# INFLUENCE OF FEEDING RICE WHOLE-CROP SILAGE AFTER GRAZING ON GROWTH PERFORMANCE AND MEAT QUALITY IN JAPANESE BLACK STEERS

Masahiro Shibata[1], Yasuko Hikino[1], Mai Imanari[2], Kazunori Matsumoto[1] and Naoyuki Yamamoto[1]

[1] Livestock Production and Wildlife Management Research Division, NARO Western Region Agricultural Research Center, Ohda, Shimane 694-0013, Japan;

[2] Livestock and Forage Research Division, NARO Tohoku Agricultural Research Center, Morioka, Iwate 020-0198, Japan

**Abstract – This study aimed to investigate the differences in growth performance, carcass characteristics, and meat quality between Japanese Black steers fed rice whole-crop silage (WCS) after grazing during the early fattening period (GR) and those fed concentrate (CT). Ten 10-month-old steers were randomly assigned to either of the two dietary groups (five/group). All steers were slaughtered at 28 months of age and production and meat quality parameters were assessed. There were no between-group differences in body weight (BW) after grazing. Significant decreases in the TDN intake and daily gain were observed in the GR group during the late fattening period. Although final BW did not differ between the two groups, carcass weight was significantly lower in the GR group than in the CT group. A decrease in fat accumulation, an increase in protein content, and a very large increase in α-tocopherol and β-carotene content were detected in the muscles of the GR group relative to the CT group. Drip loss from muscles of the GR group was lower than in the CT group. These results suggest that feeding steers a large amount of rice WCS after grazing is an effective management strategy for beef production.**

**Key Words – drip loss, fattening, vitamin**

## I. INTRODUCTION

Beef cattle in Japan are generally reared under restricted movement conditions, are finished indoors, and fed a concentrate-based diet throughout the fattening period until slaughter. Recently, several studies of Japanese beef cattle production have investigated the use of grazing to effectively utilize roughage in the field. However, these production systems need improvements to achieve productivity that is comparable with that of conventional systems. We previously showed that feeding a large amount of grass hay to steers indoors led to an increase in protein content and a decrease in fat accumulation in their muscle compared with that of steers fed a concentrate-based diet, but grass hay-fed steers had a lower final body weight (BW) because of their lower total digestible nutrient (TDN) intake [1]. Another previous report found a decrease in final BW, rib thickness, beef marbling standard (BMS), and crude fat content in the muscle of steers fed rice whole-crop silage (WCS) *ad libitum* after grazing during the mid-fattening period when compared with steers fed concentrate *ad libitum* [2]. On the other hand, the quality of the beef produced using roughage-based production systems tends to be, with roughage-fed steers producing low fat, lean meat. The crude fat content in the muscle has been shown to be much lower in grass hay-fed steers [3] and pasture-fed steers [4] than in concentrate-fed steers.

Recently, 'Tachisuzuka', a new rice cultivar for WCS, has been developed as a roughage source at the NARO Western Region Agricultural Research Center (NARO/WARC), Japan. This cultivar has a high straw yield, high sugar content, high fiber digestibility, and low grain yield [5].

The purpose of the present study was to investigate the influence of feeding rice WCS *ad libitum* after grazing during the early fattening period on the growth performance, carcass characteristics, and meat quality of Japanese Black steers.

## II. MATERIALS AND METHODS

### *Animal Management and Diets*

The management of the steers and all procedures were performed according to the Animal Experimental Guidelines of the National Agriculture and Food Research

Organization/Western Region Agricultural Research Center (NARO/WARC). Ten 10-month-old Japanese Black steers, bred at NARO/WARC, were randomly divided into two groups; the GR group was fed rice WCS and limited concentrate after grazing during the early fattening period, and the CT group was fed a conventional, mainly concentrate-based diet. Five steers in the GR group were rotationally grazed on Italian ryegrass pasture from 10 to 16 months of age. After this period, the steers were reared individually in a tie stall barn and fed rice WCS *ad libitum* with restricted feeding of the concentrate diet until 28 months of age. The amounts of concentrate fed were 6.5 kg/day and 3.5 kg/day during the periods from 16 to 22 (WCS feeding period 1) and 22 to 28 (WCS feeding period 2) months of age, respectively. The other five steers in the CT group were housed individually in a tie stall barn and fed a concentrate diet *ad libitum* with 1.5 kg/day grass hay from 10 until 28 months of age. All steers were weighed every 1–2 weeks. Food intake was measured daily except during the grazing period. All steers were slaughtered at 28 months of age.

*Carcass Evaluation and Sample Preparation*

After slaughter, the carcasses were chilled at 0°C for 24 hours. Their dressing percentage, and the rib eye area, rib thickness, subcutaneous fat thickness, BMS, beef fat color standard (BFS), and beef color standard (BCS) of the section between the sixth and seventh ribs were evaluated according to the Japanese New Beef Carcass Grading Standards [6]. Skeletal muscle samples from the *longissimus lumborum* (LL) and *semitendinosus* (ST) muscles were obtained for analyses of nutrient content, drip loss, cooking loss, and Warner-Bratzler shear force (WBSF). Samples of the muscle tissues were minced to determine their crude protein, crude fat, and vitamin content. The minced meat samples were vacuum-packed in an aluminum bag and then stored at −80°C until analysis. The muscles were processed into 2.5-cm (thickness) steaks, vacuum-packed, stored in a refrigerator at 2°C for 2 and 30 days after slaughter, and then frozen at −80°C until analysis.

*Meat Characteristics*

The crude protein in each muscle was calculated by quantitative analysis of nitrogen using the Kjeldahl method with copper sulfate and potassium sulfate as catalysts [7]. The crude fat in each muscle was extracted with diethyl ether for 16 h using a Soxhlet extractor [7]. Muscle α-tocopherol content was assayed as described by Ueda and Igarashi [8] using high-performance liquid chromatography. Muscle retinol and β-carotene content were assayed at the Japan Food Research Laboratories (Tokyo, Japan). Steaks were thawed for 12 h at 4°C and then carefully wiped dry using paper tissue. Drip loss was calculated from the weight difference before and after storage [4]. Following the drip loss measurement, the samples were broiled on electric grills to an internal temperature of 70°C; they were then wrapped in plastic to prevent desiccation and stored at 4°C for approximately 12 h [9, 10]. Cooking loss was calculated from the difference in weight before and after cooking [3, 9]. Six 1.3-cm diameter cores were removed from each steak parallel to the longitudinal orientation of the muscle fibers [9, 10]. The peak shear force of all cores was measured using a WBSF machine. Drip loss and cooking loss were used as indicators of water-holding capacity.

*Statistical Analysis*

All measurements are presented as means. The significance of between-group differences was analyzed using one-way analysis of variance with a post-hoc Fisher's least significant difference test. $P$ values of $< 0.05$ were considered to be statistically significant.

## III. RESULTS AND DISCUSSION

The growth performance and TDN intake of the GR and CT groups are shown in Table 1. The TDN intake of the GR group during WCS feeding period 1 was significantly greater than that of the CT group, but there were no significant between-group differences in daily gain (DG) during that period or in BW at 22 months of age. The mean BW of the groups also did not differ at 16 months of age (immediately after the grazing period for the GR group). We previously showed that steers grazed during the mid-fattening period had lower BWs after grazing than concentrate-fed steers [2]. We speculate that the difference in the effects of grazing on BW seen in our current and previous studies is due to differences in the age at grazing start and in the rearing environment before grazing. In the present study, the steers started grazing during the early fattening period after being housed in a free stall barn; in contrast, in the previous study [2], the steers started grazing during the mid-fattening period after being individually reared in a tie stall barn.

Table 1 Growth performance and feed intake of steers

| | GR | CT |
|---|---|---|
| Body weight (BW), kg | | |
| Before grazing (10 mo) | 315 | 305 |
| After grazing (16 mo) | 469 | 505 |
| WCS feeding (22 mo) | 655 | 670 |
| Final (28 mo) | 705 | 742 |
| TDN intake, kg/day | | |
| Grazing period | - | 6.52 |
| WCS feeding period 1 (16-22 mo) | 7.81 * | 6.62 |
| WCS feeding period 2 (22-28 mo) | 5.12 * | 5.86 |
| Daily gain (DG), kg/day | | |
| Grazing period | 0.88 * | 1.15 |
| WCS feeding period 1 (16-22 mo) | 0.95 | 0.84 |
| WCS feeding period 2 (22-28 mo) | 0.32 * | 0.50 |

mo: months, TDN: total digestible nutrients.
Values are expressed as means. *$P < 0.05$

The carcass characteristics of the GR and CT groups are shown in Table 2. Most of the indices of beef productivity, such as dressing percentage, rib eye area, and rib thickness, did not differ between the two groups. The dressed carcass weight was significantly less in the GR group than in the CT group (Table 2). However, there was no difference in final BW between the GR and CT groups, although significant decreases in TDN intake and DG were observed during WCS feeding period 2 (Table 1). The reduction in the dressed carcass weight likely resulted from the 53-kg difference in final BW between the groups. This final BW difference is attributed to the decreased DG that occurred because of the decline in TDN intake in the GR group during WCS feeding period 2.

Table 2 Carcass characteristics

| | GR | CT |
|---|---|---|
| Dressed carcass weight, kg | 423 * | 476 |
| Dressing percentage, % | 72.4 | 71.9 |
| Rib eye area, $cm^2$ | 47.2 | 52.4 |
| Rib thickness, cm | 7.16 | 7.48 |
| Subcutaneous fat thickness, cm | 2.98 | 3.74 |
| Beef marbling standard (BMS), No. | 4.4 | 4.4 |
| Beef color standard (BCS), No. | 4.8 | 4.0 |
| Beef fat color standard (BFS), No. | 5.8 * | 2.8 |

Values are expressed as means. *$P < 0.05$

Rib thickness did not differ between the two groups (Table 2), although a reduction in rib thickness has been shown in steers grazed on pasture [2] or fed large amounts of grass hay [1, 3]. The BFS, which is an indicator of the yellowness of beef fat, was significantly higher in the GR group than in the CT group (Table 2). This increase in the BFS is thought to result from the carotene content of rice WCS and pasture.
Nutrient content, water-holding capacity, and the Warner-Bratzler shear force of muscle samples from the GR and CT groups are shown in Table 3. The extracted lipid from the LL and ST muscles was significantly lower in the GR group than in the CT group (Table 3). Previous reports have also described a decrease in the extracted lipid from the muscles of grass hay-fed [3], pasture-fed [4], and grazed [2] steers in comparison with those of concentrate-fed steers. In contrast, the muscle crude protein content was significantly higher in the GR group than in the CT group. This result is similar to our previously reported findings [2].

Table 3 Nutrient content, water-holding (WH) capacity, and Warner-Bratzler shear force (WBSF) of LL and ST muscles

| | L L | | S T | |
|---|---|---|---|---|
| | GR | CT | GR | CT |
| Crude protein, % | 18.2 * | 16.2 | 20.8 * | 20.1 |
| Extract lipid, % | 21.7 * | 30.0 | 6.4 * | 11.3 |
| Vitamin | | | | |
| Retinol, μg/100g | 26.2 | 22.2 | 7.0 | 8.4 |
| β-CA, μg/100g | 21.0 | ND | 8.8 | ND |
| α-Toc., mg/kg | 17.2 * | 3.5 | 12.1 * | 2.8 |
| WH capacity | | | | |
| Drip loss, % | 2.2 * | 3.8 | 5.5 * | 6.9 |
| Cooking loss, % | 36.6 | 35.3 | 39.8 | 39.0 |
| (WBSF), kg | 1.0 | 1.2 | 2.5 | 2.6 |

LL: *M. longissimus lumborum*, ST: *M. semitendinosus*, CA: Carotene, Toc.: Tocopherol, Values are expressed as means. *$P < 0.05$

The α-tocopherol and β-carotene contents of the muscle samples from the GR group were very high, and significantly greater than in samples from the CT group (Table 3). Beef from cattle finished on grass has been shown to have greater α-tocopherol, β-carotene, and ascorbic acid content, as well as better lipid stability, than beef from cattle finished on concentrate [11]. Drip loss from the LL and ST muscles of steers from the GR group was significantly lower than that of the CT group (Table 3). The α-tocopherol within the cell membrane inhibits membrane disruption by reacting with free radicals [12]. High α-tocopherol concentrations in frozen meat minimizes drip loss during thawing, possibly because the α-tocopherol may preserve the fluidity of the cell membranes [13]. This may explain the decrease in drip loss in the muscles of the steers in the GR group, which had very high levels of α-tocopherol and β-carotene.

## IV. CONCLUSION

Although the rearing system, which combined grazing and feeding a large amount of rice WCS, resulted in a lower carcass weight, the other carcass characteristics of steers raised in this manner compared favorably to those of steers fed a concentrate-based diet. These results suggest that feeding steers rice WCS *ad libitum* after grazing results in reduced muscle fat accumulation and increased muscle protein content compared with concentrate-fed steers. The decrease in the drip loss of meat from steers fed rice WCS suggests that the water holding capacity of their meat may be improved by feeding rice WCS after grazing. Furthermore, our results suggest that the rice WCS-based diet led to an improvement in lean meat quality because of an increase in the functional nutrient content of the beef from rice WCS-fed steers.

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