MEAT QUALITY AND FATTY ACID COMPOSITION OF BEEF FROM DAIRY STEERS FINISHED ON TOTAL MIXED RATION OR *PHALARIS ARUNDINACEA* HAYLAGE

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Abstract – Ten Friesian-Holstein steers (344 ± 12.21 kg) were finished on two different diets (n=5); about 18 kg daily intake per animal of total mixed ration (TMR) or ad libitum *Phalaris arundinacea* haylage for 150 days. Physicochemical properties, fatty acid composition and sensory scores of *longissimus lumborum* were evaluated. The meat of grass-fed group was more lean, darker and tougher in appearance; it had higher moisture content, pH, hardness, gumminess, chewiness, CIE a* and CIE b* values with lower fat content, tenderness, cooking yield and CIE L* value. Lower omega-6 to omega-3 ratio was found in beef from grass-fed group which had significantly higher α-linolenic acid (ALA), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) than TMR group. Nevertheless, sensory scores revealed that roasted grass-fed beef had less acceptability because it was less tender, less juicy and had undesirable aroma. Proper cooking should be applied for serving omega-3 rich beef which is sensitive to oxidation by high temperature. The use of *Phalaris arundinacea* haylage in dairy steers production is considered giving advantage to produce lean and healthy beef.

Key Words – Haylage, healthy beef, α-linolenic acid.

I. INTRODUCTION

In general, omega-3 and omega-6 fatty acids are well-known to be essential for human health. However, health problems may arise when it is consumed at imbalance ratio (1:10). The consumption of beef from grass-fed cattle with higher omega-3 fatty acid concentrations than grain-fed cattle contribute to maintaining human health. French et al. [1] mentioned that grass intake could decrease the deposition of omega-6 fatty acid in the muscle of the bovine and conversely increased omega-3 fatty acids. Further study regarding the effects of grass feeding in this respect is thus necessary. As feeding high-energy diet in order to produce high-quality beef from dairy industry is quite expensive, utilizing grass haylage from existing pasture around the industry to dairy steers is considered more efficient. This study presents the differences of meat quality, fatty acid composition and eating scores of Friesian-Holstein steers finished on total mixed ration or haylage.

II. MATERIALS AND METHODS

Animals and feeding management

A total of 10 Friesian-Holstein steers were grown on pasture until the age of 21 months and then randomly divided into two different pens (3.0 x 10.0 m) consisting of five animals under commercial operations run by Samyang Foods Co., Ltd., Korea with free access to water. Five animals were finished on ad libitum *Phalaris arundinacea* haylage which was harvested and wrapped from pasture around the dairy industry, while the other five were fed approximately 18 kg individual daily intake of total mixed ration (TMR). TMR was composed of 12.35% dry-rolled corn, 5.70% cottonseed meal, 2.80% corn gluten meal, 4.30% oat straw, 6.80% raygrass, 21% brewers grain, 13.50% spent mushroom substrate, 9.40% soy pulp, 0.40% mineral premix, 0.15% vitamin premix, 5.80% probiotics and 17.80% feed base. Nutrient composition of each diet shown in Table 1. Cattle were weighed monthly until 5 months of feeding treatment was done.

Table 1 Nutrient composition of experimental diets

Item	TMR	Haylage
Dry matter (DM), %	59.13	54.69
Crude protein, % DM	10.96	11.12
Ether extract, % DM	6.73	2.61
Crude fiber, % DM	8.29	38.47
Neutral detergent fiber, % DM	18.72	66.59
Ash, % DM	4.97	7.31
Total digestible nutrient, % DM	86.88	26.09
Metabolisable energy, cal/g	3,301.43	3,034.24
C18:2n6, % fatty acids	45.16	19.30
C18:3n3, % fatty acids	1.55	29.15
n6/n3*	29.14	0.66

*C18:2n6/C18:3n3; TMR, total mixed ration

Physical properties analyses

Animals were slaughtered in a commercial meat plant using standard procedure. The *longissimus lumborum* muscle of each animal was removed from carcasses for meat quality analyses 48-h postmortem. Samples were vacuum-packaged, distributed to laboratory within ice box and immediately arranged for physicochemical analyses and sensory evaluation. The instrumental surface color was recorded by measuring CIE lightness (L*), redness (a*) and yellowness (b*) using a chromameter (CR-400, Konica Minolta Sensing Inc., Japan). Proximate composition was determined by AOAC official methods [2]. The pH value of the homogenized samples were recorded using a pH meter (Seven Easy pH, Mettler-Toledo GmbH, Switzerland). Water holding capacity (WHC) was defined as the percentage of moisture content that remained in meat during heating with centrifugation method [3]. Cooking loss was expressed as the percentage of weight loss after cooking at 80°C for 30 min. The cooked samples were then cut (1 x 1 x 1 cm) and subjected to texture profile analysis and shear force measurement using TA-XT2i Plus (Stable Micro Systems, UK). For shear force measurement, the cut sample was placed on the table, under the V blade, and was cut through as the blade moved down with a constant speed through the slit of the table (assay parameters were: pre-test speed: 2.0 mm/s; test speed: 1.0 mm/s; post-test speed: 5.0 mm/s). A cylindrical 10 mm-diameter probe was used for all texture profile analysis (TPA) tests in this study. The sample was placed under the probe that moved downwards at a constant speed of 2.0 mm/s (pre-test), 1.0 m/s (test), and 5.0 mm/s (post-test). Each sample was assessed 8 times.

Fatty acid composition

Fatty acid composition was determined using a gas chromatography (YL6500, YL Instrument, Korea). Meat fat was extracted according to Folch et al. [4] with chloroform-methanol (2:1 v/v). Each sample was assessed twice. Fatty acids were converted into methyl esters as described by AOAC method [2]. Fatty acid methyl esters were dissolved in 1.5 mL of hexane. One μL of sample was injected into the column in the split ratio (1:5). Fatty acid methyl esters were separated using an omegawax-320 fused silica capillary column (30 m × 0.32 mm i.d., 0.25 μm film thickness; Supelco, Inc., Bellefonte, PA, USA) with a 1.0 mL/min of helium flow. The oven temperature was increased from 130 to 200 °C at 10 °C/min. Temperatures of the injector and detector were 250 °C. The fatty acid peaks were identified and quantified by comparison with the retention time and peak area of fatty acid standards (47015-U, Supelco, Bellefonte, PA, USA).

Sensory evaluation

A total of 21 panelists, consisting mainly of college student, evaluated sensory attributes of 10 beef samples. The sensory evaluation consisted of two sessions: the first one was to visually evaluate the attributes of the raw beef, and the second to evaluate the roasted beef. To rate the samples, the panelists used 9-point scales (1 = extremely unacceptable; 9 = extremely acceptable). Prior to being presented to the panelists, the vacuum-packaged frozen samples (2.5 cm thick) were thawed for 12 h at 2°C and exposed to air for 30 min at 4 °C to allow for blooming completely. The panelists visually evaluated color, aroma and overall acceptability of the raw beef. For roasted beef evaluation, the steaks were roasted on electric roasting pan (HM-2002, Daewon Home Electrics, Korea) set at 180 °C, cooked until internal temperature of 72 °C was reached. The cooked steaks were cut into 1×1×1 cm pieces, placed on aluminum plates, and served immediately to each panelist. The roasted samples were evaluated for juiciness, tenderness, taste, aroma, and overall acceptability.

Statistical analysis

One-way analysis of variance (ANOVA) was used to compare the effects of different diets. Sensory evaluation data were analyzed by ANOVA, with panelist within animal as the block structure and different diets as the treatment. All analyses were performed using R-version 3.2.0 with "Agricolae" library (The R-foundation for Statistical Computing, Austria).

Table 2 Meat proximate composition (%)

	TMR	Haylage	SEM	SL
Moisture	75.49	78.95	0.50	***
Crude fat	4.36	1.07	0.49	***
Crude protein	20.93	19.41	0.30	**
Ash	0.96	0.94	0.001	ns

TMR; total mixed ration, SEM; standard error of the means, SL; significant levels, *** (p<0.001), ** (p<0.01), ns (not significant, p>0.05).

III. RESULTS AND DISCUSSION

The differences in proximate composition as affected by different diets are shown in Table 2. TMR group gained more fat and protein, resulting lower moisture content than grass-fed group (P<0.001). These was caused by different digestible nutrient content which was found higher in TMR than haylage. So that, TMR group got more energy from the diet. No significant effects were found on ash content.

Table 3 Meat physical properties

	TMR	Haylage	SEM	SL
pH	5.75	5.88	0.04	*
CIE L*	41.02	38.66	0.45	***
CIE a*	17.29	20.88	0.51	***
CIE b*	7.38	10.43	0.41	***
WHC, %	55.46	50.45	1.41	*
Cooking loss, %	37.83	44.94	0.91	***
Shear force, kg	6.81	8.54	0.26	***
Hardness, kg	24.51	26.18	0.67	*
Gumminess	7.02	13.44	1.06	***
Chewiness	3.16	6.91	0.58	***

TMR; total mixed ration, SEM; standard error of the means, SL; significant levels, *** (p<0.001), ** (p<0.01), * (p<0.05).

In this study, effects of diet were also found in meat pH, instrumental surface color, cooking yield, tenderness and texture (Table 3). Higher pH was found in grass-fed beef (p<0.05), which indicates less energy reserves in muscle affected by diet. Darker, redder and more yellow surface of grass-fed beef appeared as assumedly affected by less amount of energy reserves, higher heme iron and carotenoids content. Grass is renowned as the source of iron and fat-soluble pigment such us lutein and β-carotene for ruminants [5]. As TMR-fed beef contained higher fat content, it was observed more tender than grass-fed beef (p<0.001), which agrees with Wood *et al.* [6] that total lipid content in muscle plays role in the tenderness. Moreover, grass-fed beef had tougher texture with more gummy and chewy characteristics.

Table 4 Meat fatty acid composition (%)

	TMR	Haylage	SEM	SL
C14:0	2.94	2.48	0.07	*
C16:0	27.85	25.61	0.29	**
C16:1n7	3.15	2.66	0.14	*
C18:0	16.97	17.40	0.06	ns
C18:1n9	42.31	44.47	0.28	*
C18:2n6	4.48	3.36	0.16	***
C18:3n6	0.07	0.08	0.01	ns
C18:3n3	0.40	1.06	0.09	***
C20:1n9	0.08	0.15	0.01	*
C20:4n6	1.30	1.49	0.03	ns
C20:5n3	0.24	0.88	0.09	***
C22:4n6	0.15	0.20	0.01	**
C22:6n3	0.05	0.15	0.01	***
SFA	47.76	45.49	0.29	ns
MUFA	45.54	47.28	0.24	ns
PUFA	6.69	7.23	0.11	ns
PUFA/SFA	0.14	0.16	0.00	ns
n6	6.00	5.13	0.12	*
n3	0.70	2.10	0.19	***
n6/n3	8.58	2.44	0.80	***

TMR; total mixed ration, SFA; saturated fatty acids, MUFA; monounsaturated fatty acids, PUFA; polyunsaturated fatty acids, SEM; standard error of the means, SL; significant levels, *** (p<0.001), ** (p<0.01), * (p<0.05), ns (not significant, p>0.05).

The fatty acid composition of *longissimus lumborum* fat for TMR-fed and grass-fed cattle are presented in Table 4. Palmitic (C16:0), stearic (C18:0) and oleic (C18:1n9) acids were predominant fatty acids compared with the others. Among these major fatty acids, TMR-fed group had higher C16:0 but lower C18:1n9. No differences were found in C18:0. Other mid-chain fatty acids such as myristic (C14:0) and palmitoleic (C16:1n7) acids were significantly higher in TMR-fed beef (p<0.05). Eicosenoic acid (C20:1n9) was higher in grass-fed beef. Furthermore, grass-fed beef was observed containing remarkably higher omega-3 fatty acids and lower omega-6 fatty acids, resulting lower omega-6 to omega-3 ratio. Among omega-6 fatty acids, only arachidonic acid (C22:4n6) was higher in grass-fed beef. These indicate that grass-fed beef is healthier than TMR-fed beef according to the recommended ratio of omega-6 and omega-3 fatty acids (less than 4:1). Since essential fatty acids cannot be synthesized by mammals due to the absence of necessary enzymes [7]. Scollan *et al*. [8] reported that hay can be used to manipulate fatty acid composition in beef.

Table 5 Sensory scores of raw and roasted meat

	TMR	Haylage	SEM	SL
Raw				
Color	6.42	7.69	0.29	*
Aroma	3.45	4.09	0.43	ns
Overall acceptance	6.31	6.00	0.37	ns
Roasted				
Juiciness	6.56	4.38	0.43	***
Tenderness	6.50	4.38	0.46	**
Taste	6.63	6.27	0.32	ns
Aroma	5.44	3.07	0.46	**
Overall acceptance	7.19	4.25	0.49	***

TMR; total mixed ration, SEM; standard error of the means, SL; significant levels, *** ($p<0.001$), ** ($p<0.01$), * ($p<0.05$), ns (not significant, $p>0.05$). Sensory scores; from 1 (extremely unacceptable) to 9 (extremely acceptable).

No differences were found in the aroma and overall acceptance of raw beef (Table 5). However, panelists preferred the surface color of grass-fed beef ($p<0.05$). The deeper red color appeared on grass-fed beef, as recorded by chromameter, was more likely attracting the panelists than the pale surface of TMR-fed beef. The roasted beef of TMR-fed cattle, which has higher fat content, was dominant in juiciness, tenderness, aroma and overall acceptance even though different diets did not affect the taste. The aroma of cooked grass-fed beef is well-known a main drawback since omega-3 fatty acids are sensitive to high temperature, when lipid oxidation rapidly occurs.

IV. CONCLUSION

Phalaris arundinacea haylage could be used as finishing feed for producing lean beef with recommended n6/n3 ratio for human health from dairy steers.

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