Conjugated lineolic acid and other beneficial fatty acids in lamb produced on different feeding systems

FINAL REPORT

Agri-Futures Nova Scotia
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Executive summary

The diet of most people is generally considered to be insufficient in its content of certain vital essential and non-essential fatty acids, particularly the omega-3 fatty acids. While cold water marine fish and some vegetable oils are a good source of beneficial fatty acids, ruminant animal meat can be another option. Modifying the diets of lambs to include red clover and supplemental oils could result in healthier and higher value meat products. A trial was conducted in 2010 and 2011 at the Nappan Experimental Farm in Nova Scotia, using 2-3 month old lambs. The animals were grazed on one of two pasture types, for three months: 1) > 30% red clover/tall fescue or 2) a pure stand of tall fescue. After pasturing the lambs received hay and grain with one of four oil supplements, three weeks prior to market: 1) no supplemental oil; 2) soybean oil (SBO); 3) CLA + soybean oil (C+S); 4) fish oil (FO). Pasture productivity, lamb growth, glucose/insulin levels, plasma metabolites and fatty acid profiles of blood and carcasses of lambs, as well as detailed molecular analyses of tissues as well as the evaluation of reproductive aspects were monitored throughout the 2010 trial. As forage production and other environmental factors can influence animal production and performance response, the field experimentation was repeated in 2011 followed by the lipid supplementation during finishing. The purpose of the 2011 trial was to verify reproducibility of results obtained with respect to commercially important parameters. Data collection in 2011 trial was focused on animal growth performance and fatty acid composition of muscle and adipose tissues only.

Lambs grazed on Tall Fescue with red clover gained significantly more weight per day than those on the Tall Fescue alone in both years of the study. The red clover treatment pastures were approximately 70% red clover in the first year and 30% in the second year. The red clover group achieved a heavier weight gain resulting in , a larger carcass and muscle scores were higher for the red clover lambs as well, increasing carcass value. Lambs assigned to Red Clover had 38.9% greater weight gains on pasture, 8.52% higher carcass weights and 20.7% higher fat depth measurements at the twelfth rib, when compared to lambs on Tall fescue pasture. Supplementation with fish oil resulted in a dramatic increase in the amount of beneficial fatty acids for both pasture treatments; soybean oil actually decreased these levels slightly. Lipid treatment had significant effects on carcass weight (SBO: 20.8, C+S: 21.6, FO: 19.6 and control: 21.7kg; $P \leq 0.001$). Fat depth at the twelfth rib was significantly affected by pasture type (RC: 11.9, TF: 9.42mm; $P \leq 0.05$) and lipid supplement (SBO: 10.5, C+S: 11.8, FO: 9.5 and control: 10.8mm; $P \leq 0.1$). In comparison to TF, RC tended to increase the fat content of the *longissimus dorsi* muscle from 11.3 to 12.3% ($P \leq 0.1$) while lipid treatment had no significant effect. There were significant effects of pasture on EPA (eicosapentaenoic acid) content of muscle (RC: 2.14%, TF: 1.61%; $P \leq 0.06$) and EPA and DHA (docosahexaenoic acid) content of subQ (RC: 0.08%, TF: 0.16%; $P \leq 0.03$ and RC: 0.10%, TF: 0.24%; $P \leq 0.05$, respectively), five wk post grazing. With no supplemental lipid, the EPA and DHA content of muscle and subQ tended to be greater in lambs that had grazed RC. Lipid supplementation significantly affected the EPA and DHA content of both tissues studied and the CLA content of subQ adopose tissue.

From a reproductive standpoint, ram lambs grazing RC had heavier testes and potentially greater sperm production than those grazing on TF only. The type of oil supplemented to ram lambs may affect potential sperm production. Neither pasture type nor oil supplementation appeared to impact blood LH pulsatility in males. There may be an interaction between pasture type and oil supplementation on LH pulsatility and the number of ovulations. Ewe lambs that grazed on RC may produce more progesterone- the hormone of pregnancy. Ewe lambs that grazed on RC were just as likely to become pregnant as those that grazed on TF. In addition, the type of oil supplementation or no oil supplementation appeared to have no effect on pregnancy outcomes. The grazing of RC by lambs does not appear to be detrimental to their

reproductive health; however, the supplementation of lambs with various oils and their interaction with pasture type may impact the animal's reproductive health.

Background

The current North American diet contains insufficient amounts of vital essential and non-essential fatty acids, particularly the omega-3 fatty acids (Hayes, 2002). While cold water marine fish and some vegetable oils are a good source of some beneficial fatty acids, feeding management of ruminants results in meat can provide these and other beneficial fatty acids (Higgs et al., 2002). Feeding red clover forage has been shown to improve the omega-3 fatty acid content of lamb, while supplementation of the diet with marine oil has been shown to increase levels of specific fatty acids associated with health benefits (Lee et al., 2005). Modifying the diets of lambs to include red clover and supplemental oils could result in healthier and higher value meat products.

The fats and oils in our diet are comprised of different types of fatty acids, two of which are essential, meaning we cannot synthesize them ourselves and must consume them in the diet. These are linoleic (LA) and alpha linolenic acid (LNA). While the 18 carbon omega-6 fatty acid, LA, is readily available in commonly consumed oils, the 18 carbon, omega-3 fatty acid, LNA, is generally present in oils in small amounts unless consumers choose specific oils such as flaxseed. From LNA our bodies can synthesize two longer omega-3 fatty acids: EPA (eicosapentaenoic acid), and DHA (docosahexaenoic acid) however this conversion provides sub-optimal levels. Both EPA and DHA are involved in the regulation of lipid and carbohydrate metabolism and extensive research is being conducted to understand the role these fatty acids have in helping ameliorate the development of obesity and related disorders, as well as cardiovascular disease and chronic inflammation (Belluzzi, 2002). Current intakes of EPA+DHA are approximately 15% of recommended levels. Conjugated linoleic acid (CLA), is the name given to specific conformational variants of LA produced in the rumen, some of which have been linked to decreased fat deposition, protection against types of cancers, improved immune response and normalization of insulin levels. Ruminant food products are currently the best source of these fatty acids.

Red clover, more than any other forage, has been shown to increase the CLA and omega-3 fatty acid content in ruminant meat such as lamb, while fish oil supplements have been shown to alter the long chain omega-3 fatty acid profile, favoring higher content of EPA and DHA (Lee et al., 2005). Thus, by modifying forage-based lamb production systems already in use in Nova Scotia, it should be possible to produce lamb rich in CLA and the beneficial omega fatty acids, EPA and DHA.

Grazing legumes that are high in phytoestrogens, such as red clover, may also positively impact growth and timing of sexual development in the market lamb. Clovers and soybean oil contain phytoestrogens and estrogens regulate gonadotropin secretion. However, the effects of these phytoestrogens vary with the source, perhaps as a function of the type and amount of the phytoestrogen supplied. Adverse reproductive effects have been reported in some studies of ewes consuming some, but not all, clover types. No research group has compared the effects of grazing red clover and/or feeding dietary fat supplements with contrasting levels of linoleic acid, CLA or omega-3 fatty acids on reproductive hormones and sexual development of prepubertal lambs.

Objectives and Deliverables

The ultimate goal of this research is the development of feeding protocols for the production of nutrient-enhanced lamb products that will increase consumer demand and command premium prices for the sheep producers in this region. More specifically the focus of this research is to improve the quality of lamb meat by increasing the content of CLA and omega-3 fatty acids thus providing opportunities to uniquely market Nova Scotia lamb products to the health conscious consumer. The use of pasture species (in particular red clover) as a way to alter the fatty acid profile of lamb meat will be studied and compared to dietary supplementation with various sources of polyunsaturated fatty acids during the finishing stages of lamb production. Polyunsaturated fatty acids have significant biological activity and hence effects on energy metabolism and sexual maturation will also be studied to increase our understanding of the impact of dietary polyunsaturated fatty acids on lamb growth and development.

Experimental Procedure

In July of 2010 (first year of this study), 64 cross-bred lambs (Leicester/Romanov dams, Suffolk sire) were purchased and randomly assigned to either red clover/tall fescue pasture or tall fescue pasture. Half of the animals were ram lambs, half ewe lambs; they were evenly distributed on pastures comprised of either Tall fescue pasture (AC Courtenay), established in 2004, or red clover (AC Christie). Red clover was no-till seeded into the tall fescue in the spring of 2009 and 2010. There were two pastures of each forage type. Tall fescue pastures averaged 7% red clover, 60% tall fescue, 32 % bluegrass and 1% other. The red clover pastures averaged 72% red clover, 15% tall fescue, 12 % blue grass and 1% other. Each pasture was divided into 12 paddocks for rotational grazing. Lambs were moved when an estimated 70% of pasture was consumed from each paddock. Pasturing began July 27th. Weights, body condition scores, and scrotal circumference measurements were taken every second week.

In early October, and for each consecutive week over 4 weeks, one quarter of lambs from each treatment paddock were removed (based on weight) from pasture, weighed, and a subcutaneous fat biopsy was taken. Lambs removed from pasture were transitioned to hay and grain in the barn and gradually introduced (2 week period) to one of four lipid supplements [soybean oil (SBO), 50% *c*9*t*11 and *t*10*c*12 conjugated linoleic acid (CLA) isomers + 50% SBO (C+S), enriched fish oil (FO) or control (no supplemental oil)], receiving 50mL/d for two weeks prior to slaughter. Pasture productivity and growth of lambs were monitored throughout the trial. Scrotal circumference and ultrasonography were used to monitor gonadal development. Blood samples were collected to monitor hormone levels. At slaughter parameters related to carcass composition were measured and samples of adipose, muscle, liver, ovary and testes were collected. Fatty acid analysis of tissues will be conducted as well as detailed molecular analyses of tissues collected and histology of reproductive tissues. Due to a large percentage of the ewe lambs becoming pregnant, only data from the ram lambs is reported for this portion of the 2010 trial.

As forage production and other environmental factors can influence animal production and performance response, the field experimentation was repeated in 2011 followed by the lipid supplementation during finishing. The purpose of the 2011 trial was to verify reproducibility of results obtained with respect to commercially important parameters. Data collection in 2011 was focused on animal growth performance and fatty acid composition of muscle and adipose tissues only. Seventy-two lambs were used to allow for some extras should there be problems with any lambs. The lambs started the trial in early July, and were younger and smaller than those involved in the 2010 trial. Lambs were again removed from pasture over 4 consecutive weeks equally from each pasture group based on body weight. Again there was a short adaptation period to the finishing diet including a gradual introduction to one of four lipid supplements. The lipid supplements in 2011 included a control of no supplemental oil, SBO, FO, safflower oil and a control of no supplemental oil and were administered at half the rate of the 2010 experiment (25ml/d).

Results

Lamb production on contrasting pasture types

In the first year (2010) trial the average lamb weight in each pasture treatment was the same at the start of the trial. Lambs grazed on red clover pastures gained more weight than those on tall fescue (172 g/day vs. 108 g/day) (Table 1). Although all lambs lost body condition on pasture those on red clover lost less body condition than tall fescue lambs (0.31 points vs. 0.53 points on a 5 point scale). The ram lambs and ewe lambs performed similarly on each pasture type. Despite the high clover content there were no cases of bloat with the red clover pastures. Lambs assigned to RC had 20.7% ($P \leq 0.04$) higher fat depth measurements at the twelfth rib, when compared to lambs on TF.

In the second year (2011) trial, lambs were younger and smaller going on pasture. The trial began in early July, but grazing continued until October. The red clover pasture had a lower level of red clover than the previous year at 30%. Despite the lower red clover content, lamb gains on red clover were higher than those on tall fescue (160 vs. 130 g/day; Table 1). Body condition scores did not show large differences between pastures.

Table 1. Effect of pasture type on lamb weights, daily weight gain, and body condition score in 2010 and 2011

	2010		2011	
	Tall Fescue	Red Clover	Tall Fescue	Red Clover
Initial weight, kg	21.7	21.6	19.4	19.4
Final weight, kg	29.9	34.6	28.3	31.5
Average gain, g/d	108	172	130	160
Body condition score change	-0.53	-0.31	-0.30	0.22

Lamb production on different lipid supplements following grazing of different pasture types

In 2010 for ram lambs there was statistically significant difference between oil supplements in final lamb live weight or average lamb gain per day over the 5 week finishing period (Table 2). After analyzing lamb chop composition, there were significant gains in lamb chop size per kg carcass weight, lamb loin muscle size per kg carcass weight, and lamb bone size per kg of carcass weight with fish oil supplemented lambs over those with no supplementation (Table 3). However, there were no differences in chop fat percent or fat depth over the 12th rib, suggesting an opportunity for increased carcass value with fish oil supplementation based on more saleable meat. This trend appeared to be consistent with all of the oil treatments over no supplementation.

Table 2: Effect of dietary lipid supplement on average daily gain, final weight, dressing percent and carcass quality

Item	Treatment[a] CON	FO	SBO	CLA+	SEM[c]	Contrast[b] FO v. CLA+	FO v. SBO	FO v. CON
ADG (g/d)	318	210	244	327	18.7	**	ns	*
Final wt (kg)	48.7	43.6	46.1	49.4	0.70	**	*	*
Carcass wt (kg)	21.7	19.6	20.8	21.6	0.30	**	*	10
Dressing (%)	46.9	44.9	48.5	46.4	1.67	ns	ns	ns
Fat depth (mm)	10.8	9.5	10.5	11.8	0.57	ns	ns	ns
Kidney fat (g)	364	319	344	445	[d]	ns	ns	ns
Stomach fat (g)	793	635	770	818	[d]	ns	ns	ns

[a]Treatments = basal ration without lipid supplementation (CON) or basal ration with enriched fish oil (FO) or basal ration with soybean oil (SBO) or basal ration with 50:50 CLA isomers and SBO (CLA+).
[b]*P*-values (** = $P \leq 0.01$, * = $P \leq 0.05$ and 10 = $P \leq 0.1$) of single degree of freedom non-orthogonal contrasts of importance to study.
cSEM= standard error of the mean; n = 4 lambs/treatment, 7df.
[d]n= 2 lambs/treatment due to missing data.

Table 3: Effect of dietary lipid supplement on chop measures as a proportion of carcass weight from 2010 lambs (Year 1) only.

Item	Treatment[a] CON	FO	SBO	CLA+	SEM[c]	Contrast[b] FO v. CLA+	FO v. SBO	FO v. CON
Total chop wt log(g·kg^{-1})	0.90	0.93	0.94	0.95	0.012	10	ns	ns
Chop bone wt log(g·kg^{-1})	0.21	0.35	0.28	0.32	0.016	**	*	ns
Chop loin wt log(g·kg^{-1})	0.37	0.42	0.40	0.39	0.011	**	ns	ns
Total muscle wt log(g·kg^{-1})	0.58	0.56	0.63	0.59	0.011	ns	**	10
Chop fat wt log(g·kg^{-1})	0.38	0.42	0.42	0.45	0.044	ns	ns	ns
Loin muscle fat (%) [d]	10.7	12.5	11.4	12.6	1.00	ns	ns	ns

[a]Treatments = basal ration without lipid supplementation (CON) or basal ration with enriched fish oil (FO) or basal ration with soybean oil (SBO) or basal ration with 50:50 CLA isomers and SBO (CLA+).
[b]*P*-values (** = $P \leq 0.01$, * = $P \leq 0.05$ and 10 = $P \leq 0.1$) of single degree of freedom non-orthogonal contrasts of importance to study.
[c]n = 4 lambs/treatment, 11df.
[d]Percent fat of chop loin muscle (*Longissimus dorsi*).

In 2011 fish oil supplemented lambs gained at a slightly lower rate than those with no supplement or safflower oil supplement (data not shown). No large differences were present in body condition scores. Due to the larger body weight at slaughter carcass weights were greater in un-supplemented lambs than fish oil supplemented lambs (41 lb vs. 38 lb); a similar trend was present in carcass dressing percent (46% for no supplement vs. 44% for fish oil). Fish oil supplemented lambs had the lowest fat depth at 12th rib (7.8 mm vs. 8.6 mm for rest of treatments). Numerically fish oil supplemented lambs had lower shoulder, loin, and leg muscle scores than other treatments while soy oil supplemented lambs had higher scores than the other lambs.

Lamb muscle and subcutaneous fatty acid profile on different lipid supplements following grazing of different pasture types

With no supplemental lipid, the EPA and DHA content of muscle and subQfat tended to be greater in lambs that had grazed RC. Lipid supplement had significant effects on percent EPA and DHA in muscle (P<0.001) (Figure 1) and in subQ (P$\leq$0.001) (Figure 2) with fish oil drastically increasing percentage of both fatty acids compared to the other 3 treatments. Lipid supplementation significantly affected the EPA and DHA content of both tissues and the CLA content of subQ. The CLA+soy oil treatment increased percent CLA of sub Q compared to other 3 treatments (P$\leq$0.07).

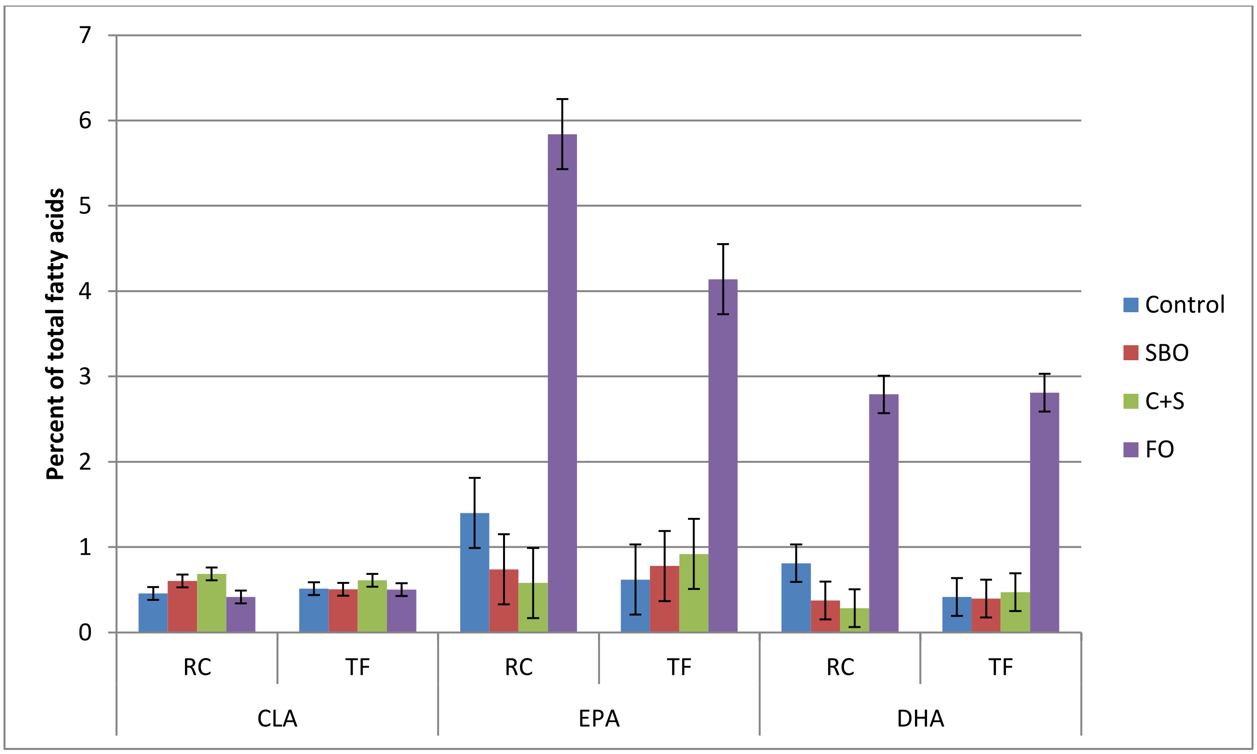

Figure 1: Effect of pasture type and lipid supplement on FA composition of muscle

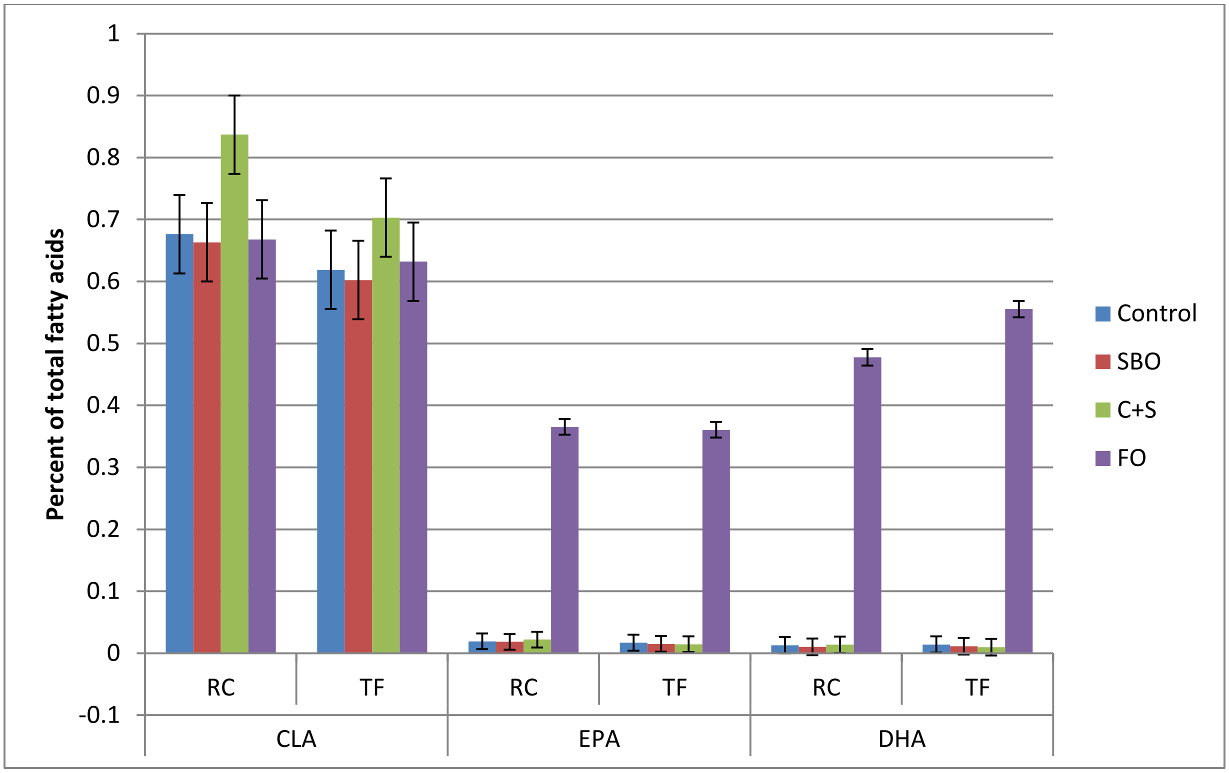

Figure 2: Effect of pasture type and lipid supplement on FA composition of subQ fat

Gene Expression Analysis of Carbohydrate and Lipid Metabolism

Polyunsaturated fatty acids (PUFA) especially EPA and DHA, the long chain fatty acids found in fish oil, have been shown in many animal and animal models to alter lipid metabolism. Furthermore CLA has also been shown to impact lipid metabolism. PUFA and CLA act at the transcriptional level modulating the expression of genes involved in regulation of lipid metabolism and fatty acid synthesis. Pasture type significantly altered the expression of the Δ9 desaturase gene in the liver (Table 4). This gene converts saturated fatty acids to monounsaturated fatty acids and is principally responsible for the formation of the oleic acid which is the predominant fatty acid in animal adipose tissue. Expression of the Δ9 desaturase gene was lower in the liver of lambs that had grazed the RC pasture. Expression of the Δ9 desaturase gene also tended to be lower in the enteric adipose tissue of lambs that had grazed the RC pasture but this effect was not significant at $p<0.05$. The FO supplementation also reduced the expression of the Δ9 desaturase gene in liver and enteric adipose tissue however this effect was statistically significant in the adipose tissue only.

In liver, the expression of sterol regulatory element binding protein (SREBP-1c) was significantly affected by the lipid supplements (Table 4). SREBP -1c is a primary regulator of lipid metabolism and was reduced in liver by the FO treatment. This would be expected to result in a decrease in lipid synthesis by the liver.

In enteric adipose tissue the expression of three genes was reduced by the FO treatment: adiponectin and leptin, both hormones produced by adipose tissue and Spot14, a protein expressed in lipogenic tissues (Table 5). These three genes are all involved in the regulation of lipid metabolism and a reduction in their expression would be expected to reduce fatty acid synthesis and increase fatty acid oxidation.

Results of the gene expression data agree with the observed reduced internal and subcutaneous fat content of the lambs receiving the fish oil treatment. However intramuscular fat content was not altered by the fish oil treatment. Feeding the CLA+soy oil treatment did not change expression of genes involved in lipid metabolism nor reduce fat content of the lambs. These indicate that carcass composition/leanness can be modified by feeding specific lipid supplements.

Table 4: Effect of dietary lipid supplement on gene expression in lamb liver

Gene[c]	**Treatment[a] CON**	**FO**	**SBO**	**CLA+**	**SEM[d]**	**Contrast[b] FO v. SBO**	**CLA+ v. SBO**	**FO v. CON**
ACC	0.21	0.28	0.25	0.28	0.040	ns	ns	ns
ChREBP	0.26	0.24	0.28	0.32	0.025	ns	ns	ns
D9D	0.24	0.06	0.21	0.36	0.071	ns	ns	ns
FAS	0.26	0.20	0.28	0.35	0.062	ns	ns	ns
HL	0.21	0.20	0.24	0.21	0.024	ns	ns	ns
PPARα	0.21	0.24	0.23	0.23	0.015	ns	ns	ns
PPARδ	0.36	0.41	0.25	0.31	0.100	ns	ns	ns
SCAP	0.18	0.27	0.21	0.22	0.041	ns	ns	ns
SREBP-1c	0.17	0.11	0.19	0.21	0.023	ns	*	ns

[a]Treatments = basal ration without lipid supplementation (CON) or basal ration with enriched fish oil (FO) or basal ration with soybean oil (SBO) or basal ration with 50:50 CLA isomers and SBO (CLA+).
[b]*P*-values (** = $P \leq 0.01$, * = $P \leq 0.05$ and 10 = $P \leq 0.1$) of single degree of freedom non-orthogonal contrasts of importance to study.
[c]Genes = acetyl-CoA carboxylase (ACC), carbohydrate response element binding protein (ChREBP), delta-9-desaturase (D9D), fatty acid synthase (FAS), hepatic lipase (HL), peroxisome perliferator-activated receptor alpha (PPARα), peroxisome perliferator-activated receptor delta (PPARδ), sterol regulator element binding protein-cleavage activating protein (SCAP) and sterol regulator element binding protein-1c (SREBP-1c).
[d]n = 4 lambs/treatment, 11df.

Table 5: Effect of dietary lipid supplement on gene expression in enteric adipose tissue

Gene[c]	**Treatment[a] CON**	**FO**	**SBO**	**CLA+**	**SEM[d]**	**Contrast[b] FO v. SBO**	**CLA+ v. SBO**	**FO v. CON**
Adiponectin	0.22	0.18	0.29	0.23	0.032	ns	10	ns
D9D	0.14	0.19	0.16	0.20	0.023	10	ns	ns
PPARγ	0.20	0.23	0.22	0.20	0.026	ns	ns	ns
Leptin	0.12	0.04	0.17	0.25	0.034	10	*	ns
LPL	0.18	0.24	0.19	0.25	0.025	ns	ns	ns
Spot14	0.25	0.08	0.29	0.36	0.051	*	*	ns

[a]Treatments = basal ration without lipid supplementation (CON) or basal ration with enriched fish oil (FO) or basal ration with soybean oil (SBO) or basal ration with 50:50 CLA isomers and SBO (CLA+).
[b]*P*-values (** = $P \leq 0.01$, * = $P \leq 0.05$ and 10 = $P \leq 0.1$) of single degree of freedom non-orthogonal contrasts of importance to study.

[c]Genes = delta-9-desaturase (D9D), peroxisome proliferator-activated receptor gamma (PPARγ), lipoprotein lipase (LPL), thyroid responsive spot 14 (Spot14).
[d]n = 4 lambs/treatment, 11df.

Reproductive Analysis

In 2010 lambs grazing RC had a significantly larger scrotal circumference than those grazing TF on the last day of pasturing and throughout the finishing period. Testicular mean numerical pixel value (NPV; measure of tissue density) was significantly higher before slaughter compared to before the finishing diet. Before slaughter, testicular mean NPV was significantly lower for lambs supplemented with FO compared to those supplemented with CLA or no oil. Before slaughter for lambs grazing RC, testicular mean NPV was lower for those supplemented with SBO or FO compared to those not fed oil. Before slaughter for lambs not fed oil, those grazing TF had a lower testicular mean NPV than those grazing RC. Testicular pixel heterogeneity was not affected by pasture type or lipid supplement. Ram lambs grazing RC had heavier combined testes and epidydimal weights than those grazing TF. Half the ewe lambs grazing RC and half the ewe lambs grazing TF were pregnant. Also, half the ewe lambs on no lipid supplement or each lipid supplement were pregnant. Female postmortem results are currently being statistically analyzed. Gonadotropin and testosterone levels are currently being analyzed. Preliminary analyses of luteinizing hormone (LH) pulses reveal no impact of pasture type or oil supplement in males. However, LH pulses appear to be affected in females. Oil supplementation seems to increase mean LH levels in ewe lambs grazing RC, especially in those supplemented with FO, but decrease mean LH concentrations in those grazing TF. Ewe lambs grazing RC with no oil supplement seem to have lower mean LH concentrations than those grazing TF with no oil supplement. Ewe lambs grazing RC and supplemented with FO seem to have higher mean LH concentrations than those grazing TF and supplemented with FO.

In 2011 scrotal circumference was not affected by pasture type or lipid treatment. Semen quality data was collected in the second year instead of the first year because it was not logistically possible to conduct this evaluation in the first year. Data is currently being summarized for statistical analysis. Ram lambs grazing RC tended to have heavier testes and combined testes and epidydimal weights (carcass weight adjusted). The carcass weight adjusted epidydimal weights were not significantly different. Only one female became pregnant in 2011, but males and females were separated from each other when they were taken off pasture. Female postmortem results revealed that the ovary was not affected by treatment apart from some corpora lutea (CL) characteristics. For ewe lambs grazing TF, SBO supplemented lambs had more CL than those supplemented with SAF. For ewe lambs supplemented with SBO, those grazing RC had more CL than those grazing TF. There was a tendency for ewe lambs grazing RC to have larger CL. Gonadotropin and testosterone levels will be assayed within the next 3 months.

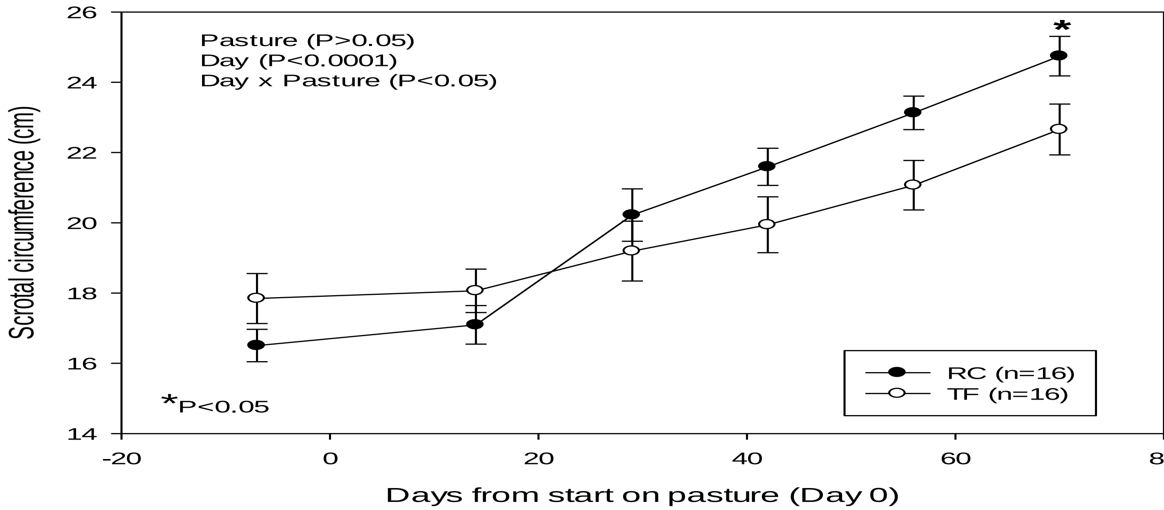

Figure 2. Scrotal circumference of mixed breed ram lambs grazing red clover/ tall fescue (RC) or tall fescue (TF) pasture for 10 weeks.

Conclusions:

Lamb productivity, carcass composition and fatty acid composition were altered by the pasture types and lipid supplements used in this study. The lambs that had grazed the red clover pasture gained more and had enhanced EPA and DHA content in comparison to the tall fescue pasture, five weeks after being removed from the pasture. With respect to lipid supplementation the fish oil substantially increased the content of EPA and DHA in both the muscle and subcutaneous adipose tissues. While the lambs receiving the fish oil were smaller at slaughter, carcass fat and chop analyses suggest these lambs fed FO are leaner and loin muscle size/ kg carcass weight was increased. Analysis of genes involved in lipid metabolism also indicates that fat synthesis in fish oil supplemented lambs would be reduced. However, intramuscular fat content was not affected. Whole loins were collected at slaughter in the second year of this study to confirm these carcass composition results but have yet to be analyzed as it was felt important to also conduct a taste panel assessment Samples were saved for this should funding for this element be secured.

An opportunity to produce a nutritionally enriched lamb product with increased carcass value and beneficial fatty acid profile can be accomplished through grazing and limited fish oil supplementation during finishing was developed.

References:

Higgs, J., Food to Fit and Mulvihill, B. 2002. Chapter 4: The nutritional quality of meat. Meat Processing: Improving Quality. CRC Press LLC and Woodhead Publishing Ltd. Cambridge, England. Pages 75-92.

Hayes, K.C. 2002. Dietary fat and heart health: in search of the ideal fat. J. Clin. Nutr. 11:394-400.

Higgs, J., Food to Fit and Mulvihill, B. 2002. Chapter 4: The nutritional quality of meat. Meat Processing: Improving Quality. CRC Press LLC and Woodhead Publishing Ltd. Cambridge, England. Pages 75-92.

Lee, M.R.F., Shingfield, K.J., Tweed J.K.S., Toivonen, V., Huws, S.A. and Scollan, N.D. 2008. Effect of fish oil on ruminalbiohydrogention of C18 unsaturated fatty acids in steers fed grass or red clover. Animal. 2:12;1859-1869.

The primary targets/beneficiaries of your project?

Agricultural producers, Consumers, Educators, Farm Families, and Research Community.

The knowledge generated by this research will be beneficial to all ruminant sectors including sheep, beef and dairy industries. The above sectors would benefit from the local data produced to develop a unique market identity associated with improved human nutrition. Furthermore the ruminant dairy industries including sheep and goat should also benefit from this research when considering the development of CLA or omega-3 fatty acid enriched milk products.

Information shared with target groups/project stakeholders: Describe how you shared information about the project.

In addition to posting a 'paid' ad in Farm Focus on the research, appropriate newsletters (SPANS, AgriPoint and Federation of Agriculture) received materials from the research and updated results were also post on websites (SPANS, AgriPoint and Federation of Agriculture).

Media representatives were contacted by AAFC using Media Pitch which tracked coverage (shown below):
2010
Media Pitch - Nappan Beef and Lamb Research Field Day - Pitched October 17 to Amherst Daily News, The Herald, Atlantic Beef magazine, and Truro Daily News, Farm Focus, CTV and CBC Halifax:
Tracked coverage: Amherst Daily News, Farm Focus, Atlantic Beef.
2011
Media Pitch - Nappan Beef and Lamb Research Field Day. Pitched October 17 to Amherst Daily News, The Herald, Atlantic Beef magazine, Truro Daily News, and Farm Focus:
Tracked coverage: Amherst Daily News, Farm Focus, and Atlantic Beef: *Better quality beef and lamb starts with the right feed*
You are what you eat holds true not only for humans, but for beef cattle and sheep too.A sheep and beef research field day, being held at the Agriculture and Agri-Food Canada Nappan Experimental Farm on Saturday, October 22, will show the importance of the right pasture grasses and feed supplements on the quality of beef and lamb. Feeding red clover forage has been shown to improve the omega-3 fatty acid content of lamb. Modifying the diets of lambs to include red clover and supplemental oils could result in healthier and higher value meat

products. Researchers are fine tuning feeding systems for the production of nutrient-enhanced lamb products that will command premium prices, increase consumer demand, and increase the competitiveness of the Canadian lamb industry. The workshop starts at 10:00 am and aside from the sheep research will include a talk on the impact of finishing beef cattle on various pastures and the effects of different forage mixtures on cattle performance. The day includes a beef and lamb lunch and a tour of pastures. Media are welcome interviews can be arranged. For more information contact:

John Morrison Agriculture and Agri-Food Canada Communications 902 566-7308	Yousef Papadopoulos Agriculture and Agri-Food Canada Scientist 902 305-0740 (cell)

2012
Media Pitch - Nappan Beef and Lamb Research Field Day. Pitched October 17 to Amherst Daily News, The Herald, Atlantic Beef magazine, Truro Daily News, Farm Focus: *Annual Sheep and Beef Research Field Day* Agriculture and Agri-Food Canada's Nappan Experimental Farm is hosting a sheep and beef research field day October 20, to showcase results from feed and forage research projects. Some of the leading scientists in the field of feed for sheep and beef cattle will be on hand. There will be presentations on:
best management of forage crops for winter rations
silage-based diet for winter
Increasing beneficial fatty acids in lamb
Clover, supplemented fats and lamb reproduction
Finishing beef cattle on different pasture types and effect of forage mixtures on cattle performance
Media are welcome interviews can be arranged. For more information contact:

John Morrison Agriculture and Agri-Food Canada Communications 902 566-7308	Yousef Papadopoulos Agriculture and Agri-Food Canada Scientist 902 305-0740 (cell)

Field trial sites were available for producer visitations during the project. Results were disseminated to the industry during annual meetings (AGM and special meetings which included presentations on research findings of early results from the study) and annual field day for producers and industry specialists. Interim reports were prepared using posters at producers' events, scientific conferences and factsheets (http://nssheep.ca/for-members/research/).

Is project information available to the general public/Canadians? How? Is it available through a web site, press release or other type of media?

Interviews and media articles are accessible by the public. These included:
2011Sheep and beef research trials at Nappan Experimental Farm. Farm Focus of Atlantic Canada Vol 41 No. 2 Decmber 2011 [p.7]
Take good care of your grass-Beef and sheep farmers get the (forage) word. Atlantic Beef, Winter 2011 [p.21]
2012Sheep and beef farmers learn new ways to produce better quality product http://www.atlanticfarmfocus.ca/Agriculture/2012-10-24/article-3106603/Sheep-and-beef-farmers-learn-new-ways-to-produce-better-quality-product/1
Sheep and beef farmers learn new ways to produce better quality product. Amherst Daily News, October 20, 2012, Jocelyn Turner.

Producers and Workshop Presentations

Barrett, D.M.W. Research Update. Annual General Meeting of the Purebred Sheep Breeders Association of NS, NSAC. November 24, 2012

Glover, K.E. J. Duynisveld, D. Barrett, Y. Papadopoulos, A. Fredeen and J. Wort. 2012. Lamb performance and carcass composition on diverse pasture types and oil supplements. Sheep Producers Association of Nova Scotia Field Day, Oct. 20, 2012, Nappan Experimental Farm, Nappan, Nova Scotia.

Barrett, D.M.W. ., K.E. Glover, J. Duynisveld, Y. Papadopoulos, A. Fredeen and J. Wort. 2012. Clover, supplemented fats, and lamb reproduction. Sheep Producers Association of Nova Scotia Field Day, Oct. 20, 2012, Nappan Experimental Farm, Nappan, Nova Scotia.

Duynisveld, J, Glover, K.E., D. Barrett, Y. Papadopoulos, A. Fredeen and J. Wort, 2012. Grazing research update for Nappan. Sheep Producers Association of Nova Scotia Field Day, Oct. 20, 2012, Nappan Experimental Farm, Nappan, Nova Scotia.

Barrett, D.M.W. ., K.E. Glover, J. Duynisveld, Y. Papadopoulos, A. Fredeen and J. Wort. Ruminant reproductive performance with beneficial fatty acids, phytoestrogens & controlled breeding. Reproductive Science & Medicine Seminar, July 25, 2012, University of Saskatchewan, Saskatoon, Saskatchewan

Glover, K.E., J. Duynisveld, D. Barrett, Y. Papadopoulos, A. Fredeen and J. Wort. Increasing beneficial fatty acids in lamb: From lamb diet to your plate. 2012. Poster presentation at the All Canada Sheep Classic, June 14-16, 2012, Truro, Nova Scotia (http://nssheep.ca/for-members/research/).

Glover, K.E. 2012. Lamb performance and carcass composition on diverse pasture types and oil supplements. Prince Edward Island Sheep Breeders Assoc. Research Day, April 20, 2012,

Glover, K.E. 2012. Lamb performance and carcass composition on diverse pasture types and oil supplements. Annual Meeting of the Sheep Producers Association of Nova Scotia, January 21, 2012, Windsor, Nova Scotia.

Barrett, D.M.W. 2012. The effects of consuming red clover pasture and beneficial fatty acid supplements on lamb reproductive performance. Annual Meeting of the Sheep Producers Association of Nova Scotia, January 21, 2012, Windsor, Nova Scotia.

Barrett, D.M.W. Research Update. Annual General Meeting of the Purebred Sheep Breeders Association of NS, NSAC. November 26, 2011.

Glover, K.E. Lamb growth and carcass composition on diverse pasture types and oil supplements. 2011. New Brunswick Sheep Producers Association Tour, NSAC, Truro, Nova Scotia, Nov. 6, 2011.

Barrett, D.M.W. The effects of consuming red clover pasture and beneficial fatty acid supplements on lamb reproductive performance. New Brunswick Sheep Producers Association Tour, NSAC, Truro, Nova Scotia, Nov. 6, 2011.

Glover, K.E. J. Duynisveld, D. Barrett, Y. Papadopoulos, A. Fredeen and J. Wort. 2011. Lamb performance and carcass composition on diverse pasture types and oil supplements. Sheep Producers Association of Nova Scotia Field Day, Oct. 22, 2011, Nappan Experimental Farm, Nappan, Nova Scotia.

Barrett, D.M.W. ., K.E. Glover, J. Duynisveld, Y. Papadopoulos, A. Fredeen and J. Wort. 2011. The effects of consuming red clover pasture and beneficial fatty acid supplements on lamb reproductive performance. Sheep Producers Association of Nova Scotia Field Day, Oct. 22, 2011, Nappan Experimental Farm, Nappan, Nova Scotia.

Duynisveld, J., Papadopoulos, Y.A., Glover, K.E. 2011. Finishing Ruminants on Different Pasture Types and Effect of Forage Mixtures on Cattle Performance. Sheep Producers Association of Nova Scotia Field Day, Oct. 22, 2011, Nappan Experimental Farm, Nappan, Nova Scotia.

Glover, K.E. 2011. CLA and other beneficial fatty acids in lamb produced on different feeding systems. Annual Meeting of the Canadian Sheep Breeders' Association, March 5, 2011, Truro, Nova Scotia.
Glover, K.E. 2011. CLA and other beneficial fatty acids in lamb produced on different feeding systems. Beef Regional Research Users Meeting. July 25, 2011, Nappan Experimental Farm, Nappan, Nova Scotia.
Glover, K.E. 2011. Lamb: More than just great taste. Annual General Meeting of the Sheep Producers Association of Nova Scotia, Feb. 5, 2011, Salmon River, Nova Scotia.
Glover, K.E. J. Duynisveld, D. Barrett, Y. Papadopoulos, A. Fredeen and J. Wort. 2010. CLA and other beneficial fatty acids in lamb produced on different feeding systems. Sheep Producers Association of Nova Scotia Field Day, Aug. 14, 2010, Nappan Experimental Farm, Nappan, Nova Scotia.
Barrett, D.M.W., K.E. Glover, J. Duynisveld, Y. Papadopoulos, A. Fredeen and J. Wort., 2010. CLA and other beneficial fatty acids in lamb produced on different feeding systems-Reproduction. Sheep Producers Association of Nova Scotia Field Day, Aug. 14, 2010, Nappan Experimental Farm, Nappan, Nova Scotia.
Duynisveld, J., Glover, KE, Barret, D., Papadopoulos, Y.A. 2010. An overview of the sheep grazing project. Sheep Producers Association of Nova Scotia Field Day, Aug. 14, 2010, Nappan Experimental Farm, Nappan, Nova Scotia.
Glover, K.E., J. Duynisveld, D. Barrett, Y. Papadopoulos, A. Fredeen and J. Wort. 2010. Improving the fatty acid profile of lamb. Sheep Producers Association of Nova Scotia Research Day, February, 2010, AgriTech Park, Bible Hill, Nova Scotia

Conference Presentations and Abstracts:

Brooks, N.S., J.L. Duynisveld, D.M.W. Barrett, Y.A. Papadopolous, J. Wort, A.H. Fredeen, K.E. Glover. Effect of pasture type and dietary lipid supplementation on animal performance, carcass composition and fatty acid composition of muscle and adipose tissue in lamb. CSAC, ASAS, and ADSA Joint Meeting 2012 (http://nssheep.ca/for-members/research/).
Veysey, P. K., N. Brooks, M. Bidarimath, K. Glover, Y. Papadopoulos1, J. L. Duynisveld, A. H. Fredeen, and D. M. W. Barrett. 2011. The effects of consuming red clover pasture and beneficial fatty acid supplements on ram lamb growth performance. Can. J. Anim. Sci. 91: 490.

Students in Research and Independent Study Programs

Nadine Brooks – Master student (2010-present)
Project title: Effect of the omega-3 and CLA dietary lipid supplementation on production performance, tissue fatty acid composition and lipid metabolism of ram lamb that had previously grazed grass or legume-based pasture.
Lacey Skaling - 4th year project student (2012)
Project title: Effects of dietary beneficial fatty acids and phytoestrogens on lamb sexual maturation.
Ashton Howard- 4th year project student and student research assistant (2011-2012)
Project title: Effect of pasture species on parasite load of lambs.
Michelle Shearer - 4th year project student (2010-2011)
Project title: The effects of pasture species and lipid supplements on lamb carcass characteristics.
Anhao Wang - 4th year project student (2010-2011)
Project title: Effects of dietary beneficial fatty acids and phytoestrogens on ewe lambs' sexual maturation.

Paige Veysey - 4th year project student and student research assistant (2010-2011) Project title: The effects of phytoestrogen and polyunsaturated fatty acid rich diets upon ram lamb sexual maturation.

The latest factsheet summarizing the results was posted on SPANS website (http://nssheep.ca/for-members/research/) on June 2012 and was distributed at the above events and meetings and through newsletters.

Post project performance story: The purpose is to describe what the project accomplished; to be included in this summary is a brief introduction to the project, its activities, results, lessons learned and next steps; this information may be used for publication on the CAAP web-site; the following items should be addressed in the story:

What issue/challenge/problem/opportunity did this project address?

This project provides producers with key information on an opportunity to develop a value-added omega-3 enriched lamb product for a health conscious consumer market that can provide income stability separate from commodity driven prices.

Include a very brief overview of purpose and activities: Summarize very briefly the activities funded under this agreement, highlighting key achievements and results.

Two years of grazing and finishing trials were the core of the research. In both years lamb growth on pasture was enhanced by including red clover in the pasture, and these gains continued into the finishing period. Supplementation with fish oil in the final 5 weeks of feeding resulted in a product that had greatly enhanced levels of essential fatty acids. The data in these results show producers the vital steps needed to enhance lamb production on pasture and the potential that comes from omega-3 supplementation in finishing diets.

Why are the project and its results significant for the target group and/or stakeholders? Include an estimate or statement of the number of persons reached; the number of persons attending meetings, etc.

There was extensive producer interaction with this project as shown in the above report – 3 well attended field days as well as numerous invited presentations at Maritime sheep association events in all three provinces and a poster presentation at the Canadian Sheep Federation meeting in June 2012. We also had 1 graduate student working on this project that received invaluable training and presented results to a North American audience. There was extensive media coverage across Maritime agricultural publications.

What has been learned? Identify the lessons learned from this project.

Our producers now have scientifically proven method to produce a specialty lamb product (omega-3 enhanced).

What are the next steps?
Is the solution or strategy likely to be further implemented?
Yes
or
Is the innovative product, process or technology likely to be adopted by the sector?
Yes

If you answered yes to the preceding, describe what you expect will be the next activities. If you answered no, explain why not. Not all projects will have next steps but often there are activities planned for after the end of the project that are directly or indirectly a result of the project.

The next steps for development of this product include taste-panel testing on the enhanced product and market development. Adaptation of the research methodology into a practical feed supplementation approach should happen at the same time.