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Effects of Soybean Based Supplements on Lamb Growth Performance and Muscle Fatty Acid Composition of Pasture Reared Lambs Finished on a High Forage Diet

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Abstract

The effects of fat (F), protein (PR), and fat enriched protein (FP) soybean-based supplements on growth performance and muscle fatty acid profile of lambs were investigated. Thirty-three lambs (19.71 ± 1.74 kg) were randomly assigned to receive one of three supplements for the final 29 days of an 81-day stay on mixed pastures and then for an additional 39 days finishing period on drylots. During this latter period, lambs were fed orchard grass and alfalfa hay (1:1) along with the supplement. At the end of the study overall ADG, HCW and the fatty acid profile of lamb muscle were determined for 3 lambs in each treatment group. The quantity and quality of forage available to lambs while on pasture and accessibility to that forage ere similar across treatments. The average quantity of supplement and hay consumed daily was above 80% of what was offered and was similar across treatments. Daily gains of lambs after 29 days supplementation while on pasture differed (F=0.30, PR=0.22, FP=0.27 ± 0.02 kg/d, P=0.05). During the first 2 weeks in the drylot, ADG differed amongst treatments (F= - 0.05, PR=0.23, FP= 0.11 ± 0.05 kg/d, P<0.01). Overall, ADG of lambs, and HCW of lambs were similar across treatments (P>0.05), but dressing percentage tended to be higher in PR than in F and FP wethers (46.62, 44.27 and 43.85 ± 0.76%, P=0.08). The SFA: UFA of lamb muscle was lower in the F and FP than in PR treatments (0.98 *vs*. 1.38 and 1.22 ± 0.07, P=0.02). Feeding of soybean based non-commercial fat supplements achieved targeted increases in average daily gains in high forage fed lambs and influenced fatty acid profile of lamb muscle.

Keywords: Fat; Protein; Feed; Ruminant tissue development

Abbreviations: ADG: Average Daily Gain; HCW: Hot Carcass Weight; SFA: Saturated Fatty Acids; UFA: Unsaturated Fatty Acids; kg: Kilograms; d: Days.

Introduction

Profitable lamb muscle food production demands that producers limit the cost of producing each pound of lamb. Feed cost can contribute as much as 75% of the overall production cost for a lamb producer operation and when possible, producers can effectively reduce their overall cost of production by feeding higher quantities of high quality pasture or forage to develop lambs to market weight [1]. Forage finished lambs are leaner, have higher content of CLA; conjugated linoleic acid [2,3] which is purported to affect human health [4]. However, average daily gains in forage finished lambs is usually lower than in lambs finished on high grain diets [5,6]. The use of supplemental protein or high calorie rations for grazing lambs can enhance the provision of their daily nutrient requirements and increase growth rates during periods of insufficient forage availability [7,8]. As such, fat supplements ostensibly offered as protein supplements have been used to increase average daily gain by increasing the energy density of high forage diets that are fed to ruminants [9], including lambs. In addition, fat supplementation can effectively alter fatty acid composition of ruminant muscle and adipose tissue thus, effectively altering the nutritional value of these ruminant food products [10,11]. Consequently, the development of inexpensive non-commercial supplements which effectively synchronize protein and energy nutrient availability and enhance lamb growth performance for high forage fed lambs offers small scale producers increased opportunity to become profitable [12]. However, the absolute need for synchronized nutrient availability is debatable and the inclusion of protein typically inflates the cost of supplements. Attainment of increases in average daily gains and enhanced muscle fatty acid profile by feeding of low levels of supplemental fat with relatively low protein value to high forage fed (≥ 90% of estimated daily intake) ruminants has not been widely reported. In particular, reports wherein the low-level fat supplements are fed once per day at a time when adverse effects of supplementation on digestive functions are minimized are sparse. This sparsity of reports exists, despite early research reports which indicate effects of time of supplementation of energy [13], protein [14,15], and amino acid [16,17] on ruminal digestive function. In addition, a preponderance of reports [18-26] provide significant evidence of researchers' awareness of the time effect and possibly modifying the time of feeding fat supplements to facilitate sufficient consumption of low, medium and high levels of rumen active fats to enhance rumen food product fatty acid profile, while avoiding associated adverse effects on ruminal fermentation. The practical use of feeding strategies which rely on feeding several times per day is often limited to small producers, time consuming and not sustainable. Nevertheless, development and use of relatively cheap non-commercial fat supplements could present small producers with great opportunities for achieving targeted increases in average daily gains in high forage fed lambs. Therefore, we investigated the growth performance of high forage finished lambs that were fed fat, protein or fat enriched protein supplements, wherein supplements were fed once per day at a time when adverse effects of supplementation on digestive functions are arguably minimized. The effects of supplement type on lamb muscle fatty acid profile were also determined.

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Materials and Methods

Animals, diets and growth performance

The first stage of the experiment was conducted at the Reedsville Experimental Farm located in Preston County, WV. Three well-established permanent pastures, consisting of Kentucky bluegrass (*Poa pratensis* L.), orchardgrass (*Dactilis glomerata* L.), white clover (*Trifolium repens* L.) and red clover (*Trifolium pratense* L.) were used. This study used thirty-three Dorset x Suffolk crossbred 3-month-old lambs (19.71 ± 1.74 kg; Table 1, stocked at a rate of 11 (6-7 ewes and 3- 4 wethers) lambs per hectare of pasture. After 38 days of grazing, and prior to initiating supplementation (52 days), pasture accessibility was improved through grazing intensification and mechanical clipping which removed dead material, floral stems and promoted vegetative tillering. Lambs were blocked by sex and weight and then randomly allocated to receive one of three supplements (= treatments). Supplements were offered at 10 (F=fat and PR=protein), and 13% (FP=fat enriched protein) of estimated daily dry matter intake (4.3% BW) based on recommendations [27] for 30 kg lambs finishing at 40 kg. The Fat supplement (F) consisted of 70% soybean hull and 30% soybean oil. The protein supplement (PR) consisted of 49.99% soybean hull and 49.99% soybean meal. The fat and protein supplement (FP) consisted of 23.00% soybean oil, 38.64% soybean hull and 38.64% soybean meal. Supplements FP and PR were designed to provide equally higher crude protein than supplement F. Supplements FP and F (30% soybean oil and 70% soybean hull) were designed to provide equally higher fat content than supplement PR. Prior to the supplementation period; lambs accessed a fresh supply of water and were provided with mixed minerals daily. During the supplementation period minerals were mixed into the supplements which were offered at 1600 h throughout the trial along with continued access to fresh supply of water. Supplements were offered for the final 29 d of an 81 day stay on mixed pastures. During the period of supplementation on pasture, herbage mass, herbage accumulation rate, botanical composition and forage quality were ascertained [28] for each experimental plot.

Supplemental treatments					
Variables	Fat	Protein	Fat and protein	± SE	P-value
Pasture (81 days)					
n	11	11	11		
Initial weight (kg)	20.16	19.42	19.54	1.74	0.95
Weight at start of supplementation (kg)	31.08	30.34	32.02	1.64	0.86
ADG (52 days) before starting supplementation (kg/d)	0.21	0.21	0.24	0.01	0.25
ADG after 29 days of supplementation (kg/d)	0.36	0.09	0.41	0.02	0.05
Final weight (kg)	39.66	36.69	38.50	2.07	0.60
ADG* (kg/d)	0.24	0.21	0.25	0.01	0.16
Drylot (39 days)					
n	11	11	11		
ADG during 1st two weeks (kg/d)	-0.05b	0.23a	0.11a	0.05	0.003
Final weight (kg)	41.81	41.06	41.77	1.99	0.96
ADG† (kg/d)	0.07	0.14	0.10	0.03	0.31
TADG‡ (kg/lamb/d)	0.16	0.15	0.16	0.01	0.83
Carcass Data					
n	3	3	3		
Hot weight (kg)	22.22	22.83	20.26	1.69	0.57
Dressing Percentage (%)	44.27	46.62	43.85	0.76	0.08

*ADG- Overall ADG determined for entire 81 days duration (52 days without and 29 days with supplementation).
†ADG- ADG determined for entire 39 days duration of supplementation on drylots.
‡TADG- Overall ADG determined for entire 68 days duration of supplementation while on pasture (29 days) and drylots (39 days).
³a, b Within a row means without a common superscript letter differ (P< 0.05).

Table 1: Growth performance of lambs (on pasture and in drylots) and Carcass data for slaughtered lambs.

The second stage of the experiment was conducted at the Livestock Experimental Farm located in Monongalia County, WV. When lambs were 5 months old they were transferred to 3 separate drylot pens, provided with a 1:1 mixture of alfalfa and orchard grass hay together with previously prescribed supplements, and a fresh supply of water. Supplements were offered at 1600 h for each day of a 39 days period, at the end of which a final dry lot finishing weight was taken. While in dry lot s, lambs were offered hay at a minimum of 4% of their average flock BW to meet the needs of 40 kg lambs finishing at 50 kg [27]. Daily hay refusals were weighed, and these measurements were used to adjust the quantity of hay that was fed to lambs. Supplements were offered at 10 (F and PR), and 13% (FP) of daily hay allotments. Initial bodyweights were determined by averaging the weight of lambs taken on two consecutive days at the start of the study. In addition, lambs were weighed every two weeks throughout the grazing and drylot periods. Average daily gains for all lambs were determined for the first 52 days (P0) of the grazing period, and at 14 (P14) and 29 (P29) days after beginning supplementation during pasture grazing. Similarly, lamb's average daily gains at 43, 57 and 68 days (P43, P57 and P68) after beginning supplementation were determined while the lambs were on drylots.

Forage analysis

Pasture forage samples were taken daily on 5 days during each week of the final three weeks of supplementation between 1300 h and 1400 h. Samples were obtained by observing lambs as they were grazing and then clipping samples from potential grazing areas. Clipped samples were placed in paper bags, weighed and then freeze dried to a constant weight, and allowed to air-equilibrate. Dry matter was then determined from the differences in sample weight pre and post drying. Samples were ground in a Wiley Mill (Thomas Scientific, Swedesboro, NJ) through a 1-mm screen, and stored in plastic bags. Pasture composite samples were made for each sampling period by combining an equal weight of ground sample from each of the five-day samples taken within a pasture plot. Weekly supplement samples were taken during the grazing trial and composited. The composite forage and supplement samples were then analyzed in duplicate for organic matter (OM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL), and ether extract (EE) content. Organic matter was measured as weight loss following combustion for 8 h at 500°C. Crude protein concentration was determined by use the Kjeldahl method. Concentrations of ash-free NDF, ADF, and ADL were determined using an Ankom 200 fiber analyzer (Ankom Technology Corp., Fairport, NY). Ether extract was determined following extraction of a 1 g sample with diethyl ether for 18 h [29]. Weekly hay and supplement samples were taken and composited. Samples were dried in a 55°C forced-air oven, and ground (Wiley mill; Thomas Scientific, Swedensboro, NJ) to pass through a 1-mm screen. Composite hay and supplement samples were then analyzed identically to pasture composite samples.

Feeding performance in pasture and drylot

Feeding performance data was recorded for descriptive purposes.

Refused supplement was weighed and the total quantity of supplement consumed each day was determined for 22 d during the grazing trial. The quantity of hay and supplement consumed throughout the dry lot finishing period was determined and the data for 22 d of the final 29 d of the finishing period was recorded.

Tissue collection and fatty acid determination

Following the sacrifice of the three heaviest lambs in each treatment group (Young and Stout, Clarksburgh WV) hot carcass weight (HCW) was recorded before chilling the carcass at 4°C. Dressing percentage (DP) was determined based on the final weight at the end of P68. Longissimus dorsi muscle samples were harvested between the 10th and 12th rib immediately after the lambs were slaughtered to determine fatty acid profiles of lamb muscle. Muscle tissue samples were immersed in liquid nitrogen and then ground to a fine powder using a waving blender (Fred Stein Laboratories Inc., Atchison, KS). Ground tissues were immediately transferred to Whirl Pak (Nasco, Modesto, CA) freezer bags and stored at −80°C. Tissue lipids were extracted by the established methods [30] and fatty acids were esterified in a 4% sulfuric acid and anhydrous methanol solution [31]. The method used by Kamireddy [32] was used to identify and quantify fatty acid methyl esters (FAME). Fatty acid content was measured in mg of fatty acids detected in 1 g samples of lamb muscle tissue.

Data Analysis

Two weeks prior to the end of the grazing trial one wether lamb from the FP treatment died from non-treatment related causes and hence data collected beyond this point was analyzed accordingly. Data was analyzed as a completely randomized design using the GLM procedures of SAS [33]. Each pasture or dry lot pen served as the sole experimental unit per treatment for descriptive data on botanical composition, herbage mass, herbage accumulation rate, and hay or supplement intake. The model for growth performance included effects due to treatment and lamb within each pasture plot or dry lot pen served as an experimental unit. Analyses were applied to all lambs and slaughtered wether lamb served as the experimental unit for carcass and fatty acid data. There were no adjustments made for multivariate analysis.

Results

Herbage mass, growth, botanical composition and quality

Herbage mass (F=4088.79; PR=4072.49; FP=3929.45 ± 344.07 kg/ha) and accumulation rates (F=89.83; PR=100.26; FP=92.20 ± 6.68 kg/ha/d) were similar amongst experimental plots. Average botanical composition of experimental plots during the period of supplementation was 56.32% grass, 5.25% legumes, 4.56% weed and 33.87% dead material. Nutrient profile of weekly composite forage did not differ across treatment plots and therefore the average of all three plots is reported in Table 2. The nutrient profile of the pasture samples showed that high quality pasture was selected by all treatment groups throughout the supplementation periods. Hence, a homogenous high-quality forage supply was available and selected by all treatment groups throughout the supplementation period during grazing of pastures. Nutrient profile of orchard grass and alfalfa hay samples (Table 3) also indicate that all lambs received high quality forage during the drylot feeding period.

Lamb performance

Lamb performance is shown in Table 4. While on pasture, F (0.14 kg/d), FP (0.13 kg/d) and the PR lambs (0.18 kg/d) consumed over 80% of their daily allotted supplement. During the period in the dry lot, within each treatment group lambs completely consumed the supplement that was offered. Similarly, the daily intake of forage was over 80% and similar in all treatment groups (F: 1.4 kg/d, FP: 1.45 kg/d and PR: 1.4 kg/d) when lambs were housed on drylots. Despite the latter, there was a significant treatment by period interaction effect (P<0.05) observed for average daily gain (Figure 1).

The average daily gain (ADG) of lambs (0.22 kg/d) prior to the start of supplementation (P0) was similar amongst treatments (P>0.05) but within 2 weeks after treatment began the ADG of FP (0.12 kg/d), PR (0.35 kg/d) and F (0.23 kg/d) lambs declined, increased to maximum value (P<0.05) or was unchanged, respectively. By the 29th day (P29) after commencing supplementation on pasture, higher average daily gains (P=0.04) were observed in F (0.36 kg/d) and FP (0.41 kg/d) lambs than in PR (0.09 kg/d) lambs. During the first 2 weeks in the drylot (P43), ADG also differed amongst treatments (F= -0.05, PR=0.23, FP=0.11 ± 0.05 kg/d, P<0.01). Differences in ADG amongst treatment groups were not apparent at P57, but there was a tendency (P=0.09)

	Supplemental treatments			Forage		
Nutrient (%)	Fat	Protein	Fat and Protein	Pasture Forage	Orchard grass	Alfalfa
Dry Matter	90.99	88.87	92.65	30.06	83.13	82.43
Organic Matter	90.32	88.02	92.88	91.49	93.69	92.09
Neutral Detergent Fiber	55.35	38.10	32.13	44.12	70.97	42.77
Acid Detergent Fiber	33.71	23.87	18.62	22.08	36.86	30.84
Acid Detergent Lignin	3.63	0.30	0.07	1.63	4.38	7.30
Crude Protein	7.56	30.26	20.35	25.91	15.46	23.46
Ash	9.68	11.98	7.12	8.51	6.31	7.91
Ether Extract	29.89	1.36	33.12	4.32	2.14	1.64

Table 2: Nutrient profile of supplements, and forage used in experiment.

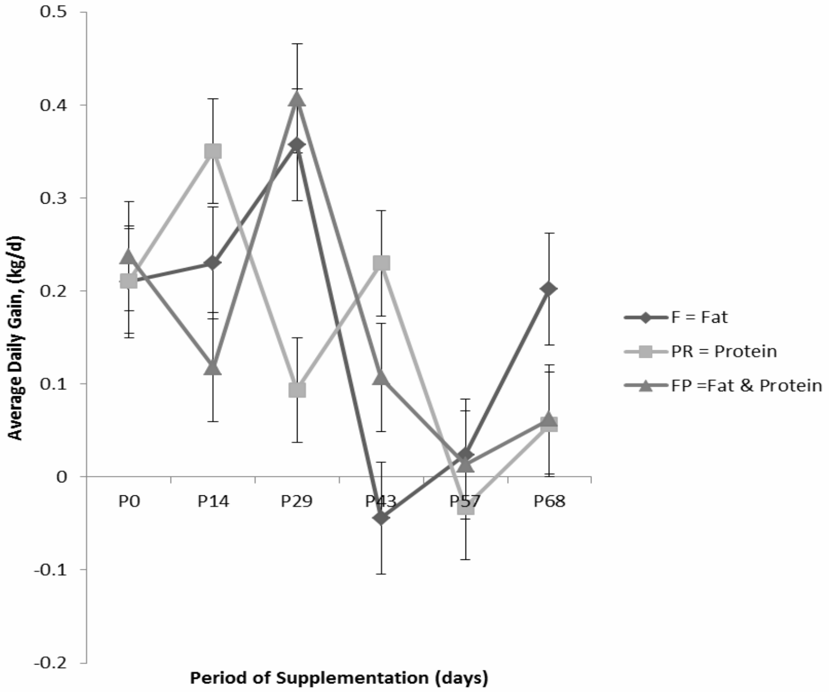
	Supplemental treatments		
Ingredient (%)	Fat	Protein	Fat and protein
Soybean oil	30 .00	0	23.00
Soybean hull	69.99	49.99	38.64
Soybean meal	0.00	49.99	38.64

*Mixed mineral was included at equal levels in all supplemental treatments.

Table 3: Ingredient composition of supplemental treatments.*

	Supplemental treatments		
	Fat	Protein	Fat and protein
Pasture			
n	11	11	11
Supplement offered (kg/lamb/d)	0.16	0.16	0.20
Supplement intake (kg/lamb/d)	0.14	0.13	0.18
Percent supplement intake (%)	88.63	81.01	88.14
Drylot			
n	11	11	11
Hay offered (kg/lamb/d)	1.70	1.70	1.70
Hay intake (kg/lamb/d)	1.40	1.45	1.40
Percent hay intake (%)	81.92	85.10	82.14
Supplement offered (kg/lamb/d)	0.17	0.17	0.22
Supplement intake (kg/lamb/d)	0.17	0.17	0.22
Percent supplement intake (%)	100	100	100

Table 4: Feeding performance of lambs on pasture and in drylots.



P0, P14, P29, P43, P57, P68 refer to 0, 14th, 29th, 43rd, 57th, and 68th days post initiation of supplementation.

Figure 1: Average daily gain (kg/day) of lambs supplemented with fat (♦, n = 3), protein (■, n = 3) or fat enriched protein (▲, n = 3) supplement.

for treatment effects at P68 where ADG of F (0.20 kg/d) lambs was numerically greater than that of FP (0.06 kg/d) and PR (0.06 kg/d) lambs. Live weight of lambs (Figure 2) in all treatment groups generally increased continuously throughout the period of supplementation. Live weight increases were more apparent between P0 to P29, beyond which live weight increase tapered off up until P68. Live weights were unaffected by treatment prior to and after P29 but live weight at P29 was higher ($P<0.05$) in F (39.66 kg) and FP (39.62 kg) than in PR (36.69 kg) treatment. In addition, the liveweight of F lambs was numerically higher than those of FP and PR lambs at P68. Hot carcass weight of slaughtered wether lambs were similar across treatments ($P>0.05$), but dressing percentage tended to differ. Fat supplemented lambs had lower (PR=46.62, F=44.27 and FP=43.85 ± 0.76 %: P=0.08) dressing percentage than lambs which received protein supplement devoid of fat.

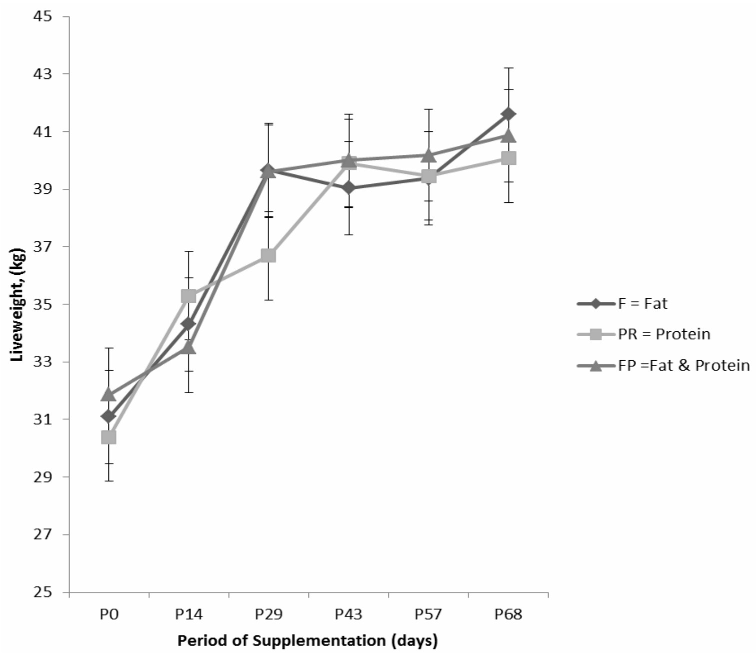
Muscle fatty acid profile

The fatty acid composition of longissimus muscle is shown in Table 5. The data illustrates the C14 to C18 fatty acids profiles, and various fatty acid ratios. Treatment did not affect any individual unsaturated and saturated fatty acids in muscle tissue except for elaidic acid. Lambs fed the fat supplement tended to have the highest elaidic acid content (F=8.95, PR=4.07 and FP=4.18 ± 1.48 mg/g P=0.10). Consequently, total saturated fatty acid (SFA), total unsaturated fatty acid (UFA), monounsaturated fatty acid (MUFA), polyunsaturated fatty acids (PUFA), n3 fatty acid, n6 fatty acids, and MUFA: PUFA ratio were unaffected by treatment. Conversely, the SFA:UFA ratio was smallest (P=0.02) in F (0.98) lamb muscle as compared to those of muscle tissue from FP (1.38) and PR (1.22) lambs. Similarly, treatment tended to affect (P=0.07) the n6/n3 fatty acid ratio. The n6/n3 fatty acid ratio was highest in fat supplemented lambs (F=3.88, PR=2.64 and FP=2.40 ± 0.39).

Discussion

The average daily gain (ADG) of lambs in all treatments fluctuated throughout the 68 days supplementation period but generally declined as lambs approached target weights (Figure 1 and Table 6). The decline was most pronounced after lambs were transferred to the dry lot. However, the ADG (0.16 kg/d) obtained over the 68 days duration of supplementation in this study was within range expected for grazing lambs which were finished on high forage diets [27]. In the past other researchers [1,5] have achieved similar rates of gain when lambs were finished on high forage rations. In the current study grazing lambs initially responded positively to protein supplementation (PR lambs), which contrasted with a lack of response in F lambs and a negative response in FP lambs by P14. These responses were short lived and altered over the course of the following two weeks leading up to the end of P29. These data indicated that the synchrony of energy and protein nutrient supply affected lamb growth performance. Indeed, [12] alluded to the occurrence of synergistic effects of supplemental energy and protein on the enhancement of animal performance in forage fed ruminants. The influence of a multitude of factors, including the forage supplement matrix interaction [34] and the negative effects of nutrient synchrony [12] on the enhancement of animal performance has been noted. The extent to which lambs substituted supplement for forage intake and digestion was not determined in the current study. Perceivably such substitution did occur, and likely impacted the lamb's daily metabolizable energy intake, protein utilization and animal growth performance as has been reported by others [12,35].

In contrast, when lambs were transferred to drylots and fed measured amounts of hay, growth performances during the initial two weeks was affected by treatment and there was a tendency for treatment effects in the final two weeks on drylots. Descriptive data in Table 4 suggest that both hay and supplement consumption were similar



P0, P14, P29, P43, P57, P68 refer to 0, 14th, 29th, 43rd, 57th, and 68th days post initiation of supplementation.

Figure 2: Liveweight (kg) of lambs supplemented with fat (♦, n=3), protein (■, n=3) or fat enriched protein (▲, n=3) supplement.

	Treatments				
Fatty acid (mg/g)	Fat (n = 3)	Protein (n = 3)	Fat and protein (n = 3)	± SE	P- value
n	3	3	3		
Myristic	0.95	1.22	1.12	0.27	0.77
Myristoleic	-	-	-	-	-
Pentadecanoic	0.28	0.31	0.40	0.06	0.44
cis-10-Pentadecanoic	-	-	-	-	-
Palmitic	9.53	10.09	11.18	1.78	0.81
Palmitoleic	0.78	0.73	0.78	0.18	0.98
Heptadecanoic	1.58	0.75	0.90	0.49	0.49
cis-10-Heptadecanoic	0.10	0.18	0.13	0.05	0.59
Stearic	9.84	10.12	14.20	1.68	0.20
Elaidic	8.95	4.07	4.18	1.48	0.10
Oleic	10.66	11.95	12.74	2.17	0.80
Linolelaidic	0.12	0.12	0.13	0.03	0.98
Linoleic	1.96	1.39	1.61	0.34	0.52
γ -Linolenic	-	-	-	-	-
Linolenic	0.53	0.55	0.73	0.10	0.35
Saturated	22.18	22.48	27.80	3.56	0.50
Unsaturated (UFA)	23.10	18.98	20.29	3.59	0.72
MUFA	20.48	16.93	17.83	3.16	0.72
PUFA	2.62	2.05	2.46	0.46	0.68
n6	2.08	1.50	1.74	0.37	0.58
n3	0.53	0.55	0.73	0.10	0.35
Fatty acid ratios					
SFA/UFA	0.98a	1.22b	1.38b	0.07	0.02
MUFA/PUFA	7.82	8.25	7.23	0.55	0.29
n6/n3	3.88	2.64	2.40	0.39	0.07
PUFA/SFA	0.12	0.09	0.09	0.01	0.21

'a, b within a row means without a common superscript letter differ (P< 0.05)

Table 5: Fatty acid profile of longissimus muscle harvested from wethers.

	Supplemental treatments				
Periods	Fat	Protein	Fat and protein	± SE	P-value
n	11	11	11		
P0	0.21	0.21	0.24		
P14	0.23	0.35	0.12		
P29	0.36	0.09	0.41		
P43	0.05	0.23	0.11		
P57	0.02	-0.03	0.01		
P68	0.20	0.06	0.06		

P0, P14, P29, P43, P57, P68 refer to ADG at 0, 14th, 29th, 43rd, 57th, and 68th days post initiation of supplementation.

Table 6: Biweekly average daily gains of lambs.

across treatments. Therefore, the effects of treatment on lamb growth performance that were observed could be attributable to differences in the nutrient content of the supplements and differences in the extent to which supplements improved the synchrony of energy and protein nutrients supply to lambs.

Thus, changes in lamb live weights (Figure 2) were reflective of the fluctuating ADG as influenced by the lamb management strategy, especially the type of supplement they received. Indeed, live-weight of fat supplemented lambs (F, FP) approached maximum values after 29 days of supplementation on pasture and seemed to flat line throughout the drylot rearing period. Similarly, the lambs that were supplemented with protein (PR) attained peak weights after 43 days of supplementation, but live weight flat lined beyond this point, suggesting that there was no real benefit to be derived from supplying supplemental protein beyond this stage. Conversely, these contrasting patterns of live weight changes might exemplify the responsiveness of high forage finished lambs at this stage of physiological development to a fat supplement under this type of management system. Indeed, the F lambs' longissimus muscle had lower SFA:UFA ratios and tendencies for higher elaidic acid content, and n6/n3 ratio, all indicative of supplemental fat treatment effects on body tissue growth and final composition.

The effects of ruminal digestive activity, rates of daily gain and duration of finishing in dry lot on muscle fatty acid profile of lambs fed fat supplements has been previously emphasized [6] and similar effects might have been existent in this study. Furthermore, even though dressing percentage tended to be generally low relative to the values that others have reported in similar studies [1,5,36], a tendency for significantly lower values were observed in F and FP lambs than in PR lambs. The relatively higher ADG of F lambs in the final period of the trial may explain the tendency for lower dressing percentages of F and probably FP lambs, if a relatively higher proportion of the weight gain in these lambs was due to fat deposition. Lower dressing percentages would then be associated with the removal of a higher percentage of seam and visceral fat from the carcass of F and FP lambs as compared to PR lambs. Arguably, the small weight gains observed in the final stages of development in the drylot could be attributable to fat deposition associated with the consumption of soybean oil supplement. These observations would be in agreement with the small increases of fat deposition and reduction of carcass muscle in lambs with time spent on a supplemental soybean oil diet that were reported [37]. Therefore, despite initial retardation in growth performance all lambs adjusted to the drylot and maintained back-grounded weights, but F lambs probably achieved best finishing by P68.

The initial reduction in growth performance seen in the fat supplemented lambs in response to changes in their diet (pasture forages to hay in drylot) is comparable to previously reported data when lambs developed on a high forage diet were finished on diets supplemented with soybean [37]. These researchers [37] observed that in lambs that were previously fed lucerne that live weight was enhanced with increasing time spent on a soybean oil supplemented diet during the finishing stages of development. Accordingly, an apparent positive growth response of high forage fed lambs to supplemental soybean oil following an initial adjustment period was evident in this study, during the final stages of development on pasture and again during the final stages of development on drylot. Other reports have alluded to the adverse impacts on growth performance when diets are changed during short trial periods and upon lambs being transferred to drylot stalls for finishing [6,38]. Furthermore, these reports also indicated that a long duration of time (37-40 days) spent in the stall [6,38] or (39 days) on drylot in this study might erase most of the benefits to fatty acid profile that were derived from grazing pastures. Indeed, even though lambs in this study were finished on high forage diet in contrast to concentrate finishing diets in the other studies [6,38], supplemental soybean oil only effected minimal changes in muscle fatty acid profile in F and FP lambs as compared to and PR lambs.

Summarily, the results of this study indicate that greater ADG, higher finishing weights and more favorable muscle fatty acid profiles may have been achieved by feeding of low level fat supplements to grazing lambs from an earlier age. Alternatively, finishing the lambs on the pasture with the use of low level fat supplement might have also been more efficient than transferring them to the drylot. Suggestively, future investigations into the effectiveness of low level fat supplementation should include cost analysis of the feeding strategies that are used to develop lambs. Conclusively, there is potential for enhancing lamb growth performance and muscle fatty acid profile by supplementing low levels of fat to pasture reared lambs once per day at a time when adverse effects of supplementation on digestive functions are minimized. The effectiveness of the latter feeding strategy, in producing healthy food product will however be significantly impacted by the production environment and the physiological responsiveness of lambs to the environment. Ultimately, these physiological responses manifested as growth and tissue development throughout the process of muscle food production determines food value.

References

1. McClure KE, Van Keuren RW, Althouse PG (1994) Performance and carcass characteristics of weaned lamb either grazed on orchardgrass, ryegrass, or alfalfa or fed all concentrate diets in drylot. J Anim Sci 72: 3230-3237.
2. McClure KE, Solomon MB, Parrett NA, Van Keuren RW (1995) Growth and tissue accretion of lambs fed concentrate in drylot, grazed on alfalfa or ryegrass at weaning, or backgrounding on ryegrass. J Anim Sci 73: 3437-3444.
3. Daniel ZCTR, Wynn RJ, Salter AM, Buttery PJ (2004) Differing effects of forage and concentrate diets on the oleic acid and conjugated linoleic acid content of sheep tissues: the role of stearoyl- CoA desaturase. J Anim Sci 82: 747-758.
4. Daley CA, Abbott A, Doyle PS, Nader GA, Larson S (2010) A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. Nutr J 9: 1-12.
5. Borton RJ, Loerch SC, McClure KE, Wulf DM (2005) Comparison of characteristics of lambs fed concentrate or rygerass to traditional or heavy slaughter weights. I. Production, carcass, and organoleptic characteristics. J Anim Sci 83: 679-685.
6. Aurousseau B, Bauchart D, Faure X, Galot AL, Prache S, et al. (2007) Indoor fattening of lambs raised on pasture: (1) Influence of stall finishing duration on lipid classes and fatty acids in the longissimus thoracis muscle. Meat Sci 76: 241-252.
7. Canton JS, Dhuyvetter DV (1997) Influence of energy supplementation on grazing ruminants: requirements and responses. J Anim Sci 75: 533-542.
8. Hess BW, Moss GE, Rule DC (2008) A decade of development in the area of fat supplementation research with beef cattle and sheep. J Anim Sci 86: E188-E204.
9. Palmquist DL (1994) The role of dietary fats in efficiency of ruminants. J Nutr 124: 1377S-1382S.
10. Bolte MR, Hess BW, Means WJ, Moss GE, Rule DC (2002) Feeding lambs high oleate safflower seeds differentially influences carcass fatty acid composition. J Anim Sci 80: 609-616.
11. Kott RW, Surber LMN, Grove AV, Hatfield PG, Boles JA, et al. (2010) Feedlot performance, carcass characteristics, and muscle CLA concentration of lambs fed diets supplemented with safflower seeds and vitamin E. Sheep Goat Res J 25: 16-22.
12. Hersom MJ (2008) Opportunities to enhance performance and efficiency through nutrient synchrony in forage fed ruminants. J Anim Sci 86: E306-E317.
13. Adams DC (1985) Effect of time of supplementation on performance, forage intake, and grazing behavior of yearling beef steers grazing Russian wild ryegrass in the fall. J Anim Sci 61: 1037-1042.
14. Barton RK, Krysl LJ, Judkins MB, Holcombe DW, Broesder JT, et al. (1992) Time of daily supplementation for steers grazing dormant intermediate wheatgrass pasture. J Anim Sci 70: 547-558.
15. Robinson PH, Gill M, Kennelly JJ (1997) Influence of time of feeding a protein meal on ruminal fermentation and forestomach digestion in dairy cows. J Dairy Sci 80: 1366-1373.
16. Wiley JS, Petersen MK, Clark CK, Ansotegui RP, Lodman DW (1991) The influence of timing and addition of urea to supplements containing DL-methionine on ruminal fermentation and cow weight change in beef cows. J Anim Sci 69: 4617-4627.
17. McCracken BA, Judkins MB, Krysl LJ, Holcombe DW, Park KK (1993) Supplemental methionine and time of supplementation effects on ruminal fermentation digesta kinetics, and in situ dry matter and neutral detergent fiber disappearance in cattle. J Anim Sci 71: 1932-1939.
18. Ikwuegbu OA, Sutton JD (1982) The effect of varying the amount of linseed oil supplementation on rumen metabolism in sheep. Br J Nutr 48: 365-375.
19. Ueda K, Ferlay A, Chabrot J, Loor JJ, Chilliard Y, et al. (2003). Effect of linseed oil supplementation on ruminal digestion in dairy cows fed diets with different forage: concentrate ratios. J Dairy Sci 86: 3999-4007.

20. Loor JJ, Ueda K, Ferlay A, Chilliard Y, Doreau M (2004) Short communication: Diurnal profiles of conjugated linoleic acids and trans fatty acids in ruminal fluid from cows fed a high concentrate diet supplemented with fish oil, linseed oil or sunflower oil. J Dairy Sci 87: 2468-2471.

21. Loor JJ, Ueda K, Ferlay A, Chilliard Y, Doreau M (2004) Biohydrogenation, duodenal flow, and intestinal digestibility of trans fatty acids and conjugated linoleic acids in response to dietary forage: concentrate ratio and linseed oil in dairy cows. J Dairy Sci 87: 2472-2485.

22. Kucuk O, Hess BW, Ludden PA, Rule DC (2001) Effect of forage: concentrate ratio on ruminal digestion and duodenal flow of fatty acids in ewes. J Anim Sci 79: 2233-2240.

23. Kucuk O, Hess BW, Rule DC (2004) Soybean oil supplementation of high-concentrate diet does not affect site and extent of organic matter, starch, neutral detergent fiber, or nitrogen digestion, but influences both ruminal metabolism and intestinal flow of fatty acids in limit fed lambs J Anim Sci 82: 2985-2994.

24. Kucuk O, Hess BW, Rule DC (2007) Fatty acid compositions of mixed ruminal microbes isolated from sheep supplemented with soybean oil. Res Vet Sci 84: 215-224.

25. Boles JA, Kott RW, Hatfield PG, Bergman JW, Flynn CR (2005) Supplemental safflower oil affects the fatty acid profile, including conjugated linoleic acid, of lamb. J Anim Sci 83: 2175-2181.

26. Kim S, Adesogan AT, Badinga L, Staples CR (2007) Effect of dietary n-6:n-3 fatty acid ratio on feed intake, digestibility, and fatty acid profiles of the ruminal contents, of liver and muscle of growing lambs. J Anim Sci 85: 706-716.

27. Committee on Animal Nutrition (1985). Nutrient Requirements of Sheep (6th rev Edn). National Academy Press, Washington, DC, pp: 46-47.

28. Rayburn EB, Rayburn SB (1998) A standardized plate meter for estimating pasture mass in on-farm research trials. Agron J 90: 238-241.

29. AOAC (1990) Official Methods of Analysis (15th Edn). Association of official analytical chemists, Arlington, VA, USA.

30. Bligh EG, Dyer WJ (1959) A rapid method of total lipid extraction and purification. Can J Biochem Physiol 37: 911-917.

31. Fritshe KL, Johnston PU (1990) Effect of dietary-linolenic acid on growth, metastasis, fatty acid profile and prostaglandin production of two murine mammary adenocarcinomas. J Nutr 120: 1601-1609.

32. Kamireddy N, Kenney PB, Jittinandana S, Slider SD (2008) Acidified sodium chlorite solution as an antimicrobial treatment for rainbow trout (Oncorhynchus mykiss) fillets. J Food Prot 71: 973-978.

33. SAS (2004) SAS/STAT® 9.1 users guide. SAS Institute Inc. Cary, NC, USA.

34. Young Yang J, Seo J, Kim HJ, Ha JK (2010) Nutrient synchrony: Is it a suitable strategy to improve nitrogen utilization and animal performance. Asia-Aust J Anim Sci 23: 972-979.

35. Walker EL, Nusz SA, Keisler DH, Brown MA (2011) Value of protein supplement for lambs and meat goat kids grazing Bermuda grass in Central Oklahoma. J Anim Sci Vet Adv 10: 2582-2587.

36. Notter DR, Greiner SP, Wahlberg ML (2004) Growth and carcass characteristics of lambs sired by Dorper and Dorset rams. J Anim Sci 82: 1323-1328.

37. Bessa RJB, Lourenco M, Portugal PV, Santos-Silva J (2008) Effects of previous diet and duration of soybean oil supplementation on light lambs carcass composition, meat quality and fatty acid composition. Meat Sci 80:1100-1105.

38. Scerra M, Luciano G, Caparra P, Foti F, Cilione C, et al. (2011) Influence of stall finishing duration of Italian Merino lambs raised on pasture on intramuscular fatty acid composition. Meat Sci 89: 238-242.