SHORT TERM-HEAT STRESS AND -VITAMIN E SUPPLEMENTATION AFFECT CARCASS WEIGHT, MUSCLE OMEGA-6 FATTY ACID AND MEAT QUALITY IN LAMBS

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Abstract - The effect of short term-heat stress and -vitamin E supplementation on carcass traits and muscle quality – vitamin E, nutritional value and retail colour of lambs was investigated. Forty-eight lambs (crossbred; 42 ± 2 kg body weight, 7 mo age) were randomly allocated by body weight to one of three groups (n = 16) and fed 3 different doses of Vitamin E and Se. The doses of Vitamin E and Se for control (CON), moderate (MOD), and supranutritional (SUP) diets were 28, 130, 228 mg/kg DM as α-tocopherol acetate and 0.16, 0.66, 1.16 mg Se as SelPlex™ kg/DM, respectively. Lambs were fed for 4 weeks followed by a week of exposure to heat treatment. After 4 weeks feeding in individual pens, including 1 week of adaptation, lambs were moved to metabolism cages for 1 week and allocated to one of 2 heat regimes (8 per feeding group): thermoneutral (TN) (18–21◦C and 40–50% relative humidity) or heat stress (HS) (28–40◦C and 30–40% relative humidity) conditions. Final body weight (*P* = 0.05, 44.1 vs 46.6 kg) and hot carcass weight (*P* = 0.01, 21.1 vs 22.5 kg) were significantly affected by diet such that lambs supplemented with SUP levels of antioxidants had a higher FBW and HCW as compared with lambs fed MOD and CON antioxidant diets, respectively. Vitamin E concentration in the *longissimus lumborum (LL)* muscle tended to be higher in lambs fed moderate or supranutritional levels of antioxidants compared with control lambs and values from all treatments were below the threshold (3.2 mg/kg muscle) for optimal maintenance of retail colour. Vitamin E supplementation also reduced lipid oxidation of aged meat, as assessed by thiobarbituric acid reactive substances (TBARS) formation after 72 h of display. One week of heat stress to lambs significantly increased muscle linoleic acid concentration, which in turn increased total n-6 concentration compared with the control group. Results demonstrate that 4 weeks of vitamin E supplementation or 1 week heat stress might not have been adequate to make significant changes in muscle vitamin E concentration and fatty acid composition, which in turn can influence retail colour stability of meat.

Keywords: Heat stress, vitamin E supplementation, carcass weight, muscle fatty acid composition, meat quality, sheep

I. INTRODUCTION

With the advancement in technology and media, consumers are well informed about nutritional characteristics of food and its effects on human health, thus increasing the focus on selection of food that has a high nutritional value and quality. On the other hand, color is one of the major factors that can affect consumer perception of meat at the retail level because it indicates the freshness of meat (quality). Environmental heat stress can cause economic losses not only due to a decline in animal productivity but also due to a reduced muscle quality (colour, lipid oxidation) associated with poor feed intake and health status [1, 2]. Vitamin E is known to improve antioxidant potential in muscle and meat quality by avoiding/delaying muscle from lipid and colour deterioration [3]. This study investigated the effect of short term-heat stress and -vitamin E supplementation on carcass traits, muscle antioxidant status, meat nutritive value/quality.

II. MATERIALS AND METHODS

An experiment [4] was conducted in intensive pen facilities with 4 weeks of feeding followed by a week of exposure to heat treatment. Briefly, forty-eight lambs (crossbred; 42 ± 2 kg body weight, 7 mo age) were allocated to one of three groups (n = 16) and fed 3 different doses of Vitamin E and Se. The doses of Vitamin E and Se for control (CON), moderate (MOD), and supranutritional (SUP) diets were 28, 130, 228 mg/kg DM as α-tocopherol acetate and 0.16,

0.66, 1.16 mg Se as SelPlex™ kg/DM, respectively. After 4 weeks feeding in individual pens, including 1 week of adaptation, lambs were moved to metabolism cages for 1 week and allocated to one of 2 heat regimes (8 per feeding group): thermoneutral (TN) (18–21ºC and 40–50% relative humidity) or heat stress (HS) (28–40ºC and 30–40% relative humidity) conditions. The temperature was set to rise daily at 0900 h to eventually reach a maximum of 40ºC by 1400 h and then maintained at 39 ± 1ºC until 1700 h followed by a decline to reach 28ºC at 2000 h. At the end of feeding, body weight was recorded, and the lambs transported (300 km) to a commercial abattoir in Melbourne Victoria, where they were kept in lairage overnight and subsequently slaughtered.

Hot carcass weight (HCW) and GR fat depth were recorded and the carcasses were chilled for 24 h. At 24 h post-slaughter, the muscle *longissimus lumborum* (LL) was removed from the left side of the carcass (from the 9th and 10th lumbar vertebrae to the caudal end), trimmed of external fat and connective tissue, and sampled for meat quality analysis. Samples collected for the evaluation of aged meat retail color were vacuumed packed, stored for 42 days at 2°C. For both fresh and aged meat retail colour assessment, the LL muscle was sliced (2 cm thick) at day 1 and 42 post slaughter, respectively and then placed on black foam trays and over wrapped with a PVC food film (15 μm thickness). Trays were maintained at 3–4°C under fluorescent light (1000 lux) for 72 h. Lightness (L*-value), redness (a*-value) and yellowness (b*-value) of meat at 0 (allowed to bloom 30 minutes), 24, 48 and 72 h of retail display were measured in duplicate on each sample using a Hunter Laboratory Mini Scan XE Plus meter with a 25-mm aperture, light source set to illuminant D-65 with a 10 degree standard observer (model 45/0-S, Hunter Associates Laboratory Inc., Reston VA, USA) [5]. An estimate of the oxy/met myoglobin ratio was calculated by dividing the percentage of light reflectance at wavelength 630 nm by the percentage of light reflectance at wavelength 580 nm ($R_{630/580}$), which was used as a proxy for brownness formation on the meat surface. Lipid oxidation was assessed by measuring the concentration of malondialdehyde (MDA, expressed in mg/kg of muscle) using the thiobarbituric acid reactive substances (TBARS) procedure [6] on samples collected at 0 h and 72 h of retail display for both fresh and aged meat. A homogeneous sample of freeze dried ground material (approximately 0.5 g) was used for the determination of fatty acid composition [5].

The data were analysed using GenStat statistical package (14th Edition). The design was 2 × 3 factorial with heat stress, dietary vitamin E as main effects and heat stress × dietary vitamin E level as an interaction term. The variables tested for significance were carcass traits, muscle fatty acid and vitamin E concentrations and lipid oxidation. The effect of diet and heat treatment on meat colour traits (Hunter Lab L*, a*, b* and reflectance 630/580) over the simulated display time was statistically analysed using display time (0, 24, 48 and 72 h) points as repeated measurements using an ANOVA. *F*-tests were used to determine the overall significant difference among the predicted means, whereas the difference between two predicted means was judged to be significant if it was at least two times the average standard error of difference (SED).

III. RESULTS AND DISCUSSION

Final body weight (FBW), hot carcass weight (HCW), and GR fatness were adjusted to body weight of lambs at the commencement of feeding. Final body weight (P = 0.05, 44.1 vs 46.6 kg) and HCW (P = 0.01, 21.1 vs 22.5 kg) were significantly affected by diet such that lambs supplemented with supranutritional levels of antioxidants had a higher FBW and HCW as compared with lambs fed control and moderate antioxidant diets, respectively (Table 1). However, there was no effect of heat treatment (heat stress) or the interaction of dietary vitamin E by heat stress on FBW, HCW and GR fat depth. Vitamin E concentration in the *Longissimus lumborum* (LL) muscle tended (P = 0.15) to increase with the higher antioxidant supplementation such that lambs fed moderate or supranutritional levels of antioxidants had a greater concentration compared with control lambs (Table 1). There was no effect of heat stress on muscle vitamin E concentration and nor was any interaction between heat stress and dietary vitamin E. For this study, a commercial feedlot ration was fed to all three treatment groups, but it only differed in vitamin E concentration (control, moderate and supranutritional levels). There was no effect of diet, heat stress or the interaction between diet and heat stress observed for any of the muscle

fatty acid concentrations except for linoleic acid (LA) and total n-6 (Table 2).

Table 1: Effect of dietary vitamin E and selenium supplementation on carcass traits, muscle vitamin E content and lipid oxidation in meat of lambs fed for 4 weeks of experimental diets and then exposed to hot conditions for 7 days during the finishing phase

	Thermoneutral (TN)			Heat stress (HS)				P-value		
	CON	MOD	SUP	CON	MOD	SUP	SED (D x HS)	Diet (D)	HS	D x HS
Body weight at start (kg)	41.9	43.3	42.3	42.9	42.3	41.4	1.29	0.58	0.74	0.46
Body weight at end (kg)	44.2	44.1	46.3	44.6	43.5	47.3	1.77	**0.05**	0.77	0.83
Carcass weight (kg)	21.2	21.2	22.7	21.4	20.7	22.4	0.75	**0.01**	0.70	0.74
GR fat depth (mm)	9.67	7.91	9.75	9.92	8.00	10.20	0.98	**0.01**	0.63	0.96
Muscle 24 h pH	5.66	5.64	5.60	5.60	5.59	5.58	0.05	0.81	0.31	0.77
Muscle Vitamin E (mg/ kg)	1.75	1.92	1.96	1.72	2.13	2.07	0.25	0.15	0.50	0.79
TBARS fresh day 0[#]	0.07	0.07	0.08	0.08	0.09	0.07	0.02	0.85	0.45	0.62
TBARS fresh day 3[#]	0.38	0.33	0.36	0.46	0.48	0.32	0.11	0.54	0.33	0.48
TBARS aged day 0[#]	0.59	0.33	0.40	0.46	0.54	0.41	0.12	0.34	0.68	0.17
TBARS aged day 3[#]	4.91	4.08	3.57	4.40	4.14	2.66	0.67	**0.01**	0.25	0.59

[#]Values are reported in mg malondialdehyde/kg of meat. Experimental diets: CON = control, MOD = moderate, SUP = supranutritional

Table 2: Fatty acid composition (mg/ 100 g muscle) in muscle *longissimus lumborum* of lambs fed for 4 weeks of experimental diets and then exposed to hot conditions for 7 days during the finishing phase

	Thermoneutral (TN)			Heat stress (HS)			SED (D x HS)	P-value		
	CON	MOD	SUP	CON	MOD	SUP		Diet (D)	HS	D x HS
C10:0	4.8	4.8	4.7	5.5	5.5	4.3	0.82	0.43	0.44	0.59
C12:0	5.9	5.5	5.2	6.4	6.5	4.8	1.17	0.32	0.60	0.69
C14:0	97.9	96.1	91.4	116	108	86.8	17.0	0.31	0.38	0.61
C14:1	2.9	2.9	2.4	3.5	3.3	2.5	0.64	0.20	0.30	0.81
C15:0	10.6	10.9	10.9	13.4	12.3	10.8	1.74	0.65	0.19	0.50
C16:0	710	716	719	864	806	690	98.6	0.49	0.22	0.42
C16:1	44.6	45.8	41.3	54.1	48.6	41.1	6.74	0.22	0.31	0.58
C18:0	496	501	564	607	660	534	77.2	0.91	0.30	0.44
C18:1n-9cis	1204	1209	1233	1456	1345	1241	165	0.73	0.18	0.58
C18:2n-6 (LA)	87.3	88.6	81.1	97.1	89.2	89.8	4.95	0.17	**0.03**	0.37
C18:3n-3	32.8	33.8	33.1	35.6	36.0	34.4	4.21	0.93	0.38	0.97
C20:4n-6	17.0	16.8	16.7	17.3	17.5	17.6	1.15	1.00	0.37	0.93
C20:5n-3 (EPA)	11.7	12.8	12.9	12.0	12.1	13.0	1.22	0.42	0.92	0.79
C22:5n-3 (DPA)	11.6	12.6	12.8	12.4	12.3	12.5	0.68	0.43	0.92	0.41
C22:6n-3 (DHA)	4.1	4.4	3.6	4.2	4.4	4.4	0.45	0.34	0.22	0.37
Total n-6	109	110	103	119	111	112	4.91	0.16	**0.02**	0.34
Total n-3	60.4	60.9	62.6	64.5	61.5	64.7	4.74	0.93	0.65	0.61
Total muscle fat	2790	2809	2884	3363	3115	2839	363	0.71	0.19	0.49

Experimental diets: CON = control, MOD = moderate, SUP = supranutritional

One week of heat exposure to lambs significantly increased muscle LA (85 vs 92 mg/ kg; $P < 0.03$), which in turn increased total n-6 concentration (107 vs 114 mg/ kg; $P < 0.03$) compared with control group (Table 2). The LA and total n-6 concentrations in the LL muscle also tended ($P = 0.15$) to increase with the control diet such that lambs fed supranutritional levels of antioxidants had a lower concentration compared with control lambs (Table 2). This implies that even a short period of heat stress, i.e., one week of heat exposure to lambs

significantly alters the muscle n-6 fatty acid concentration. This may have implications in animal health (glucose intolerance, inflammation) and muscle quality (lipid oxidation and colour stability of meat) when muscle vitamin E concentration is under threshold levels. However, muscle vitamin E concentration was below the threshold level of 3.2 mg/kg muscle for all treatment groups.

Recently, we have observed [7] that feeding a feedlot ration to lambs for 6 weeks with additional 2 weeks of adaptation during late spring, significantly increased the oxidative stress status of lambs as assessed by blood isoprostanes concentration when compared with lambs fed a pasture diet (392 vs 275 pg/mL for feedlot vs pasture, $P < 0.001$). The significant increase in blood isoprostanes was highly and positively related to muscle LA (140 vs 96 for feedlot vs pasture, $P < 0.001$) and total n-6 (180 vs 130 for feedlot vs pasture, $P < 0.001$) concentrations, which in turn was significantly and positively related to lipid oxidation (TBARS 5.4 vs 3.5 for feedlot vs pasture, $P < 0.05$) in meat aged for 60 days at 2^{o}C and then displayed under simulated retail conditions for 72 h. In the current study, the small increase in LA (but significant) with one week exposure to heat treatment did not affect lipid oxidation of fresh and aged (stored for 42 days) meat that also displayed under refrigerated conditions for 72 h. It implies the increase in total n-6 with one week exposure to heat might not have been adequate to increase the lipid oxidation in meat as observed [7] with 8 weeks of feeding a feedlot ration to lambs. At the same time, the supranutritional vitamin E diet significantly reduced lipid oxidation of aged meat at 72 h display compared with the CON group. However, 1-week heat stress or 4-week vitamin E supplementation did not affect colour stability, as assessed by redness or brownness formation of meat, displayed under simulated retail condition. The analyses showed that there were no interactions of dietary vitamin E × heat treatment × time (not presented) on retail colour parameters.

IV. CONCLUSION

Results indicate that supplementation of a supranutritional level of vitamin E in the feedlot diet for 4 weeks tended to increase muscle vitamin E concentration compared with a control feedlot diet, but the levels were below the recommended threshold. Supranutritional vitamin E diet also increased carcass weight and reduced lipid oxidation of aged meat compared with the moderate or control vitamin E diet group. One week of exposure to heat stress significantly increased the muscle linoleic and total n-6 fatty acid concentrations but did not alter the muscle vitamin E concentration or retail colour stability of meat compared to control group. It implies that although there were changes observed in muscle vitamin E and n-6 fatty acid concentrations, the short term-heat stress (1 week) or -vitamin E supplementation (4 week) might not be long enough to make significant changes in muscle vitamin E and fatty acid composition thus leading to changes in colour.

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