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Research Article
Meat Quality, Fatty Acid Composition, Blood Parameters and Nucleotide Compounds Analysis Fed Long Chain Fatty Acid Calcium Salts in Hanwoo Steers (Korean Native Cattle)

Shah Ahmed Belal, Da Rae Kang, Sung Woon Choi, Ki Duk Song, Jae Don Oh, Hak Koy Lee, Mun Jun Lee, Chong Sam Na, Ho Sung Choe and Kwan Seob Shim

Department of Animal Biotechnology, Chonbuk National University, 561-756 Jeonju, Republic of Korea

Abstract

Objective: This study was conducted to evaluate the effect of feeding long chain fatty acid calcium salts (LCFA-Ca) on meat quality, blood parameters and nucleotide compounds of Hanwoo (Korean native cattle). **Methodology:** A total of 69 animals with mean body weight of 599±5 kg were divided into three treatments as control (n = 20), group 1 (n = 25) and group 2 (n = 24) were fed (1) control diet with no added fat, (2) 50% linoleic acid and 24% oleic acid containing LCFA-Ca and (3) 26% linoleic acid and 50% oleic acid containing LCFA-Ca, respectively 100 g day^{-1} animal^{-1} on Dry Matter Required (DMR) basis. **Results:** For meat quality, highest cooking loss, shear force and lowest pH was observed in group 1, compared with other two groups, but not reached significant level. The CIE a* value was significantly higher in control group ($p<0.05$), whereas no significant differences of L* and b* among the groups. Nucleic acid related compounds IMP, ADP and inosine tended ($p<0.05$) to be greater in group 2 compared to other two groups, whereas AMP was high in control. Group 1 had the highest MDA content than other groups ($p<0.05$). Fatty acid compositions including SAF, PUFA and ω^6/ω^3 were significantly higher in group 2 than the rest of 2 groups ($p<0.05$) but did not affect the percentage of MUFA. Serum concentration of triglycerides and calcium were greater ($p<0.05$) in Hanwoo steers fed LCFA-Ca than control group. Cholesterol, low-density lipoprotein (LDL) and high-density lipoprotein (HDL) concentrations were greater in group 2 without any significant effect. **Conclusion:** Therefore, it can be concluded that LCFA-Ca had impact on meat quality traits of Hanwoo including blood parameters and nucleotide compounds.

Key words: Long chain fatty acid calcium salt, meat quality, blood parameters, nucleotide compounds

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Corresponding Authors: Kwan Seob Shim, Department of Animal Biotechnology, Chonbuk National University, 561-756 Jeonju, Republic of Korea Tel: +82-63-270-2609 Fax: +82-63-270-2614
Ho Sung Choe, Department of Animal Biotechnology, Chonbuk National University, 561-756 Jeonju, Republic of Korea Tel: +82-63-270-2513 Fax: +82-63-270-2614

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Long Chain Fatty Acids (LCFAs) are fatty acids with aliphatic tails longer than 12 carbons[1] and physiologically important because they combine to form triacylglycerol and provide energy storage form in adipose tissue of animals[2]. Supplemental fats differing in origin are used to improve the energy density of diets in ruminant production. Fats are an effective energy supplement, being very digestibility with a high metabolic use for animals[3]. Several studies conducted on cattle and sheep showed inconsistent results about the utilization efficiency of the use of fats[4]. Feeding Ca salts of long chain fatty acids calcium salt (LCFA-Ca) with diet may minimize any bad effects on ruminal fermentation when excess amounts of fat supplemented to the ruminants diet.

Feeding diets with Ca salts of fatty acids is a practical way to bypass rumen bio-hydrogenation. The LCFA-Ca was slightly protected from ruminal bio-hydrogenation because net bio-hydrogenation of unsaturated fatty acid of LCFA-Ca was approximately 50%, while poly unsaturated fatty acids range from 60-90%. Consumers are commonly believed that saturated fatty acids increased plasma LDL-cholesterol which has been linked with cardiovascular disease. Additional supplemental fat to beef cattle diets may stimulates blood LDL and HDL cholesterol[5] and feeding high lipid containing diets to cows and heifers resulted increased HDL in blood serum[6]. In ewes fed supplemental fat, studies showed increased plasma concentrations of cholesterol, triglycerides, HDL and LDL[7,8]. Fatty acid composition of beef fat can also effect on human palatability. Kimura[9] showed that fatty acid composition and sensory evaluation scores are positively correlated and play an important role in beef flavor and quality. Feeding various kinds of fat (animal fats or vegetable oils) affected meat fatty acid composition consistently[10-14].

Published reports were already documented that long chain fatty acid calcium salts had positive impact on small ruminants (sheep and goat) and dairy cows. Feeding calcium salts of fatty acids based on vegetable oils, increased milk productivity in cows[15] and improved reproductive efficiency[16]. However, a few studies are available on the effect of feeding long chain fatty acid calcium salts on meat quality of Hanwoo steers. Therefore, the objectives of this study was to determine the effects of LCFA-Ca on meat quality traits, hematological factors like glucose, triglyceride and to determine the nucleotide compounds which affect the taste and flavor of meat.

MATERIALS AND METHODS

Experimental animals and diets: Sixty nine Hanwoo steers (Korean native cattle) at 26 months of age with mean body weight of 599±5 kg were used in this experiment. The trial was carried out with three dietary treatments as control (n = 20), group 1 (n = 25) and group 2 (n = 24) were fed (1) control diet (concentrate mix and rice straw) with no added fat, (2) 50% linoleic acid and 24% oleic acid containing LCFA-Ca and (3) 26% linoleic acid and 50% oleic acid containing LCFA-Ca respectively 100 g day^{-1} $animal^{-1}$ on Dry Matter Required (DMR) basis. The nutrient content of commercial control diet was crude protein 12.50%, crude fat 2.50%, crude fiber 15%, crude ash 10%, calcium (Ca) 0.70%, phosphorous (P) 1.20% and Total Digestible Nutrients (TDN) 75%. The control diet was supplied by Nonghyup Feed Co., Ltd., in Korea. The diets were fed for 180 days (6 months) until the animals were slaughtered. The animals within each treatment were housed in similar pens equipped with feeder and water supply. Animals were fed for *ad libitum* intake. The LCFA-Ca salt was top-dressed at each feeding time. Feed was supplied twice per day at morning and evening. The concentrate mix was fed *ad libitum* and rice straw was restricted to approximately 10% of the concentrate. All animal care protocols were approved by the Chonbuk National University Institutional Animal Care and Use Committee.

Fatty acid composition of LCFA-Ca salts: The chemical composition of LCFA-Ca salts presented in Table 1. The vital fatty acids components of LCFA-Ca salts were (1) palmitic acid (11.87%), oleic acid (24.84%), linoleic acid (50.03%), stearic acid (7.41%) and (2) palmitic acid (10.80%), oleic acid (55.54%), linoleic acid (26.97%) and stearic acid (3.13%). The ratio of Saturated Fatty Acids (SFA) and unsaturated fatty acids (USFA) was 19.55:31.86 and 14.15:57.47, respectively.

Sample collection: The animals were slaughtered for the evaluation of carcass characteristics. At 30 months of age steers were withdrawn from the experimental diets 24 h before slaughter and strip loin samples (*Longissimus dorsi*) were taken from the right side of the carcass. At the end of feeding trial, blood samples were collected from the jugular vein. The blood samples were collected in evacuated tubes and centrifuge at 1500 rpm for 5 min and collect the serum and stored at -20°C prior to analysis. Meat quality traits was analyzed immediately after 24 h post-mortem and rest of the samples were separate 2 parts that made powder form by

Table 1: Fatty acid composition of long chain fatty acid calcium salts (LCFA-Ca)*,#

	Groups (%)	
Fatty acid	1*	2#
C14:0	0.27	0.22
C14:1	0.05	-
C16:0	11.87	10.80
C16:1	0.36	0.41
C18:0	7.41	3.13
C18:1	24.84	50.54
C18:2	50.03	26.97
C18:3	6.38	0.69
C20:0	0.33	0.81
C20:1	0.24	0.79
C20:2	0.04	0.04
C22:0	0.41	0.32
C24:0	0.09	0.13
SAF:USFA	19.55:31.86	14.15:57.47

*Group 1: Control diet with 50% linoleic acid and 24% oleic acid containing LCFA-Ca salt, #Group 2: Control diet with 26% linoleic acid and 50% oleic acid containing LCFA-Ca salt, SFA: Saturated fatty acids, UFA: Unsaturated fatty acids

liquid nitrogen for nucleotides and another part (freeze dried) for fatty acids. The samples of all groups were stored at -70°C until further analysis.

Measurement of pH: The pH (at 24 h post-mortem) was measured in duplicates using a portable pH meter (Orion model 301, Orion, Beverly, MA, USA).

Measurement of cooking loss and shear force values: Cooking loss was measured by the method of Honikel[17]. Samples were weighed and put in a plastic bag, which was placed in at 80°C water bath until the internal temperature reached 75°C. When this temperature was reached, the samples were cooled and weighed again. The difference in weight before and after boiling was expressed as percentage cooking loss.

Warner-Bratzler Shear Force (WBSF) was determined by taking approximately 300 g of meat sample blocks. After cooling three representative 1.27 cm diameter cores were removed parallel to the muscle fiber from each steak. Warner-Bratzler Shear Force (WBS) was measured using an Instron universal testing machine (Model 3342, Instron Corporation, Norwood, MA, USA). Every core sample was sheared once parallel to the muscle fiber direction. The value was expressed as kilogram of force.

Color measurement: Three color (L*, a* and b*) coordinates measurements per sample were measured at three different locations on the bloomed cut surfaces of the meat sample blocks with D65 illuminant and 10° observers via a film lid using a Konica Minolta spectrophotometer (CM-2500d, Milton, Keynes, UK). According to the Commission International de l'Eclairage (CIE) system color was expressed as CIE L* (lightness), CIE a* (redness) and CIE b* (yellowness).

Measurement of fatty acids: Fatty acids were measured by Gas Chromatography (GC). Powdered meat samples (0.5 g) were added to 2 mL of boron-trifluoride in methanol and 2 mL of methanol in glass tubes. The tubes were capped with teflon-lined caps to prevent loss of volume and the samples were placed on a heating block at 80°C. After 10 min, the tubes were vortexed individually every 5 min for 2 h. After 2 h of repeated vortex mixing the samples were allowed to cool at room temperature and then by adding 3 mL of distilled water and 3 mL of hexane, the tubes were capped again and mixed by vortexing for 15 sec. After centrifugation (2,000 rpm, 5 min) to separate the phases, the supernatant was transferred to GC vials for analysis. The GC was performed for 1 µL samples on a Shimadzu GC-2014 instrument (Shimadzu Co., MD, USA) using a FAMEWAX column (30 m×0.32 mm i.d., 0.25 µm, column temperature, 250°C) and nitrogen/air as a carrier gas at 53.8 mL min^{-1} (split ratio 30:1). The temperature started at 150°C and increased to 250°C with an equilibration time of 3 min.

Measurement of nucleotide compounds: The meat samples make fine powder with liquid N_2, mortar and pestle (0.30 g) were mixed with 5 mL of 0.5 M perchloric acid and keep in ice for 15 min and then centrifuged at 9200×g for 5 min at 4°C to extract nucleic acids. The extracted 1 mL nucleic acids were transferred in 2 mL Eppendorf and mixed 0.25 mL of 2.1 M potassium hydrogen carbonate ($KHCO_3$) very carefully and keep in ice for 15 min. Then again centrifuged at 9200×g for 5 min at 4 and filtered through a syringe filter (HLB-M, 0.45 µm particle size, 13 mm, Futecs Co., Ltd.). The filtrate was analyzed using HPLC (Shiseido Nanospace SI-2, Shiseido Co., Ltd. Tokyo, Japan). Regarding analytical conditions for HPLC, a Imtakt Cadenza CD-C18 reverse phased column (4.6×250 mm, 3 µm, Imtakt Corp., USA) was utilized with two mobile phase of A: 1000 mL distilled water+5 mL TBA-OH (tert-butyl ammonium hydroxide) (40%)+1 mL H_3PO_4 (Phosphoric acid) and B: 1000 mL methanol+5 mL TBA-OH (40%)+1 mL H_3PO_4. Mobile phase flow rate was 0.7 mL min^{-1} and injection volume was 5 µL. The column temperature was maintained at 40°C and the detection wavelength 250 nm. The peaks of the individual nucleotides were identified using the retention times for standards: Hypoxanthine, inosine, inosine-5'-phosphate (IMP), adenosine-5'-phosphate (AMP) (Sigma, St., Louis, MO, USA) and the concentration was calculated using the area for each peak.

Measurement of malondialdehyde (MDA): The homogenate samples were prepared by mixing 0.5 g of meat with 2.5 mL of 0.25 M, trizma base buffer pH 7.4 (containing 0.2 M sucrose and 5 mM DTT) and homogenized by a homogenizer (Ultra-Turrax T25, IKA-Labotechnik). The homogenate was centrifuged in an automatic high-speed cold centrifuge at 10000×g for 20 min under 4°C (High speed centrifuge 2236 HR, Labocene, Korea). Two hundred microliters of supernatant was transferred in a 1.5 mL Eppendorf and add 50 µL of 6 M NaOH. Incubate this mixture in a 60°C water bath (WiseBath, Daihan Scientific Co., Ltd., Korea) for 30 min (repeat 3 times) for alkaline hydrolysis of protein bound MDA. Then centrifuge at 2800×g for 10 min after adding 125 µL of 35% (v/v) perchloric acid. A 200 µL volume of supernatant was placed on an Eppendorf and mixed with 25 µL of DNPH (5 mM solution in 2 M HCl). Finally, reaction mixture was incubated for 30 min in dark at room temperature and filtered through a syringe filter (HLB-M, 0.45 µm particle size, 13 mm, Futecs Co., Ltd.). The filtrate was analyzed using HPLC (Shiseido Nanospace SI-2, Shiseido Co., Ltd., Tokyo, Japan). Regarding analytical conditions for HPLC, an Imtakt Cadenza CD-C18 reverse phased column (150×4.6 mm, 3 µm) was utilized with a mobile phase of a mixture of 0.2% (v/v) acetic acid in distilled water and acetonitrile (40:60, v/v). Mobile phase flow rate was 1 mL min^{-1} and injection volume was 20 µL. The column temperature was always maintained at 40°C and the chromatograms were acquired at 310 nm.

Measurement of blood parameters: Blood serum glucose, triglyceride, total cholesterol, HDL-cholesterol, LDL-cholesterol concentrations were measured using analytical kits purchased from Asan Pharm., Co., Ltd., Seoul, Korea and Ca concentration was measured by Samkwang Medical Laboratories, Seoul, Korea.

Statistical analysis: All data were analyzed using an ANOVA (analysis of variance) followed by the Duncan's multiple range test procedure with SAS software version 6.12. Statistical significance was indicated at $p<0.05$.

RESULTS AND DISCUSSION

Meat quality: Table 2 showed meat quality parameters such as pH, cooking loss, shear force and color under the different LCFA-Ca feeding conditions. It was observed that highest cooking loss, shear force and lowest pH in group 1, compared with other two groups, but not reached significant level. The meats of the heifers fed soybean oil had no differences in the pH, cooking loss, shear force and color[18]. Kim *et al.*[19] showed that feeding rumen-protected Palm Oil Calcium Soap (POCS) did not affect water holding capacity, cooking loss, pH, moisture of longissimus muscle ($p>0.05$). The CIE a* value was significantly higher in control group ($p<0.05$), whereas no significant differences of L* and b* among the groups. Similar response was observed feeding by Palm Oil Calcium Soap (POCS)[19]. In recent report Suksombat *et al.*[20] showed that beef color and shear forces unaffected by feeding palm oil and linseed oil in crossbred Wagyu beef steers. Feeding various fats or oils to beef cattle improved meat quality including marbling[10,12,13,21] but in contrast did not affect meat quality in other studies[22,23]. However, limited studies are available on the effect of feeding LCFA-Ca salts on meat quality of Hanwoo steers.

Table 2: Effect of LCFA-Ca salts on meat quality of Hanwoo

Items	Control	Group 1	Group 2
pH	5.62±0.01	5.60±0.01	5.61±0.01
Cooking loss (%)	16.30±0.36	16.45±0.37	16.34±0.30
Shear force (kg)	3.15±0.18	3.35±0.11	3.27±0.95
Color			
CIE L* (Lightness)	18.07±0.94	19.11±0.52	19.52±0.57
CIE a* (Redness)	40.09±0.73^{a}	38.56±0.64^{ab}	37.66±0.47^{b}
CIE b* (Yellowness)	21.32±0.42	21.56±0.34	21.69±0.37

Mean values are presented as Mean±SE. Values in a row with different superscript letters are significantly different ($p<0.05$). Lack of superscript letters indicates no significant difference. Control: Control diet with no added fat, Group 1: Control diet with 50% linoleic acid and 24% oleic acid containing LCFA-Ca salt, Group 2: Control diet with 26% linoleic acid and 50% oleic acid containing LCFA-Ca salt

Table 3: Effect of LCFA-Ca salts on blood serum concentrations

Items (mg dL^{-1})	Control	Group 1	Group 2
Glucose	101.51±23.18^{a}	102.90±16.03^{a}	92.59±26.66^{b}
CHOL	214.86±53.43	232.50±47.98	240.66±36.16
TG	25.92±4.57^{b}	29.84±4.5^{ab}	33.36±10.17^{a}
Ca	9.36±0.15^{ab}	9.67±0.10^{a}	9.30±0.09^{b}
HDL	77.82±11.81	77.90±9.52	79.38±11.32
LDL	148.43±42.77	160.57±45.15	171.95±32.85

CHOL: Total cholesterol, TG: Triglyceride, Ca: Calcium, HDL: High density lipoprotein, LDL: Low density lipoprotein, mean values are presented as Mean±SE. Values in a row with different superscript letters are significantly different ($p<0.05$). Lack of superscript letters indicates no significant difference. Control: Control diet with no added fat, Group 1: Control diet with 50% linoleic acid and 24% oleic acid containing LCFA-Ca salt, Group 2: Control diet with 26% linoleic acid and 50% oleic acid containing LCFA-Ca salt

Blood parameter: In Table 3, group 2 had greater amounts of triglyceride but Ca in group 1 than other groups ($p<0.05$). The LCFA-Ca salt in the diet significantly affected triglyceride and glucose in blood serum. Previous studies reported that the fat level in the diet affected serum concentration of triglyceride in Atabay lambs[24]. Increase of triglycerides levels in calcium salts of fatty acid treated ewes was reported by Ghoreishi *et al.*[8] and Liel *et al.*[25]. The greater serum calcium concentrations for group 1 indicate a negative effect of 50%

linoleic acid and 24% oleic acid containing LCFA-Ca salt treatment, which may cause formation of insoluble calcium salts[4]. However, these results were inconsistent with results reported by Ghoorchi *et al.*[24]. Other serum concentration of lipid metabolites total cholesterol, LDL higher in group 2 but HDL in group 1 without showed significant differences. A similar response was observed by Espinoza *et al.*[16] in beef cows. Baldi *et al.*[26] also reported that goats fed fatty acids calcium salts had increases in plasma cholesterol. In cows fed high lipid diets, higher concentrations of CHOL, HDL and TG were also observed by Morgan and Williams[27]. O'Kelly[28] reported that beef calves had more serum cholesterol in preweaning stage and declined after weaning. Increased serum/plasma cholesterol and free fatty acids level with protected fat supplementation have also been reported earlier[29-31]. Another study demonstrated that LCFA-Ca feeding group of Awassiewe lambs calcium, cholesterol and high-density lipoprotein (HDL) increased in blood serum[4].

Nucleotide compound: According to Sasaki *et al.*[32], meat components such as inosine, IMP and peptides are correlated for the sensory taste of meat, especially umami. Table 4 showed nucleotide compounds between the groups. In terms of the nucleic acid related compounds, IMP, ADP and inosine tended ($p<0.05$) to be greater in group 2 compared to other 2 groups, whereas AMP was high in control. There was no significant effect of hypoxanthine between the groups. Jo *et al.*[33] reported that IMP generally responsible for flavor to the meat. Tikk *et al.*[34] also found that higher hypoxanthine content makes the flavor bitter and IMP positively associated with umami taste. Bitter taste is done by hypoxanthine and inosinic and glutamic acid had synergistic effect on umami taste[33,35]. Results indicated group 2 can be regarded more desirable than group 1.

Fatty acid: Composition of meat fatty acids is in Table 5. Fatty acid compositions including SAF, PUFA and ω^6/ω^3 were significantly higher in 26% linoleic acid and 50% oleic acid containing LCFA-Ca feeding group 2 than the rest of two groups ($p<0.05$) but did not affect the percentage of MUFA. But this is inconsistent with recent study[20]. This report demonstrated that SFA, UFA, MUFA and PUFA in LD muscle were unaffected by dietary treatment. Fatty acid profiles in the longissimus muscle did not differ ($p>0.05$) by different forms of soybean oil[18] and calcium soap of palm fatty acids[36]. The fatty acid affects the taste and quality of meat[37] and PUFA lowers LDL-cholesterol. Kim *et al.*[19] reported that feeding of Palm Oil Calcium Soaps (POCS) did not affect percentage of mono-unsaturated fatty acids (MUFA). Feeding 3-5% POCS to lambs also decreased MUFA content[38]. In group 2, also observed that palmitic acid (C16:0) and linoleic acid (C18:3) was increased. A similar response was observed by Chilliard *et al.*[39] reported that feeding calcium salts of long

Table 4: Effect of LCFA-Ca salts on nucleic acid compounds (mg/100 g) of Hanwoo muscle

Items	Control	Group 1	Group 2
AMP	11.51±0.10^a	10.46±0.10^b	9.16±0.12^c
IMP	124.13±0.19^b	128.43±0.14^b	130.90±0.16^a
ADP	20.91±5.48^b	22.64±0.74^b	31.80±0.86^a
Hypoxanthine	28.05±0.15	28.26±0.10	28.23±0.10
Inosine	21.19±0.18^c	22.98±0.13^b	23.88±0.12^a

AMP: Adenosine monophosphate, IMP: Inosine monophosphate, ADP: Adenosine diphosphate, mean values are presented as Mean±SE. Values in a row with different superscript letters are significantly different ($p<0.05$). Lack of superscript letters indicates no significant difference. Control: Control diet with no added fat, Group 1: Control diet with 50% linoleic acid and 24% oleic acid containing LCFA-Ca salt, Group 2: Control diet with 26% linoleic acid and 50% oleic acid containing LCFA-Ca salt

Table 5: Effect of LCFA-Ca salts on fatty acid composition (%) in Hanwoo muscle

Items	Control	Group 1	Group 2
C14:0	3.330±0.19^a	2.890±0.11^b	3.600±0.13^a
C14:1	0.780±0.03^a	0.580±0.01^b	0.720±0.03^a
C16:0	22.130±0.44^b	22.180±0.35^b	23.990±0.54^a
C16:1	3.580±0.23	3.760±0.12	3.480±0.11
C18:0	15.870±0.62^a	14.510±0.35^b	14.270±0.35^b
C18:1 cis	48.270±0.64	46.840±0.40	47.890±0.59
C18:1 trans	4.690±0.21	4.350±0.11	4.490±0.12
C18:2	0.060±0.002	0.060±0.002	0.060±0.002
C18:3	0.310±0.009^{ab}	0.290±0.01^b	0.320±0.01^a
C20:0	0.120±0.003	0.130±0.004	0.120±0.002
C20:1	0.480±0.02^a	0.410±0.014^b	0.460±0.02^{ab}
C20:2	0.070±0.003	0.060±0.002	0.070±0.002
C20:4	0.460±0.02^b	0.470±0.02^b	0.620±0.01^a
C20:3	0.013±0.003	0.020±0.005	0.010±0.006
C20:5	0.018±0.002	0.015±0.001	0.020±0.002
C22:0	0.012±0.001	0.010±0.001	0.011±0.0005
C22:1	0.050±0.003	0.050±0.003	0.050±0.002
C22:6	0.015±0.001	0.013±0.001	0.020±0.004
C24:0	0.014±0.001	0.015±0.002	0.012±0.001
C24:1	0.040±0.002^b	0.050±0.003^a	0.029±0.002^c
ΣSFA	41.330±0.70^{ab}	39.570±0.54^b	41.870±0.73^a
ΣMUFA	52.330±0.66	51.000±0.43	51.830±0.61
ΣPUFA	0.940±0.022^b	0.920±0.03^b	1.110±0.02^a
ΣUSFA	53.260±0.60	51.930±0.56	52.940±0.55
$\Sigma\omega^6$	0.530±0.02^b	0.540±0.02^b	0.690±0.02^a
$\Sigma\omega^3$	0.340±0.01^{ab}	0.320±0.01^b	0.360±0.01^a
$\Sigma\omega^6/\omega^3$	1.580±0.07^b	1.750±0.08^b	1.970±0.07^a

SFA: Saturated fatty acid, MUFA: Mono-unsaturated fatty acid, PUFA: Poly-unsaturated fatty acid, USFA: Unsaturated fatty acid, ω^6: Omega 6 fatty acid, ω^3: Omega 3 fatty acid, ΣSFA: C14:0+C16:0+C18:0, ΣMUFA: C16:1+C18:1+C20:1, ΣPUFA: C18:3+C20:5+C20:3+C20:5+C22:6+C20:2, ΣUSFA: (C16:1+C18:1+C20:1)+(C18:3+C20:5+C20:3+C22:6+C20:2), $\Sigma\omega^6$: C18:3+C20:5+C20:3, $\Sigma\omega^3$: C18:3+C20:5+C22:6, $\Sigma\omega^6/\omega^3$: (C18:3+C20:5+C20:3)/(C18:3+C20:5+C22:6), mean values are presented as Mean±SE. Values in a row with different superscript letters are significantly different ($p<0.05$). Lack of superscript letters indicates no significant difference. Control: Control diet with no added fat, Group 1: Control diet with 50% linoleic acid and 24% oleic acid containing LCFA-Ca salt, Group 2: Control diet with 26% linoleic acid and 50% oleic acid containing LCFA-Ca salt

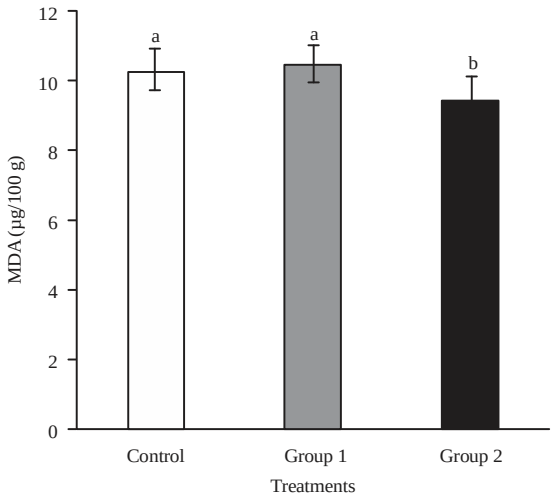

Fig. 1: Effect of long chain fatty acid calcium salts (LCFA-Ca) on malondialdehyde (MDA)

chain fatty acids increased percentages of palmitoleic (C16:1) and linoleic acids (C18:3) in milk. Bhatt *et al.*[40] showed that Ca-FA supplementation was significantly increase in serum non-esterified fatty acid (NEFA) during 90 days but dropped to intermediate level during 180 days.

Malondialdehyde (MDA): Figure 1 presented, group 1 had the highest MDA content than other groups ($p<0.05$). In relation to the oxidative status of the muscle, MDA ranged from 9.50-10.53 µg/100 g. The mean values were obtained in the group 2, which is positive and protects the health of the consumer.

CONCLUSION

This study clearly demonstrated that long chain fatty acid calcium salts (LCFA-Ca) did not affect meat quality of Hanwoo without color (redness) but improved the nucleotide compounds which related to taste and flavor. Blood metabolites were moderately influenced, specifically increased blood triglycerides, cholesterol, LDL and HDL in Hanwoo supplemented by long chain fatty acids calcium salts.

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