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Growth Performance, Carcass Characteristics and Meat Quality of Boer-Cross Wether and Buck Goats Grazing Marshall Ryegrass

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ABSTRACT : An experiment was conducted to evaluate the effects of castration on growth performance, carcass characteristics, and meat quality of goat kids. Fourteen Boer-cross buck and wether goat kids (n = 7; initial body weight (BW) 38.0±0.35 kg and 34.8± 0.35 kg, for bucks and wethers, respectively) were grazed on annual Marshall ryegrass (*Lolium multiflorum* Lam.) for 56 days. Body weights were recorded after 4 h withdrawal from feed and water for two consecutive days, every 2 wk. After d 56, animals were harvested and hot carcass weight (HCW), cold carcass weight (CCW), dressing percent (DP), kidney and pelvic fat (KPF), *longissimus* muscle (LM) area, back fat (BF), and other carcass parameters were measured. Day 0 BW was used as a covariate for analyses. However, bucks were heavier than wethers at d 15 (p = 0.09), 42 (p = 0.001) and 56 (p = 0.001). Bucks had higher ADG (146 vs. 74 g/d; p = 0.001), HCW (21.2 vs. 18.8 kg; p = 0.06) and CCW (20.3 vs. 17.9 kg; p = 0.04) when compared with wether goats. Dressing percentage (51 vs. 47%; p = 0.06), KPF (0.44 vs. 0.16%; p = 0.02) and BF (0.41 vs. 0.21 cm; p = 0.05) were higher in wethers vs bucks, respectively; however, USDA live or carcass grades were similar. *Longissimus* muscle tissue from wethers and bucks were similar in darkness (*L**) and redness (*a**), but wethers had more (p = 0.02) yellow tint (*b**). Palmitic (C16:0), stearic (C18:0) and oleic (C18:1) acids were higher (p = 0.001) in muscle tissue from wethers compared to bucks. The saturated fatty acid (SFA) and monounsaturated fatty acid (MUFA) contents of muscle tissue were lower (p = 0.001) for bucks with no difference in polyunsaturated fatty acids (PUFA). *Longissimus* muscle initial temperature was higher in bucks (p<0.04) and pH change post-mortem was similar for bucks and wethers. These results indicated that castration of young market goats reduced growth performance and produced carcasses with more fat and higher SFA. (**Key Words :** Buck, Carcass Characteristics, Fatty Acids, Growth, Wether)

INTRODUCTION

For the ease of management, majority of male goats used for meat production are castrated in the U.S. The process of castration causes animal stress, is associated with extra costs, lowers ADG (Mahgoub and Lodge, 1996), and produces carcasses with higher fat contents (Mahgoub et al., 2004). Goats, like other ruminants have different growth and development patterns, and data on live goat measurements of different breed types, ages, and gender classes are necessary to establish classification groupings of live goats (McMillin et al., 1999). The carcass characteristics have been well studied in sheep (Butterfield, 1988), cattle (Berg and Butterfield, 1976), and to a certain extend in goats (Warmington and Kirton, 1990; Colomer-Rocher et al., 1992). However, limited work has been done on carcass characteristics and fatty acid (FA) profiles of Boer cross wethers compared to intact male goats.

Fatty acids are the major component of lipids and affect meat quality. The fatty acid composition of fats determines its degree of saturation, and therefore, significantly affects its quality. Fatty acid content of body tissues is affected by nutrition as was evidence in goats grazing on pasture having more unsaturated intermuscular fat than those fed grain (Rhee et al., 2000). Few researchers (Banskalieva et al., 2000; Sheradin et al., 2003) have reported FA profiles of goat meat. Webb et al. (2005) have reported factors affecting goat meat quality and compared FA profiles of goat meat to sheep. However, research evaluating the effects of castration on carcass characteristics and quality of meat in male and castrated goat kids is lacking. Therefore, the objectives of this study were to determine carcass characteristics and FA profiles of Boer cross wethers and

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intact male goats grazed on annual ryegrass pasture.

MATERIALS AND METHODS

Animals and diet

The Auburn University and Tuskegee University Animal Care and Use Committees approved the animal care, handling and sampling procedures for this experiment. Fourteen Boer-cross wethers (body weight (BW), 34.5±0.35 kg) and intact male goats (BW, 38.0±0.35 kg) were randomly selected for this study to evaluate the effect of castration on animal performance, carcass characteristics, and meat quality of goat kids. Goats were purchased as wethers or bucks from a producer in Boaz, Alabama. Upon arrival, animals were weighed, vaccinated with a s.c. injection of Clostridium perfringens type C and D-Tetani Bacterin-Toxoid (Bayer: Bayer Corp., Animal Health, Shawnee Mission, Kansas), and dewormed orally with Cydectin (Moxidectin, Fort Dodge Animal Health, Fort Dodge, Iowa) under supervision of a veterinarian. The grazing trial was conducted at the Alabama Agricultural Experiment Station, E.V. Smith Research Center, Beef Unit, Shorter, AL.

Marshall ryegrass (*Lolium multiflorum* Lam.) was planted on a prepared seedbed in September at a seeding rate of 37 kg/ha. Nitrogen fertilizer was applied at 123 kg nitrogen (N)/ha at planting, and 74 kg N/ha again in February. Goats were placed on annual ryegrass pastures and rotated between 2 one-ha paddocks as needed. Body weights were recorded every 2-wk after 4-h withdrawal from feed and water and the experiment was carried out for 56 d. Animals had free access to water and trace mineral blocks at all times.

Forage grab samples (n = 8 to 10) were randomly collected across each pasture every 4-wk. Composite samples were dried for 48 h at 55°C in a convection oven (model 420, NAPCO, Pittsburgh, PA) and equilibrated to room temperature for 24 h to determine partial DM. Samples were ground in a Thomas-Willey mill (model 4, Thomas Scientific, Philadelphia, PA) to pass through a 1-mm mesh screen. Ground composite samples were analyzed for DM, ash, and CP according to the methods described by AOAC (1998). Nitrogen was determined using a Leco TruSpec (Leco Corporation, St. Joseph, MI) and CP was calculated by multiplying N by 6.25. Forage NDF and ADF were determined on composite samples according to Van Soest et al. (1991) using an Ankom 200 fiber analyzer and ANKOM F57 filter bags (Ankom Technology Corp., Fairport, NY).

Carcass characteristics and evaluation

Final BW was obtained after 56 d on two consecutive days, and goats were transported approximately 40 km to the Auburn University Lambert Meat Laboratory Abattoir and were harvested according to the USDA approved guidelines. The Institutional Meat Purchase Specifications for fresh goat, series 11, (IMPS; USDA, 2001) was used to report live and carcass selection criteria. According to the IMPS, selection criteria range from No. 1 to No. 3. Selection No.1 designated the highest proportion of muscle to bone ratio while selection No. 3 designated the lowest muscle to bone ratio evaluated on live animals or carcasses of animals. Hot carcass weight was determined on the day of slaughter and carcasses were chilled at 4°C for 48 h, then carcass selection grade, chilled carcass weight (CCW), and carcass shrink weight were measured. Carcasses were ribbed between the 12^{th} and 13^{th} rib for further evaluation. Fat depth (BF) over the midpoint of longissimus muscle (LM) at the 12^{th} rib, body wall fat (BWF) measured at lower point of the12^{th} rib, adjusted fat thickness (ADFT; estimated using BF and BWF), kidney and pelvic fat weight (KPF), dressing percentage (DP) and LM area (LMA) were determined by certified USDA grader 48 h postmortem. Longissimus muscle pH and temperature were measured at the 12^{th} to 13^{th} rib 1, 3, 5 and 24 h postmortem using a pH and temperature meter with piercing electrode and temperature probes (Thermo Orion meter, Orion Research, Boston, MA). Ribbed carcasses were allowed to bloom for approximately 30 min at 4°C and evaluated for objective color measurements. Commission Internationale de l'Eclairage (CIE) lean color L* (muscle lightness), a* (muscle redness), and b* (muscle yellowness) values were measured from two readings at the 12^{th} rib LMA with a Hunter Miniscan XE Plus (HunterLab, Reston, VA) and averaged to obtain a representative measure of initial lean color. The Miniscan utilized a D65 light source, a 10° viewing angle, and a 35 mm viewing area. The Miniscan was calibrated according to manufacturer's recommendations.

Fatty acid and cholesterol analysis

Samples for FA and cholesterol analyses were taken from the right half of the carcass, across the whole width of the longissimus dorsi muscle at the 12^{th}-13^{th} rib. Samples were vacuum-packaged and stored at -80°C. Total lipid extraction was done following the chloroform-methanol procedure of Folch et al. (1957). Nonadecanoate acid (C19:0) (Avanti Polar Lipids Inc., Alabaster, AL) was added as an internal standard. Fatty acid methyl esters (FAME) were prepared following the procedure of Park and Goins (1994). The FAME were analyzed using a Agilent Technologies 6890N gas chromatograph (Agilent Technologies Inc. Santa Clara, CA), and separated using a 60-m DB-23 capillary column (0.25 mm i.d. and 0.25 um film thickness). Individual fatty acids were identified by

comparison of retention times with standards (Nu-chek Prep, Inc. Elysian, MN) and quantified as mg/g of muscle using the internal standard.

Statistical analysis

Data were analyzed by the Mixed Model procedure of the Statistical Analysis Systems (SAS, Inst., Inc., Cary, NC) for completely random design, with the factors examined being gender treatments (wether vs. buck). Animals were the experimental unit and were treated as a random effect. Mean separation was performed using Fisher's Protected Least Significant Differences at probability level $p<0.05$. Animal BW change, muscle temperature and muscle pH were analyzed as a repeated measures design with gender, day and gender×day interactions. The relationships between carcass weight and fatty acid composition were further examined by linear regression analysis. The variables included were forage chemical composition, ADG, carcass characteristics, FA profile, muscle temperature, and muscle pH. Initial data (d 0) for BW and ADG were used as a covariate for statistical analysis. Data are presented as mean values together with the standard error of the mean. There were no treatment×day interaction ($p>0.35$); hence only main effects are reported in the result section.

Table 1. Chemical composition of Marshall ryegrass pastures during grazing season[1]

Parameter[2]	February-March	March-April	SE
	---------- % ----------		
Crude protein	24.3	20.2	1.54
Neutral detergent fiber	40.3	45.2	1.96
Acid detergent fiber	20.4	25.5	1.45
Ash	6.24	6.96	0.72

[1] February-March was first 28 days and March-April was second 28 days.
[2] All values are on DM basis.

RESULTS AND DISCUSSION

Ryegrass pasture provided a high quality feed for goats having 20-24% CP, 40-45% NDF, 20-25% ADF, and 6-7% ash on DM basis (Table 1). Goats consumed Marshall ryegrass readily with no evidence of bloat or other nutritional disorders. Ryegrass pasture met and exceeded the maintenance and gain requirements of growing goats according to NRC (2007). Body weight, ADG, carcass traits and selection criteria of Boer cross wethers and bucks are summarized in Table 2. Although Bucks were initially

Table 2. Least-square means of body weight (BW), average daily gain (ADG), carcass traits and selection scores in Boer cross goats grazing on ryegrass pasture

Item	Date	Groups		SEM	p-value
		Wether	Buck		
Number of animals		7	7		
BW[1]					
	0 d	36.41	36.41	0.0	1.0
	15 d	37.3	38.5	0.41	0.09
	42 d	39.8	43.8	0.54	0.001
	56 d	39.8	44.2	0.86	0.006
ADG (g/d)	56 d	73.7	146.2	15.3	0.001
Carcass characteristics[2]					
Harvest weight (kg)		38.3	45.7	2.01	0.004
HCW (kg)		18.8	21.2	1.17	0.06
CCW (kg)		17.9	20.3	1.09	0.04
Dressing %		51.0	47.0	0.14	0.06
48 h cooler shrink (%)		4.0	3.0	0.09	0.46
KPF (%)		0.44	0.16	0.09	0.02
BWF (cm)		0.41	0.21	0.09	0.05
ADFT (cm)		0.23	0.14	0.06	0.18
LMA (cm^2)		12.5	12.4	0.94	0.88
Live grade[3]		2.61	2.29	0.17	0.10
Carcass grade[3]		2.68	2.38	0.19	0.14

[1] Initial data (d 0) for BW and ADG were used as a covariate for statistical analysis. However, harvest weight is actual BW at harvest.
[2] CCW = Cold carcass weight; dressing percentage = (HCW×100)/starved live weights; KPF = Kidney pelvic fat; BWF = Body wall fat; ADFT = Adjusted fat thickness; LMA = Longissimus muscle area.
[3] USDA selection criteria range, 1 = Superior meat type conformation, thickly muscled throughout the body; 2 = Average meat type conformation, moderately muscled throughout the body; 3 = Inferior meat type conformation, narrow in width and very angular in appearance.

heavier than wethers (38.0±0.35 kg vs. 34.8±0.35 kg), after covariate data analysis by d 0, all goats had similar BW. By d 15, bucks tended to have higher ($p<0.09$) BW and remained heavier ($p<0.006$) through the rest of the grazing period. This was also reflected in higher ($p<0.001$) ADG that was nearly doubled for bucks as compared to wether goats. Similar results have been reported for wether sheep and steers (Field, 1971) when compared with their intact male counterparts. This practice and resultant reduced gains, justified the use of synthetic hormones for those species without having the management problems found in intact males.

Increased interest in goat meat production from intact males is related to the declining demand for animal fat, the increased importance on more efficient red meat production, and the need for superior amount of animal protein. Final harvest weight ($p<0.004$), HCW ($p<0.06$), and CCW ($p<0.04$) were higher, but DP ($p<0.06$), KPF ($p<0.02$), and BWF ($p<0.05$) were lower for buck kids as compared to wether goat kids. No differences ($p>0.10$) were detected in cooler shrink %, ADFT, LMA, live grade and carcass grade values between two genders. This is similar to the result obtained by Field (1971), who found bulls had higher feed efficiency (13%), ADG (14 to 15%), greater muscle to bone ratios and less fat thickness (9.6 vs. 14.0 mm, respectively) compared to steers. Subsequent work reported that rams grow faster (0.23 vs. 0.20 kg, respectively) and had higher (12 to 15%) feed efficiency than wethers (Field, 1971).

In the present study, although bucks had higher final and harvest BW, they failed to produce higher DP when compared to wethers. Differential body tissue growth in bucks and wethers may contribute to higher non-edible body parts that lowered DP in bucks and higher proportion of carcass fat (KPF; $p<0.02$) in wethers that may have contributed to higher DP in wether goats. Goats generally tend to have a lower DP compared to sheep (Tshabalala et al., 2003). The carcass fat content is highly variable and can be influenced by breed, age, sex, nutrition, BW, physiological condition and physical activities (Owen et al., 1978; Kirton, 1988). In agreement with our results, Mahgoub et al. (2002, 2004) reported faster rate of deposition for carcass and non-carcass fat and total fat for Jebel Akhdar Omani does and wethers raised under intensive management as compared to bucks. Goats tend to deposit most of their fat in the visceral rather than carcass depot and produce leaner carcasses (Devendra and Owen, 1983). Similarly, wether goats had higher KPF than intact male goats in the present study.

Hunter colorimetric co-ordinates L*, a*, and b* for LM of Boer cross bucks and wethers are reported in Table 3. There was no difference in meat color of bucks and wethers except for wethers having higher b* values associated with more yellow color of lean. Goat meat is reported to have lower L* (darker) and b* (yellow) values and higher a* (red) values when compared to lamb meat (Babiker et al., 1990). The Hunter colorimetric co-ordinate L* was lower (darker), and a* (red) and b*(yellow) were higher for LM of buck and wether goats in our study compared to values for Boer crosses reported by Dhanda et al. (1999).

Drop in temperature and pH of buck and wether muscles during 24 h postmortem are presented in Figure 1a and b, respectively. Although initial muscle temperature for wethers was higher ($p<0.04$), rate of drop in temperature was similar for both groups. The ultimate pH is important to the chilled meat because it affects its shelf life, color, and quality. Initial muscle pH and drop in pH were similar for buck and wether goat LM postmortem, and ultimate pH for both groups was higher than desirable values of 5.5 to 5.8 where meat is light colored and tender (Gardner et al., 1999). High ultimate pH values for goat muscle have been reported in the literature reviewed by Webb et al. (2005). Ultimate pH for buck and wether LM was in the range of 5.99-6.02, similar to those reported by Simela et al. (2004; pH 5.88-6.03) for South African goats. This range of pH is more closely associated with the pH (5.9-6.2) of dark and tough meat with high water holding capacity that is more prone to bacterial damage and consequently shorter shelf life (Warris et al., 1984; Warner et al., 1998). According to Cornforth et al. (1980), both buck and wether muscles were prone to cold shortening having a pH of above 6.00 at 10°C.

Fatty acid composition of LM in Boer cross buck and wether goats is presented in Table 4 and Figure 2. Total fatty acid content of muscle from Boer cross wether goats was higher ($p<0.001$) than bucks. Muscle from both groups contained fatty acids oleic (18:1), palmetic (16:0) and stearic (18:0) as most prominent acids. The degree of

Table 3. Hunter colorimetric co-ordinates *L**, *a** and *b** of longissimus muscle (LM) from Boer cross goat kids measured 48 h postmortem

Parameter	Wether	Buck	SEM	p-value
Number of animals	7	7		
*L** value[1]	28.05	29.91	1.40	0.92
*a** value	17.35	16.21	0.81	0.18
*b** value	16.82	15.44	0.52	0.02

[1] *L** values are a measure of lightness (higher value indicates a lighter color); *a** values are a measure of redness (higher value indicates a redder color); *b** values are a measure of yellowness (higher value indicates a more yellow color).

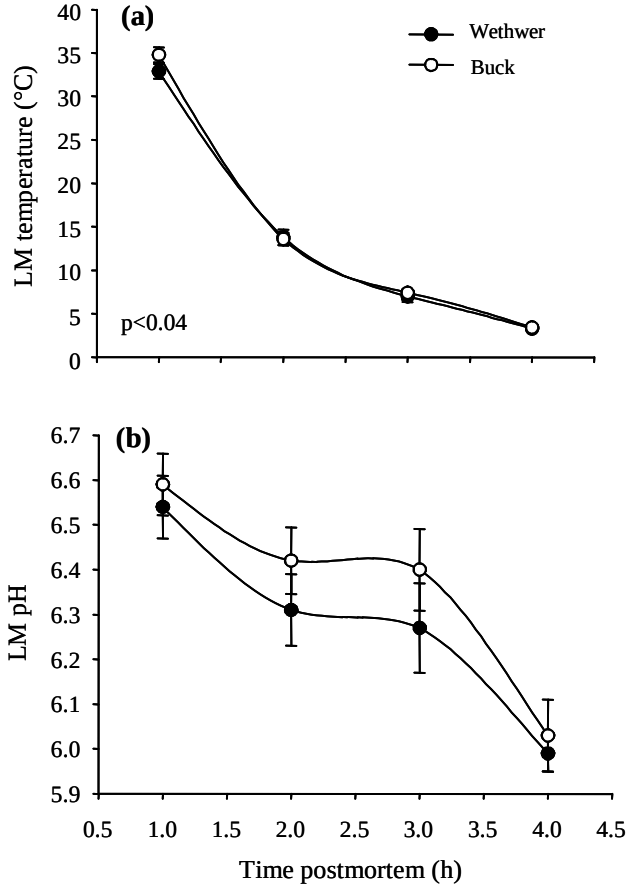

Figure 1. The effect of castration and postmortem time (h) on longissimus muscle (LM) temperature (a) and pH (b) in Boer cross buck and wether goat kids (n = 7) grazed on annual Marshall ryegrass for 56 d.

saturation of fat is one of the most important characteristics affecting the quality of meat. Long chain SFA solidify easily upon cooling and affect the meat palatability. The most prominent saturated fatty acids 16:0 and 18:0 were higher ($p<0.001$) in wethers than bucks that may contribute to better quality meat of wethers than bucks. Unsaturated fatty acids (UFA) having more double bonds in their carbon chain are prone to direct oxidation and indirectly through lipolytic enzyme activity that splits fatty acids from glycerol (Webb et al., 2005). Chemical oxidation produces peroxides with free radicals that damages proteins and enzymes that maybe less important in affecting meat quality than enzymatic action of lipase; however, both affect flavor, odor, and shelf life of meat. Mono unsaturated fatty acid (C18:1) was higher ($p<0.001$) in muscles from wethers as compared to bucks, which may promote direct and indirect chemical oxidation of meat from wether goats.

Fatty acids also play an important role in human nutrition. Desirable fatty acids (DFA) are stearic (C18:0) and all unsaturated fatty acids (Banskalieva et al., 2000). In the present study, total DFA (C18:0+polyunsaturated fatty acid (PUFA)+monounsaturated fatty acid (MUFA)) were higher ($p<0.001$) in wether goat muscles than bucks; however, both groups had high percentage of DFA (75.6 vs.

Table 4. Intramuscular fatty acid and cholesterol compositions (mg/g of tissue) of longissimus muscle (LM) from Boer cross goat kids

Item	Wether	Buck	SEM	p-value
Number of animals	7	7		
14:00	0.72	0.18	0.05	0.001
14:01	0.03	0.01	0.01	0.11
15:0	0.13	0.06	0.02	0.02
15:1	0.02	0.02	0.03	0.95
16:0	8.92	3.1	0.62	0.001
16:1t	0.23	0.09	0.02	0.001
16:1c	0.67	0.10	0.11	0.001
17:0	0.49	0.18	0.05	0.001
17:1	0.32	0.06	0.06	0.003
18:0	7.08	2.92	0.67	0.001
18:1 n11c	0.83	0.25	0.11	0.003
18:1 n9c	19.31	6.2	1.51	0.001
18:1 n7c	0.52	0.17	0.07	0.001
18:2 n6t	0.02	0.08	0.008	0.42
18:2 n6c	1.36	0.98	0.11	0.03
18:2 n9-t11(CLA)	0.16	0.04	0.03	0.01
18:3 n6	0.0	0.004	0.0003	0.33
18:3 n3	0.22	0.19	0.02	0.39
19:01	0.0	0.01	0.004	0.15
20:00	0.0	0.004	0.004	0.33
20:1 n12	0.0	0.07	0.003	0.16
20:1 n9	0.0	0.007	0.003	0.15
20:2 n6	0.12	0.10	0.03	0.63
20:3 n6	0.0	0.04	0.006	0.01
20:4 n6	0.67	0.61	0.07	0.51
20:5 n3 epa	0.09	0.12	0.02	0.43
22:4 n6	0.0	0.02	0.01	0.07
22:5 n3	0.0	0.1	0.03	0.02
24:1 n9	0.18	0.06	0.03	0.02
SFA	16.9	6.14	1.15	0.001
MUFA	22.3	6.30	1.77	0.001
PUFA	2.61	2.23	0.24	0.19
n-6	2.09	1.77	0.19	0.18
n-3	0.32	0.42	0.05	0.23
n-6:n3	7.34	4.86	0.66	0.02
PUFA/SFA	0.18	0.40	0.03	0.01
Total FA, mg/g	42.1	14.8	2.80	0.001
DFA	31.8	11.30	2.19	0.001
% DFA	75.6	74.6	3.24	0.82
Cholesterol, mg/g tissue	66.0	65.0	2.00	0.53

FA = Fatty acids; DFA = Desirable fatty acids = C18:0+all unsaturated fatty acids; PUFA = Polyunsaturated fatty acid; SFA = Saturated fatty acid.

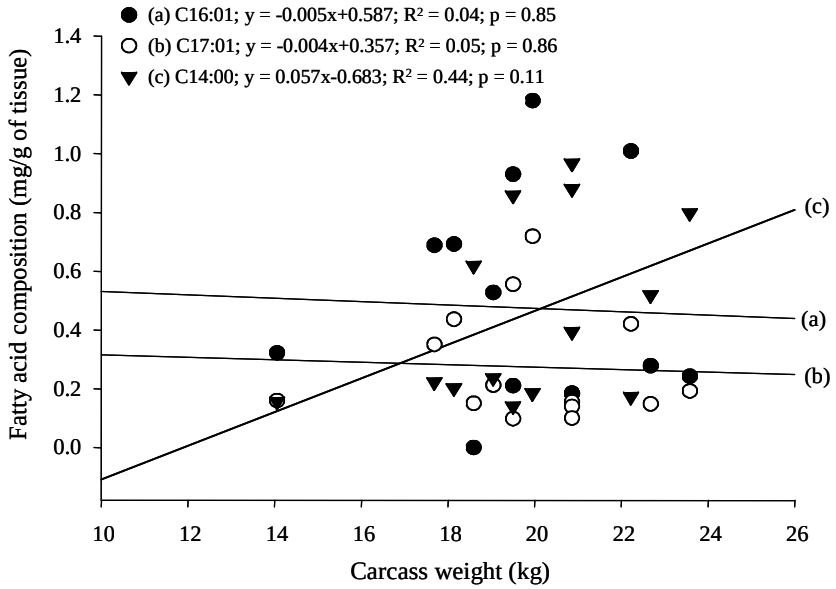

Figure 2. The relationships between carcass weight (kg) and monounsaturated fatty acid (MUFA) composition in Boer cross buck and wether goat kids (n = 14) grazed on annual Marshall ryegrass for 56 d.

74.6%, wethers vs. bucks) in their meat, similar to those reported for Boer goat kids (Sheradin et al., 2003). Ratio of PUFA/SFA of 0.45 or higher (Enser et al., 1998) and high proportion of n-3 PUFA along with a ratio of n-6/n-3 that is closer to unit and less than 5 is desirable (Raes et al., 2004). In the present study, ratio of PUFA/SFA for wethers (0.18) was lower ($p<0.01$) than bucks (0.40), thus, buck LM had more desirable ratio for consumer health. These ratios are within range of 0.16-0.49 reported in literature reviewed by Banskalieva et al. (2000). Linoleic acid (C18:2n-6) yields n-6 and linolenic acid (C18:3n-3) produces n-3 acids. Higher n-6 PUFA yields more thrombotic tendencies than n-3 PUFA derivatives that predispose consumers to coronary diseases (Enser, 2000; Simopoulos, 2008). There was no difference ($p>0.10$) in n-3 or n-6 PUFA in meat samples from Boer cross wethers or bucks; however, the ratio of n-6/n-3 was in the rage of 7.3 to 4.9, approaching undesirable ratios for consumer health. These results were similar (4.4-5.9) to those reported by Sheradin et al. (2003) for Boer kids. Conjugated linoleic acid (CLA) isomers have been reported to be anti-carcinogenic, immunomudulator, anti-atherosclerosis, and may promote protein rather than fat deposition (Enser, 2000). In the present study, CLA content (C18:2 n9-t11) was higher ($p<0.01$) in wether goat muscles than bucks. Usually browse fed goats tend to have higher CLA content (Solaiman et al., 2006).

To further understand the effect of carcass weight on fatty acid composition in wether and buck goat kids, carcass weights were regressed against fatty acid composition in muscle (Figure 2). Palmitoleic (C16:1) and heptadecenoic (C17:1) acids are MUFA and were not affected ($p = 0.85$) by carcass weight, but myristic acid (C14:0, saturated FA) tended to increase ($R^2 = 0.44$; $p<0.11$) as carcass weight increased. Studies carried out by Kosulwat et al. (2003) in weaned lambs indicated that the proportion of myristic acid increased and stearic acid decreased as carcass fatness increased. There was no difference ($p>0.10$) in cholesterol content between buck and wether muscle in the present study.

Raising goats for meat is gaining popularity in the western countries specially the U.S. Although goats are often castrated at a young age for ease of management, castration has a negative impact on animal gain and carcass composition. Additionally, the meat from castrated male goats is higher in total fat content and has less desirable poly-unsaturated fatty acid to saturated fatty acid ratios.

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