Factors which Impact the Fatty Acid Profile of Ruminant Meat

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Abstract: Research pertaining to factors impacting fatty acid (FA) profiles of meat products when ruminant diets are made up of entirely pasture/forage is minimal. Information that is available indicates that both management and forage species consumed can have an effect on product FA profile. Of the FAs found in ruminant fat, major emphasis is usually given to cis-9, trans-11 conjugated linoleic acid (CLA, also known as rumenic acid), linoleic (LA, an omega-6 [n-6] FA), alpha-linolenic (ALA, an omega-3 [n-3] FA), and the polyunsaturated FAs (PUFAs) omega-6 to omega-3 ratio. However, the dietary value of trans-11 vaccenic acid (TVA) is often overlooked. During the rumen fermentation process, TVA is produced and then converted to CLA by the ruminant. When ruminant fat is consumed by humans, CLA may have immediate health benefits, but the TVA present in the fat can also provide health benefits after being converted to CLA after human ingestion. It is generally accepted that the omega-6 to omega-3 ratio should be around 4:1 or less in our diet. During forage finishing of livestock, research shows time on pasture impacts the FA profiles of meat. After feeding starch-based energy supplements prior to finishing on pasture (Noci et al., 2005), TVA and CLA increased linearly with increasing days on pasture. Without starch-based supplements during forage stockering (Fincham et al., 2009; Duckett et al., 2014), CLA content stayed constant over time in fatty tissue while TVA increased with increased days on pasture. Available research also indicates there is no effect due to forage type during pasture-finishing regarding meat TVA, CLA, LA contents or PUFA n-6:n-3 (Duckett et al., 2013; Chail et al. 2016). The implications of the reviewed research are:1) starch based concentrate supplementation followed by pasture-finishing impacts meat fatty acid profile, even when animals grazed pasture alone for 118 days post supplementation; 2) producers of pasture finished beef can utilize forages best suited for their farm and management, while still producing a product containing a typical pasture finished FA profile; 3) meat trans-11 vaccenic acid content should be included in discussions concerning the healthy properties of beef.

Key words: Beef, Fatty Acid Profile, Pasture Finished, CLA, vaccenic acid

Introduction

Research which evaluates various methods for changing the fatty acid profiles of ruminant products through livestock diet manipulation is readily available (Griswold et al., 2003; Elmore et al., 2004; Lorenzen et al., 2006). However, research pertaining to factors impacting fatty acid (FA) profiles of meat products when ruminant diets are made up of entirely pasture/forage is minimal. Of the FAs found in ruminant fat, major emphasis is usually given to cis-9, trans-11 conjugated linoleic acid (CLA, also known as rumenic acid), linoleic (LA, an omega-6), alpha-linolenic (ALA, an omega-3), and the polyunsaturated FA (PUFA) omega-6 to omega-3 ratio. This emphasis is due to the potential healthful benefits these FAs have when consumed in human diets. The human health benefits of CLA has long been noted by dieticians. However, the dietary value of trans-11 vaccenic acid (TVA) is often overlooked. During the rumen fermentation process, TVA is produced and then converted to CLA by the ruminant. When ruminant fat is consumed by humans, CLA may have immediate health benefits, but the TVA present in the fat can also provide health benefits after being converted to CLA by the human. This conversion occurs at the rate of approximately 20% TVA to CLA. Linoleic and alpha-linolenic fatty acids are considered essential to humans. Our bodies cannot produce them on their own, but they are required for proper physiological function and human health. The essentiality of these FAs gives rise to the importance of the recommended omega-6 to omega-3 dietary ratio with regard to human health. For proper absorption rates of both essential FAs, it is generally accepted that the omega-6 to omega-3 ratio should be around 4:1 or less in our diet. However, the typical human diet within the United States contains an omega-6 to omega-3 ratio of around 10:1. An imbalance of either FA category (n-6 or n-3) would result in over absorption of one or the other. The aim of this presentation is to provide the available research findings with regard to factors impacting the fatty acid profiles of meat produced from ruminants fed solely pasture/forage.

Effect of time on pasture

During forage finishing of livestock, research shows that time on pasture impacts the FA profiles of meat. **In 2005, Noci et al.** utilized crossbred Charolais heifers (732 lb. start weight) to examine the impact of grass silage plus 6.6 lb./d of a barley-based concentrate versus pasture-finishing on primarily ryegrass for variable periods of time. Heifers were finished under one of the four following protocols: 1) Fed silage and con-centrate in a slatted floor barn for 158 days w/o any pasture; 2) Initial 99 days in the barn and then 59 days on pasture; 3) Initial 40 days in the barn and then 118 days on pasture; 4) 0 days in the barn and 158 days on pasture (100% pasture finished). Across all treatments, ADGs and final weights were 2.0 and 1074 lb., respectively. Results pertinent to FAs of interest are presented in Table 1.

Table 1. Noci, et al., 2005 (JAS 83:1167), fatty acids presented as a % of total FAs.

Days grazing pasture Fatty Acid	0 d	59 d	118 d	158 d	Effect
trans-11 Vaccenic Acid, %	1.35	1.93	2.27	3.01	linear
CLA (9,11), %	0.5	0.5	0.57	0.71	linear
alpha-Linolenic Acid (n-3) %	1.03	1.14	1.02	1.29	cubic (0.06)
n-3 PUFA, %	1.59	1.90	1.88	2.37	cubic (0.054)
PUFA, n-6:n-3	2.21	1.99	1.63	1.46	linear (0.054)

After feeding a starch-based energy supplement and grass silage for 100% of the time, or for increasingly shorter periods of time prior to finishing on pasture, TVA and CLA increased linearly ($P<0.05$) with increasing days on pasture. Additionally, the PUFA n-6 to n-3 ratio decreased linearly ($P=0.054$) with increasing days on pasture (not greater that 2:1 for any treatment). Their work also revealed a cubic increase ($P=0.06$) in ALA and n-3 PUFA with increased pasture time.

In another study, **Fincham et al. (2009)** looked at the impact of time on finishing diets with regard to the FA profile of subcutaneous fat. Both pasture (cool-season mixed: blue-grass, white clover and fescue) and concentrate-finishing diets were examined. Angus crossbred steers were utilized (593 lb. start weight), with cattle being stockered to gain either 0.5, 1.0 or 1.5 pounds average daily gain (ADG) during winter. The winter stocker-ing diets consisted of a timothy hay base, with soybean meal added to provide a 10% total crude protein diet. Cattle were then supplemented with soybean hulls as needed to produce the ADG desired for each level. Animals received no growth promotants through-out the study. During the finishing period (mid-April through mid-September), pasture cattle had an ADG of 1.9 lb. while the concentrate fed had an ADG of 2.7 lb. Pasture and concentrate cattle had final weights of 1045 and 1190 lb., respectively. Results with re-gard to the changes in fat FA profiles are presented in Table 2.

Table 2. Fincham, et al., 2009 (JAS 87:3259), fatty acids presented as % of total FAs.

Day of Finishing Fatty Acid	Pasture 0 d	Pasture 28 d	Pasture 84 d	Pasture 140 d		Conc. 0 d	Conc. 28 d	Conc. 84 d	Conc. 140 d	Effect P =
trans-11 Vaccenic Acid, %	3.2	7.0	7.9	7.2		3.1	1.7	2.7	2.7	Inter. 0.003
CLA (9,11), %	1.2	1.4	1.3	1.2		1.2	0.7	0.3	0.2	Inter. 0.002
Linoleic Acid (n-6), %	0.7	0.7	0.7	0.6		0.8	0.9	1.4	1.5	Inter. <.001
alpha-Linolenic Acid (n-3), %	0.6	0.8	0.7	0.8		0.5	0.3	0.3	0.2	Inter. 0.05
PUFA, n-6:n-3	1.2	1.0	1.03	0.9		1.3	1.9	4.3	5.2	Inter. <.001

During pasture-finishing, fatty tissue CLA content stayed constant over time while TVA doubled after 28 days on pasture. Trans-11 vaccenic acid then remained relatively constant during the remaining pasture-finishing process. For concentrate-finished cattle, TVA appeared to decrease after 28 days, and then return to approximately pre-finishing period level at 84 days. During concentrate-finishing, CLA content decreased steadily through day 84. For the pasture-finishing treatment, the PUFA n-6:n-3 remained relatively constant during the finishing period, while concentrate cattle reached a ratio greater than 4 to 1 after 84 days on feed.

Duckett et al. (2014), also looked at the effect of time on pasture on beef FA profile. Utilizing Angus crossbred steers (593 lb. starting weight) in southern West Virginia, cattle were stockered on forage diets, and began pasture-finishing in mid-April (cool-season mixed: bluegrass, white clover and fescue). Animals were harvested at one of three different times: 1) after pasture "spring flush" (early- to mid-July); 2) the end of summer (mid-September); or 3) after the 1st frost (around the 1st of November). Period ADGs were 2.7, 2.1 and 2.0 respectively, while days on pasture were 89, 146 and 201. Treatment hot carcass weights were 438, 472 and 545 lb. respectively. Results with regard to the changes in fat FA profiles are presented in Table 3.

Table 3. Duckett et al., 2014 (JAS 92:4767), fatty acids presented as % of total FAs.

Days on Pasture Fatty Acid	89 d	146 d	201 d	Effect
trans-11 Vaccenic Acid, %	2.8	3.1	3.3	linear
CLA (9,11), %	0.5	0.6	.5	
Linoleic Acid (n-6), %	0.06	0.08	0.08	
alpha-Linolenic Acid (n-3), %	1.4	1.2	1.0	linear
PUFA, n-6:n-3	1.5	1.4	1.4	linear

Their work showed a linear decrease in ALA and the PUFA n-6:n-3, and a linear increase in TVA, as time on pasture increased. However, the biological significance in all instances is questionable.

Effect of forage species

Two research studies looked specifically at the impact of forage species utilized during pasture-finishing, on meat FA profiles. **In 2013, Duckett et al.** utilized Angus crossbred steers (594 lb. start weight) in southern West Virginia to assess the impact of forage species grazed during the final 40 days of pasture finishing. Finishing treatments were: 1) continued grazing of mixed cool-season pasture (bluegrass, white clover, and fescue); 2) grazing Alfalfa hayfield regrowth; or 3) grazing of a warm season annual, Pearl Millet.

Each grazing treatment was applied during the final 40 days of pasture finishing. Over the last 40-day grazing period, ADGs were 2.4, 2.5 and 3.5 lb. for each treatment respectively. All cattle were harvested in mid-September and hot carcass weights were 541, 554 and 574 lb. for treatments 1, 2 and 3, respectively. Results with regard to the changes in fat FA profiles are presented in Table 4.

Table 4. Duckett et al., 2013 (JAS 91:1454), fatty acids presented as % of total FAs.

Forage Species / Fatty Acid	Mixed Pasture	Alfalfa	Pearl Millet	Effect P =
trans-11 Vaccenic Acid, %	3.6	3.3	3.6	
CLA (9,11), %	0.6	0.6	0.7	
Linoleic Acid (n-6), %	0.06	0.05	0.07	
alpha-Linolenic Acid (n-3), %	1.2[B]	1.3[A]	1.1[B]	0.017
PUFA, n-6:n-3	1.3	1.3	1.3	

The only impact of forage species on FA profile was for ALA content, with it being greater in alfalfa-finished cattle. The biological significance of the greater ALA level is questionable.

Chail et al. (2016) fed steers corn silage and alfalfa hay from fall-weaning through May 1, and then finished them on 1 of 3 diets for 105 days: 1) Concentrate; 2) 45 days of fescue pasture and then 60 days on meadow brome pasture (grass); or 3) 100% birdsfoot trefoil pasture. Cattle were yearlings when finishing treatments began (997 lb. start weight), and all were slaughtered at 18 months of age. Final weights were 1418, 1124 and 1225, and hot carcass weights were 815, 640 and 761 lb. for concentrate, grass pasture and trefoil pasture respectively. Results with regard to the changes in fat FA profiles are presented in Table 5.

Table 5. Chail et al., 2016 (JAS 94:2184) fatty acids presented as mg per g of wet product.

Forage Species / Fatty Acid	Conc.	Grass	Trefoil	Effect P =
trans-11 Vaccenic Acid, mg/g (wet)	0.3	0.5	0.8	
CLA (9,11), mg/g (wet)	0.1	0.1	0.2	
Linoleic Acid (n-6), mg/g (wet)	1.2	0.8	1.1	
alpha-Linolenic Acid (n-3), mg/g (wet)	0.2[B]	0.3[B]	0.5[A]	<.001
PUFA, n-6:n-3	5.7[B]	3.4[A]	2.4[A]	<.001

Their work shows an increased level of ALA within the trefoil (legume) treatment. This agrees with research conducted by Duckett et al. (2013), in that trefoil and alfalfa are both legumes and both forages resulted in an increased ALA content. There was no difference between forage species regarding the PUFA n-6:n-3. The research also agrees with other work presented that shows a lower PUFA n-6:n-3 for forage versus concentrate-finished product.

Summary

Available research indicates that content of TVA in the fat of pasture-finished animals can range from 2-10X that of concentrate-finished. The value of TVA in ruminant fat is often overlooked, given the fact that humans can produce CLA from TVA at the approximate rate of 1-part CLA from 5-parts of TVA. When feeding starch-based energy supplements and silage prior to forage finishing, both meat CLA and TVA increased with increasing days of grazing straight pasture. When cattle were fed forage or forage + soyhull diets prior to pasture-finishing, TVA content increased, while CLA remained generally steady with increased grazing time. During pasture-finishing, the PUFA n-6 to n-3 ratio generally decreases with increasing grazing time when concentrate supplementation and silage is fed prior to pasture-finishing. The ratio remains relatively steady if animals are stockered on forage diets prior to pasture-finishing. Different forage species utilized during pasture-finishing had no impact on TVA, CLA, LA concentration or PUFA n-6:n-3. There was a legume effect with regard to ALA, in that legume-finished cattle had greater ALA than those finished on grass-based pasture. The implications of the reviewed research are: 1) starch based concentrate supplementation followed by pasture finishing impacts meat fatty acid profile, even when animals grazed pasture alone for 118 days post supplementation; 2) producers of pasture-finished beef can utilize forages best suited for their farm and management, while still producing a product containing a typical pasture-finished FA profile; 3) meat trans-11 vaccenic acid content should be included in discussions concerning the healthy properties of beef.

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