Effect of optimal sodium stearoyl-2-lactylate supplementation on growth performance and blood and carcass characteristics in Hanwoo steers during the early fattening period

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INTRODUCTION

Hanwoo steers are usually fattened until almost 30 months and are normally fed high-density concentrate diets from the fattening period onwards. This is to encourage a high degree of marbling, as suggested by Lee et al [1], who reported that Hanwoo steers distinctly improved their marbling between 12 and 27 months of age. Feeding of high-density concentrate diets is used to improve meat quality with high marbling, which is one of the main distinguishing factors determining Hanwoo quality grade [2]. However, feeding of high-density concentrate diets can have a negative effect on digestive metabolism, feed efficiency, and feed intake during the final fattening period [3]. To address these questions, various studies have been carried out on supplementation of emulsifiers in diet [4,5].

Dietary lipid is the nutrient with the highest energy density and needs to be broken down to be readily and efficiently absorbed by the small intestine [6], thus improving dietary lipid digestibility, palatability of the diet and fat yield of cattle [7]. To improve absorption and digestion of lipids, oil in water system surfactants like sodium stearoyl lactylate (SSL) are...
more effective emulsifiers (hydrophilic lipophilic balance, 10 to 12), than water-in-oil system surfactants like lecithin, in resolving the immiscibility of oil and water and to provide stability to an oil/water system [8].

Previous studies have explored different ways of improving lipid utilization [9,10], more specifically, surfactant supplementation for emulsification purposes in ruminants [11]. For example, the beneficial effects of surfactants have been confirmed in ruminal microbial growth rates [10,12], nutrient digestibility [13,14], feed intake [12,15], growth performance [5,16], and ruminal enzyme activity and accessibility [12,17]. However, responses to surfactants have not always shown positive effects on ruminal fermentation and growth performance [18]. As such, the present study was conducted to investigate the efficiency of 0.1% SSL supplementation with different levels of total digestible nutrients (TDN, 0.5% or 1.0% reduction) on growth performance and blood and carcass characteristics in Hanwoo steers during the early fattening period.

**MATERIALS AND METHODS**

All experimental protocols used in this study were approved by the Animal Care Committee of Gyeongsang National University (Jinju, Gyeongsangnam-do, Republic of Korea).

**Chemicals**

SSL is composed of lactic acid mono-esters with sodium salt and its IUPAC (International Union of Pure and Applied Chemistry) chemical name is isocadecanoic acid, 2-(1-carboxyethoxy)-1-methyl-2-oxoethyl ester, sodium salt. SSL has the molecular formula C_{24}H_{43}O_{24}Na (MW, 450.58 g/mol), and is a versatile organic compound with several qualities as a food additive; it improves the volume and mix tolerance of processed foods and is approved by the FDA [19]. Having both lipid utilization [9,10], and ruminal enzyme activity and accessibility [12,17]. However, responses to surfactants have not always shown positive effects on ruminal fermentation and growth performance [18]. As such, the present study was conducted to investigate the efficiency of 0.1% SSL supplementation with different levels of total digestible nutrients (TDN, 0.5% or 1.0% reduction) on growth performance and blood and carcass characteristics in Hanwoo steers during the early fattening period.

**Diet chemical analysis**

Experimental diet samples were dried in a forced-air oven at 130°C for 2 h, then finely ground to a size that could pass through a 2 mm sieve in a Wiley mill (Model 4, Thomas Scientific, Swedesboro, NJ, USA). The ground samples were analyzed for dry matter (Method 930.15), crude protein (Method 990.13), Ca (Method 984.01), and P (Method 965.17) according to AOAC procedures. Ether extraction was measured by the diethyl ether extraction method using a Buchi B-811 Universal Extraction System (Buchi, Flawil, Switzerland); crude fiber was analyzed by the filter bag technique using the ANKOM 220 Fiber Analyzer (Mill tech, Seongnam, Republic of Korea).

**Physical and carcass traits**

The BW was recorded individually at the beginning of the experiment, after a 2-month interval, and at the end of the experiment. Weight gain was calculated the difference between initial and final BW, and feed efficiency by dividing BW by

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**Table 1. Animal characteristics and dietary treatments**

| Item                | CON     | TRT 0.5 | TRT 1.0 |
|---------------------|---------|---------|---------|
| No. of heads        | 20      | 20      | 20      |
| Body weight (kg)    | 333.2 ± 45.0 | 333.0 ± 28.1 | 331.7 ± 36.1 |
| Age (month)         | 13.7 ± 0.7 | 13.8 ± 0.8 | 13.5 ± 1.0 |
| Castration (month)  | 8.5     | 8.5     | 8.5     |

CON, control; TRT, treatment; TDN, total digestible nutrients; SSL, sodium stearoyl-2-lactylate.

* CON, basal diet; TRT 0.5, 0.5% downspec of TDN with 0.1% addition of SSL; TRT 1.0, 1.0% downspec of TDN with 0.1% addition of SSL.

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Blood samples were obtained by direct venipuncture of the jugular vein at the end of the experimental period, prior to the morning feeding. Whole blood samples (3 mL) were collected into 10 mL BD vacuum tubes with sodium heparin (Becton and Dickinson, Franklin Lakes, NJ, USA). After allowing to clot at 4°C for 24 h, samples for serum analysis were centrifuged at 3,000 rpm for 10 min at 4°C, and then separated and stored at –70°C. Blood samples were analyzed using a Hitachi 7020 automatic blood analyzer (Hitachi, Tokyo, Japan) for total protein, phosphorus, albumin, total bilirubin, cholesterol, aspartate aminotransferase (AST), alanine aminotransferase (ALT), Ca, gamma glutamyl transferase, blood urea nitrogen (BUN), creatinine, total triglycerides, non-esterified fatty acid, and glucose.

Whole blood samples were used to measure hematological parameters including red blood cell (RBC), hemocrit (HCT), hemoglobin (HGB), mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, white blood cell (WBC), neutrophil (NEU), lymphocyte (LYM), monocyte (MONO), eosinophil, basophil, and platelet counts.

### Statistical analysis

All data for steers within each treatment were averaged and analyzed using the PRO GLM procedure of the SAS statistical program, version 9.1 (2005; SAS Inst. Inc., Cary, NC, USA) with the statistical model of $Y_{ij} = \mu + TRT_i + e_{ij}$, where $Y_{ij}$ is an observation on the dependent variable $ij$, $\mu$ is the overall population mean, TRT, is the fixed effect of treatments, and $e_{ij}$ was the random error associated with the observation $ij$. Duncan's multiple range test was used to identify any significant differences among the mean values of the treatments. Variability in the data was expressed as the standard error of the mean, and $p<0.05$ was considered statistically significant, whereas $p<0.10$ was considered a tendency.

## RESULTS AND DISCUSSION

### Growth performance

This experiment was conducted to evaluate the effect of different levels of TDN (CON, 72.54%; TRT 0.5, 72.2%; TRT 1.0, 71.5%) and SSL supplementation (TRT 0.5 and TRT 1.0; additional SSL 0.1%) on growth performance in Hanwoo steers. Throughout the experiment, a major source of the diet (i.e. concentrates and forages) supplied to the steers was restricted and others were similar among different treatments. Therefore, feed intakes divided into three periods are presented as mean values: each total feed intake was 6.66 kg DM/d (4.86 kg of concentrate and 1.8 kg of forage) for days 0 to 60; 7.20 kg DM/d (5.85 kg of concentrate and 1.35 kg of forage) for days 61 to 120; and 7.65 kg DM/d (6.75 kg of concentrate and 0.9 kg of forage) for days 121 to 200, according to a commercially used early fattening program for Hanwoo steers.
As shown in Table 3, the final body weight for TRT 0.5 (392.4, 442.1, and 502.1 kg) increased as compared with CON (385.5, 439.9, and 496.8 kg) and TRT 1.0 (376.3, 429.1, and 487.7 kg) in all three periods; however, the difference was not significant (p>0.05) indicating that SSL supplementation had no negative effect. Our results are in agreement with Jeong et al [5] who reported that TDN down spec with SSL 0.03% supplementation showed no significant differences in average daily gain and final body weight in the final fattening period of Hanwoo steers as compared with CON. Why the different TDN levels with 0.1% SSL supplementation had no significant negative effect on final body weight may be that supplemented non-ionic surfactants can enhance ruminal fermentation and improve feed utilization efficiency, which can be attributed to stimulating effects of non-ionic surfactants on growth performance, as demonstrated by Lee et al [17] and Wang et al [15]. Furthermore, Nylander and Wang [8] demonstrated that SSL is an extremely efficient at facilitating the formation of fat-in-water emulsions for lipid digestion in the small intestine and can therefore lead to improved growth performance. However, TRT 1.0 (TDN 1.0% down spec with SSL 0.1%) was shown to reduce body weight as compared with CON and TRT 0.5 (TDN 0.5% down spec with SSL 0.1%). During the early fattening period, steers need relatively high levels of TDN in their diets to support normal and sustained growth [23,24] and, even a 1% lower TDN may significantly affect growth performance despite SSL supplementation.

Feed efficiency, which results in either greater body weight or less feed intake [25], improved with TRT 0.5 (15.12 and 10.03) as compared with CON (13.30 and 9.42) and TRT 1.0 (11.35 and 9.70) at 1 to 60 and 121 to 200 days, but was not statistically significant (p>0.05) as shown in Table 3. Nonetheless, SSL supplementation in Hanwoo steers improved feed efficiency, which is in agreement with previous studies by Jeong et al [5], who showed that TDN down spec with SSL 0.03% supplementation had no significant negative effect on feed efficiency when compared to controls.

In general, the purpose of adding appropriate fats or oils to the feed of high-producing steers, in the early fattening period is to supply available energy for the rumen microbes resulting in improvements in feed efficiency and growth performance [26]. Consequently, average daily gain and feed efficiency in the whole early fattening period of TRT 0.5 (0.85 and 11.68 kg) was higher than CON (0.82 and 11.27 kg) or TRT 1.0 (0.78 and 10.74 kg), suggesting that a 0.1% SSL supplementation in the feed of early fattening steers can potentially result in a net a saving of 0.5% TDN without any negative effect.

**Table 3.** Effects of sodium stearoyl-2-lactylate (SSL) supplementation on growth performance during the early fattening stage in Hanwoo steers

| Item                        | Treatment 0.5 | Treatment 1.0 | SEM | p-value |
|-----------------------------|---------------|---------------|-----|---------|
| Final body weight (kg)      | 385.5         | 392.4         | 376.3 | 484.8   | 0.4015 |
| Average daily gain (kg)     | 0.89          | 1.01          | 0.76 | 0.05    | 0.1405 |
| DM intake, concentrate      | 4.86          | 4.86          | 4.86 | -       | -       |
| rice straw                  | 1.80          | 1.80          | 1.80 | -       | -       |
| Feed efficiency             | 13.30         | 15.12         | 11.35 | 0.76   | 0.1410 |

| Item                        | Treatment 0.5 | Treatment 1.0 | SEM | p-value |
|-----------------------------|---------------|---------------|-----|---------|
| Final body weight (kg)      | 439.9         | 442.1         | 429.1 | 5.07   | 0.5362 |
| Average daily gain (kg)     | 0.89          | 0.81          | 0.87 | 0.02    | 0.3065 |
| DM intake, concentrate      | 5.85          | 5.85          | 5.85 | -       | -       |
| rice straw                  | 1.35          | 1.35          | 1.35 | -       | -       |
| Total DM intake, concentrate | 7.20          | 7.20          | 7.20 | -       | -       |
| Feed efficiency             | 12.40         | 11.32         | 12.02 | 0.29   | 0.3209 |

**Table 4.** Effects of sodium stearoyl-2-lactylate (SSL) supplementation on blood metabolite values during the early fattening stage in Hanwoo steers

| Item                        | Treatment 0.5 | Treatment 1.0 | SEM | p-value |
|-----------------------------|---------------|---------------|-----|---------|
| Total protein (g/dL)        | 6.29          | 6.23          | 6.19 | 0.07    | 0.5216 |
| Phosphorous (mg/dL)         | 7.93          | 7.72          | 7.45 | 0.06    | 0.2514 |
| Albumin (g/dL)              | 3.53          | 3.46          | 3.41 | 0.03    | 0.1432 |
| Total bilirubin (mg/dL)     | 0.28          | 0.27          | 0.27 | 0.004   | 0.5389 |
| Cholesterol (mg/dL)         | 146.21        | 155.58        | 166.50 | 1.96   | 0.3204 |
| ALT (IU/L)                  | 67.08         | 64.67         | 64.73 | 0.44    | 0.2956 |
| Ca (mg/dL)                  | 4.43          | 4.62          | 4.71 | 0.08    | 0.1977 |
| GGT (mg/dL)                 | 21.35         | 21.75         | 23.56 | 0.32   | 0.1538 |
| BUN (mg/dL)                 | 10.07         | 10.96         | 9.93 | 0.14    | 0.2548 |
| Creatine (mg/dL)            | 1.19          | 1.15          | 1.16 | 0.02    | 0.2648 |
| Total glyceride (mg/dL)     | 23.47         | 23.25         | 22.75 | 0.21   | 0.3512 |
| NEFA (μEq/L)                | 199.68        | 166.28        | 141.23 | 4.63   | 0.4155 |
| Glucose (mg/dL)             | 117.29        | 108.33        | 109.90 | 1.23   | 0.1258 |

CON, control; TRT, treatment; SEM, standard error of the mean; AST, aspartate aminotransferase; ALT, alanine aminotransferase; GGT, gamma glutamyl transferase; BUN, blood urea nitrogen; NEFA, non-esterified fatty acid; TDN, total digestible nutrients.

1) CON, basal diet; TRT 0.5, 0.5% downspec of TDN with 0.1% addition of SSL; TRT 1.0, 1.0% downspec of TDN with 0.1% addition of SSL.

Blood characteristics

Blood metabolite concentrations and blood corpuscle of early fattening steers supplemented with 0.1% SSL and different levels of TDN down spec (0.5% and 1.0%) are shown in Table 4 and 5, Blood metabolite concentrations is considered a useful in-
indicator for monitoring nutrient status, and body condition, for prevention of disease [27,28], and to evaluate the internal metabolic changes and the function of different organs in cattle, including the kidneys and liver. No significant differences were observed amongst all treatments (p>0.05) and the values of all blood metabolite concentrations were all within the normally accepted ranges for healthy steers, as suggested by Alex [29]. In particular, the levels of albumin, creatinine, BUN, AST, ALT, all associated with liver and tissue damage, did not show any significant differences, indicating that different levels of TDN down spec (0.5% and 1.0%) are shown in Table 5. Carcass yield decreased with TRT 0.5 (UBE, 4.62 mm and UEMA, 64.04 cm²) as compared with CON (UBE, 5.33 mm and UEMA, 63.45 cm²) and TRT 1.0 (UBE, 5.45 mm and UEMA, 64.04 cm²); however, no significant differences were observed amongst all the treatments (p>0.05). Value for meat quality traits also decreased with TRT 0.5 (UMB, 3.00, meat quantity grade, 2.70 and meat quality grade 1.30) as compared with CON (UMB, 3.60, meat quantity grade, 2.60 and meat quality grade 1.40) and TRT 1.0 (UMB, 3.50, meat grade quantity, 2.70 and meat quality grade 1.40); again, no significant differences were observed amongst all the treatments (p>0.05).

Realini et al [30] have suggested that backfat thickness increases noticeably in the final fattening period, from the growing period to 14 days before slaughter. Additionally, Kim [31] suggested that backfat thickness of Hanwoo steers generally develops rapidly, after the steers had attained 500 kg BW. As research was conducted during the early fattening period when the average BW of steers ranged from 332.63 to 495.53 kg, further studies are needed to better understand how TDN downspec and SSL supplementation can subsequently influence carcass yield and quality.

CONCLUSION

In summary, in this study we demonstrated that average daily

**Table 5. Effect of sodium stearoyl-2-lactylate (SSL) supplementation on blood corpuscle values during the early fattening stage in Hanwoo steers**

| Item      | Treatment 1) | SEM | p-value |
|-----------|--------------|-----|---------|
|           | CON | TRT 0.5 | TRT 1.0 |
| RBC (M/μL) | 8.26 | 8.70 | 7.86 | 0.16 | 0.2151 |
| HCT (%)    | 34.40 | 36.76 | 35.10 | 0.29 | 0.1263 |
| HGB (g/dL) | 12.13 | 12.83 | 12.15 | 0.07 | 0.1684 |
| MCV (fl)   | 41.69 | 42.33 | 44.75 | 0.33 | 0.2084 |
| MCH (pg)   | 14.71 | 14.78 | 15.50 | 0.18 | 0.1634 |
| MCHC (g/dL)| 35.31 | 34.94 | 34.69 | 0.14 | 0.2441 |
| WBC (K/μL) | 10.61 | 10.51 | 11.17 | 0.14 | 0.1642 |
| NEU (K/μL) | 3.59 | 3.66 | 3.04 | 0.03 | 0.0954 |
| LYM (K/μL) | 5.80 | 5.37 | 6.28 | 0.24 | 0.0864 |
| MONO (K/μL)| 0.64 | 0.58 | 0.73 | 0.03 | 0.0674 |
| EOS (K/μL) | 0.86 | 0.86 | 1.08 | 0.03 | 0.1251 |
| BASO (K/μL)| 0.02 | 0.01 | 0.03 | 0.001 | 0.1254 |
| PLT (K/μL) | 156.61 | 208.23 | 204.50 | 0.39 | 0.2634 |

CON, control; TRT, treatment; SEM, standard error of the mean; RBC, red blood cell; HCT, hematocrit; HGB, hemoglobin; MCV, mean corpuscular volume; MCH, mean corpuscular hemoglobin; MCHC, mean corpuscular hemoglobin concentration; WBC, white blood cell; NEU, neutrophil; LYM, lymphocyte count; MONO, monocyte; EOS, eosinophil; BASO, basophil; PLT, platelet count; TDN, total digestible nutrients.

1) CON, basal diet; TRT 0.5, 0.5% downspec of TDN with 0.1% addition of SSL; TRT 1.0, 1.0% downspec of TDN with 0.1% addition of SSL.

**Table 6. Effect of sodium stearoyl-2-lactylate (SSL) supplementation on yield and quality traits during the early fattening stage in Hanwoo steers**

| Item | Treatment 1) | SEM | p-value |
|------|--------------|-----|---------|
|      | CON | TRT 0.5 | TRT 1.0 |
| UBF (mm) | 5.33 | 4.62 | 5.45 | 0.21 | 0.461 |
| UEMA (cm²) | 63.45 | 62.44 | 64.04 | 0.69 | 0.692 |
| UMS (No. 1 – 9) | 3.60 | 3.00 | 3.50 | 0.26 | 0.538 |
| Meat quantity grade 2) | 2.60 | 2.70 | 2.70 | 0.06 | 0.825 |
| Meat quality grade 3) | 1.40 | 1.30 | 1.40 | 0.06 | 0.783 |

CON, control; TRT, treatment; SEM, standard error of the mean; UBF, ultrasound backfat thickness; UEMA, ultrasound eye muscle area; UMS, ultrasound marbling score; TDN, total digestible nutrients.

1) CON, basal diet; TRT 0.5, 0.5% downspec of TDN with 0.1% addition of SSL; TRT 1.0, 1.0% downspec of TDN with 0.1% addition of SSL.

2) Meat quantity grade (A grade = 3; B grade = 2; C grade = 1).

3) Meat quality grade (2 to 3 grade = 1; 1 to 2 grade = 2; 1+ to 1++ grade = 3).

**Carcass characteristics**

Carcass yield and quality traits of early fattening steers supplemented with 0.1% SSL and different levels of TDN downspec (0.5% and 1.0%) are shown in Table 6. Carcass yield decreased with TRT 0.5 (UBE, 4.62 mm and UEMA, 62.44 cm²) as compared with CON (UBE, 5.33 mm and UEMA, 63.45 cm²) and TRT 1.0 (UBE, 5.45 mm and UEMA, 64.04 cm²); however, no significant differences were observed amongst all the treatments (p>0.05). Value for meat quality traits also decreased with TRT 0.5 (UMB, 3.00, meat quality grade, 2.70 and meat quality grade 1.30) as compared with CON (UMB, 3.60, meat quality grade, 2.60 and meat quality grade 1.40) and TRT 1.0 (UMB, 3.50, meat grade quantity, 2.70 and meat quality grade 1.40); again, no significant differences were observed amongst all the treatments (p>0.05).

In summary, in this study we demonstrated that average daily
gain and feed efficiency improved with TRT 0.5 as compared to CON and TRT 1.0 and without causing any adverse effects, implying that 0.1% SSL supplementation in the feed of early fattening steers may potentially result in a saving of 0.5% TDN. With respect to blood and carcass characteristics, no significant differences were observed amongst all treatments (p>0.05). The values of all blood parameters were within the normally accepted range for healthy steers. Therefore, SSL supplementation with TND down-speccing appears to be a viable feed cost-saving measure for fattening of Hanwoo steers, without any adverse effects. However, further studies are needed to better understand the effect of TND down-speccing and SSL supplementation on growth performance and blood and carcass characteristics, in both the early and final fattening periods of Hanwoo steers.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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