumbar vertebrae and between the last lumbar and first sacral vertebrae) was used for sensory analysis. The samples for sensory

analysis were vacuum-packaged into polyamide-polyethylene bags and stored at –20 °C after 3 days ageing at 4 °C. Before the analysis began samples were thawed overnight at 4 °C.

Fatty acid analysis

Total intramuscular fat in LD muscle samples was analysed according to manufacturer's protocol (Foss, Application note). Briefly, meat samples were firstly hydrolysed in 4 M HCl and dried. In hydrolysed samples crude fat was determined by solvent extraction using petroleum ether (40-60 °C) in Soxtec 2050 extraction system (Foss Analytical, Hilleroed, DK). Fatty acid methyl esters were determined according to ISTE method (Park & Goins 1994). Separation and quantification of fatty acid methyl esters was carried out using a gas chromatograph Agilent 6890 (Agilent Technologies, Santa Clara, CA, USA) fitted with an automatic sampler Agilent 7683 (Agilent Technologies, Santa Clara, CA, USA) and a flame ionization detector. Fatty acid methyl esters were separated on a SP-2560 fused-silica capillary column (100 m × 0.25 mm i.d., 0.2 µm film thickness; Supelco Inc., Bellefonte, PA, USA) using a split/splitless injection system and helium as carrier gas at a flow rate of 0.9 ml/min. Separated fatty acid methyl esters were identified using their retention times and quantified using response factors derived from external standards GLC 85, GLC 411 and GLC 68a (Nu-Chek Prep, Inc., Elysian, MN, USA). Results are expressed as a weight percentage (wt %) of the total identified fatty acids. For each sample 34 fatty acids were evaluated altogether. They were used for the saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), n-3 PUFA, n-6 PUFA and n-6/n-3 PUFA ratio evaluation.

Sensory analysis

Samples were thawed overnight prior to sensory evaluation. Sensory evaluation was carried out on the samples by six trained panellists of Biotechnical Faculty, Food Science and Technology Department. Two identical ovens were used at a grilling temperature of 200 °C to cook the meat. Baking trays with grilling racks were placed on the middle shelf position. The meat was cooked by grilling until the internal endpoint temperature was 75 °C. Samples were dissected immediately after cooking, wrapped in aluminium foil and kept in warming ovens (set at 100 °C) until serving within 20 min. Sensory evaluation was carried out in a sensory analysis laboratory with individual booths. Sensory evaluation was carried out for 4 consecutive days with two sessions per day. During the session each panellist tasted four different samples serviced on a clean plastic plate each time. Water and fresh apple slices were used as mouth cleansers before tasting and in between tasting samples. The panellists were instructed to take a bite of the apple followed by a sip of water and wait for 30 s in order to restore the normal environment in the mouth between samples. Samples were coded with sample number and panellist number and the serving sequence was randomised. Before thermal treatment, panellists assessed fresh meat colour (1=extremely bright; 7=extremely dark) and marbling (1=extremely low; 7=extremely high) of the samples using a seven-point scale. After cooking the panellists assessed sensory characteristics of goat meat using a seven-point scale for off-odour (1=extremely bland; 7= extremely intense), flavour (1=extremely undesirable; 7=extremely desirable), juiciness (1=extremely dry; 7=extremely juicy) and tenderness (1=extremely tough; 7=extremely tender).

Statistical analysis

The effects of sex and slaughter weight on fatty acid composition and sensory analysis were analysed using MIXED procedures of SAS/STAT software package v9.2 (SAS Institute Inc., Cary, NC, USA). The analysis was performed according to the following linear model:

$$y_{ijk} = \mu + S_i + G_j + (SG)_{ij} + e_{ijk} \quad (1)$$

where y_{ijk} is the dependent variable, μ is the overall mean, S is the fixed sex effect ($_i$=male, female), G is the fixed group effect ($_j$=group 1, group 2), $(SG)_{ij}$ is the interaction between sex and group effect and e_{ijk} is the residual error. The interaction between sex and group was analysed and there were no significant differences found for the parameters evaluated in the present study. Therefore, only the fixed sex and group effects are presented and discussed. Differences of least squares means of fatty acid composition and sensory analysis were tested using Scheffe's test. Significance levels between least squares means (LSM) for a particular parameter were assessed at $P<0.05$.

Results and discussion

Fatty acid composition of LD muscle in male and female Boer kids at two different slaughter weights is presented in Table 1. Predominant fatty acids in LD muscle tissue of Boer kids are oleic (32.0-48.3 %), palmitic (17.7-25.2 %) and stearic (5.0-13.9 %), and account about 72 % of total fatty acids. Results of these fatty acids in the present study are lower than the ones reported by Mahgoub *et al.* (2002) of Omani Jebel Akhdar goats and Werdi Pratiwi *et al.* (2006) of Boer and Australian feral goats. Since a change in diet after weaning and the increase of slaughter weight may change significantly the fatty acid profiles (Dhanda *et al.* 2003, Beserra *et al.* 2004) these differences may relate primarily to differences in the feeding regimes. Nevertheless, we must also consider breed differences and a wider range of slaughter weights used in the studies.

Sex had significant influence on lauric ($P\leq0.01$), myristic ($P\leq0.01$), pentadecanoic ($P\leq0.05$), oleic ($P\leq0.001$), linolenic ($P\leq0.05$) and docosapentaenoic ($P\leq0.01$) acids. The percentage amounts of lauric (0.60 vs. 0.36), myristic (5.35 vs. 4.09), pentadecanoic (0.80 vs. 0.63), linolenic (1.03 vs. 0.74) and docosapentaenoic (0.90 vs. 0.50) acids were significantly higher in male kids than in females. Contrary to males, female kids had only higher percentage amount of oleic acid (38.74 vs. 43.55). Bonvillani *et al.* (2010) also found significant influence of sex on fatty acid muscle composition, where male kids had significantly higher percentages of capric, lauric and myristic acids and the female kids had higher percentages of stearic and linoleic acids. In the present study the percentages of SFA ($P\leq0.01$), MUFA ($P\leq0.001$), PUFA ($P\leq0.05$) and n-3 PUFA ($P\leq0.01$) were significantly affected by sex. Male kids had higher percentage amounts of SFA (44.16 vs. 41.03), PUFA (10.90 vs. 9.41) and n-3 PUFA (2.79 vs.1.91) than females. Contrary to males, female kids had higher percentage amounts of MUFA (44.91 vs. 49.53).

Slaughter weight significantly affected the fatty acid muscle profiles of Boer kids. The percentage amounts of lauric (0.69), myristic (5.85) and margaric (0.67) acids in the lighter group of kids were significantly higher than those of lauric (0.69), myristic (5.85) and margaric (0.67) acids determined in the heavier kids. Mahgoub *et al.* (2002) found significant decrease only in amounts of decanoic and lauric acids of Omani Jebel Akhdar goats slaughtered

at similar weights as in the present study. Heptadecenoic and oleic acids significantly increased at higher slaughter weights ($P \leq 0.001$). Lighter kids had 1.26 % of heptadecenoic and 37.66 % of oleic acid, while heavier kids had 1.85 % of heptadecenoic and 44.64 % of oleic acid. Partially, this agrees with the findings of Werdi Pratiwi *et al.* (2006) who found at higher slaughter weights a significant increase ($P \leq 0.01$) of oleic and palmitoleic acid. In the present study palmitoleic acid was not significantly different at higher slaughter weights. Furthermore, significant decrease ($P \leq 0.001$) in the content of PUFA such as linoleic, linolenic, arachidonic and docosapentaenoic at higher slaughter weights was noticed. Lighter kids had 5.72 % of linoleic, 1.18 % of linoleinic, 1.95 % of arachidonic and 1.02 % of docosapentaenoic acids, while heavier kids had 4.27 % of linoleic, 0.58 % of linoleinic, 1.13 % of arachidonic and 0.47 % of docosapentaenoic acids.

Table 1
Fatty acid composition of *longissimus dorsi* muscle of male and female Boer kids at two different slaughter weights (LSM±SE)

Fatty acid	Sex effect			Group effect		
	Male (n=17)	Female (n=15)	*P*	G1 (n=16)	G2 (n=16)	*P*
C12:0	0.60±0.05	0.36±0.052	**	0.69±0.050	0.27±0.050	***
C14:0	5.35±0.28	4.09±0.306	**	5.85±0.296	3.59±0.298	***
C15:0	0.80±0.050	0.63±0.053	*	0.70±0.052	0.73±0.052	ns
C16:0	21.88±0.326	21.54±0.347	ns	22.08±0.336	21.34±0.338	ns
C17:0	0.63±0.033	0.59±0.035	ns	0.67±0.034	0.56±0.034	*
C18:0	0.68±0.020	0.69±0.021	ns	0.69±0.021	0.68±0.021	ns
C16:1	3.38±0.223	3.41±0.237	ns	3.14±0.229	3.64±0.231	ns
C17:1	1.51±0.094	1.61±0.100	ns	1.26±0.097	1.85±0.098	***
C18:1	38.74±0.594	43.55±0.632	***	37.66±0.611	44.64±0.616	***
C18:2 n-6	5.13±0.258	4.85±0.275	ns	5.72±0.266	4.27±0.268	***
C18:3 n-3	1.03±0.077	0.74±0.082	*	1.18±0.080	0.58±0.080	***
C20:4 n-6	1.68±0.140	1.41±0.149	ns	1.95±0.144	1.13±0.145	***
C22:5 n-3	0.90±0.067	0.59±0.072	**	1.02±0.069	0.47±0.070	***
∑SFA	44.16±0.622	41.03±0.663	**	44.59±0.640	40.61±0.645	***
∑MUFA	44.91±0.684	49.53±0.728	***	43.25±0.703	51.19±0.709	***
∑PUFA	10.90±0.461	9.41±0.491	*	12.13±0.475	8.18±0.478	***
n-3 PUFA	2.79±0.211	1.91±0.224	**	3.25±0.217	1.45±0.219	***
n-6 PUFA	7.36±0.387	6.76±0.412	ns	8.17±0.398	5.96±0.402	***
n-6/n-3 PUFA	2.64±0.287	3.54±0.306	ns	2.74±0.296	4.11±0.298	**

∑SFA: sum of saturated fatty acids=C12:0+C13:0+C14:0+C15:0+C16:0+C17:0+C18:0+C19:0+C20:0+C22:0; ∑MUFA: sum of monounsaturated fatty acids=C13:1 n-1+C14:1 n-5+C15:1 n-5+C16:1 n-7+C17:1 n-7+C18:1 n-9+C19:1 n-9+C20:1 n-12+C20:1 n-9+C24:1 n-9; ∑PUFA: sum of polyunsaturated fatty acids=C18:2 n-6+C18:2 c9 t11+C18:3 n-3+C18:3 n-6+C18:4 n-3+C20:2 n-6+C20:3 n-3+C20:3 n-6+C20:4 n-6+C20:5 n-3+C22:3 n-3+C22:4 n-6+C22:5 n-3+C22:6 n-3; n-6/n-3 PUFA: ratio of the sum of n-6 and n-3 polyunsaturated fatty acids=C18:2 n-6+C18:3 n-6+C20:2 n-6+C20:3 n-6+C20:4 n-6+C22:4 n-6/C18:3 n-3+C18:4 n-3+C20:3 n-3+C20:5 n-3+C22:3 n-3+C22:5 n-3+C22:6 n-3, G1: predetermined slaughter weight of 20 kg, G2: predetermined slaughter weight of 30 kg, ns: not significant; *$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$

The percentage amounts of SFA, MUFA and PUFA were 37.4-49.9, 36.4-54.6 and 6.1-16.1, respectively. Higher amounts of MUFA and PUFA, from a human health viewpoint, indicate that Boer kids contain more desirable fatty acids, which according to Rhee (1992) have either a neutral or cholesterol-lowering effect. In our study the minimal n-6/n-3 PUFA ratio was 1.5

and the maximal 6.4. The average value of n-6/n-3 PUFA ratio was 3.6 which is within the recommended range (< 4) for human health (World Health Organization 2003). The average value of n-6/n-3 PUFA ratio was higher than those reported by Talpur *et al.* (2008) for naturally reared male goat kids of Pateri breed and within that reported by Todaro *et al.* (2006) for male goat kids of Girgentana breed fed on concentrate. The higher value of the n-6/n-3 ratio in the heavier kids of our study could be due to feeding with concentrate. De Smet *et al.* (2004) reported that the n-6/n-3 PUFA ratios are mainly affected by animal feeds. The possible reason for different n-6/n-3 ratio between mentioned studies could be also because of the difference in calculating the ratio. Todaro *et al.* (2006) and Talpur *et al.* (2008) calculated the ratio only from the presented fatty acids and in the present study the ratio was calculated from the whole sample.

Contrary to results of the present study, Bonvillani *et al.* (2010) found no significant influence of slaughter weight on the main fatty acid percentages. As expected, muscles from lighter kids contained more SFA (44.59 %) compared to kids slaughtered at heavier weights (40.61 %). This could be because younger kids were still suckling, and at this stage the fatty acid composition of their muscle is still dependent on the fatty acid composition of the consumed milk (Pratiwi *et al.* 2004, Ribeiro *et al.* 2011). Due to the higher percentage of oleic acid in muscles at heavier slaughter weights, the percentages of unsaturated fatty acids (UFA) and MUFA significantly increased ($P \leq 0.001$) and were higher than SFA (Table 1). Werdi Pratiwi *et al.* (2006) also presented data which indicate that muscles at higher slaughter weights had higher percentages of UFA and MUFA, and compared to them, a lower percentage of SFA. The percentages of n-3 PUFA and n-6 PUFA in our study significantly decreased at higher slaughter weights ($P \leq 0.001$). Lighter kids contained 3.25 % of n-3 PUFA and 8.17 % of n-6 PUFA, while heavier kids contained 1.45 % of n-3 PUFA and 5.96 % of n-6 PUFA. Consequently, n-6/n-3 PUFA ratio at higher slaughter weights significantly increased ($P \leq 0.01$). The n-6/n-3 PUFA ratio in lighter kids was 2.74, while in heavier ones was 4.11. This result could be primarily due to the concentrate diet of heavier kids which increased n-6/n-3 PUFA ratio. Enser *et al.* (1998) reported that finishing ruminants on pasture can decrease the n-6/n-3 PUFA ratio to a value of two or less, while concentrate-fed ruminants gave ratios around 6-10. Ryan *et al.* (2007) also found that LD samples from range-fed Boer crossbreed goats had significantly lower n-6/n-3 PUFA ratio than LD samples from concentrate-fed goats.

Sensory panel scores of LD muscle in male and female Boer kids at two different slaughter weights are presented in Table 2. Except for meat colour, sex and slaughter weight did not show significant influence on the analysed sensory traits. Meat quality and acceptability is determined by its physicochemical characteristics, especially its colour as the most important deciding factor for consumers at purchase, and fat composition (Tejeda *et al.* 2008, Nassu *et al.* 2012). Beside that, LSU AgCenter (2010) reported that goat meat consumers have indicated a preference for meat with lighter colour. In our study male kids had significantly darker meat colour (4.04) than female kids (4.97) with estimated difference higher for 0.9 units ($P \leq 0.001$). Although sex affected meat colour, these differences were not high. The effect of sex on the sensory traits is not clear yet. In agreement with results of the present study, Germano Costa *et al.* (2008), Madruga *et al.* (2008) and Bonvillani *et al.* (2010) did not find the effect of sex on the sensory traits, and contrary to them Dawkins *et al.* (2000) and Rodrigues & Teixeira (2009) did find it.

Table 2
Sensory traits of *longissimus dorsi* muscle of male and female Boer kids at two different slaughter weights (LSM±SE)

Sensory traits	Sex effect			Group effect		
	Male (n=17)	Female (n=15)	P	G1[1] (n=16)	G2[1] (n=16)	P
Meat colour	4.04±0.165	4.97±0.175	***	4.24±0.169	4.77±0.171	*
Marbling	1.56±0.087	1.73±0.093	ns	1.53±0.090	1.75±0.091	ns
Off-odour	1.44±0.128	1.70±0.136	ns	1.56±0.131	1.57±0.132	ns
Flavour	5.53±0.058	5.50±0.062	ns	5.50±0.060	5.53±0.060	ns
Juiciness	5.53±0.065	5.37±0.069	ns	5.46±0.067	5.43±0.068	ns
Tenderness	4.93±0.137	4.78±0.146	ns	4.85±0.141	4.87±0.142	ns

G1: predetermined slaughter weight of 20 kg, G2: predetermined slaughter weight of 30 kg, ns: not significant, *$P \leq 0.05$, ***$P \leq 0.001$

Heavier kids had significantly darker meat colour (4.77) than the lighter ones (4.24) with estimated difference for 0.5 units ($P \leq 0.05$).The meat colour score in the present study tends to increase as slaughter weight increases, as expected because as maturity increases, muscle colour becomes darker in goats (Peña *et al.* 2009). This is similar to the results reported by Pratiwi *et al.* (2004), where muscle redness (a* values) and subjective muscle scores (1: pale red, 9: dark red) were positively correlated with muscle pigment concentrations, meaning that muscle colour from heavier Boer bucks was darker. Dhanda *et al.* (1999) also reported darker meat of chevon (slaughter weight in range of 30-35 kg) in comparison to capretto meat (slaughter weight in range 14-22 kg).

In the present study no significant effect of slaughter weight on flavour, juiciness or tenderness of cooked meat was detected. Dhanda *et al.* (2003) found similar results with no significant effect of age/body weight on flavour, juiciness and tenderness between capretto and chevon meat at comparable slaughter weights. Schönfeldt *et al.* (1993) reported that there was no indication of any off flavour or odour from cooked goat meat. This appears contradictory to the concept that the meat from heavier and older goats has a strong unattractive flavour. The main reason for such results in the present study could be due the smaller difference between experimental slaughter weights of the groups.

It can be concluded that male and female Boer kids, across the range of 20-30 kg of slaughter weight, produced meat of different fatty acid composition with no difference in juiciness, tenderness and flavour. Slaughtering of Boer kids at 30 kg could be recommended as increased the goat meat production with still good meat quality. As sensory evaluation of goat meat has relatively limited research, we recommend that in the future, as goat meat is gaining popularity, it is necessary to conduct more detailed studies with consumers included.

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