Influence of Dietary Addition of Dried Wormwood (*Artemisia* sp.) on the Performance, Carcass Characteristics and Fatty Acid Composition of Muscle Tissues of Hanwoo Heifers

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ABSTRACT : An experiment was conducted to examine the performance and carcass characteristics of Hanwoo (Korean native beef cattle) heifers and the fatty acid composition of muscle tissues of the heifers when the animals fed diets containing four levels of dried wormwood (*Artemisia* sp.). For the experiment the animals were given a basal diet consisting of rice straw and concentrate mixed at 3:7 ratio (on DM basis). The treatments were designed as a completely randomized design with two feeding periods. Heifers were allotted in one of four dietary treatments, which were designed to progressively substitute dried wormwood for 0, 3, 5 and 10% of the rice straw in the basal diet. There was no difference in body weight gain throughout the entire period between the treatment groups. Feed conversion rate was improved ($p<0.05$) only by the 3% dried wormwood inclusion treatment compared with the basal treatment. Carcass weight, carcass yield and backfat thickness of all treatment groups were not altered by wormwood inclusion. The 5% dried wormwood inclusion significantly increased ($p<0.05$) the size of loin-eye area over the other treatments. The higher levels (5 and 10%) of dried wormwood inclusion resulted in the higher ($p<0.05$) water holding capacity (WHC) in loin than the lower levels (0 and 3%) of wormwood inclusion. The redness (a*) and yellowness (b*) values of meat color were significantly lower ($p<0.05$) in the top round muscle of heifers fed the diet containing 3% dried wormwood. There was a profound effect of the progressively increased intake of dried wormwood led to the linear increase of unsaturated fatty acid content and the linear decrease of saturated fatty acid content in the muscle tissues of Hanwoo heifers. It is concluded that the feeding diets containing dried wormwood substituted for equal weights of rice straw at 5% levels would be anticipated to provide better quality roughage for beef heifer production and economical benefits for beef cattle producers. ***(Asian-Aust. J. Anim. Sci. 2002. Vol 15, No. 4 : 549-554)***

Key Words : Wormwood, Hanwoo Heifers, Performance, Carcass Characteristics, Fatty Acids

INTRODUCTION

The use of herbs and spices has seen a significant growth spurt throughout the world in the last few years. These materials have gone from items hidden in the corner of health food stores to supplements found in supermarkets and convenience stores. Likewise, interest in herbs in the livestock and companion animal feed sector has also changed from the mildly curious in traditional livestock production to a full-blown booming the horse industry. Especially, herbs such as wormwood used as feed additives contain active ingredients such as essential micronutrients, unknown factors, hormone-like agents, antimicrobial agents, probiotics, antioxidants and immune-promoting agents. The oriental wormwood composes of alkaloid, vitamins (vitamin A, B_1, B_2 and C) and minerals (Ca, P and Fe) (Lee, 1965). It is used to aid digestion, exterminate parasites, and cure gastroenteric disorders, constipation and neuralgia in Chinese medical practices (Kim, 1984).

Besides, it is a problem to be urgently solved in Korea that livestock industry should intensify the international competitiveness, reduce the production cost and stabilize the price fluctuations of livestock products due to the complete market opening of beef products in 2001. Intensive researches have been carried out to improve the meat quality and feeding management of Hanwoo (Korean native beef cattle). However, the current many studies are only focusing on Hanwoo steers. Therefore, it is also required to establish the rational feeding system of Hanwoo heifers and cows for the production of good quality meat.

As wormwood is known as a functional and medical plant, it is expected that dietary supplementation of wormwood should result in good quality meat production. None of research has been conducted to examine the effect of wormwood supplementation in the practical diets of beef cattle, especially Hanwoo heifers, on performance or meat quality. An experiment was conducted to determine the effect of dietary inclusion of dried wormwood in three levels on the growing performance, carcass characteristics and commercial concentrates and fatty acid composition of selected muscle tissues of Hanwoo heifers fed rice straw.

MATERIALS AND METHODS

Experimental animals and their management

The experiment was conducted for 6 months on a beef

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cattle farm located in Geochang-gun, Korea. Twenty four Hanwoo heifers were used. Heifers (360±15 kg) were purchased at a local livestock market. The animals were given a diet at 3.0% of body weight in dry matter (DM) basis. Food was given in two equal meals at 08:00 and 17:00. Water and mineral blocks were freely accessed. For the experiment the animals were given a basal diet consisting of rice straw and concentrate mixed at 3:7 ratio (on DM basis). Wormwood (*Artemisia* sp.) was cut between May and June, 2000 in the fields around the farm and then sun-dried for 2 days. The chemical compositions of rice straw and dried wormwood are shown in table 1. The concentrations of crude protein for rice straw and dried wormwood are 5.39 and 16.20%, respectively. The concentrate supplements were supplied by a feed manufacture and were fed at different compositions depending on the age of the animals (table 2).

Experimental design and treatments

The experiment was designed as a completely randomized design. Following 5 day adjustment period, the heifers were assigned randomly to one of four dietary treatments and housed individually in stanchion stalls. The four dietary treatments were designed to progressively substitute 0, 3, 5 and 10% of the rice straw with equal weights of dried wormwood in the basal diet as described above. Each treatment diet was fed individually to six heifers. The experimental period was divided to two stages, which are early fattening period and late fattening period. Steers were weighed every month throughout the fattening periods. Feed intake was measured daily from each stall. Feed samples were collected weekly, and were bulked on a monthly basis before chemical analysis.

Chemical analysis

Feed samples were taken from a daily ration, dried in a forced-air oven at 60°C, ground to pass a 1 mm screen, and analyzed for DM, nitrogen (N), ether extract, crude fiber and crude ash (AOAC, 1990).

For the fatty acid analysis, fresh samples were obtained from the loin and top round muscles of heifers and stored at 0°C until the analysis was carried out. The extraction of lipids from the muscles was done according to the procedure described by Folch et al. (1957). Twenty grams of muscle samples were minced, blended twice with chloroform-methanol (2:1, v/v) as an extraction solvent and filtered in a separatory funnel. Then the methanol aqueous phase was discarded and the lipid fraction in the chloroform fraction was quantitatively collected into a 200 ml volumetric flask containing a small amount of anhydrous sodium sulfate. A 30 mg quantity of lipid in chloroform lipid extract was transferred to reaction tubes where the chloroform was evaporated by passing a steady flow of

Table 1. The chemical composition (%, DM basis) of rice straw and dried wormwood (*Artemisia* sp.) used in the experiment

Item	Rice straw	Dried wormwood
Dry matter	86.21	79.70
Crude protein	5.39	16.20
Ether extract	1.48	4.20
Crude fiber	33.35	22.35
Crude ash	15.97	8.70
Nitrogen-free extract	43.81	48.55

Table 2. Formula and chemical composition (% DM basis) of the concentrate supplements in the experiment

	Early fattening	Late fattening
Ingredients		
Yellow corn, ground	41.46	53.92
Wheat grain, 11.5%	10.00	8.00
Wheat flour	-	4.00
Lupin, 31%	5.00	-
Wheat bran	8.00	5.00
Corn gluten feed	-	1.14
Mixed fiber	-	8.00
Tapioca pellet	8.80	-
Cane molasses	5.00	5.00
Rapeseed meal	3.72	2.52
Distllers grain	3.72	-
Coconut meal, 20.5%	3.00	2.00
Palm kernel meal	6.50	5.50
Kapok seed meal, 33.5%	1.00	1.50
Salt	0.60	0.60
TCP, 18%	0.34	0.32
Limestone, 1 mm	2.30	2.10
Calcium sulfate	0.10	-
Vitamin premix[1]	0.10	0.10
Mineral premix[2]	0.10	0.10
Urea	0.26	-
Fresh aroma extra	-	0.05
Kelp meal	-	0.15
Total	100	100
Chemical composition[3]		
Crude protein	12.03	10.00
Ether extract	3.28	3.36
Crude fiber	4.67	5.46
Crude ash	6.31	5.59
Ca	1.20	1.09
P	0.40	0.37
TDN	71.02	68.18

[1] Vitamin premix contains: Vit. A, 2,700,000 IU; Vit. D3, 400,000 IU; Vit. E, 15,000 IU; Vit. K_3, 850 mg; Vit. B_1, 500 mg; Vit. B_2, 25,000 mg; Vit. B_6, 850 mg; Vit. B_{12}, 8 mg; pantothenic acid, 6,000 mg; Niacin, 15,000 mg; biotin, 225 mg; folic acid, 250 mg; and antioxidants, 6,000 mg.

[2] Mineral premix contains: $FeSO_4$, 39,500 mg; $CoSO_4$, 156 mg; $CuSO_4$, 67,000 mg; $MnSO_4$, 20,840 mg; $ZnSO_4$, 40,000 mg; and Se (Na), 100 mg.

[3] Calculated value.

nitrogen gas over the solution held in a 40°C heating block. Derivatization of fatty acid methyl esters (FAME) was performed by a modified procedure of Jham et al. (1982). Tricosanoic acid ($C_{23:0}$) was added to the lipid material as an internal standard prior to saponification. Lipid content was saponified to release free fatty acids by heating at 100°C for 5 min. in the presence of 1 ml of 0.5 N KOH in MeOH. Methylesters of the fatty acids were prepared by the addition of 0.4 ml MeOH:HCl (4:4, v/v) to the reaction mixture and heating at 100°C for 5 min. After 10 min. 2 ml distilled water was added to the reaction mixture and FAME were extracted with 6 ml of hexane. The FAMEs in the hexane fractions were determined by gas chromatography (GC) with reference to known amounts of authentic standards which were positively identified by GC.

GC quantification of fatty acids was carried out by using a Shimadzu GC-14A instrument fitted with a flame ionization detector (FID) and a fused silica capillary column (30 m×0.32 mm ID×0.25 μm film thickness, Alltech AT). The sample solution (2.5 to 3.0 μl) in n-hexane was introduced into the injection port of the gas liquid chromatographic instrument. The flame gas was hydrogen and the carrier and make-up gas was helium. Carrier gas flow rate was 50 ml/min. The column initial and final temperatures were 140 and 230°C, respectively, with a temperature ramping program at 2°C/min. The injector and detector temperatures were maintained at 240 and 250°C. The peaks were identified by comparing the retention times of the peaks of individual standard fatty acids. The percentage of each fatty acid component was calculated by dividing the area of each peak by the total area of peaks.

Carcass evaluation

Heifers at the end of the experiment were slaughtered after fasting for 24 h. Carcasses were chilled at 0 to 2°C for 24 h and graded for quality and yield factors by trained carcass evaluators, guided by the Korean meat-grading scheme. Carcass weight, carcass yield, back-fat thickness and size of loin-eye area were assessed. Carcass grade was scored by combination of carcass yield and quality grade. Carcass yield was classified with a scale of A+, A, B+, B, C+ or C. Quality grade was scored on a scale of 1 to 3, which was mainly determined by marbling score but also by meat color, fat color and maturity.

The meat surface color of loin and top round muscles was measured with a CromaMeter (Minolta, CR 301, Minolta Camera company, Japan). After chopped surface of each sample was exposed in air for 30 min, meat color was expressed by Commission International de Leclairage (CIE) in L* (lightness), a* (redness) and b* (yellowness) values. The surface color in the muscle samples was measured by white tile of standard plate (CIE L*=89.2, CIE a*=0.921, CIE b*=0.783). Water holding capacity of the muscle samples was measured by the filter paper fluid uptake method according to Kauffman et al. (1986).

Statistical analysis

The data were analyzed as a completely randomized design using GLM (general linear model) procedures of SAS (1990) and statistical significance among treatment means was determined by Duncan's multiple range test.

RESULTS AND DISCUSSION

Feed intake and average daily gain

The performance data and feed intake data for four dietary treatments for the whole trial period are shown in table 3. There was no difference in final body weight, total

Table 3. Effects of dietary inclusion of dried wormwood (*Artemisia* sp.) on the growth, feed intake and feed conversion rate of Hanwoo (Korean native beef cattle) heifers fed the diet containing rice straw and concentrate in the experiment

Items	Percentage of wormwood in roughage				SEM
	0	3	5	10	
Growing performance					
Initial body weight (kg)	360.7	350.5	360.3	370.8	4.90
Final body weight (kg)	537.6	524.1	539.3	540.1	6.10
Body weight gain (kg)	176.9	173.6	179.0	169.3	3.76
Average daily gain (g/d)	0.98	0.96	0.99	0.94	0.04
Roughage					
Total intake (kg DM)	186.0	190.5	195.3	204.7	8.20
Daily intake (kg DM/d)	1.03	2.06	1.09	1.14	0.05
Concentrate					
Total intake (kg DM)	1,689.4^{a}	1,482.8^{b}	1,614.5^{a}	1,661.9^{a}	40.80
Daily intake (kg DM/d)	9.16^{a}	8.24^{b}	8.97^{a}	9.23^{a}	0.23
Total feed intake (kg DM)	1,875.4^{a}	1,673.3^{b}	1,809.8^{a}	1,866.8^{a}	32.70
Feed conversion rate[1]	10.60^{a}	9.64^{b}	10.11^{ab}	11.03^{a}	0.32

[1] Feed conversion rate: Total feed intake/body weight gain.

[a,b] Means in the same row with different superscripts differ significantly ($p<0.05$).

SEM=Standard error of the mean.

body weight gain and average daily gain (ADG) throughout the entire period between the treatment groups. Total and daily intakes of roughage were not altered by all dried wormwood inclusion. The 3% dried wormwood-feeding group showed the lowest ($p<0.05$) total and daily intakes of concentrate and consequently the lowest ($p<0.05$) total feed intake. Feed conversion rate was improved ($p<0.05$) only by the 3% dried wormwood inclusion treatment compared with other treatments. The 5% dried wormwood inclusion tended to improve ($p<0.10$) the feed conversion rate compared with the control treatment. The results indicated that although there was no significant positive effect of dried wormwood inclusion in the diet containing rice straw and concentrate on body weight gain, the 3 and 5% dried wormwood inclusion should provoide economical benefits for beef production by the better feed conversion rate. It is very difficult to explain why the concentrate intake in the 3% wormwood-feeding group, the lowest inclusion level, was lower than the higher levels of wormwood inclusion since elevated doses of some herbs can stimulate undesirable side effects such as reducing feed intake (Vandergrift, 1998). Again, wormwood has strong flavors, which may alter feed sensory characteristics and therefore affect feed intake. However, in the present study, as the wormwood inclusion levels decreased in the basal diet, the total feed intake was linearly decreased. Therefore, above explanation is not proper in the present study. There should be some other factors which affect feed intake. It is suggested that although the higher levels of wormwood inclusion might more strongly inhibited voluntary feed intake than the lower (3%) levels of wormwood inclusion, the higher supply of nutritional and functional ingredients (e.g. micronutrients and antioxidants) influenced digestibility and consequently maintained the feed intake in the groups fed the diets containing higher levels of wormwood similar to that of the control group.

Carcass characteristics

The effect of the experimental diets on carcass characteristics is shown in table 4. Carcass weight, carcass yield and backfat thickness of all treatment groups were not altered by dried wormwood inclusion. The 5% dried wormwood inclusion significantly increased ($p<0.05$) the size of loin-eye area by 1.5 to 6.3 cm^2 over the other treatments. The effect of dried wormwood inclusion on the WHC and meat color of loin and top round muscles of Hanwoo heifers is presented in table 5. The higher levels (5 and 10%) of dried wormwood inclusion were resulted in the higher ($p<0.05$) WHC in loin than the lower levels (0 and 3%) of dried wormwood inclusion. However in top round muscle, the 3% dried wormwood inclusion led to the lowest WHC ($p<0.05$). The mechanical measurements, CIE L* (lightness), a* (redness) and b* (yellowness), of meat color in loin muscle were not altered by all treatments. The redness (a*) and yellowness (b*) values were significantly lower ($p<0.05$) in the top round muscle of heifers fed the diet containing the 3% dried wormwood inclusion.

Table 4. Effects of dietary inclusion of dried wormwood (*Artemisia* sp.) on carcass characteristics of Hanwoo (Korean native beef cattle) heifers fed the diet containing rice straw and concentrate in the experiment

Items	Percentage of wormwood				SEM
	0	3	5	10	
Carcass weight (kg)	355.2	348.1	355.7	362.6	8.40
Carcass yield (%)	68.05	68.26	68.41	69.20	0.65
Backfat thickness (mm)	10.7	10.0	10.8	9.5	0.02
Loin-eye area (cm^2)	72.7^b	74.2^b	79.0^a	74.8^b	1.15

[a,b] Means in the same row with different superscripts differ significantly ($p<0.05$).

SEM=Standard error of the mean.

Table 5. Effects of dietary inclusion of dried wormwood (*Artemisia* sp.) on water holding capacity (WHC) and meat color of selected tissues of Hanwoo heifers fed the diet containing rice straw and concentrate in the experiment

Items	Percentage of wormwood in roughage				SEM
	0	3	5	10	
Loin					
WHC	66.02^b	65.00^b	76.63^a	72.37^a	1.86
Meat color, L*[1]	35.57	31.07	38.31	34.47	3.04
, a*	17.94	14.85	18.61	17.31	1.52
, b*	7.85	5.05	8.77	6.97	1.39
Top round					
WHC	72.56^a	54.55^b	83.55^a	73.60^a	4.21
Meat color, L*	33.00	28.40	33.65	32.31	5.92
, a*	18.22^a	12.93^b	18.10^a	17.88^a	1.54
, b*	7.89^a	4.59^b	7.55^a	6.90^a	0.71

[1] Meat color was expressed by Commision International de Leclairage (CIE) in L* (lightness), a* (redness), and b* (yellowness) values.

[a,b] Means in the same row with different superscripts differ significantly ($p<0.05$).

SEM=Standard error of the mean.

Fatty acid composition of muscles

Fatty acid profiles of the loin and top round muscles of Hanwoo heifers fed the diets containing the increased levels of dried wormwood are shown in table 6. The linolenic acid ($C_{18:3}$) content in the fatty acid profile of the loin muscle of all dried wormwood inclusion groups was significantly increased ($p<0.05$) compared with that of the control group. Although there was no significant difference of the linolenic acid content in the loin muscle between the dried wormwood-feeding groups, there was a tendency of the linear increase of linolenic acid by the increased inclusion levels of dried wormwood. The arachidonic acid ($C_{20:4}$) content in the loin of heifers fed 5 and 10% dried

Table 6. Effects of dietary inclusion of dried wormwood (*Artemisia* sp.) on fatty acid content in the selected tissues of Hanwoo (Korean native beef cattle) heifers fed the diet containing rice straw and concentrate in the experiment

Fatty acid (wt. %)	Percentage of wormwood in roughage				SEM
	0	3	5	10	
Loin					
14:0 (myristic)	5.13^{a}	4.04^{b}	3.10^{bc}	2.78^{c}	0.31
16:0 (palmitic)	30.38^{a}	30.02^{ab}	29.00^{b}	26.15^{c}	0.28
16:1 (palmitoleic)	5.21^{a}	4.50^{ab}	4.23^{b}	3.31^{c}	0.29
18:0 (stearic)	12.12	10.65	11.63	11.54	0.57
18:1 (oleic)	38.20^{b}	41.02^{b}	40.28^{b}	43.00^{a}	0.64
18:2 (linoleic)	7.48	6.70	6.77	7.89	0.41
18:3 (linolenic)	0.20^{b}	0.98^{a}	1.07^{a}	1.26^{a}	0.17
20:4 (arachidonic)	1.28^{b}	1.88^{b}	3.68^{a}	3.76^{a}	0.52
22:6 (docosahexaenoic)	tr.	0.21	0.24	0.31	0.04
UFA[1]	52.37	55.29	56.27	59.53	2.36
Top round					
14:0 (myristic)	4.31^{a}	3.82^{a}	3.79^{a}	2.36^{b}	0.29
16:0 (palmitic)	29.27^{a}	30.98^{a}	28.44^{a}	23.48^{b}	1.49
16:1 (palmitoleic)	5.25	4.84	4.43	4.05	0.46
18:0 (stearic)	12.11	10.25	11.52	12.56	0.87
18:1 (oleic)	42.63	43.99	44.06	44.20	0.72
18:2 (linoleic)	3.72^{b}	3.27^{b}	3.50^{b}	7.69^{a}	0.85
18:3 (linolenic)	0.12^{c}	0.69^{b}	1.53^{a}	1.64^{a}	0.14
20:4 (arachidonic)	2.59^{b}	2.02^{b}	2.58^{b}	3.82^{a}	0.40
22:6 (docosahexaenoic)	tr.	0.14	0.15	0.21	0.04
UFA	54.31	54.95	56.25	61.61	2.57

[1] Unsaturated fatty acids.

[a,b,c] Means in the same row with different superscripts differ significantly ($p<0.05$).

SEM=Standard error of the mean.

wormwood was significantly higher ($p<0.05$) than that of the 0 and 3% dried wormwood-feeding-groups. In contrast to the other unsaturated fatty acid profiles, however, the progressively increased intake of dried wormwood led to the linearly decreased content of palmitoleic acid ($C_{16:1}$) in loin muscle. The oleic acid ($C_{18:1}$) content in the loin muscle of the 10% dried wormwood-feeding group was significantly increased ($p<0.05$) compared with other treatments. The myristic acid ($C_{14:0}$), a saturated fatty acid, content of the loin muscle of the control group was highest ($p<0.05$). Again, the palmitic acid ($C_{16:0}$) in the loin muscle of the control group was higher ($p<0.05$) than that of the 5 and 10% dried wormwood-feeding groups. The docosahexaenoic (ω 3) acid (DHA; $C_{22:6}$) was not detected in the loin muscle of the control group but the progressively increased intake of wormwood tended to linearly increase the DHA content of loin muscle.

Myristic and palmitic acids in top round muscle were significantly ($p<0.05$) reduced by the 10% wormwood inclusion compared with other treatments. On the contrary, linoleic ($C_{18:2}$) and arachidonic acids in top round muscle were significantly ($p<0.05$) increased by the 10% dried wormwood inclusion compared with other treatments. The linolenic acid content in the top round muscle of all dried wormwood-feeding groups was higher ($p<0.05$) than that of the control group, showing a tendency of the linear increase of the fatty acid content by the progressively increased intake of dried wormwood.

Ruminant fat tissue differs from that of the single-stomached species in containing a higher proportion of saturated and a lower proportion of polyunsaturated fatty acids (Enser et al., 1996). This results from the hydrogenating action of the rumen bacteria which convert a high proportion of polyunsaturated fatty acids from forage or concentrate diets into saturated fatty acids or unsaturated fatty acids with fewer double bonds. However there are many reported examples of tissue fatty acid composition being changed via the diet, all of which involve manipulation of rumen fermentation patterns. This is pertinent that there was the profound effect of the progressively increased intake of wormwood led to the linear increase of unsaturated fatty acid content and the linear decrease of saturated fatty acid content in the muscle tissues of Hanwoo heifers in the present study.

Wormwood contains enumerous phenolic acids such as catechol, vanillin, umbelliferone, ρ-coumaric acid, ferulic acid, caffeic acid, protocatechuic acid, ρ-hydroxy benzoic acid, syrigic acid and flavonoids (Hoffmann and Herrmann, 1982; Lee et al., 1992; Lee et al., 1999) which are antioxdants. Wormwood also contains high content of vitamin E (Kim and Kim, 1999), which is non-phenolic antioxidant. It is likely that these antioxidants in wormwood resulted in the higher content of unsaturated fatty acids in muscles of heifers fed diets containing dried wormwood through regulating the mechanism of the peroxidation of unsaturated fatty acids. For example, feeding flavonoids to rats led to the reduced rate of lipid peroxdation (Tore et al., 1986; Isabelle et al., 1993).

In conclusion, the 5% inclusion of dried wormwood resulted in improved feed conversion rate, the higher content of unsaturated fatty acids, the biggest loin-eye area and the higher WHC in loin muscle. Therefore, the 5% dried wormwood inclusion would be the reasonable and economical level to supply to Hanwoo heifers in finishing period.

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