COLOR AND LIPID OXIDATIVE STABILITY AND SENSORY CHARACTERISTICS OF OMEGA-3 ENHANCED LAMB MUSCLE

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Abstract – The objective of this study was to evaluate color and lipid oxidative stability and sensory properties of lamb meat as affected by lamb feeding strategies used to enhance omega-3 content. Forty lambs with initial body weight of 37.7 ± 5.87 kg were fed with one of the five dietary treatments (control (CONT), flax (FL), flax + tannin (FL+T), co-extruded flax with field pea (EFFP), and co-extruded flax with field pea + tannin (EFFP+T)) for 60 d. Then, lambs were slaughtered and fabricated. Sections of the Longissimus thoracis were removed and fatty acid profile, color stability and lipid oxidation were evaluated. For sensory, Longissimus lumborum roasts were oven-cooked and evaluated by a 13-member sensory panel. Data were analyzed as a randomized complete block design using MIXED procedure of SAS. Among the five dietary treatments, feeding lamb with FL+T, EFFP and EFFP+T resulted in muscle with highest omega-3 fatty acids. This increase in omega-3 fatty acids did not affect (*P*>0.05) lipid oxidation and most sensory characteristics of cooked loin meat. The overall results showed that increased omega-3 fatty acids in muscle through dietary treatments had no negative impact on lipid oxidation during retail display as well as on sensory characteristics of lamb meat.

Key Words – flax, tannins, co-extruded, aroma.

I. INTRODUCTION

There are a number of studies showing the health benefits of increasing intake of long chain polyunsaturated fatty acids (PUFA) in the human diet, specifically n-3, such as ALA (α-linolenic acid, 18:3 n-3), EPA (eicosapentaenoic acid, 20:5 n-3), and DHA (docosahexaenoic acid, 22:6 n-3) [1]. Meat and meat products can be a potential source of omega-3. The fatty acid profile of meat can be modified by animal nutrition, i.e., supplementation of ALA-rich feed ingredient such as flaxseed [2].

In ruminants, some feeding approaches, i.e., supplementation of tannins [3] and extrusion o f feed ingredients [4] showed promising results in increasing availability of PUFA in the intestine hence modifying fatty acid composition of animal products. However, enhancing meat with omega-3 fatty acids could pose potential meat quality issues due to unsaturated fatty acids being a substrate for lipid oxidation and the oxidative products negatively affecting color, flavor, and nutritive value of meat [5]. Therefore, this study was designed to evaluate color and lipid oxidative stability and sensory properties of lamb meat as affected by lamb feeding strategies used to enhance omega-3 content.

II. MATERIALS AND METHODS

Forty Sufflock × Arcott lambs (22 females and 18 males; average body weight = 37.7±5.87 kg) were assigned to 1 of 5 dietary treatments in a randomized complete block design. Treatments included:

Treatment	**Diet**
CONT	Barley-based diet (ground barley and barley silage)
FL	Inclusion of 8.6% flaxseed
FL+T	8.6% flaxseed + 4% tannin
EFFP	20.5% co-extruded flaxseed and field pea
EFFP+T	20.5% co-extruded flaxseed and field pea + 4% tannin

After 60 days of receiving the diet, the lambs were slaughtered, chilled and fabricated into wholesale cuts. Samples of Longissimus muscles (right side of the carcass) were taken and portioned for retail color display, lipid oxidation determination and sensory studies. The Longissimus muscle from the left side of each carcass was used for proximate composition and fatty acid analyses.

Fatty acid analysis. Fatty acids from Longissimus muscles were extracted and analyzed following the procedure described by Bligh and Dyer [6].

Color oxidation. Lamb chops were placed onto styrofoam trays with soaker pads, over-wrapped with an oxygen permeable film and placed into a refrigerated display case for 6 d. Color oxidation was instrumentally (Hunter Lab Miniscan 45/0-L XE, Hunter Association Laboratory Inc., Reston, VA) and subjectively evaluated (descriptive scoring: surface discoloration, 7- no discoloration and 1- 100% discoloration; lean color, 8- extremely bright cherry red and 1- extremely dark red) by a 5-member viewing panel.

Lipid oxidation analysis. Lipid oxidation was evaluated by measuring the formation of thiobarbituric acid reactive substances (TBARS) (Bedinghaus and Ockerman [7]). Lamb chops were pulled from the retail display case on days 1, 3 and 6 and analyzed for TBARS formation.

Cooking and sensory evaluation. Bone-in loin roasts were thawed for 48 h at 4ºC and cooked in a preheated convection oven until internal temperature reached 71ºC. Cooked samples were cut into 1.25 cm^3 cubes. Three cubed samples placed in a pre-coded covered glass container were served to each sensory panel member. Prior to the sensory study, a series of screening tests and training sessions were conducted (American Meat Science Association [8]). Thirteen trained panelists evaluated samples for aroma intensity, aroma desirability, juiciness, tenderness, flavor desirability, and overall palatability using descriptive scoring (8 as extremely strong, desirable, juicy, tender and 1 as extremely weak, undesirable, dry, tough). The sensory data are means of 13 panelists × 8 lambs (muscle) per treatment. The sensory protocol was evaluated by the University of Saskatchewan Behavioral Research Ethics Board.

Statistical analyses. Data were analyzed as a randomized complete block design using the MIXED procedure of SAS. For lipid oxidation, the statistical model included the fixed effect of diets, day and the interaction. The PDIFF option was used to separated and compare differences among least square means. Significance was declared at $P<0.05$.

III. RESULTS AND DISCUSSION

PUFA of Longissimus muscle. Effects of diets on the PUFA composition of longissimus muscles are presented in Table 1. All four diets containing flaxseed significantly ($P<0.001$) increased C18:3 n-3, C20:5 n-3 components and total omega-3 fatty acid content of longissimus muscle. An increase of 205-280% total omega-3 relative to CONT was noted from all flaxseed-containing diets. Incorporation of tannins and use of co-extruded flaxseed with field pea (EFFP+T) further increased ($P<0.001$) the C18:3 n-3 component. The CONT treatment had the greatest proportion of omega-6 fatty acids, particularly C20:2 n-6 and C20:3 n-6. Feeding lambs with flaxseed with or without tannin, ground or co-extruded with field pea, resulted in a 50-60% reduction in the omega-6/omega-3 ratio relative to the CONT. Calculated omega-6/omega-3 ratios for CONT, FL, FL+T, EFFP, EFFP+T are 5.83, 2.41, 1.97, 2.18, and 2.18, respectively. Medical studies have shown that a lower omega-6/omega-3 ratio is more desirable in reducing the risk of many chronic diseases [9].

Color and lipid oxidation. Dietary treatments affected a* (redness) but not L* and b* of lamb chops during display (Table 2). Muscles from FL fed group had higher a* than FL+T, EFFP, EFFP+ T. As expected, there was a significant change in color values as a result of day of storage. Continuous reduction of L*, a* and b* during storage was observed. On the other hand, panelists did not observe effect of dietary treatments on lean color and % discoloration of samples during simulated retail display. In agreement with instrumental color data, panelists noted discoloration of samples as a result of storage time. At day 3, panelists noted small to modest discoloration (20-59% discoloration) (Table 2) of all displayed muscles.

Neither the diet nor interaction of diet × day affected lipid oxidative stability of lamb muscle (Table 2). As expected, TBARS increased with storage time (Table 2). The lack of change in lipid oxidative stability of PUFA enhanced muscles could be due to the natural antioxidants components such as lignans, phenolics, tannins [10] in flaxseed containing diets. Studies have shown that antioxidants in animal diets could influence lipid oxidation stability of meat. For example, Luciano et al. [11] reported that inclusion of quebracho (rich in tannin) in diets for lambs improves overall antioxidant status of meat, increasing its reducing ability and radical scavenging ability.

Sensory properties. Mean sensory scores for aroma, juiciness, tenderness, flavor desirability and overall palatability of cooked lamb meat are presented in Table 3. Among the sensory properties, juiciness was the only characteristic significantly affected by dietary treatments. Panelists perceived meat from lambs fed with CONT and EFFP+T diets as more juicy, followed by FL+T and EFFP; and those from animals fed FL as the least juicy. Panelists did not report any perceivable unusual aroma that may influence flavor desirability.

IV. CONCLUSION

The marked increase in long chain omega-3 fatty acids observed in meat from lambs fed flaxseed-containing diets did not adversely affect color and lipid oxidative stability as well as sensory characteristics of cooked lamb meat. This study clearly shows the effectiveness of designed feed rations in improving nutritional quality of lamb specifically offering the market with desirable omega-6/omega-3 ratio of < 3/1.

V. ACKNOWLEDGEMENTS

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Table 1. Fatty acid profile of the Longissimus muscle of lambs consuming diets containing flaxseed (FL) or co-extruded flaxseed and field pea (50:50) (EFFP) with or without tannins (T)

	Dietary treatment[2]						P-values
Item	CONT	FL	FL+T	EFFP	EFFP+T	SEM[1]	Trt
Fat content, %	4.29	4.56	4.34	4.52	4.02	2.24	0.95
Total Omega-3, mg/g fat	10.9^{a}	22.4^{b}	30.7^{c}	27.8^{c}	27.6^{bc}	0.25	<0.001
C18:3 n-3	6.4^{a}	16.2^{b}	23.9^{c}	20.5^{c}	19.9^{bc}	0.18	<0.001
C18:4 n-3	0.1	0.0	0.1	0.2	0.1	0.01	0.93
C20:3 n-3	0.0	0.1	0.3	0.2	0.1	0.01	0.28
C20:5 n-3	1.2^{a}	2.2^{b}	2.8^{b}	2.6^{b}	2.7^{b}	0.04	0.001
C22:5 n-3	2.5	3.0	3.5	3.3	3.6	0.04	0.09
C22:6 n-3	0.7	0.9	1.0	1.0	1.2	0.02	0.24
Total Omega-6, mg/g fat	63.6	53.9	60.6	60.7	60.1	0.58	0.58
C18:2 n-6	46.8	40.7	46.4	46.4	46.9	0.44	0.58
C18:3 n-6	0.9	1.3	1.4	1.2	0.7	0.03	0.25
C20:2 n-6	2.3^{b}	1.1^{a}	1.2^{a}	1.4^{a}	0.8^{b}	0.02	<0.001
C20:3 n-6	1.7^{b}	1.0^{a}	1.2^{a}	1.1^{a}	0.9^{a}	0.02	0.007
C20:4 n-6	11.1	9.3	9.8	10.0	10.2	0.09	0.68
C22:5 n-6	0.8	0.5	0.6	0.6	0.6	0.01	0.15

[1]Standard error of the mean; [2]CONT-Control, FL – inclusion of 8.6% flaxseed, FL+T – inclusion of 8.6% flaxseed + 4% tannin, EFFP – inclusion of 20.5% co-extruded flaxseed and field pea, EFFP + T – inclusion of 20.5% co-extruded flaxseed and field pea + 4% tannin; [abc]Values with different letters within a row differ significantly (P<0.05)

Table 2. Color (instrumental and visual) and TBARS values of Longissimus muscle during retail display from lamb fed various rations of flaxseed.

Item	DIET[4]					SEM[1]	DAY			SEM[1]	P-value		
	CONT	FL	FL+T	EFFP	EFFP + T		0	3	6		DIET	DAY	Diet x Day
L*	41.81	40.32	41.76	42.69	40.96	1.34	42.32^{b}	42.26^{b}	40.67^{a}	1.18	0.272	0.0002	0.821
a*	20.58^{a}	22.29^{b}	20.33^{a}	20.41^{a}	20.63^{a}	1.49	24.78^{c}	20.12^{b}	18.14^{a}	1.45	0.010	<0.0001	0.921
b*	16.51	17.64	16.64	16.73	16.85	1.03	18.20^{c}	16.68^{b}	15.68^{a}	1.00	0.159	<0.0001	0.899
Lean color[2]	4.38	4.79	4.27	4.40	4.39	0.59	6.46^{c}	3.88^{b}	2.72^{a}	0.52	0.806	<0.0001	0.975
Surface discoloration[2]	4.63	4.96	4.59	4.68	4.59	0.24	6.84^{c}	4.18^{b}	2.73^{a}	0.11	0.726	<0.0001	0.946
TBARS[3]	0.44	0.49	0.37	0.42	0.44	0.05	0.38^{a}	0.45^{b}	0.46^{b}	0.03	0.048	0.0026	0.395

[1]Pooled standard error of the mean; [2]Descriptive scores: Lean color – 8-Extremely bright cherry red to 1-Extremely dark red; % Surface discoloration – 7-no discoloration to 1-total discoloration; [3]mg malonaldehyde per kg muscle
[4]For diet descriptions refer to Table 1. ; [abc]Values with different letters within a row differ significantly (P<0.05)

Table 3. Sensory properties[1] of cooked Longissimus muscle from lamb fed various flaxseed-containing rations

DIET[1]	Aroma intensity	Aroma desirability	Juiciness	Tenderness	Flavor desirability	Overall palatability
Control	5.24	5.37	5.67^{a}	5.30	5.12	5.55
FL	5.14	5.31	5.14^{c}	5.21	5.28	5.45
FL+T	5.19	5.55	5.28^{b}	5.62	5.31	5.57
EFFP	5.14	5.57	5.33^{b}	5.21	5.14	5.52
EFFP+T	5.19	5.45	5.62^{a}	5.37	5.24	5.50
P-value	*0.971*	*0.403*	*0.023*	*0.412*	*0.660*	*0.963*
SEM	0.14	0.14	0.13	0.25	0.11	0.26

[1]For diet descriptions refer to Table 1; [abc]Values with different letters within a column differ significantly (P<0.05);
[1]Descriptive scores: 8 as extremely strong aroma, desirable aroma/flavor/palatability, juicy, tender --- 1 as extremely weak, undesirable, dry, tough.