International Journal of Animal and Veterinary Advances 6(6): 162-168, 2014
ISSN: 2041-2894; e-ISSN: 2041-2908

Submitted: May 31, 2014 Accepted: June 20, 2014 Published: December 20, 2014

Effect of Sodium Bicarbonate Supplementation on Fatty Acid Composition of Lambs Fed Concentrate Diets at Different Ambient Temperature Levels

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Abstract: The objective of this study was to evaluate the effect of ambient temperature and sodium bicarbonate ($NaHCO_3$) supplementation in diets for growing lambs on meat fatty acids composition. A slaughter study was carried out on 12 male Black Belly Barbados lambs randomly drawn from a prior growth trial (245 days). The lambs were divided into four equal groups and allotted in a 2×2 factorial design. The lambs were allotted at random to two dietary treatments of a basal diet (35: 65 roughage: concentrate) or basal diet supplemented with 4% $NaHCO_3$ at different ambient temperatures (20 and 30°C) in an environment controlled chamber for 10 days. Lambs were slaughtered for carcass evaluation at about 262 days of age (245 days of growth trial, 7 days adaptation and 10 days of experimental period). Samples for fatty acids analysis were taken from the leg muscles and *longissimus dorsi* region (between the 12^{th} and 13^{th} rib). Ambient temperature influenced ($p<0.05$, $p<0.01$, $p<0.001$and $p<0.05$) C18:2t isomers, C20:4, C20:3 *n*-6 and C20:4 *n*-6 levels on the *longissimus dorsi* muscle, with higher C20:3 *n*-6 ($p<0.001$) but lower C20:4 *n*-6 ($p<0.05$) levels in lambs under the higher ambient temperature. The fatty acids C18:1c, C18:2t and C20:5 levels on the leg muscle were also significantly influenced ($p<0.01$, $p<0.001$ and $p<0.01$ resp.) by dietary treatments with higher levels in lambs fed $NaHCO_3$ diet. These results indicated that $NaHCO_3$ supplementation at low ambient temperatures significantly decreased fatty acids levels.

Keywords: Ambient temperature, fatty acids, lambs, sodium bicarbonate

INTRODUCTION

In response, to consumer demands for lean and easily digestible meat of high quality and good taste, fattening schemes wean lambs approximately 6-8 weeks and place them on high-concentrate diets for an extra 5-7 weeks (Bodas *et al*., 2010; Mohammad *et al*., 2010). This is done in order to obtain high energy intakes, rapid attainment of adequate slaughter weight, reduced days in feed and shortened slaughter cycle (Perlo *et al*., 2008; Bodas *et al*., 2010). However, disadvantages of the use of such diets include:

- Digestive disturbances
- Extensive bio hydrogenation and conversion to saturated fatty acids in the small intestines
- The production of soft fat resulting from excessive ruminal propionate production beyond the liver's gluconeogenic capacity and its utilisation for the production and deposition of odd-numbered methyl-branched long chain fatty acids (Kawas *et al*., 2007a, b). To avoid such incidence, several nutritional therapies have been suggested including the use of dietary buffers.

Although there is evidence supporting the use of $NaHCO_3$ in small ruminant production, few studies on meat fatty acid composition of sheep with *ad libitum* access to concentrate have appeared in literature (Bodas *et al*., 2010) particularly, in tropical conditions. High ambient temperatures elicit physiological changes in the digestive system and Bodas *et al*. (2007) associated the inclusion of this salt in diets to changes in blood biochemical profile, increases in bicarbonate, base excess and pCO_2 which influenced pH fall post-mortem and meat characteristics by modifying the activity of enzymes associated with carbohydrate metabolism. $NaHCO_3$ could alter the proportions of the volatile fatty acids in the rumen by modifying either bacteria and ciliate protozoal population or rate and extent of degradation of feed (Santra *et al*., 2003). These changes in volatile fatty acid pattern could affect fatty acid composition of the meat. Thus, the objective of this study was to evaluate the effect of ambient temperature on meat fatty acid composition of lambs' concentrate diets with or without $NaHCO_3$ supplementation.

MATERIALS AND METHODS

Animals, housing and feeding: A slaughter study was carried out on 12 male lambs (17.0 kg average live weight, 3 months old) randomly drawn from a growth trial and allotted by a 2×2 factorial design for a period of 10 days. The lambs (Black Belly Barbados), were

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divided into four equal groups and fed basal diet (35: 65 roughage: concentrate) or basal diet supplemented with 4% $NaHCO_3$ at different ambient temperatures (20 and 30°C) all through the 10 days experimental period. Diet comprised of DM: 55%, NE for milk: 1.092%, CP: 8.15%, Ca: 0.8%, P: 0.59% and ADF: 39.91%. The animals were balanced for body weight and housed in individual pens of size (1×1.5 m) with steel slatted floors. Feed was offered *ad libitum*. All animals had free access to water through automatic drinkers. Prior to the experiment, the animals were dipped in a solution of Gematox to eliminate ectoparasite. All animals were injected with Ivomec for control of endo and ectoparasites. Lambs were slaughtered for carcass evaluation. Samples for fatty acids analysis were taken from leg muscles and *longissimus dorsi* region (between the 12^{th} and 13^{th} rib).

Slaughter and carcass evaluation: Final Slaughter Weight (FSW) was obtained by averaging live weights records during the experimentation period. At the end of the growth trial, animals were slaughtered for carcass evaluation age (245 days of growth trial, 7 days adaptation and 10 days of experimental period). The animals were fasted for 6 h before slaughter. All animal however had free access to water until slaughtered in the abattoir following routine commercial slaughterhouse standard procedures. The animals were transported in a truck and were subsequently held in the slaughter house lairage for about 1 hour before slaughter. Each animal was carefully handled to minimize excitement. After 1 hour the animals were weighed again, stunned, bled, skinned and eviscerated. Each carcass was split along the vertebral column into left and right halves using a knife. *Longissimus dorsi* and leg muscles from the half carcasses were collected within 20 min of slaughter, trimmed and analyzed for meat quality traits.

Fatty acid analysis: Samples were taken from both the leg and *logissimus dorsi* muscle minced and vacuum packed in zipped plastic backs (100 g for each animal) and stored at -20°C until fatty acids analysis. Prior to grinding with a domestic grinder all harvested samples were stripped off of all fat cover, subcutaneous and intramuscular fat and connective tissues. Fatty acids analyses were performed following the method described by Manso *et al*. (2009) using 300 mg of freeze dried minced leg and *Longissimus dorsi* muscles. Anhydrous HCl/methanol was used for the methylation of the fatty acids and tridecanoic acid (C13:0) was used as internal standard (4 mg/mL). Methyl esters of fatty acids were quantified by GC (HP 5890 GC, Hewlett-Packard, USA) using a capillary column (HP 88, 100 m ×0.25 mm, Agilent Technologies, USA). The injector and detector temperatures were of 200 and 300°C respectively and the helium flow ratio was 1 mL/min. An automatic split/splitless injector was used with a ratio 30:1 split and pressure of 16 psi. After injection (1 μL), the column temperature was held at 50°C for 1 min and then increased to 180°C at 10°C/min. The temperature was kept at 180°C for 25 min, followed by an increase of 2°C/min to 220°C and, finally, held at 260°C for 5 min. The identification of peaks was made by comparison of retention times with the ones obtained for Fatty Acid Methyl Ester (FAME) standard mixtures acquired from Un-Check-Prep Inc. (Elysian, MN, USA) and from Supelco Inc. (Bellefonte, PA, USA). All fatty acids were expressed as weight in percentages of total fatty acids measured in each sample. The total saturated fatty acids (ΣSFA) were calculated by adding together the C4:0, C6:0, C10:0, C12:0, C14:0, C15:0, C16:0, C17:0 and C18:0 fatty acids. The total polyunsaturated fatty acids (ΣPUFA) were calculated by adding together the C18:2t, C18:2c, C20:0, C20:5, C22:6, C18:3*n*-3 and C20:4*n*-6 fatty acids. Atherogenicity (AI) and Thrombogenicity (TI) indexes were calculated according to Barton *et al*. (2010) and Lazzaroni *et al*. (2009): AI = [C12:0+(4 * C14:0)+C16:0]/[(ΣPUFA) + (ΣMUFA)]; TI = [C14:0+C16:0+C18:0]/[(0.5 * ΣMU FA)+(0.5 * *n*-6)+(3 * *n*-3)+(*n*-3/*n*-6)].

Statistical analysis: Data on fatty acids composition were analysed using the GLM (General Linear Model procedures) SAS (Statistical Analysis System) version 6.21. All data on meat fatty acids quality traits were subjected to an ANOVA by the GLM procedure. Means were compared using the least square means procedure SAS (Statistical Analysis System) and the level of significance declared at $p<0.05$.

RESULTS

The effects of ambient temperature on individual fatty acid composition (%) of meat from leg muscles of the experimental lambs are presented in Table 1. Among the SFA, C4:0, C10:0 and C18:0 were significantly affect ($p<0.05$; $p<0.001$ and $p<0.05$, respectively) by ambient temperature. Higher levels for the fatty acids (C4:0 and C18:0) were observed on lamb meat from those exposed to the lower ambient temperature than the other group. Likewise, on the same muscle, the C18:2t isomer and the PUFA C18:3 *n*-6, C20:3 *n*-6 and C20:4 *n*-6 were significantly affected ($p<0.001$; $p<0.01$; $p<0.01$ and $p<0.5$, respectively) by ambient temperature. Effect of ambient temperature on the levels of ΣFA composition and their ratios on leg muscles of lamb are shown in Table 2. The levels of ΣPUFA were significantly affected ($p<0.01$) by ambient temperature with higher levels from those lambs exposed to the lower ambient temperature group compared to the ones from the lower ambient temperature group.

The effects of dietary treatments on individual fatty acid profile composition (%) of meat from leg muscles of the experimental lambs are presented in Table 3. There were significant differences ($p<0.05$, $p<0.01$ and $p<0.05$) in C6:0, C10:0 and C18:0 levels on the meat

Table 1: Effect of ambient temperature on individual fatty acid composition of leg muscles of the experimental lambs

	Leg muscle			
FA (%)	20°C	30°C	SEM	Sig.
C4:0	0.1984[a]	0.0149[b]	20.2470	*
C6:0	0.0233	0.0152	4.21420	NS
C10:0	0.01183[b]	0.0431[a]	3.51360	***
C12:0	0.0358	0.0657	4.36490	NS
C14:0	1.3043	1.3903	4.47080	NS
C15:0	1.4559	0.5247	2.47900	NS
C16:0	14.3690	13.9540	0.55010	NS
C17:0	1.6021	1.2084	3.42410	NS
C18:0	10.1550[a]	5.6430[b]	0.94620	*
C14:1	0.7277	0.3073	3.72670	NS
C15:1	1.9120	0.7830	1.40760	NS
C16:1	5.4540	6.3530	0.62580	NS
C17:1	1.3554	1.2267	3.90340	NS
C20.1	0.8020	0.6594	11.4292	NS
C18:1t	0.9242	0.7697	5.25340	NS
C18:1c	35.2580	43.7110	0.39450	NS
C24:1	0.1049	0.0731	9.76910	NS
C20:2	3.2310	1.6420	0.58800	NS
C18:2t	2.0753[a]	0.5639[b]	18.8847	***
C18:2c	23.3800	15.4660	0.30230	NS
C18:3 *n*-3	1.8337[a]	0.3145[b]	1.43250	**
C20:4	4.6880	3.3080	1.31360	NS
C20:5	0.4184	0.4402	25.4342	NS
C22:6	0.0547	0.0582	49.4468	NS
C20:3 *n*-6	1.1397[a]	0.0685[b]	23.9617	**
C20:4 *n*-6	4.017[a]	1.109[b]	1.69120	*

[a,b]: Means within row without common superscript differ significantly (p<0.05); *p<0.05; **p< 0.01; ***p<0.001; NS: Not Significant (p>0.05)

Table 2: Effect of ambient temperature on total fatty acid composition and their ratios of leg muscles of the experimental lambs

	Leg muscle			
FA (%)	20°C	30°C	SEM	Sig.
ΣSFA	28.96700	24.87700	0.42070	NS
ΣMUFA	39.50300	52.97200	0.22920	NS
ΣPUFA	31.5300[a]	22.1500[b]	0.43310	**
MUFA/SFA	0.006200	0.004400	18.7867	NS
PUFA/SFA	0.004700	0.001900	8.83880	NS
n-3/*n*-6	0.002400	0.001900	9.67850	NS
AI	0.001200	0.000600	10.6798	NS
TI	0.002600	0.001700	0.03060	NS
ΣFA	325.9500	508.2800	0.01690	NS

[a,b]: Means within row without common superscript differ significantly (p<0.05); **p< 0.01; NS: Not Significant (p>0.05); AI = [C12:0+(4 * C14:0)+C16:0]/[(ΣPUFA)+(ΣMUFA)]; TI = [C14:0+C16:0+ C18:0]/[(0.5 * ΣMUFA)+ (0.5 * *n*-6) + (3 * *n*-3)+(*n*-3/*n*-6)]; ΣSFA: Saturated fatty acids (C4:0+C6:0+C10:0+C12:0+C14:0+C15:0+ C16:0+C17:0+C18:0); ΣMUFA: Monounsaturated fatty acids (C14: 1+C15:1+C16:1+C17:1+C20.1+C18:1t+C18:1c+C24:1); ΣPUFA: Polyunsaturated fatty acids (C20:2+C18:2t+C18:2c+C18:3 *n*-3+ C20:4+C20:5+C22:6+C20:3 *n*-6+C20:4 *n*-6)

from this muscle with higher C6:0 and C10:0 from lambs offered the $NaHCO_3$ diet. The fatty acids C18:1c, C18:2t and eicosapentaenoic acid (C20:5) levels were also significantly affected (p<0.01; p<0.001 and p<0.01 respectively) by the dietary treatments with higher levels in the $NaHCO_3$ supplemented group than the non-supplemented group. No dietary treatments effects were observed on the levels of ΣFA composition and their ratios on the leg muscles (Table 4).

Table 3: Effect of diet on individual fatty acid composition of leg muscles of the experimental lambs

	Leg muscle			
FA (%)	SB	WSB	SEM	Sig.
C4:0	0.13910	0.0734	6.53470	NS
C6:0	0.03190[a]	0.0082[b]	16.7600	*
C10:0	0.03880[a]	0.0244[b]	10.5409	**
C12:0	0.06123	0.0513	88.9284	NS
C14:0	1.44560	1.2490	4.47080	NS
C15:0	1.32720	0.6533	2.47900	NS
C16:0	13.2490	15.0740	0.55010	NS
C17:0	1.27540	1.53510	3.42410	NS
C18:0	4.47500[b]	10.2220[a]	0.94620	*
C14:1	0.62550	0.51470	3.84890	NS
C15:1	2.03400	0.62100	1.40760	NS
C16:1	5.52200	6.28600	0.62580	NS
C17:1	1.11670	1.46540	3.90340	NS
C20.1	0.67940	0.74640	11.8040	NS
C18:1t	1.08740	0.52490	5.25340	NS
C18:1c	38.0900[b]	42.0030[a]	0.39450	**
C24:1	0.06680	0.11130	30.8926	NS
C20:2	3.70700	1.00800	0.58800	NS
C18:2t	1.92700[a]	0.38020[b]	19.9063	***
C18:2c	17.9640	19.9800	0.30230	NS
C18:3 *n*-3	1.87960	0.67560	1.43250	NS
C20:4	3.78600	4.21000	1.31360	NS
C20:5	0.51620[a]	0.36690[b]	25.4342	**
C22:6	0.05120	0.06170	49.4468	NS
C20:3 *n*-6	0.20610	0.10210	23.9617	NS
C20:4 *n*-6	2.64090	1.48510	1.69120	NS

[a,b]: Means within row without common superscript differ significantly (p<0.05); *p<0.05; **p<0.01; ***p<0.001; NS: Not Significant (p>0.05); SB-Sodium Bicarbonate; WSB: Without Sodium Bicarbonate

On the *longissimus dorsi* muscle, C6:0 and MUFA C14:1 were higher (p<0.01 and p<0.05) in the meat of lambs exposed to the lower ambient temperature than those exposed to the higher temperature treatment (Table 5). Likewise, on the same muscle, C18:2t isomers, C20:4 and the PUFA C20:3 *n*-6 and C20:4 *n*-6 levels significantly differed (p<0.05; p<0.01; p<0.001and p<0.05, respectively) between temperature treatments with more C18:2t but less C20:4 levels for lambs reared under the lower temperature group. However, the long-chained PUFA composition of meat from the *longissimus dorsi* muscle showed higher C20:3 *n*-6 (p<0.001) but lower C20:4 *n*-6 (p<0.05) levels in lambs under the higher ambient temperature compared to those raised under the lower ambient temperature. There were no ambient temperature effects on the levels of ΣFA composition and their ratios on the *longissimus dorsi* muscles (Table 6).

Effects of dietary treatments on individual fatty acid composition of *longissimus dorsi* muscle of the experimental lambs are shown in Table 7. The C18:2t isomer more commonly known as CLA, showed significant differences with higher (p<0.05) levels in the meat (*longissimus dorsi*) of lambs that did not receive the $NaHCO_3$ diet. Among the PUFA, the levels of C20:4 were higher (p<0.01) on *longissimus dorsi* muscle from the non $NaHCO_3$ supplemented

Table 4: Effect of diet on total fatty acid composition and their ratios of leg muscles of the experimental lambs

	Leg muscle			
FA (%)	SB	WSB	SEM	Sig.
ΣSFA	24.97500	28.86900	0.42070	NS
ΣMUFA	48.10800	44.36600	0.22920	NS
ΣPUFA	26.91700	26.76500	0.43310	NS
MUFA/SFA	0.007000	0.003600	18.7867	NS
PUFA/SFA	0.004200	0.002400	2.79440	NS
n-3/*n*-6	0.002500	0.001800	3.06060	NS
AI	0.000600	0.000900	3.55990	NS
TI	0.002400	0.001800	3.06480	NS
ΣFA	362.6300	471.5900	0.01690	NS

NS: Not Significant (p>0.05); SB: Sodium Bicarbonate; WSB: Without Sodium Bicarbonate; AI = [C12:0+(4 * C14:0)+C16:0]/[(ΣPUFA)+(ΣMUFA)]; TI = [C14:0+C16:0+C18:0]/[(0.5 * ΣMUFA) +(0.5 * *n*-6)+(3 * *n*-3)+(*n*-3/*n*-6)]; ΣSFA: Saturated fatty acids (C4:0 ++C6:0+C10:0+C12:0+C14:0+C15:0+C16:0+C17:0+C18:0); ΣMUFA: Monounsaturated fatty acids (C14:1+C15:1+C16:1+ C17:1+C20.1+C18:1t+C18:1c + C24:1); ΣPUFA: Polyunsaturated fatty acids (C20:2+C18:2t+C18:2c+C18:3 *n*-3+C20:4+C20:5+ C22:6+C20:3 *n*-6+C20:4 *n*-6)

Table 5: Effect of ambient temperature on individual fatty acid composition of *longissimus dorsi* muscles of the experimental lambs

	Longissimus dorsi muscle			
FA (%)	20°C	30°C	SEM	Sig.
C4:0	0.3585	0.33610	8.588359	NS
C6:0	3.0740[a]	0.01910[b]	21.40130	**
C10:0	0.16510	0.16550	13.81010	NS
C12:0	0.18160	0.17860	31.46840	NS
C14:0	3.36830	3.18920	2.312200	NS
C15:0	0.99140	1.10620	6.522700	NS
C16:0	25.0480	27.5370	0.283100	NS
C17:0	1.93430	1.72990	2.512400	00NS
C18:0	26.4720	19.3830	0.200000	NS
C14:1	1.1135[a]	0.4909[b]	7.323100	*
C15:1	0.6186	0.36430	4.434900	NS
C16:1	7.1320	8.62200	0.752200	NS
C17:1	2.0072	1.98750	2.070300	NS
C20.1	1.5662	1.48910	5.24400	NS
C18:1t	0.2273	0.09840	11.0026	NS
C18:1c	1.9232	1.30080	1.83180	NS
C24:1	4.1600	1.05900	0.80250	NS
C20:2	0.3540	0.37980	9.04860	NS
C18:2t	0.7487[a]	0.1093[b]	7.69540	*
C18:2c	21.7140	21.6440	0.20790	NS
C18:3 *n*-3	1.3757	1.29500	7.24410	NS
C20:4	0.0912[b]	0.4222[a]	12.5127	**
C20:5	5.3410	6.1770	0.53990	NS
C22:6	0.1980	1.4352	1.82440	NS
C20:3 *n*-6	0.0390[b]	1.0773[a]	23.9651	***
C20:4 *n*-6	1.1918[a]	0.5455[b]	4.05770	*

[a,b]: Means within row without common superscript differ significantly (p<0.05); *p<0.05; **p< 0.01; ***p<0.001; NS: Not Significant (p>0.05)

group compared to the group that received the $NaHCO_3$ supplemented diet. There were no dietary effects on ΣSFA, ΣPUFA, AI, TI, MUFA/SFA and *n*-6/*n*-3 ratios on *longissimus dorsi* muscle however, ΣFA levels were higher with the $NaHCO_3$ supplemented diet than in the meat from lambs that did not receive $NaHCO_3$ diet (Table 8).

Table 6: Effect of ambient temperature on total fatty acid composition and their ratios of *longissimus dorsi* muscles of the experimental lambs

	Longissimus dorsi muscle			
FA (%)	20°C	30°C	SEM	Sig.
ΣSFA	58.5930	53.65500	0.18160	NS
ΣMUFA	14.92200	14.82300	0.45770	NS
ΣPUFA	26.48500	31.52200	0.21090	NS
MUFA/SFA	0.000900	0.000800	40.1340	NS
PUFA/SFA	0.001600	0.001700	18.1918	NS
n-3/*n*-6	0.003700	0.005600	14.2979	NS
AI	0.002600	0.002700	0.06510	NS
TI	0.012200	0.011700	5.47720	NS
ΣFA	427.9000	429.6000	0.01240	NS

NS: Not Significant (p>0.05); AI = [C12:0+(4 * C14:0)+C16:0]/[(ΣPUFA)+(ΣMUFA)]; TI = [C14:0+C16:0+C18:0]/[(0.5 * ΣMUFA)+(0.5 * *n*-6)+(3 * *n*-3)+(*n*-3/*n*-6)]; ΣSFA: Saturated fatty acids (C4:0+C6:0+C10:0+C12:0+C14:0+C15:0+16:0+C17:0+ C18:0); ΣMUFA: Monounsaturated fatty acids (C14:1+C15:1+ C16:1 +C17:1+C20.1+C18:1t+C18:1c+C24:1); ΣPUFA: Polyunsaturated fatty acids (C20:2+C18:2t+C18:2c+C18:3 *n*-3+C20:4+C20:5+ C22:6 +C20:3 *n*-6+C20:4 *n*-6)

Table 7: Effect of diet on individual fatty acid composition of *longissimus dorsi* muscles of the experimental lambs

	Longissimus dorsi muscle			
FA (%)	SB	WSB	SEM	Sig.
C4:0	0.46450	0.23010	8.58840	NS
C6:0	0.06820	0.03490	21.4013	NS
C10:0	0.15590	0.17470	13.8101	NS
C12:0	0.19660	0.16350	9.95120	NS
C14:0	3.24050	3.31690	2.31220	NS
C15:0	1.00140	1.09610	6.52270	NS
C16:0	31.3450	21.2400	0.28310	NS
C17:0	2.02590	1.63820	2.51240	NS
C18:0	18.6200	27.2350	0.20000	NS
C14:1	0.99260	0.61180	7.32310	NS
C15:1	0.37820	0.60470	4.43490	NS
C16:1	7.17200	8.87200	0.75220	NS
C17:1	1.95770	2.04280	2.07030	NS
C20.1	1.50730	1.53610	5.24400	NS
C18:1t	0.11600	0.18390	11.2294	NS
C18:1c	1.59250	1.50700	1.86950	NS
C24:1	1.48100	3.73800	0.80250	NS
C20:2	0.42880	0.30500	9.04860	NS
C18:2t	0.38050[b]	0.92540[a]	7.85410	*
C18:2c	22.0610	21.2140	0.20790	NS
C18:3 *n*-3	1.28190	1.3889	7.24410	NS
C20:4	0.10430[b]	0.4091[a]	12.5127	**
C20:5	4.28300	7.2350	0.53990	NS
C22:6	0.23380	1.3994	1.82440	NS
C20:3 *n*-6	0.07580	0.0405	23.9651	NS
C20:4 *n*-6	1.04940	0.9878	4.05770	NS

[a,b]: Means within row without common superscript differ significantly (p<0.05); *p<0.05; **p< 0.01; NS: Not Significant (p>0.05); SB: Sodium Bicarbonate; WSB: Without Sodium Bicarbonate

Among the entire individual fatty acids measured, the most abundant fatty acid in the meat from the leg muscle, irrespective of treatment was C18:1c isomer. A similar pattern was observed for C16:0 on the *longissimus dorsi* muscle. At the end of the experiment, ΣFA levels on the leg muscles were higher from lambs under the higher ambient temperature and those that did not receive $NaHCO_3$ supplementation. As with the leg muscles, ΣFA levels on the *longissimus dorsi* muscle were higher with the lambs under the higher ambient

Table 8: Effect of diet on total fatty acid composition and their ratios of *longissimus dorsi* muscles of the experimental lambs

	Longissimus dorsi muscle			
FA (%)	SB	WSB	SEM	Sig.
ΣSFA	57.1170	55.1300	0.18160	NS
ΣMUFA	13.8330	15.9120	0.45770	NS
ΣPUFA	29.0500	28.9580	0.21090	NS
MUFA/SFA	0.00070	0.00090	12.6915	NS
PUFA/SFA	0.001500	0.001700	18.1918	NS
n-3/*n*-6	0.003700	0.005600	14.2979	NS
AI	0.003100	0.002200	20.5919	NS
TI	0.013600	0.010300	5.47720	NS
ΣFA	382.2000	475.3000	0.01240	NS

NS: Not Significant (p>0.05); SB-sodium bicarbonate; WSB-without sodium bicarbonate; AI = [C12:0+(4 * C14:0)+C16:0]/[(ΣPUFA)+(ΣMUFA)]; TI = [C14:0+C16:0+C18:0]/[(0.5 * ΣMUFA)+(0.5 * *n*-6)+(3 * *n*-3)+(*n*-3/*n*-6)]; ΣSFA: Saturated fatty acids (C4:0++C6:0; C10:0+C12:0+C14:0+C15:0+C16:0+C17:0+C18:0); ΣMUFA: Monounsaturated fatty acids (C14:1+C15:+C16:1+C17:1+C20.1+C18:1t+C18:1c+C24:1); ΣPUFA: Polyunsaturated fatty acids (C20:2+C18:2t+C18:2c+C18:3 *n*-3+C20:4+C20:5+C22:6 +C20:3 *n*-6+C20:4 *n*-6)

temperature group and the non-supplemented group compared to the other group. Significant interactions were observed between ambient temperature and dietary for C4:0, C12:0, C18:1t and C20:2 whereas interactions between meat fatty acids from the leg and *longissimus dorsi* muscles were observed on C14:0, C18:0, ΣSFA and ΣPUFA (Fig. 1 and 2).

DISCUSSION

Meat quality is considerably affected by a number of different factors such as breed, postmortem processes taking place in muscle tissue, including changes in meat pH, water content, intramuscular fat and connective tissue (Barton *et al*., 2010; Pogorzelska *et al*., 2012). In ruminants, after lipid hydrolysis in the rumen, many unsaturated fatty acids are hydrogenated or saturated by rumen micro-organisms (Scerra *et al*., 2011).

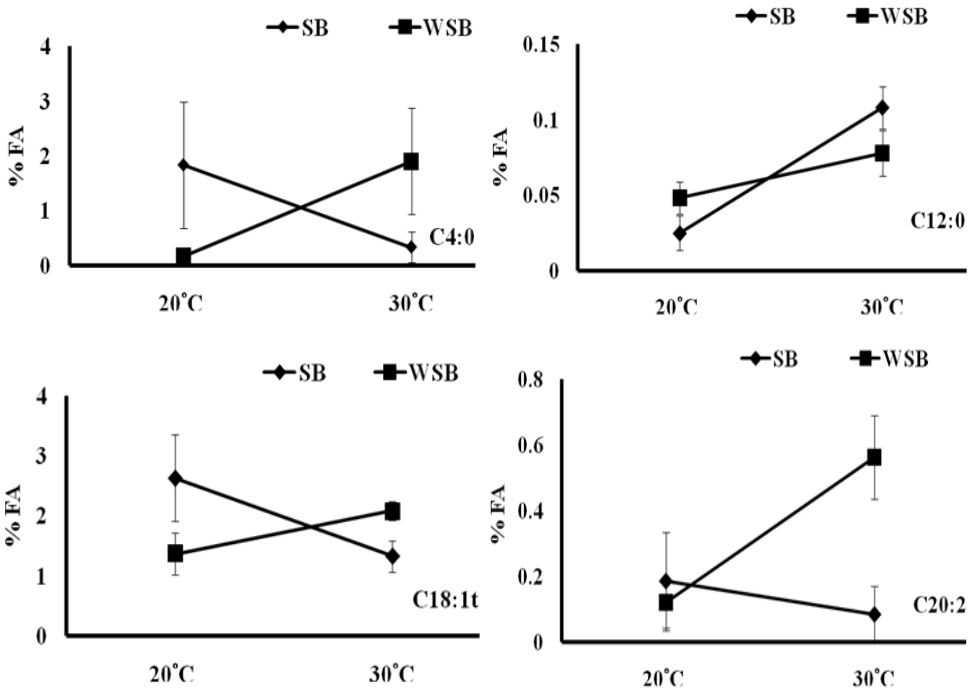
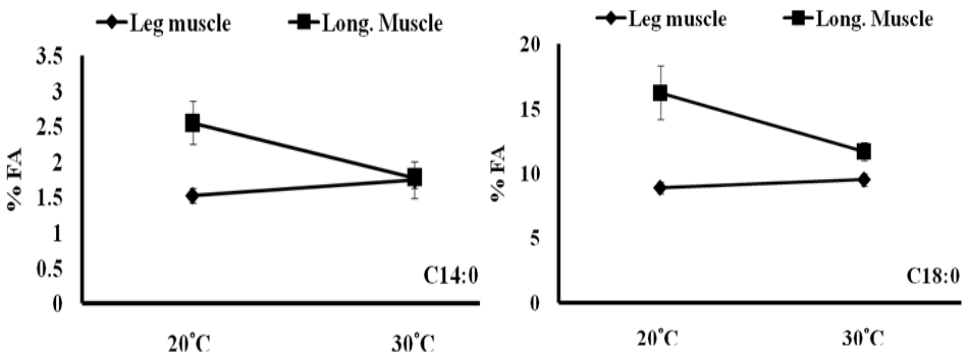


Fig. 1: Interactions between ambient temperature and dietary treatment on meat fatty acids



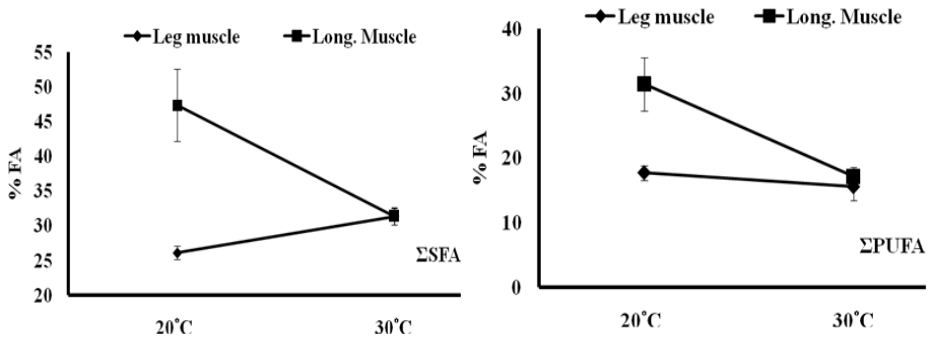


Fig. 2: Interactions between meat fatty acids from Leg and *longissimus dorsi* muscles as affected by ambient temperature

In this study, on the leg muscle, the levels of C4:0 and C10:0 SFA, with implicated risks for human health, were significant in meat from lambs of the higher temperature group compared o the other groups (Scerra *et al*., 2011). The levels of palmitic (C16:0) acid, that is reported to be involved in increasing total and LDL cholesterol in plasma and enhancing risks for human health (Scollan *et al*., 2006), were not significant ($p>0.05$) in meat from the leg muscle however, higher values were recorded in lambs in higher ambient temperature group compared to the other group. This lack of effect in C16:0 which is atherogenic is a favorable feature. Leg muscle of lambs under the lower temperature had more C18:0 compared to the other group. On the contrary, Costa *et al*. (2006) reported that calves slaughtered in spring had higher C18:0 levels than those slaughtered in autumn. A possible explanation could be that higher temperature is likely to be a factor affecting biohydrogenation. Due to the higher level of C18:3 *n*-6 in leg muscle, the arachidonic acid (C20:4 *n*-6) level, produced by the action of Δ^5 and Δ^6 enzymatic desaturation and elongation, significantly differed ($p<0.05$) in meat from the lower ambient temperature group than in meat from the higher ambient temperature group. High C20: 4 *n*-6 is not desirable because of its negative effect in heart disease and the immune response (Demirel *et al*., 2006). Because of the higher levels of some PUFA in leg muscle of lambs in the lower temperature group, the level of ΣPUFA was higher ($p<0.01$) in meat from lambs of this group. This could probably be due to a lower level of fat; in accordance with Wood *et al*. (2008) as lean animals have higher proportions of PUFA. Linolenic acid (C18:3 *n*-3), the precursor of long chain *n*-3 fatty acids that have a wide range of biological effects and which are believed to be beneficial for human health, was clearly affected ($p<0.01$) in the leg muscle by ambient temperature.

The levels of C6:0 and C10:0 fatty acids on the leg muscles were lower in meat from lambs of the non $NaHCO_3$ supplemented group compared to the other groups. Higher mean values for C18:0 for the lambs fed the non $NaHCO_3$ supplemented diet might indicate rumen biohydrogenation. Another reason could be that the presence of a greater proportion of available carbohydrates in concentrate reduces the residence time of feed in the rumen, decreasing biohydrogenation of the polyenoic acids and producing lower levels of C18:0 (Demirel *et al*., 2006).

On the *longissimus dorsi* muscle, C6:0 and MUFA C14:1 were higher ($p<0.01$ and $p<0.05$) in the meat of lambs exposed to the lower ambient temperature than those exposed to the higher temperature treatment. As was observed on the leg muscles, the levels of palmitic (C16:0) acid were not significant ($p>0.05$) in meat from the *longissimus dorsi* muscle however, irrespectively of treatment, these values were higher on the *longissimus dorsi* muscle compared to the leg muscles. This lack of effect in C16:0 is again a favorable feature.

The significance of nutrition on fatty acid comosition is clearly demonstrated when profiles are examined by omega 6 (*n*-6) and omega 3 (*n*-3) families, PUFA/SFA, the atherogenic (AI) and trombogenic (TI) index. In a balanced diet, the recommended ratio for PUFA/SFA is 0.45 or higher, AI and TI as low as possible and *n*-6/*n*-3 ratios of less than 4 (Scerra *et al*., 2011; Wood *et al*., 2008). In our study, higher *n*-3/*n*-6 ratio (0.0019 vs. 0.0056) from *longissimus dorsi* muscles obtained from lambs of higher ambient temperature treatment could probably be due to decrease in the *n*-3 PUFA levels in the former. It is thus conceivable that *n*-3 PUFA, by virtue of its location in the cell structure, maybe less accessible to ruminal lipases and to subsequent biohydrogenation. However, the negative aspects of having a high PUFA/SFA ratio need to be considered, in that, high contents of PUFA lead to oxidation, reduced shelf-life and poor texture of meat (Scerra *et al*., 2011). AI and TI indices of both muscle were lower than 1.00 and TI in particular, was lower than reported by Sargentini *et al*. (2010) in pork; beef and lamb (1.66, 1.39 and1.58 respectively), thus meat from this portion could be very favorable to human diets.

CONCLUSION

It may be concluded that inclusion of $NaHCO_3$ in concentrate diets for lambs significantly affects their

meat fatty acids composition. In general, meat from the leg muscle showed a better composition of the lipid fraction as well as lower levels of saturated fatty acids, a better PUFA/SFA ratio, a lower *n*-3/*n*-6 ratio and favorable values of AI and TI irrespective of treatment.

REFERENCES

Barton, L., D. Bures and V. Kudrna, 2010. Meat quality and fatty acid profile of the *Musculus longissimus lumborum* in czech fleckvieh, charolais and charolais x czech fleckvieh bulls fed different types of silages. Czech. J. Am. Sci., 55: 479-487.

Bodas, R., A.B. Rodriguez, S. Lopez, B. Fernandez, A.R. Mantecon and F.J. Giraldez, 2007. Effects of the inclusion of sodium bicarbonate and sugar beet pulp in the concentrate for fattening lambs on acid-base status and meat characteristics. Meat Sci., 77: 696-702.

Bodas, R., S. Lopez, A.B. Rodriguez, S. Andres, A.R. Mantecon and F.J. Giraldez, 2010. Feed intake, digestibility and carcass characteristics of lambs fed a diet supplemented with soluble fibre. Am. Prod. Sci., 50: 45-51.

Costa, P., L.C. Roseiro, A. Partidario, V. Alves, R.J. Bessa, C.R. Calkins and C. Santos, 2006. Influence of slaughter season and sex on fatty acid composition, cholesterol and α-tocopherol contents on different muscles of Barrosa-PDO veal. Meat Sci., 72: 130-139.

Demirel, G., H. Ozpinar, B. Nazli and O. Keser, 2006. Fatty acids of lamb meat from two breeds fed different forage: Concentrate ratio. Meat Sci., 72: 229-235.

Kawas, J.R., R. Garcia-Castillo, H. Fimbres-Durazo, F. Garza-Cazares, J.F.G. Hernandez-Vidal, E. Olivares-Saenz and C.D. Luc, 2007a. Effects of sodium bicarbonate and yeast on productive performance and carcass characteristics of light-weight lambs fed finishing diets. Small Ruminant. Res., 67: 157-163.

Kawas, J.R., R. Garcia-Castillo, H. Fimbres-Durazo, F. Garza-Cazares, J.F.G. Hernandez-Vidal, E. Olivares-Saenz and C.D. Luc, 2007b. Effects of sodium bicarbonate and yeast on nutrient intake, digestibility and ruminal fermentation of light-weight lambs fed finishing diets. Small Ruminant. Res., 67: 149-156.

Lazzaroni, C., D. Biagini and C. Lussiana, 2009. Fatty acid composition of meat and perirenal fat in rabbits from two different rearing systems. Meat Sci., 83: 135-139.

Manso, T., R. Bodas, T. Castro, V. Jimeno and A.R. Mantecon, 2009. Animal performance and fatty acid composition of lambs fed with different vegetable oils. Meat Sci., 83: 511-516.

Mohammad, A.A., M. Khaskheli, I.R. Rajput, S. Faraz, S. Rao, M. Umer and K. Devrajani, 2010. Effect of slaughtering age on chemical composition of goat meat. Pak. J. Nutr., 9: 404-408.

Perlo, F., P. Bonato, G. Teira, O. Tisocco, J. Vicentin, J. Pueyo and A. Mansill, 2008. Meat quality of lambs produced in the Mesopotamia region of Argentina finished on different diets. Meat Sci., 79: 576-581.

Pogorzelska, J., J. Micinski, H. Ostoja, I.M. Kowalski, J. Szarek and E. Strzyzewska, 2012. Quality traits of meat from young limousin, charolais and hereford bulls. Pak. Vet. J., 33: 65-68.

Santra, A., O.H. Chaturvedi, M.K. Tripathi, R. Kumar and S.A. Karim, 2003. Effect of dietary sodium bicarbonate supplementation on fermentation characteristics and ciliate protozoal population in rumen of lambs. Small Ruminant. Res., 47: 203-212.

Sargentini, C., R. Bozzi, G. Lorenzini, P. DeglInnocenti, A. Martini and A. Giorgetti, 2010. Productive performances of *Maremmana young* bulls reared following organic rules and slaughtered at 18 and 24 months of age. Ital. J. Anim. Sci., 9: 163-168.

Scerra, M., P. Caparra, F. Foti, C. Cilione, G. Zappia, C. Motta and V. Scerra, 2011. Intramuscular fatty acid composition of lambs fed diets containing alternative protein sources. Meat Sci., 87: 229-233.

Scollan, N.D., J.F. Hocquette, K. Nuernberg, D. Dannenberger, I. Richardson and A. Moloney, 2006. Innovations in beef production systems that enhance the nutrition and health value of beef lipids and their relationship with meat quality. Meat Sci., 74: 17-33.

Wood, J.D., M. Enser, A.V. Fisher, G.R. Nute, P.R. Sheard and R.I. Richardson, 2008. Fat deposition, fatty acid composition and meat quality: A review. Meat Sci., 78: 343-358.