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Is It Feasible Nutritionally to Improve Both Quality and Quantity of Meat Carcasses from Beef Steers?*

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ABSTRACT : Beef producers are trying to produce not only better quality but also greater quantity of beef in order to meet the preferences of some consumers at a lower cost. This can be accomplished if we understand the factors regulating lipid deposition in intramuscular adipose tissue and the tenderness of meat. Propylene glycol (PG) might be used as a precursor of intramuscular fat synthesis especially in the late period of fattening because adipose tissue in ruminants is thought to mature sequentially in abdominal, intermuscular, subcutaneous and intramuscular depots. The action of cholecalciferol supplementation has been verified in producing more tender meat through the enhancement of calpain activity over the postmortem ageing period. A synergistic effect can be expected if the dietary cation and anion difference (DCAD) technique is used in combination with dietary supplementation of cholecalciferol. In another approach, the optimization of hormonal implant use also may provide similarly marbled beef at a much lower cost. (**Key Words :** Quality, Quantity, Propylene Glycol, Cholecalciferol, Implant, Beef Steer)

INTRODUCTION

The world meat industry faces a dual challenge: it must reduce the fat content of meat carcasses in order to provide a nutritious product with a minimum of waste, while not affecting meat palatability. The positive effects of marbling on tenderness and palatability as well as a meat grading system that penalizes carcasses with little marbling make it essential that animals be produced with minimal amounts of fat stored in depots such as the subcutaneous and perirenal depots, without markedly decreasing intramuscular adipose tissue. This can be accomplished only if the factors regulating lipid deposition on intramuscular adipose tissue and other fat depots (Nade et al., 2003; Vega et al., 2004) differ substantially (Smith and Crouse, 1984). Adipose tissue depots in ruminants are thought to develop in the order of abdominal, intermuscular, subcutaneous and finally intramuscular (Vernon, 1981). The data suggest that abdominal fat changes largely in line with body weight while all other depots increase relative to carcass weight. Tenderness has also been identified as one of the most important factors affecting consumers' satisfaction and perception of beef (Cheong et al., 2006; Li et al., 2006). Results of numerous experiments have indicated that the calcium dependent calpain proteolytic system has a major role and is responsible for meat tenderization during the post mortem period. Supplemental dietary vitamin D_3 increases blood calcium markedly through the actions of additional 1, 25 dihydroxy vitamin D_3 which in turn causes increased beef steak tenderness through the activation of the calpain system during postmortem aging of beef (Horst and Littledike, 1979).

In terms of quantity of beef production, anabolic steroids have been widely used in the beef cattle industry over 50 years as feed additives and implants to increase growth performances and profitability. However, the use of implants, particularly those containing trenbolone acetate, has detrimental effects on carcass quality and beef tenderness. This procedure, therefore, has generated a negative impact on consumer satisfaction and carcass value.

This paper explores possible interactions between these established mechanisms in an endeavor to optimize animal growth and carcass composition.

PROPYLENE GLYCOL (PG) AS A PRECURSOR OF FAT SYNTHESIS

Administration of glucogenic precursors such as PG is

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Table 1. Effect of propylene glycol (PG) on ruminal VFA levels (mol/100 mol) and the acetate to propionate ratio in Korean native steers

Items[a]	Control	Treated[b]	SEM	p-value[c]
Acetate (A)	65.0	58.1	0.81	0.032
Propionate (P)	19.3	25.3	0.73	0.044
Isobutyrate	1.3	1.6	0.14	0.275
Butyrate	9.5	9.8	0.21	0.739
Isovalerate	2.4	1.9	0.18	0.070
Valerate	2.5	3.3	0.19	0.057
A:P	3.4	2.3	0.20	0.042

[a] Least square means. [b] 2.5 ml/BW$^{0.75}$ kg/d of PG. [C] n = 10.
(Kim et al., 2005)

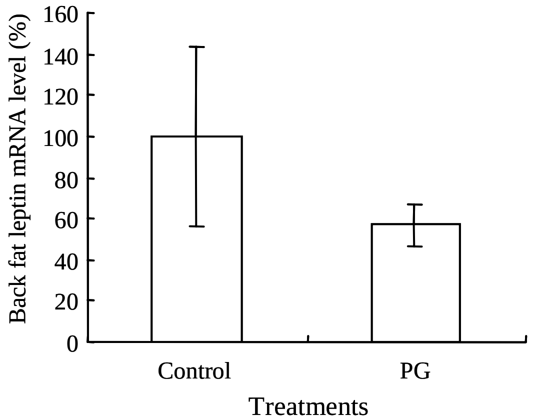

Figure 1. Leptin mRNA level in subcutaneous back fat tissue at the end of fattening period in Korean native steers non-treated (Control) and fed 2.5 ml/kg$^{0.75}$/d of propylene glycol (PG) over 120 d. The data are expressed as a percentage of the value observed in the control. The mRNA value was 100 and 57% for control and PG groups, respectively. Each bar was normalized by the quantity of cyclophilin from the same tissue. The bar graph represents the mean±SEM of 4 steers (Kim et al., 2005).

effective in reducing plasma NEFA to prevent ketosis through early lactation in dairy cows. The decrease in NEFA is probably mediated by insulin, which is anti-lipolytic and responsive to elevated blood glucose. An oral drench of 296 ml of PG once per day was effective in increasing blood glucose and insulin and in reducing plasma NEFA and BHBA (Christensen et al., 1997). Thus, an experiment was conducted based on the hypothesis that the administration of 300-500 ml of PG fed once a day for the 2-3 months prior to marketing will increase the level of marbling of beef (Kim et al., 2005). The volatile fatty acid concentrations in the rumen during the period of PG are shown in Table 1. The proportion of propionate was significantly (p = 0.044) increased due to PG feeding. However, this is unlikely to increase markedly the supply of glucose as a precursor for fat synthesis through gluconeogenesis in the liver because PG is rapidly absorbed from the rumen and gut. PG significantly increased (p = 0.047) serum insulin concentration while only a slight

Table 2. Effect of propylene glycol (PG) on serum glucose and insulin levels in Korean native steers

Items[a]	Control	Treated[b]	SEM	p-value[c]
Glucose (mg/dl)	75.4	86.2	6.31	0.161
Insulin (μIU/ml)	30.6	40.5	2.23	0.047

[a] Least square means. [b] 2.5 ml/BW$^{0.75}$ kg/d of PG. [C] n = 10.
(Kim et al., 2005)

Table 3. Effect of propylene glycol (PG) on carcass traits of Korean native steers

Items[a]	Control	Treated[b]	SEM	p-value[c]
Final wt (kg)	644.5	656.0	37.60	0.599
Cold carcass wt (kg)	375.1	384.3	27.68	0.429
Longissmus muscle area (cm^2)	84.5	89.9	10.48	0.147
Backfat thickness (mm)	10.5	11.4	1.10	0.8613
Marbling score[d]	5.8	6.2	0.53	0.186

[a] Least square means.
[b] 2.5 ml/BW$^{0.75}$ kg/d of PG. [c] n = 10.
[d] Grading ranges are 1 to 7, higher numbers for better quality.
(Kim et al., 2005)

increase in serum glucose status was found (Table 2). This discrepancy indicates that PG may be more effective in increasing blood glucose when steers are experiencing nutrient deprivation (Christensen et al., 1997) than when steers are consuming feed *ad libitum*. The use of PG in steers improved marbling scores to some extent although this was not statistical significant. However, we also found that PG was not only used for intramuscular fat synthesis but also for subcutaneous fat synthesis as backfat thickness of PG-fed steers was increased when compared with control steers (Table 3). The back fat of PG-fed steers did not differ in leptin mRNA from control steers whereas increased leptin mRNA was found in intramuscular fat with PG feeding as shown in Figure 1 and 2, respectively. Clearly, further work is required to optimize the timing and dose rate for the use of PG in steers.

MANIPULATION OF CHOLECALCIFEROL AND CALCIUM METABOLISM

A significant body of research has been conducted to evaluate metabolic possibilities for increasing entry of calcium to blood by altering dietary cation and anion difference (DCAD) for the periparturient dairy cow to prevent milk fever. Lomba et al. (1978) summarized data showing that calcium absorption increased because of the acidic nature of anions in the intestine. Chronic metabolic acidosis caused by DCAD increases urinary excretion of calcium. If excessive anions produce metabolic acidosis and increase the excretion of calcium, calcium retention decreases resulting in the formation of 1, 25 dihydroxy cholecalciferol and release of parathyroid hormone to stimulate bone mobilization. Another possible mechanism is that the production of renal 1, 25 dihydroxy cholecalciferol

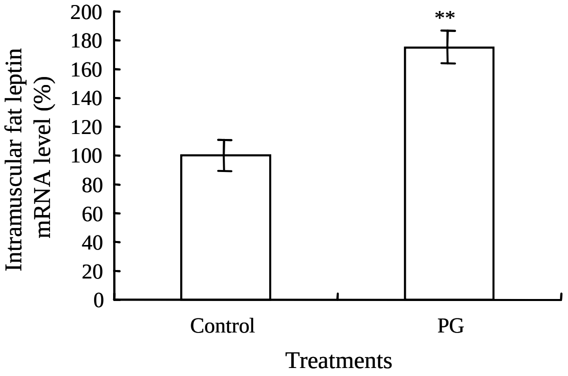

Figure 2. Leptin mRNA level in Longissimus intramuscular fat at the end of fattening period in Korean native steers non-treated (control) and fed (2.5 ml/kg$^{0.75}$/d of propylene glycol PG) over 120 d. The data are expressed as a percentage of the value observed in the control. The mRNA value was 100 and 175% for control and PG groups, respectively. Each bar was normalized by the quantity of cyclophilin from the same tissue. The bar graph represents the mean±SEM of 4 steers. The asterisks indicate that the mean for PG-fed steers differs (p<0.01) from control steers (Kim et al., 2005).

is an enzyme-dependent process that is pH-sensitive. Any changes in intracellular pH would alter the activity of enzymes. Excessive anions possibly create an intracellular pH that is more favorable for the production of 1, 25 dihydroxy cholecalciferol. This possibility is supported by the work of Gaynor et al. (1989). The control of the manipulation of DCAD, therefore, could favorably increase calcium content in the skeletal muscle of steers as well. In terms of cholecalciferol itself, supplemental dietary vitamin D_3 increases blood calcium markedly via actions of additional 1, 25 dihydroxy cholecalciferol. Skeletal muscle is an important target organ for vitamin D_3.

Tourney et al. (1990) showed that vitamin D supplementation to rats increased bound calcium at the Z-line and increased cytosolic skeletal muscle calcium. Indeed, Montgomery et al. (2002) found higher calcium concentrations in plasma from steers fed diets containing vitamin D_3 for 9 days just before market. Also loin steaks from steers fed vitamin D were more tender, presumably due to increased proteolysis induced by the calpains. As a whole, we might effectively produce more tender beef using the combination of the interventions outlined above. Thus, a trial will be implemented in which steers will be fed DCAD diets for 14 days and then supplemented with a vitamin enriched diet for 9 days prior to slaughter to increase meat tenderness. The above treatment may be more effective in aged cattle such as multiparous cows (Cho et al., 2006) rather than yearling steers.

COMBINED TRENBOLONE ACETATE AND ESTRADIOL AS A GROWTH PROMOTER

Implantation of feedlot steers with 120 mg of trenbolone acetate and 24 mg of estradiol increases rate of

Table 4. Effect of combined trenbolone acetate (TBA)+estadiol (E2) implant[a] on performance of Korean native steers

Item[b]	Control	Treaded[c]	SEM	%[d]	p-value[e]
Average daily gain (kg)	0.60	0.92	0.05	53.3	0.001
Dry matter intake (kg)	7.67	9.12	0.32	18.9	0.057
Feed/gain	12.78	9.91	0.21	28.9	0.038

[a] Steers were implanted at the age of 15 months. [b] Least square means.
[c] 120 mg of TBA and 24 mg of E2. [d] Percentage of control. [e] n = 7.

Table 5. Effect of combined trenbolone acetate (TBA)+estadiol (E2) implant[a] on carcass traits of Korean native steers

Item[b]	Control	Treaded[c]	SEM	p-value[d]
Final weight (kg)	635.4	638.7	8.3	0.85
Hot carcass weight (kg)	366.1	373.3	6.1	0.56
Longissimus muscle area (cm^2)	81.6	86.7	1.3	0.04
Backfat thickness (mm)	7.9	7.9	0.9	1.00
Marbling score[e]	4.4	3.3	0.5	0.24

[a] Steers were implanted at the age of 15 months. [b] Least square means.
[c] 120 mg of TBA and 24 mg of E2. [d] n = 7.
[e] Grading ranges are 1 to 7, higher numbers for better quality.

Table 6. Effect of combined trenbolone acetatee (TBA)+estadiol (E2) implant[a] on serum metabolite levels in Korean native steers

Item[b]	Control	Treaded[c]	SEM	p-value[d]
Glucose (mg/dl)	65.9	62.3	4.2	0.19
NEFA (μEq/L)	212.4	273.1	7.3	0.21
3-OH-butylate (μmol/ml)	0.81	0.86	0.03	0.19
Leptin (ng/ml)	2.5	2.3	0.05	0.09
IGF-1 (ng/ml)	378.9	711.7	15.1	0.001

[a] Steers were implanted at the age of 15 months. [b] Least square means.
[c] 120 mg of TBA and 24 mg of E2. [d] n = 7.

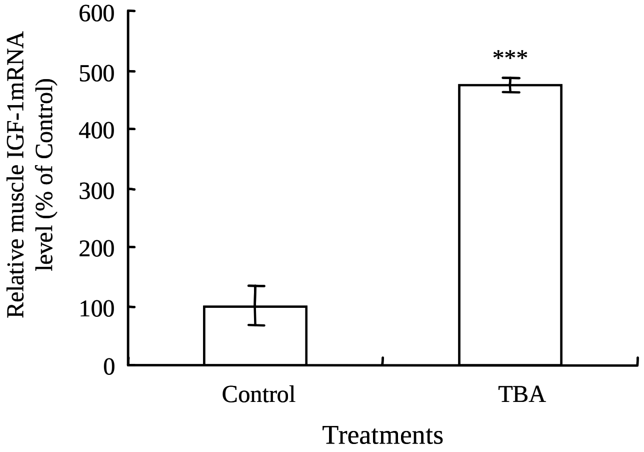

Figure 3. IGF-1 mRNA level in Longissimus muscle on d26 after implantation in Korean native steers non-implanted (Control) and TBA implanted (120 mg TBA and 20 mg E2). The bar graph indicates the mean±SEM of three independent real time PCR analyses. *** Means significantly different from control (p<0.001).

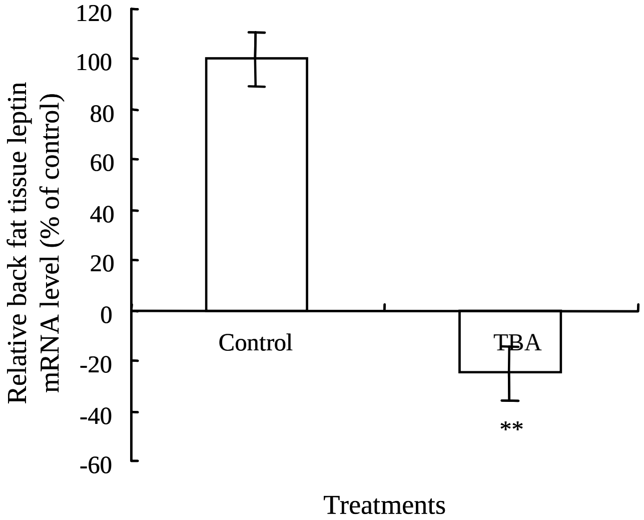

Figure 4. Leptin mRNA level in back fat tissue on d26 after implantation in Korean native steers non-implanted (Control) and TBA implanted (120 mg TBA and 20 mg E2). The bar graph indicates the mean±SEM of three independent real time PCR analyses. ** Means significantly different from control (p<0.01).

gain (20 to 25%), feed efficiency (15 to 20%), carcass protein and longissimus muscle area (Johnson et al., 1996). We also found that the implantation of combined trenbolone acetate and estradiol had almost the same effect as above (Tables 4 and 5). This enhancement of muscle growth could involve alterations in the proliferation rate and activation state of muscle satellite cells. Steers receiving the implant displayed increased circulating IGF-1 concentrations compared with nonimplanted steers (Table 6). The longissimus muscles of steers receiving the implant contained increased IGF-1 mRNA levels compared with longissimus muscles of nonimplanted steers (Pampusch et al., 2003), as we also found in Figure 3. These workers hypothesized that the increased IGF-1 level in muscle of implanted steers stimulates satellite cell proliferation and maintains a high number of proliferating satellite cells at a point in the growth curve where satellite cell numbers and activity are normally declining. This would prolong the period of rapid muscle growth resulting in the observed increased rate and efficiency of muscle deposition in implanted steers. The worst consumer perception of the use of hormonal implants might emanate from detrimental effects on carcass quality and beef tenderness. In fact, the marbling score of implanted Korean native steers decreased slightly when compared with control nonimplanted steers (Table 5). Actually, the leptin mRNA expression of the subcutaneous backfat was downregulated, as shown in Figure 4. However, this could be overcome because using a moderate implant program in cattle has no detrimental effects on beef tenderness and consumer acceptability (Barhm et al., 2003). Trenbolone acetate and estradiol implantation resulted in market live weights being achieved 4 months earlier than in control steers, which was presumably due to the increased serum IGF-1 concentration in Korean native steers. Furthermore, there was no significant deterioration of carcass traits with this treatment.

A SCHEMATIC PROGRAM FOR IMPROVING BOTH QUALITY AND QUANTITY OF CARCASS MEAT FROM KOREAN NATIVE STEERS AS A MODEL

Based on current and previous findings, it could be hypothesized if all the techniques involved in enhancing quality and quantity of beef could be managed in a program successfully, then we might be able to harvest better quality beef at a lower cost. We therefore propose a program for the improvement of both quality and quantity of carcass meat using Korean native steers as a model for which feeding situations could be altered to suit the feed-base available in the countries in which they are found (Figure 5). We propose that combined trenbolone acetate and estradiol can be implanted at 15 months of age, when animals weigh approximately 400 kg, until they reach 19 months of age at a live weight of 520 kg. Steers will be offered 2.5 ml/ $BW^{0.75}$ kg/d (300 ml) of PG in addition to a concentrate ration over the 3 months from 20 to 23 months of age to increase intramuscular fat synthesis immediately prior to slaughter. In order to improve tenderness of beef, the efficacy of two additional treatments should be assessed for use in the weeks prior to slaughter. A DCAD modified diet could be supplied to increase calcium mobilization ability from bone tissue and the activity of 1, 25 dihydroxy cholecalciferol in renal tissue over 14 days (697 to 711 days

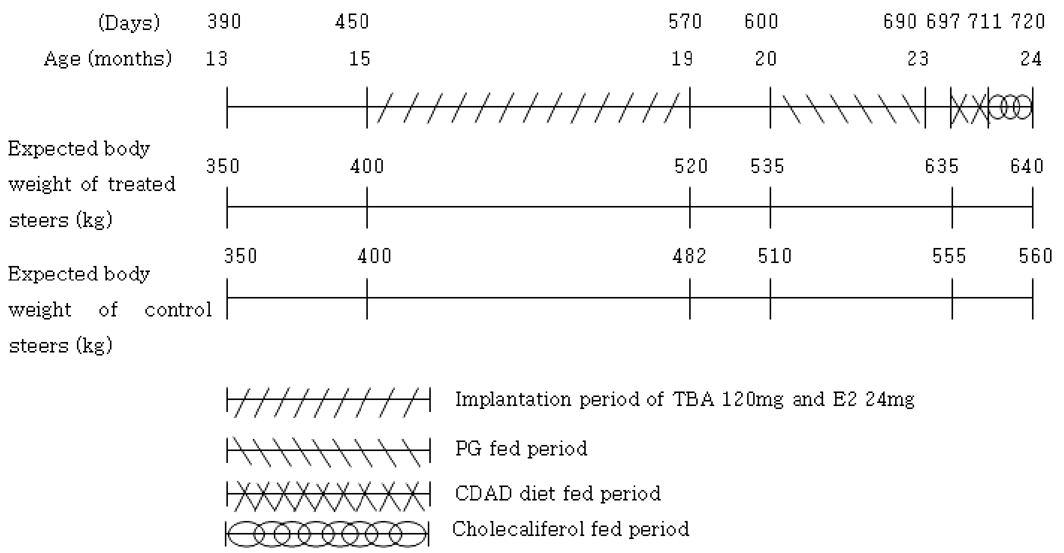

Figure 5. Time course of the program.

of age). The dietary DCAD could be adjusted to +21 mEq/100 g with $MgSO_4 \cdot 7H_2O$, $MgCl_2 \cdot 6H_2O$ and $CaCo_3$. Lastly, the calcium pool of skeletal muscle could be effectively improved by conducting force-feeding of 25-hydroxy cholecalciferol (125 mg/head/day) on day 6 before slaughter, which could stimulate calpain activity, thereby increasing tenderness for consumers (Cho et al., 2006). These three treatments could quite effectively counteract the negative perceptions for meat quality resulting from the use of anabolic steroids and related therapies proposed by certain sectors of society.

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