Effects of Rumen Protected Oleic Acid in the Diet on Animal Performances, Carcass Quality and Fatty Acid Composition of Hanwoo Steers

H-J. Lee*, **S. C. Lee, Y. G. Oh, K. H. Kim, H. B. Kim[1], Y. H. Park, H. S. Chae, I. B Chung**
National Livestock Research Institute, RDA, 564 Omokchun-dong, Suweon, 441-350, Korea

ABSTRACT : The effects of different rumen protected forms, oleamide, Ca oleate, of dietary oleic acid on the carcass quality and fatty acid composition in intramuscular and subcutaneous fat tissues of Hanwoo steer were examined. Sixty, 25 month old Hanwoo steers divided into three groups were fed no supplement (Control), 2% of oleamide (Oleamide) or Ca-oleate (Ca-Oleate) in their diet for 45 or 90 days. Disappearance rates of oleic acid supplements in digestive tracts (Rumen bypass, abomasal and intestinal disappearance rate) were 48.5, 68.4 for oleamide and Ca oleate, respectively. Both oleic acid supplements affected feed intake, growth rate, cold carcass weight and carcass fatness. Live weight gain, carcass weight, backfat thickness and marbling score were higher in the oleic acid supplemented steers compared with those from the control. Oleic acid supplements increased marbling score and ether extract in Hanwoo steer m. logissi thoracicmus. Rumen protected oleic acid increased not only the level of oleic acid but also polyunsaturated fatty acids in intramuscular and subcutaneous fat tissue. Total saturated fatty acid contents in both fat tissues were decreased whereas total unsaturated fatty acid content was increased compared with those from control. Linoleic acid, linolenic acid and polyunsaturated fatty acid contents were significantly higher in Ca oleate than any other steers. Lipid metabolites in blood were increased in rumen protected oleic acid treatments. HDL content in blood was increased in Ca-oleate supplemented steers whereas LDL was decreased compared with control. The changes of fatty acid compositions in the rumen protected oleic acid supplemented steers suggest that the oleic acid and unsaturated fatty acid were protected from rumen biohydrogenation and can be deposited in the fat tissues. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 7 : 1003-1010)***

Key Words : Oleic Acid, Rumen Protected, Hanwoo, Fatty Acid Composition, Marbling

INTRODUCTION

The consumption of saturated fatty acids has been shown to increase plasma LDL-cholesterol in man and the increase of LDL-cholesterol has been correlated with coronary heart disease. Many consumers believe that the consumption of saturated fatty acid products cause heart disease. Conversely monosaturated fatty acids such as oleic acid decrease the amount of LDL-cholesterol in man without affecting HDL-cholesterol (Mattson and Grudy, 1985). With the consumers becoming more health conscious, it is of considerable importance to meat industry to produce red meat that are perceived as being higher quality and more healthful.

Fatty acid composition of beef fat can also have an effect on human palatability. Kimura (1997) showed correlation between sensory panel scores and fatty acid composition and that oleic acid composition and total unsaturated fatty acid (UFA) composition positively correlate with flavor scores both in intramuscular fat and subcutaneous fat, finding that C16:1 and C18:1 contribute to the conditioned raw beef aroma which is produced by certain bacteria and this aroma may play an important role in preferred beef flavor and quality.

* Corresponding Author: H-J. Lee. Tel: +82-31-290-1698, Fax: +82-31-290-1792, E-mail: leehj@rda.go.kr
[1] Sawoo Oil company, Seoul, Korea.
Received August 16, 2002; Accepted April 21, 2003

The microflora in the rumen of cattle convert the majority of dietary unsaturated fatty acids to saturated fatty acids, resulting in its deposition in body fat as the saturated form. Some unsaturated fatty acid in oil seeds can be protected from ruminal biohydrogenation by the seed coat (Balwin and Allison, 1983). But feeding the whole cottonseed, which has seed coat protecting its fatty acid composition from rumen hydrogenation naturally, was shown only a minor effect on the fatty acid composition of beef adipose tissues (Huerta-Leidenz et al., 1991). As an another ruminally inert form of unsaturated fatty acid, feeding calcium salts of fatty acids changed unsaturated fatty acid composition of beef carcass fat to some extent (Kimura, 1997). The effectiveness of dietary unsaturated fatty acid deposition in ruminant can be substantially improved by protecting them from the rumen microflora.

For years it has long been interested in beef industry for the increasing the unsaturated fatty acid (UFA) composition of beef carcasses, not only to counter the human health problems, but to achieve the unique taste and flavor of beef preferred by consumers. This study was conducted to evaluate the effects of elevated amounts of rumen protected oleic acids in the diet of Hanwoo steers on animal performance, carcass composition and the fatty acid composition of intramuscular and subcutaneous fat tissue of longissmus dorsi muscle.

MATERIALS AND METHODS

Rumen protected oleic acids and rumen bypass

For the preparation of rumen protected oleic acid supplements, oleic acid were partially purified and reacted with Ca and NH_3 to produce Ca oleate and oleamide. *In situ* nylon bag test for the release of oleic acid by the rumen microbial hydrolysis and the changes of fatty acid composition after rumen retention were examined.

For *in situ* trial, oleic acid supplements were put in nylon bag of pore size 46 μm and incubated in rumen cannulated Hanwoo. After 9 h, nylon bags were taken from rumen and washed in flowing tap water for 30 min and dried overnight at 40°C. The difference of sample weight after rumen incubation was considered to be the hydrolysis of oleic acid compounds, oleamide or Ca oleate.

For the measurement of digestive availability, all oleic acid supplements in nylon bags were introduced to rumen, abomasum and then intestine sequentially and four bags were removed from each steps, washed and dried and calculated for disappearance rates. Intestinal absorption rates were deduced from the difference of residue between abomasum and feces.

Animal feeding and managements

Sixty Hanwoo steers ranged form 570 kg to 620 kg were allocated according to 2×3 factorial design in which three dietary treatments, control, oleamide, Ca oleate and two experimetal periods, 45 day and 90 days were superimposed. Each treatment consists of 10 animals. Two year old Hawoo steers were fed and managed at feeding barn in local dairy farms and offered concentrates by 1.8% and rice straw by 0.5% of body weight daily and allowed *ad libitum* access to free water. Rumen protected oleic acids, oleamide and Ca oleate were supplemented to four assigned steer groups for 45 days or 90 days and then steers were slaughtered. After slaughter, carcass quality were investigated by the national guidelines and standards of carcass quality grading. Portions of the longissimus dorsi muscle including the overlying fat tissue (6th-7th rib) were removed after slaughter and subcutaneous and intramuscular fat tissue were taken from this section and kept frozen until fatty acid analysis.

Total lipids were extracted (Chloroform: methanol) and fatty acids were determined by gas-liquid chromatography on a CP Sil 88, 0.5 cm×0.25 mm(ID) column (Varian Co, US).

Carcass quality and fatty acids analysis

Carcass qualities and yields indicating carcass characteristics were recorded 24 h postmortem on cattle by the national guidelines and standards of carcass quality grading of Animal Products Grading Service Station.

Table 1. Effect of ruminal protection treatments on the disappearance of oleamide and Ca oleate in rumen by *in situ* nylon bag technique

Feed supplement	Disappearance rate (%)		
	Rumen	Abomasum	Feces
Oleamide	6.53±0.95	8.23±0.84	55.08±11.09
Ca Oleate	10.2±0.81	89.1±3.06	99.2±0.60
P	0.001	0.001	0.001

Duplicate samples of adipose tissues of the beef were weighed to 1.0 g and homogenized in a modified Dole's reagent (Smith and Prior, 1982) using the Polytron (model s63c). The neutral lipids wee extracted using the procedure of Foch et al. (1954). The extracted lipids were converted to methyl esters according to Christopherson and Glass (1969)'s method. The methyl esters were analyzed for individual fatty acids (14:0-18:3) with the Varian 3,800 gas chromatograph packed with 10% DEGS on Chromasorb G, with detector and injection temperature of 200°C. The flow rate of the carrier gas, N_2, was 20 ml/min.

Blood metabolites analysis

Blood plasma was taken from jugler vein just before slaughter for the analysis of blood lipid metabolites and fatty acid composition. Concentrations of NEFA and total cholesterol (Sigma kit number 352; Sigma Chemical Co., St. Louis, MO) were measured in plasma. An additional 60 ml of blood were obtained for separation of lipoproteins by ultracentrifugation, and the concentration of triglyceride was determined.

Statistical analysis

Data were analyzed with the General Linear Model program (SAS, 2000). Treatment, feeding day and tissue site were the main effects. Mean separation was achieved by Duncan's multiple range test (Ott, 1984).

RESULTS AND DISCUSSION

Rumen bypass and availability in digestive tracts

Effects of ruminal protection treatments on the disappearance of oleamide and Ca oleate in rumen by *in situ* nylon bag technique were shown Table 1. Disappearance rate of oleic acid supplements from digestive tracts (Rumen bypass rate, abomasal and intestinal disappearance rate) were 48.5, 68.4 for oleamide and Ca oleate, respectively.

Oleate as calcium salt was shown to stay resistant in rumen and be released in abomasum, in which acidic condition calcium is detached from the oleate salts. It is reported that Ca soaps are very stable in rumen and can provide effective protection against rumen biohydrogenation (Bauchart, 1993).

For oleamide, it was shown quite resistable in small intestine as well as in rumen. Jenkins (1993) reported that

Table 2. Changes in fatty acid compositions of oleamide and Ca oleate before and after *in situ* rumen incubation

Fatty acid composition	Oleamide (%)			Ca oleate (%)		
	Before	After	P	Before	After	P
C14:0	2.28±0.07	2.20±0.01	NS	1.41±0.14	1.81±0.03	0.03
C16:0	7.94±0.06	7.90±0.09	NS	6.10±0.51	7.14±0.23	0.07
C16:1n-7	4.76±0.10	4.80±0.06	NS	4.03±0.19	3.92±0.30	NS
C18:0	4.7±0.05	4.73±0.06	NS	2.28±0.17	2.82±0.18	0.04
C18:1n-9	73.1±0.14	73.56±1.11	NS	74.50±0.88	73.3±2.05	NS
C18:2 n-6	5.02±0.09	4.73±0.37	NS	5.52±0.41	1.81±0.15	0.001
C18:3 n-3	1.15±0.07	0.73±0.03	NS	2.21±0.11	3.15±0.38	0.02
C20:1n9	1.02±0.05	1.37±0.41	NS	3.95±0.05	6.02±1.59	0.09

NS: p>0.1

Table 3. Effect of oleamide and Ca oleate in diet on animal performances fed for 90 days

Performances	Treatments			
	Control	Oleamide	Ca-Oleate	P
Initial weight (kg)	586±38	596.2±54	604.0±45	NS
Final weight (kg)	636.7±41	673.5±63	683.3±50	NS
Weight gain (kg)	50.7±17.97	77.4±13.65	79.3±9.07	0.001
ADG (kg/day)	0.58±0.21	0.66±0.11	0.74±0.08	0.06
Daily feed intake (kg/day)	9.6±0.4	9.0±0.2	8.9±0.39	0.08

NS: p>0.1

amide bond made by reacting the carboxyl group of fatty acid with the amino group of methionine was resistant to the bacterial degradation in rumen and normal digestion of fatty acyl amides occured in the small intestine. In contrast to Jenkins's report (1998) that fatty acyl amide are highly susceptible to hydrolytic cleavage by intestinal amidase or proteolytic enzymes in pancreatic fluid, our results by *in situ* mobile bag technique showed only 46.85% disappearance rate of oleamide in intestine.

Changes in fatty acid compositions of oleamide and Ca oleate before and after *in situ* rumen incubation by nylon bag technique were described in Table 2. There were no significant changes of fatty acid composition in oleamide but some unsaturated fatty acids were biohydrogenated or more unsaturated in Ca oleate. Aldrich et al. (1997) reported that biohydrogenation of free soybean oil in the rumen was 78% and the oil of roasted whole soybean was also hydrogenated to a similar degree. Jenkins and Palmquist (1992) reported that a free carboxyl group is required for the action of bacterial isomerases that initiate biohydrogenation. The low biohydrogenation of cacium oleate and oleamide in rumen seemed to be attributed to limited availability of free carboxyl groups associated with Ca or amine. But Fotouhi and Jenkins (1992) who fed sheep with calcium linoleate failed to increase flow of unsaturated fatty acids to the duodenum. Either extensive dissociation of Ca linoleate occurred in the rumen or biohydrogenation occurred in carboxylate salts despite the absence of a free carboxyl group. It is thought that rumen resistance of calcium fatty acid salts depend on the chemical association of fatty acid and Ca and/or physical properties of the complex.

Jenkins (1998) showed that milk oleic acid was increased from 23.16% to 48.16% by the supplementation of oleamide. Rule et al. (1994) indicated that although dietary oil seed altered the fatty acid composition of lipids of adipose tissue of beef cattle, rumen bypass treatment had the most consistent effects, suggesting that rumen bypass and subsequent absorption in abomasum and intestine was more efficient for the deposition in body.

Animal performances

Animal performances of Hanwoo steers supplemented with oleamide and Ca oleate are shown in Table 3.

Weight gain and ADG of Hanwoo steers supplemented Ca oleate and oleamide for 90 days was significantly higher than those of control steers. Weight gains and ADG of steers supplemented with oleic acids were markedly higher than those from control and it is thought that it results from more energy intake by daily fat supplementation at the level of 200 g.

Dry matter intakes of steers were reduced by the presence of either the oleamide or Ca oleate in the diet. It is widely observed that feed intakes are reduced by the fat supplements in the diet for several reasons. Reduced feed intake by feeding oleamide to Holstein cow also was reported by Jenkins (1998, 1999). The Bremmer et al. (1998) described unpublished data where infusion of fatty acids from high oleic sunflowers decreased DMI in a dose dependent manner. Scollan et al. (2001) reported that DM intake reduction was mediated by specific fatty acids produced as a result of rumen biohydrogenation. In this study, unpalatable smell from Ca oleate and oleamide which was observed in feeding adaptation periods or physiological

Table 4. Effect of oleamide and Ca oleate in diet on meat carcass quality

Carcass quality		Treatments			P
		Control	Oleamide	Ca-Oleate	
45 days feeding	Carcass weight (kg)	389.3±39.8	390.8±36.4	382.6±35.8	NS
	Back fat thickness (cm)	11.0±2.2	11.4±6.1	15.6±7.9	NS
	Loin eye area	87.2±5.6	83.1±6.6	77.9±6.9	0.02
	Carcass rate (%)	68.2±1.2	67.4±2.6	65.3±4.0	0.10
	Marbling score	5.52±1.3	4.29±2.2	3.67±1.6	0.09
90 days feeding	Carcass weight (kg)	377.6±33.5	386.4±45	410.6±37.2	NS
	Back fat thickness (cm)	11.2±2.9	12.3±4.7	11.9±4.1	NS
	Loin area	80.6±9.7	83.6±8.9	80.5±9.1	NS
	Carcass rate (%)	67.5±1.5	67.2±2.1	67.0±1.7	NS
	Marbling score	4.75±0.5	5.18±1.7	5.58±1.6	NS

NS: p>0.1

Table 5. Effect of oleamide and Ca oleate in diet on fatty acid compositions in intramuscular and subcutaneous fat tissue

Fat tissues /fatty acids	Feeding periods							
	45 days				90 days			
	Control (%)	Oleamide (%)	Ca-Oleate (%)	Significance	Control (%)	Oleamide (%)	Ca-Oleate (%)	Significance
Intramuscular								
C18:1n9	50.81	51.58	49.00		51.16	52.83	50.90	
C18:2n6	2.24^{b}	2.65^{ab}	3.38^{a}	*	2.20^{b}	3.77^{a}	3.96^{a}	*
C18:3n6	0.029	0.044	0.042		0.23	0.02	0.04	
C18:3n3	0.16	0.17	0.13		0.19	0.16	0.19	
C20:4n6	0.24	0.25	0.38		0.24	0.23	0.25	
SFA[1]	41.93	40.51	42.13		40.66^{a}	34.95^{b}	36.94^{b}	*
USFA[2]	58.07	59.49	57.87		59.34^{b}	65.05^{a}	63.06^{a}	*
Mono[3]	55.25	56.20	53.69		56.25^{b}	60.77^{a}	58.46^{b}	*
Poly[4]	2.81^{b}	3.28^{ab}	4.18^{a}	*	3.09^{b}	4.28^{a}	4.59^{a}	*
n3[5]	0.16	0.17	0.13		0.16	0.16	0.19	
n6[6]	2.65^{b}	3.11^{ab}	4.05^{a}	*	2.94^{b}	4.12^{a}	4.40^{a}	*
n6/n3	0.06	0.058	0.040		0.06^{b}	26.25^{a}	24.40^{a}	*
MUFA/SFA	1.33	1.39	1.28		1.39^{c}	1.75^{a}	1.60^{b}	*
PUFA/SFA	0.066^{b}	0.08^{ab}	0.10^{a}	*	0.08^{b}	0.12^{a}	0.13^{a}	*
Subcutaneous								
C18:1n9	52.70	54.10	52.26		52.73^{b}	56.88^{a}	50.83^{b}	*
C18:2n6	1.77^{b}	2.16^{ab}	2.59^{a}	*	2.31^{b}	2.12^{b}	4.56^{a}	*
C18:3n6	0.046	0.064	0.10		0.17^{a}	0.04^{b}	0.12^{a}	*
C18:3n3	0.32	0.26	0.26		0.28	0.32	0.31	
C20:4n6	0.025	0.011	0.017		0.005^{b}	0.0087^{b}	0.036^{a}	*
SFA	38.20	37.33	38.26		36.87^{a}	31.36^{b}	34.23^{a}	*
USFA	61.80	62.67	61.74		63.13^{b}	68.64^{a}	65.77^{b}	*
Mono	59.45	60.10	58.70		60.28^{b}	66.11^{a}	60.66^{b}	*
Poly	2.35	2.58	3.05		2.85^{b}	2.53^{b}	5.11^{a}	*
n3	0.32	0.26	0.26		0.276	0.32	0.31	
n6	2.03	2.31	2.79		2.572^{b}	2.21^{b}	4.80^{a}	*
n6/n3	0.23	0.13	0.10		0.11^{c}	7.20^{b}	15.82^{a}	*
MUFA/SFA	1.57	1.62	1.55		1.65^{b}	2.12^{a}	1.80^{b}	*
PUFA/SFA	0.06	0.069	0.080		0.078^{b}	0.081	0.16^{a}	*

^{a,b}Means in the same row with different superscripts differ. * p<0.05

[1] Saturated fatty acid. [2] Unsturated fatty acid. [3] Monounsaturated fatty acid. [4] Polyunsaturated fatty acid. [5] n-3 fatty acid. [6] n-6 fatty acid.

responses seemed to be mostly involved. Physiological responses might arise from higher energy density of the fat supplementation diet limiting intake to maintain constant digestible energy intake.

Carcass quality

Carcass details for experimental steers are given in Table 4.

Carcass weights of steers fed rumen protected oleic acids for 90 days were heavier than those of control but

carcass rates were slightly lower than that of control.

Backfat thickness, marbling score and loin areas tended to be higher for those fed rumen protected oleic acids. It is thought that higher energy intake by the supplementation of oleic acids be distributed in subcutaneous fat tissue of back and intramuscular fat tissue. Carcass fatness were shown to be increased with rumen bypass oleic acid supplementation in contrast to finding by Rule et al. (1994), in which they found that high fat diets did not necessarily increase carcass fatness. Andrae (2001) showed that when yealing steers were fed high-oil corn (82% of diet) for 84 days, marbling scores and quality grades were greater ($p<0.05$) for carcasses from steers fed the high-oil corn. In his study, 78% of steers fed the high-oil corn was graded as U.S. Choice compared with 47% for regular corn. Solomon et al. (1991) reported that carcass fatness was directly related to ME intake.

Fatty acid composition

The overall fatty acid composition of intramuscular and subcutaneous fat tissue from Hanwoo steers is shown in Table 5.

There were differences in some fatty acids of fat tissue from steers fed for 45 days ($p<0.05$) but most fatty acids were significantly different among treatments from those fed for 90 days ($p<0.05$). Overall, fatty acids were modified in fat tissues fed for 90 days rather than 45 days and the subcutaneous rather than the intramuscular. The subcutaneous fat tissue from those fed protected oleic acids were less saturated (36.9 vs. 31.4, 34.2) and more unsaturated (63.1 vs. 68.6, 65.8) than those from the control and it was also shown in the intramuscular fat tissue which was less saturated (40.7 vs. 35.0, 36.9) and more unsaturated (59.3 vs. 65.1, 63.1) as well. This resulted in higher unsaturated/saturated ratios for fat tissue from those fed rumen protected oleic acids for 90 days (subcutaneous: 1.73 vs. 2.20, 1.96; intramuscular: 1.47 vs. 1.87, 1.73) and polyunsaturated/saturated ratios (subcutaneous: 0.078 vs. 0.081, 0.16, intramuscular: 0.08 vs. 0.12, 0.13) compared with those of control ($p<0.01$). The high content of oleic acid, linoleic acid and polyunsaturated fatty acid from Ca oleate and oleamide fed steers were thought to be responsible for above differences.

There was no differences ($p<0.1$) in oleic acid content of both rumen protected oleic supplements after 9 h rumen incubation (Table 2). But it tended to be decreased in blood plasma and increased again from 20% to over 50% in fat tissues. Oleic acid, which is the predominant fatty acid in bovine muscle and adipose tissue, was significantly higher in intramuscular and subcutaneous fat tissue from steers fed with oleamide for 90 days ($p<0.01$). Oleamide increased oleic acid contents in both fat tissues more efficiently than Ca oleate. It has not been so successful to increase the oleic acid contents in beef cattle by feed supplementation. Rule et al. (1994) reported that extruded canola fed bulls had a higher percentage of 18:1 than soybean meal fed bulls by 0.4%. St. John et al. (1987) reported that Angus×Hereford steers fed with the diet supplemented with 20% rapeseed at the expense of 20% corn showed no statistical difference of oleic acid contents (47.5% vs. 47.3%) in muscle. It is thought that more subtle and sophisticated protection treatment for oleic acid is needed to change the fatty acid composition in beef cattle.

Table 6. Effect of oleamide and Ca oleate in diet on faty acid composition of blood plasma

Fatty acids	Control (%)	Oleamide (%)	Ca-Oleate (%)	P
C18:1n9	22.15±4.73	20.62±2.15	20.44±6.92	0.82
C18:2n6	28.26±6.01	29.55±2.11	26.36±6.95	0.65
C18:3n3	0.13^{b}±0.23	0.77^{a}±0.32	0.29^{ab}±0.26	0.08
SFA[1]	42.25^{b}±1.26	41.70^{b}±1.66	44.29^{a}±0.97	0.02
USFA[2]	57.75^{a}±1.26	58.30^{a}±1.66	55.71^{b}±0.97	0.02
Mono[3]	24.01±5.15	22.17±2.24	22.02±7.82	0.80
Poly[4]	33.74±6.00	36.12±1.46	33.69±8.63	0.77
n6[5]	33.60±6.04	35.35±1.54	33.40±8.45	0.85
MUFA/SFA	0.57±0.11	0.53±0.07	0.50±0.16	0.63
PUFA/SFA	0.80±0.16	0.87±0.05	0.76±0.21	0.57

[a,b]Means in the same row with different superscripts differ ($p<0.1$).
[1] Saturated fatty acid. [2] Unsturated fatty acid. [3] Monounsaturated fatty acid. [4] Polyunsaturated fatty acid. [5] n-6 fatty acid.

Linoleic acid was significantly increased in intramuscular and subcutaneous fat tissues and blood plasma from steers supplemented both for 45 days and 90 days even though it was decreased after *in situ* rumen incubation for 9 h (Table 2, 5, 6). No obvious explanation is available for this finding.

Fatty acid compositions of Hanwoo blood plasma were quite different from those of fat tissue. Oleic acid tended to be lower in plasma as 20% than in fat tissue, which is 50% and linoleic acid was higher in plasma as 30% than in fat tissue, which is 1 or 2% (Table 5, 6).

Unsaturated fatty acid was higher in both fat tissues and blood plasma from steers supplemented with oleic acids. Opposite trend was shown for saturated fatty acids. Tamaki et al. (1992) also showed that feeding calcium salts of fatty acid changed unsaturated fatty acid composition of beef carcass fat to some extent as were this results.

Polyunsaturated fatty acids also were altered by the fat supplements, although the magnitude of the changes were greater in Ca oleate. C18:2 and C18:3 were increased more than other C18 fatty acids.

Table 8 shows the effect of site and feeding day on modification of fatty acid composition in fat tissues. In keeping with other studies which showed that intramuscular fat was more saturated than subcutaneous fat (Ishida et al., 1988; Yang et al., 1999), linoleic acid and saturated fatty acid, poly unsaturated fatty acid were higher in intramuscular fat tissue than subcutaneous fat tissue. There

were no effect for the reversal of site specific deposition of fatty acid by daily 200 g of fat supplementation.

Most of fatty acids except saturated fatty acids were higher for 90 day feeding than 45 day and it is assumed that 90 day feeding is more effective than 45 day for the dietary modification of fatty acid composition. Nearly all fatty acids of subcutaneous fat fed for 90 days were changed by adding protected oleic acids to the diet and there were only a few instances especially, PUFA, where source of oleamide or Ca oleate had different effects on the composition of fatty acids in fat tissues.

Of greatest interest were the changes in unsaturated fatty acids contents of both fat tissues supplemented with Ca oleate, since both fat supplements contained similar fatty acid compositions. This demonstrates some ability of rumen protected oleic acid sources to enhance UFA in fat tissues, which could be attributable to incomplete biohydrogenation or desaturation of dietary oleic acid.

The total amount of carcass fat might affect the fatty acid composition to some extent. Sturdivant et al. (1992) showed the correlation of fatty acids from carcass fat with growth, fat quality and carcass characteristics. Average daily gain, dissected fat weight and marbling score were positively correlated with the concentration of unsaturated fatty acid in subcutaneous and kidney fat (Rule et al., 1994). Aharoni et al. examined the effect of dietary metabolic energy level on fat deposition and fatty acid composition in muscle and fat depots of fresian bull calves, and found that UFA content was positively correlated to dietary energy level in both depot fat and muscle fat. These results imply that the energy intake and growth rate can affect fatty acid composition of beef carcass. The lack of response in oleic acid in fat tissue to the Ca oleate might be explained by already high oleic acid contents of control steers which is long fed for 26 months by high ratio of grains and /or lower content of total fat compared with oleamide (Table 9).

Table 9. Chemical composition of diet and supplements

Chemical composition(%)	Concentrate	Rice straw	Oleamide	Ca oleate
Dry matter	86.85	80.41	98.5	97.9
Crude protein	12.11	4.76	6.3	-
Ether extract	4.68	0.56	93.7	63.1
Crude fiber	6.88	26.46	-	-
Crude ash	5.36	8.66	-	12.3

Blood metabolites

Lipid metabolites in blood plasmas are shown in Table 8. Total cholesterol, triglyceride, total lipid were higher in rumen protected oleic acid treatments ($p<0.1$). Results from other researchers have shown consistent changes in concentrations of metabolites in blood when various fat sources were infused or fed. Postruminal infusions of rapeseed oil (Gagliostro et al., 1991) or saturated or unsaturated FA (Drackley et al., 1992) increased concentrations of NEFA and cholesterol in plasma. Plasma

Table 7. Effect of oleamide and Ca oleate in diet on lipid metabolites in blood plasma

Blood metabolites	Treatment			P
	Control	Oleamide	Ca-Oleate	
Total Cholesterol (mg/dl)	181.64^{b}±33	212.08^{ab}±38	215.09^{a}±39	0.078
Triglyceride (mg/dl)	26.27^{a}±8	26.17^{a}±8	20.18^{a}±6	0.095
Total Lipid (mg/dl)	381.82^{b}±82	436.33^{ab}±52	451.64^{a}±88	0.086
Non esterified fatty acid (μEq/L)	176.18±46	193.33±70	180.91±55	NS
VLDL[1] (%)	13±4.26	13.5±7.29	14.9±7.49	NS
LDL [2] (%)	21.6±2.08	18.7±5.19	17.8±6.06	NS
HDL [3] (%)	65.5±4.13	67.9±5.05	67.3±5.21	NS

[a,b]Means in the same row with different superscripts differ ($p<0.1$).
[1] Very low density lipoprotein. [2] Low density lipoprotein. [3] High density lipoprotein. NS: $p>0.1$.

Table 8. Effect of site and feeding days on the modification of fatty acid composition in fat tissue

Site effects	Control	Oleamide	Ca-Oleate	Feeding days effect	Control	Oleamide	Ca-Oleate
C18:1n9	S*	S*	S	C18:1n9		90*	
C18:2n6	I	I*	I	C18:2n6			90*
C18:3n3	S*	S*	S*	C18:3n3			90*
SFA	I*	I*	I*	SFA		45*	45*
USFA	S*	S*	S*	USFA		90*	90*
Mono	S*	S*	S*	Mono		90*	90*
Poly	I	I*	I	Poly			90*
n3	S*	S*	S*	n3			
n6	I*	I*	I	n6			90*
MUFA/SFA	S*	S*	S*	MUFA/SFA		90*	90*
PUFA/SFA	I	I*	S	PUFA/SFA		90*	90*

S= Subcutaneous, I=Intramuscular, * $p<0.5$.

cholesterol and NEFA increased when cows were fed increasing amounts of canola seed (Khorasani et al., 1992). Rafalowski and Park (1982) reported that blood cholesterol increased when cows were fed 7.3 or 11.7% regular sunflower seeds.

HDL and VLDL those from fed with protected oleic acid, tended bo be higher but LDL to be lower than those of control. Rule et al. (1994) indicated that increasing the proportion of C18:0 and 18:1 would be beneficial to the beef industry because these fatty acids are hypocholesteremic in humans. Monosaturated fatty acids such as oleic acid decrease the amount of LDL-cholesterol in man without affecting HDL-cholesterol (Mattson and Grudy, 1985). As was with this results, Sturdivant et al. (1992) also reported that absorbed oleic acid reduced or maintained the LDL concentration in blood.

It was shown that amide and Ca treatment can protect the oleic acid from rumen biohydration and rumen bypassed oleic acid seemed to be absorbed in small intestine, changing the fatty acid composition of intramuscular and subcutaneous fat tissues, the concentration of blood metabolites and lipoproteins ratios.

REFERENCES

Aharoni, Y., E. Nachtomi, P. Holstein, A. Brosh, Z. Holzer, Z., Nitsan. 1995. Dietary effects on fat deposition and fatty acid profiles in muscle and fat depots of Friesian bull calves. J. Anim. Sci. 73(9):2712-20

Aldrich, C. G., Merchen, N. R., Drackley, J. K., Gonzalez, S. S., Fahey, G. C., Jr, Berger L. L., 1997. The effects of chemical treatment of whole canola seed on lipid and protein digestion by steers. J. Anim. Sci. 75(2):502-11.

Andrae, J. G., Duckett, S. K., Hunt, C. W., Pritchard, G. T., Owens, F. N. 2001. Effects of feeding high-oil corn to beef steers on carcass characteristics and meat quality. J. Anim. Sci. 79(3):582-588.

Baldwin, R. L., and M. J. Allison. 1983. Rumen metabolism. J. Anim. Sci. 57(Suppl. 2):461.

Bauchart, D. Lipid absorption and transport in ruminants. 1993. J Dairy Sci. 76(12):3864-3881.

Bitman, J., D. L. Wood, R. H. Miller, H. F. Tyrrell, C. K. Reynolds and H. D. Baxter. 1996. Comparison of milk and blood lipids in Jersey and Holstein cows fed total mixed rations with or without whole cottonseed. J. Dairy Sci. 79:1596-1602.

Bremmer, D. F., L. D. Ruppert, J. H. Clark and J. K. Drackley. 1998. Effects of chain length and unsaturation of fatty acid mixtures infused into the abomasum of lactating dairy cows. J. Dairy Sci. 81:176-188.

Chang, J. H-P., D. K. Lunt and S. B. Smith. 1992. Fatty acid composition and fatty acid elongase and stearoyl Co A desaturase activities in tissues of steers fed high oleate sunflower seeds. J. Nutrition 122:2074

Drackley, J. K., T. H. Klusmeyer, A. M. Trusk and J. H. Clark. 1992. Infusion of long-chain fatty acids varying in saturation and chain length into the abomasum of lactating dairy cows. J. Dairy Sci. 75: 1517.

Enser. M., K. Hallett, B. Hewitt. C. A. J. Fursey and J. D. Wood. 1996. Fatty acid content and composition of English beef, lamb and pork at retail. Meat Science 42:443-456.

Gagliostro, G., Y. Chilliard and M. J. Davicco. 1991. Duodenal rapeseed oil infusion in early and midlactation cows. 3. Plasma hormones and mammary apparent uptake of metabolites. J. Dairy Sci. 74:1893.

Huerta-Leidenz NO, H. R. Cross, D. K. Lunt, L. S. Pelton, J. W. Savell and S. B. Smith. 1991. Growth, carcass traits, and fatty acid profiles of adipose tissues from steers fed whole cottonseed. J. Anim. Sci. 69(9):3665-3672

Ishida, M., T. Takeda, T. Saito, Y. Kano, I. Matsum shi. 1988. Fatty acid composition of subcutaneous Wagyu Black steers during fattening. Proc. 34th Intl. (Tech., Brisbane, Australia, pp. 40-42.

Jenkins, T. C. 1993. Lipid metabolism in the rumen. J. Dairy Sci. Dec. 76(12):3851-3863.

Jenkins, T. C. 1998. Fatty acid composition of milk from Holstein cows fed oleamide or canola oil. J. Dairy Sci. 81: 794-800.

Jenkins, T. C. 1999. Lactation performance and fatty acid composition of milk from Holstein cows fed 0 to 5% oleamide. J. Dairy Sci. 82:1525-1531.

Jenkins, T. C. 2000. Feeding oleamide to lactating Jersey cows 1. Effects on lactation performance and milk fatty acid composition. J. Dairy Sci. 83(2):332-337.

Khorasani, G. R., G. DeBoer, P. H. Robinson and J. J. Kennelly. 1992. Effect of canola fat on ruminal and total tract digestion, plasma hormones, and metabolites in lactating dairy cows. J. Dairy Sci. 75: 492.

Kimura, N. 1997. Factors affecting the fatty acid composition of beef carcass fat. Rumen Microbes and Digestive physiology in ruminants (Ed. Onodera, R. et al.) Japan Sci. Soc. Press. Tokyo. pp. 157-166.

Lacount, D. W., J. K. Drackley, S. O. Laesch and J. H. Clark. 1994. Secretion of oleic acid in milk fat in response to abomasal infusions of canola or high oleic sunflower fatty acid. J. Dairy Sci. Vol. 77. No 5

Mansbridge, R. J. and J. S. Blake. 1997. Nutritional factors affecting the fatty acid composition of bovine milk. Br. J. Nutr. 78, Suppl. 1, S37-S47.

Mattson, F. H. and S. M. Grundy. 1985. Comparison of the effects of dietary saturated, Monounsaturated and polyunsaturated fatty acids on plasma lipids and lipoproteins in man. J. Lipid Res. 26:194.

Ott, L. (1984). An Introduction to Statistical Methods and Data Analysis, 2nd edn. PWS, Boston, MA.

Rafalowski, W. and C. S. Park. 1982. Whole sunflower seed as a fat supplement for lactating cows. J. Dairy Sci. 65:1484.

Rule, D. C., J. R. Busboom and C. J. Kercher. 1994. Effect of dietary canola on fatty acid composition of bovine adipose tissue, muscle, kidney and liver. J. Anim. Sci. 72:2735.

Schauff, D. J., J. P. Elliot, J. H. Clark and J. K. Drackley. 1992. Effects of feeding lactating dairy cows containing whole soybeans and tallow. J. Dairy Sci. 75:1923-1935.

Scollan N. D., N. J. Choi, E. Kurt, A. V. Fisher, M. Enser, J. D. Wood. 2001. Manipulating the fatty acid composition of muscle and adipose tissue in beef cattle. Br. J. Nutr. 85(1):115-124.

Scott. T. W. and J. R. Ashes. 1993. Dietary lipids for ruminants,

protection, utilization and effects on remodelling of skeletal muscle phospholipids. Australian Journal of Agricultural Research, 44:495-508.

Smith, S. B. and R. L. Prior. 1982. The effect of 3-mercaptopicolinic acid and substrate interactions on the incorporation of lipogenic precursors into glyceride- glycerol, glyceride-fatty acids and nonesterified fatty acids in bovine adipose tissue. Biochim. Biophys. Acta. 712:365.

Solomon, M. B., G. P. Lynch, E. Paroczay and S. Norton. 1991. Influence of rapeseed meal, whole rapesse, and soybean meal on fatty acid composition and cholesterol content of muscle and adipose tissue from ram lambs. J. Anim. Sci. 69:4055.

St. John, L. C., D. K. Lunt and S. B. Smith. 1991. Fatty acid elongation and desaturation enzyme activities of bovine liver and subcutaneous adipose tissue microsomes. J. Anim. Sci. 69:1064-1073.

St. John, L. C., C. R. Young, D. A. Knabe, L. D. Thomson, G. T. Schelling, S. M. rudy and S. B. Smith. 1987. Fatty acid profiles and sensory and carcass traits of tissues from steers and swine fed an elvated monounsaturated fat diet. J. Anim. Sci. 64:1441-1447.

Steel, R. G. D. and J. H. Torrie. 1980. Multiple comparisons. In: (Ed. R. G. D. Steel and J. H. Torrie) Principles and Procedures of Statistics (2nd Ed.) McGraw-Hill Publishing Co., New York. p. 172.

Sturdivant, C. A., D. K. Lunt, G. C. Smith and S. B. Smith. 1992. Fatty acid composotion of subcutaneous and intramuscular adipose tissues and M. longissimus drsi Wagyu Cattle, Meat Sci. 32: 449.

Wu, Z., J. T. Huber, S. C. Chan, J. M. Simas, K. H. Chen, J. G. Varela, F. Santos, C. Fontes, Jr. and P. Yu. 1994. Effect of source and amount of supplemental fat on lactation and digestion in cows. J. Dairy Sci. 77:1644-1651.

Yang, A. T., W. Larsen, V. H. Powell and R. K. Tume. 1999. A comparison of fat composition of Japanese and long term grain- fed Australian steers. Meat Sci. 51:1-9.