Journal of Animal and Feed Sciences, 16, 2007, 397–407

The effects of dietary herbs and coral mineral complex on growth performance, nutrient digestibility, blood characteristics and meat quality in finishing pigs

Y. Wang, Y.J. Chen, J.H. Cho, J.S. Yoo, Q. Wang, Y. Huang, H.J. Kim and I.H. Kim[1]

Department of Animal Resource and Science, Dankook University
#29 Ansedong, Cheonan, Choognam, 330-714, Korea

(Received 11 January 2007; revised version 1 September 2007; accepted 6 September 2007)

ABSTRACT

Eighty crossbred pigs of initial mean body weight 58 kg were used to evaluate the effect of supplemental herbs and coral mineral complex (HC) on growth performance, nutrient digestibility, blood characteristics and meat quality in a 8 weeks growth trial. Pigs were randomly allocated to 4 treatments, which comprised: 1. control, 2. HC 0.05%, 3. HC 0.1%, and 4. HC 0.2%, respectively (4 pigs/pen, 5 replicates/treatment). Gain/feed linearly increased during week 4-8 ($P<0.05$) and overall period ($P<0.10$) with increasing HC level. Digestibility of DM and N during week 0-4 increased linearly with an increasing HC level ($P<0.005$). Serum IgG concentrations linearly increased with the increase of HC supplementation ($P<0.01$). Cortisol concentrations tended ($P<0.10$) to decrease linearly with increasing level of HC. The linear reduction of subjective scores for marbling ($P<0.01$) and firmness ($P<0.01$) of the *longissimus* muscle were observed. In conclusion, supplementation of HC improved feed efficiency and increased IgG and cortisol concentration in serum.

KEY WORDS: herb, coral, IgG, cortisol, meat quality, pigs

INTRODUCTION

In recent years, the use of medical herbs are being accepted and used increasingly by either human or animals. Herbs are mainly derived from natural

[1] Corresponding author: e-mail: inhokim@dankook.ac.kr

products, with more than 80% from plants. They already have a long history that used medicinally in Asia countries since antiquity. A variety of herbs is widely utilized to treat the diseases of human and animals. This is because herbs are easy and cheap to prepare, and are effective with fewer side effects during treatment of diseases (Jian and Wu, 2003). Semen *Zizyphi spinosae,* pollen pini, cortex mori and radix *Achyranthis bidentatae*, the active components of the used herb-mix, are known for their sedative and anxiolytic properties (Mdidea, 1997; Choi, 2007). Herbs have many potential clinical and therapeutic applications in the modern medical setting. They also are rich in a wide variety of nutrients and are new additives for livestock feed, due to they can be used as attractants to increase feed intake, improve growth rate and feed utilization (Zheng and Wang, 2001). In addition, according to the medicinally effects of herbs, large amount of previous studies investigated the influence of herbs on animal's immunity and observed positive effects (Chiang et al., 2003). However, there were still several inconsistent reports that suggested such positive herbs effects can't be observed (Hermann et al., 2003). It should indicate that the different results may mainly ascribe to different sources and ingredients of herbs used by researchers. Therefore, it is necessary to evaluate certain herb products practically.

Coral mineral complex (HC) is a source of organic minerals powder from fossilized corals. These corals contain a natural balanced mixture of over 74 minerals, which is rich in calcium, magnesium and all the trace minerals needed by the human body. The organic origin of the coral minerals guarantees that they are well absorbed by the body, because of its natural ability to become ionic upon contact with moisture. This ability to combined with the full spectrum, organic formation, makes coral one of the most absorbable forms of minerals (Mcvitamins, 2000). The use of organic mineral in animal feeds brings a number of advantages for performance and meat quality (Mahan et al., 1999). Additionally, some researchers reported that magnesium (one of the components of coral mineral) is able to reduce plasma corticosteroids stimulation (Kietzmann and Jablonski, 1985).

There are limited research about dietary of herbs and coral mineral complex in finishing pigs. It was hypothesized that these two feed additives either alone or in combinations would enhance the performance by reducing the stress in pigs. Also, less stress in pig can reduce the chance of PSE (pale, soft and exudative) and DFD (dark, firm and dry) pork thereby improving meat quality (Warriss, 1993). Measuring blood parameters could be useful to detect the anti-stress effect of herbs and coral mineral complex. Therefore, the aim of this study was to evaluate: 1. the effects of HC on finishing pig performance, nutrient digestibility, immune blood characteristics and meat quality and 2. whether pig stress can be decreased by dietary HC supplementation.

MATERIAL AND METHODS

Source and composition of herbs and coral mineral complex

The herbs and coral mineral complex contained 40% herbs: semen *Zizyphi spinosae* (Spina Date Seed) 10%, pollen pini 5%, cortex mori (white mulberry root-bark) 5%, semen *Plantaginis* (*Plantago asiatica*) 5%, radix *Achyranthis bidentatae* (Achyranthes root) 5%, *Rhizoma Acori tatarinowii* (Grassleaf Sweelflag Rhizome) 5% and herb *Capsellae* (shepherds purse herb) 5%, 50% coral mineral (%: Ca 22, P 2, Mg 3, Mn 0.5, Na 2, Cl 1, Zn 0.5, Fe 1.5, Se 1 and other 16.5) and 10% carrier (Manufacturer's specification).

Experimental design, animals, housing and diets

The experimental protocol was approved by the Animal Care and Use Committee of Dankook University. A total of 80 crossbred (Landrace×Yorkshire×Duroc) pigs (58.06±1.47 kg of BW) were allotted to four dietary treatments on the basis of initial BW according to a completely randomized design, 4 pigs (2 barrows, 2 gilts) per pen (1.8 m width × 1.8 m length) and 5 replications per treatment. All the pigs were housed on a concrete, slatted floor in an environmentally-controlled room, which target room temperature and humidity was maintained at 22°C and 60%, respectively. The experimental period lasted 8 weeks.

Dietary treatments include: 1. CON (basal diet); 2. HC 0.05 (basal diet + 0.05% HC); 3. HC 0.1 (basal diet + 0.1% HC) and 4. HC 0.2 (basal diet + 0.2% HC). HC were replaced with rice bran in the diets.

Two finisher diets (Table 1) were formulated to meet or exceed of NRC (1998) recommendations for all nutrients and fed in meal form. Each pen was equipped with a one-sided self-feeder and a nipple waterer to allow *ad libitum* access to feed and water throughout the experimental periods.

Sampling and measurements

Body weight and feed intake were measured at the end of week 0, 2, 4 and 8 to determine average daily gain (ADG), average daily feed intake (ADFI) and gain/feed. Total tract apparent digestibility (CTTAD) for DM and N were determined at the end of week 4 and 8. Pigs were fed diets containing chromic oxide (0.2%) as an indigestible marker, for 7 days prior to the collection day, and fresh faecal grab samples were obtained once daily from at least two pigs in each pen. All the faecal samples, as well as feed samples were stored in refrigerator until analysis. Before chemical analysis, faecal

Table 1. Composition of experimental diets (as-fed basis)[1]

Item	Early finisher Period	Late finisher period
Ingredient, %		
ground maize	59.93	67.45
soyabean meal	23.75	18.14
rice bran	5.00	5.00
molasses	4.00	5.00
animal fat	2.61	2.00
rapeseed meal	2.00	-
phosphorus defluoronized	1.16	1.12
calcium carbonate	0.44	0.68
L-lysine, 78%	0.34	0.20
salt	0.15	0.15
vitamin premix[2]	0.25	0.15
mineral premix[3]	0.10	0.05
DL-methionine, 98%	0.10	-
choline chloride, 60%	0.08	0.04
L-threonine, 98%	0.09	0.02
Chemical composition[4]		
ME, MJ/kg	13.44	13.36
crude protein, %	17.72	14.80
lysine, %	1.02	0.89
Ca, %	0.70	0.74
P, %	0.59	0.54

[1] early finisher period = wk 0 to 4, late finisher period = wk 4 to 8, and overall = wk 0 to 8

[2] supplied per kg diet, IU: vit. A 4,000, vit. D_3 800, vit. E 171; mg: vit. K 2, vit. B_2 4, vit. B_6 1, pantothenic acid 11, niacin 20 and biotin 0.02; µg: vit. B_{12}, 16

[3] supplied per kg diet, mg: Cu 220, Fe 175, Zn 191, Mn 89, I 0.3, Co 0.5 and Se 0.4

[4] calculated values

samples were thawed and dried at 70°C for 72 h and subsequently ground to pass through a 1-mm screen. All the feed and faecal samples were analysed for DM and N according to the AOAC procedures (1995) while chromium was determined by UV absorption spectrophotometry (Shimadzu, IJV-1201, Japan) according to the methods of Fenton and Fenton (1979). Nitrogen was measured using a Kjeltec 2300 Analyzer (Foss Tecator AB, Hoeganaes, Sweden).

Blood samples were collected from cervical vein into both K_3EDTA vacuum tubes and clot activator vacuum tubes (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ, USA) from 2 pigs in each pen at the beginning and end of the experiment. Lymphocytes count in whole blood and cortisol and IgG in serum were measured; lymphocytes - using the automatic blood analyzer (ADVIA 120, Bayer, USA), serum parameters (cortisol and IgG) - using a radioimmunoassay kit (Diagnostic Products Co., USA) and Cobra 5010 Quantum (Diagnostic Products Co., USA), respectively.

Pigs were slaughtered at a local commercial slaughter house. After chilling at 2°C for at least 24 h, one 2.54-cm-thick *longissimus* muscle (LM) sample was

removed at the 10th rib (right side of carcass) and allowed to bloom for 30 min. Subjective colour, marbling, and firmness scores on the LM were evaluated on the cut surface following the procedures described by NPPC (1991). Colour, marbling and firmness were scored by sensory panel consisted of 11 trained panelists, using a 5-point scale (1 = pale, devoid of marbling, very soft; 5 = dark, moderately abundant marbling or greater, very firm). At the same time, ultimate pH values were measured directly using a combined pH electrode (NWKbinar pH, K-21, Landsberg, Germany). A 4 g meat sample 1.5-cm-diameter core about 4 cm long was taken from LM sample, perpendicular to the length of the muscle and suspended in a plastic bag for 24 h and 7 days at 4°C. The muscle sample then was reweighed to determine drip loss as a percentage of the original weight. Water holding capacity (WHC) was measured according to the methods of Kauffman et al. (1986). In brief, 0.2 g sample was pressed at 3000 psi for 3 min on 125-mm-diameter filler paper. The areas of the pressed sample and expressed moisture were delineated and then determined with a digitizing area-line sensor (MT-10S; M.T. Precision Co. Ltd., Tokyo, Japan). A ratio of water:meat areas was calculated, giving a measure of WHC (the smaller ratio indicate the higher the WHC). 2-thiobarbituric acid reactive substances (TBARS) were measured by the method of Witte et al. (1970) and expressed as mg of malonaldehyde (MDA) per kg of muscle. Trichloroacetic acid solution (20% wt/vol) was used for the extraction. A UV absorption spectrophotometry (UV-1201, Shimadzu, Japan) was used for spectrophotometric analysis.

Statistical analyses

All the data were analysed as a completely randomized design using GLM procedure of SAS (1996). The model included the effects of block (replication) and treatment. Pen served as the experimental unit. Also, the CON diet was compared with HC diets by the polynomial regression (Peterson, 1985) method to determine linear, quadratic and cubic effects. The individual pen served as the unit. Variability of all the data was expressed as standard error (SE) and a probability level of $P<0.05$ was considered as statistically significant while $P<0.10$ was considered as a tendency.

RESULTS

Effects of HC on growth performance are presented in Table 2. For 0-2 weeks, there were no significant effects of HC inclusion on ADFI and gain/feed. There was a slight quadratic effect on ADG ($P<0.10$). For 4-8 weeks, ADG was unaffected by HC and there were no significant quadratic or cubic effects due to

Table 2. Effect of herbs and coral mineral complex supplementation on growth performance in finishing pigs

Item	Con[1]	HC0.05[1]	HC0.1[1]	HC0.2[1]	SE[2]	P values for contrasts[3]		
						L	Q	C
0-2 weeks								
ADG, kg	1.033	0.978	0.998	1.066	0.037	0.27	0.06	0.46
ADFI, kg	2.394	2.298	2.390	2.340	0.079	0.90	0.62	0.49
G/F	0.431	0.426	0.418	0.456	0.024	0.30	0.23	0.92
2-4 weeks								
ADG, kg	1.066	1.042	1.020	1.068	0.038	0.76	0.30	0.66
ADFI, kg	2.502	2.518	2.410	2.432	0.085	0.34	0.76	0.28
G/F	0.426	0.414	0.423	0.439	0.011	0.93	0.14	0.49
4-8 weeks								
ADG, kg	1.000	0.938	1.008	1.023	0.039	0.48	0.39	0.28
ADFI, kg	2.552	2.486	2.444	2.378	0.063	<0.01	0.45	0.18
G/F	0.392	0.378	0.412	0.430	0.020	0.04	0.62	0.70
Overall								
ADG, kg	1.018	0.978	1.009	1.045	0.018	0.81	0.16	0.25
ADFI, kg	2.502	2.450	2.423	2.390	0.045	0.02	0.30	0.38
G/F	0.407	0.399	0.416	0.437	0.010	0.09	0.12	0.90

[1] CON, basal diet: HC 0.05, CON+0.05% HC; HC 0.1, CON+0.1% HC: HC 0.2, CON+0.2% HC, HC replaced with rice bran in the diet

[2] pooled standard error

[3] P-values for linear (L) quadratic (Q) and cubic (C) effects for the herbs and coral mineral complex

HC inclusion for ADFI or G/F. However, both ADFI ($P<0.01$) and G/F ($P<0.05$) showed a significant linear effect with HC inclusion. For the overall period, ADG was unaffected by HC. There was a significant linear response for ADFI ($P<0.05$) and a tendency for G/F ($P<0.10$).

Effects of dietary HC on CTTAD for DM and N are summarized in Table 3. At the end of week 4, both the CTTAD for DM and N was significantly linearly increased with increasing of HC content in the diets ($P<0.05$). However, neither was significantly affected by dietary treatment at the end of week 8.

Effects of HC supplementation on blood characteristics in finishing pigs are presented in Table 4. The data suggest that HC did not affect lymphocyte level at any feeding periods. At the final of experiment, IgG level was significant increased (L effect; $P<0.01$) as dietary HC concentration increased. Also, the difference of IgG level between the initial and final of experiment was significantly increased (linear effect; $P<0.01$).

Herbs and coral mineral complex did not affect drip loss, pH value, WHC and TBARS in current experiment (Table 5). In sensory evaluation, the colour of the pork did not show significant difference among the treatments. However, the marbling of the pork in pigs fed CON diet was higher than for those fed the HC in diets (L effect; $P<0.01$). The firmness of pork was significantly linear decreased as

Table 3. Effect of herbs and coral mineral complex supplementation on coefficient of total tract apparent digestibility (CTTAD) of dry matter (DM) and nitrogen (N) in finishing pigs

Item	Con[1]	HC0.05[1]	HC0.1[1]	HC0.2[1]	SE[2]	P values for contrasts[3]		
						L	Q	C
DM, %								
4 weeks	0.816	0.833	0.833	0.847	0.0077	0.02	0.83	0.41
8 weeks	0.809	0.807	0.800	0.828	0.0144	0.50	0.27	0.45
N, %								
4 weeks	0.785	0.817	0.821	0.824	0.0113	0.04	0.25	0.60
8 weeks	0.807	0.798	0.805	0.790	0.0126	0.15	0.73	0.67

[1,2,3] explanation see Table 2

Table 4. Effect of herbs and coral mineral complex supplementation on blood characteristics in finishing pigs

Item	Con[1]	HC0.05[1]	HC0.1[1]	HC0.2[1]	SE[2]	P values for contrasts[3]		
						L	Q	C
Cortisol, µg/dl								
initial	4.20	4.05	4.10	3.72	1.59	0.89	0.84	0.98
final	3.14	2.48	2.36	2.24	0.32	0.07	0.41	0.71
difference	-1.06	-1.57	-1.74	-1.48	1.62	0.62	0.90	0.81
IgG, mg/dl								
initial	769.60	841.60	750.20	936.80	86.90	0.31	0.52	0.28
final	795.80	882.40	1040.60	1312.00	78.80	<0.01	0.28	0.90
difference	26.20	40.80	290.40	375.20	81.76	<0.01	0.68	0.30
Lymphocyte, %								
initial	43.20	44.60	40.20	44.20	3.01	0.95	0.78	0.49
final	63.00	60.00	55.80	61.20	4.22	0.88	0.64	0.46
difference	19.80	15.40	15.60	17.00	7.34	0.90	0.92	0.98

[1,2,3] explanation see Table 2

Table 5. Effect of herbs and coral mineral complex supplementation on meat quality in finishing pigs

Item	Con[1]	HC0.05[1]	HC0.1[1]	HC0.2[1]	SE[2]	P values for contrasts[3]		
						L	Q	C
Sensory evaluation								
colour	2.95	2.90	2.85	2.72	0.12	0.18	0.74	0.88
marbling	2.10	1.98	2.03	1.77	0.07	<0.01	0.33	0.10
firmness	2.28	1.76	1.83	1.57	0.10	<0.01	0.22	0.06
Drip loss, %								
1 day	2.83	3.93	1.52	3.67	0.93	0.97	0.56	0.11
7 days	8.30	7.96	5.65	7.35	1.28	0.42	0.33	0.48
pH	5.65	5.66	5.68	5.60	0.05	0.85	0.28	0.68
WHC, %	33.36	38.36	42.90	38.08	4.67	0.37	0.30	0.70
TBARS, mgMA/kg	0.129	0.110	0.110	0.098	0.012	0.18	0.78	0.66

[1,2,3] explanation see Table 2

dietary HC concentration increased (P<0.01). Also, cubic effects were observed in marbling and firmness of pork (P=0.10; P<0.10).

DISCUSSION

In the present study, during week 4 to 8 and overall the period, gain/feed was linear increased with an increase of HC level. This result agreed with Park et al. (2000) who using 0.4 and 0.8% tranquilizing herb-mix diets fed pigs observed significant improvements on gain/feed from their growth trials, and they explained this improvement was due to the herbs having positive effect on growth hormone. However, our data showed ADG was not affected by the supplement of HC, but ADFI was decreased. Reasonable explanation for the lower ADFI of the pigs fed HC supplemented diets is tranquilizing effect of herbs reducing the spontaneous physical activity of pigs. Physical activity influences heat production, which can cause the additional expenditure of energy. Close and Poorman (1993) calculated that the additional expenditure of energy by growing pigs for walking was 2.80 KJ of ME/kg of BW for each kilometer. Therefore, pigs fed HC supplemented diets may be have a lower energy requirement compared with CON treatment, which may lead to the decline of ADFI.

The active components of the herbal product, cortex mori, semen *Plantaginis, Rhizoma Acori tatarinowii* and herb *Capsellae*, are known for their effects of improvement appetite, antiinflammatory for reducing diarrhoea, promoting digestive juice secretion and strengthening the stomach, respectively (Lei, 1995). All of the actions aforementioned can results in the better digestibility of DM and N at 4 week. Another reasonable explain for the improvement of CTTAD at the end of week 4 is that coral minerals are in a natural balance with all of the minerals required, especially the trace minerals, to support each mineral in its designated role. It can make sure the pig's digestive juice and enzyme well-balanced production and secretion so as to ensure better digestibility were obtained (Mcvitamins, 2000). The reason why HC supplement did not affecting the CTTAD for DM and N at the end of week 8 can not be explained from current result, further investigations are needed to determine if this is a real or spurious result.

The concentration of cortisol in plasma can be regarded as a criterion to reflect stress intensity (Webel et al., 1997). The linear decline of cortisol level in plasma in HC treatments at the end of experiment may be caused by the compositions of herbs (semen *Zizyphi Spinosae,* pollen pini and cortex mori), which are known for their tranquilizing and sedative effect (Lei, 1995; Choi, 2007). Inconsistently, Peeters et al. (2006) found no difference in the decreases or increases of cortisol between control and herb-supplemented group after a stress vibration test with pigs. However, Peeters et al. (2005) found that pigs were visually calmer than control pigs in vibrating experimental research after supplementation magnesium. Thus, the additional magnesium supplement in diets (3% magnesium in HC) might cause some positive effects on reducing stress in pigs. Cortisol produced during stress situations may suppress the body's immune response (Coe,

1997), and higher level of cortisol in the bloodstream had been shown to have negative effects, such as lowered immunity (Suzanne and Gregory, 2004). The immunomodulatory effect of semen *Plantaginis* and radix *Achyranthis bidentatae* were shown in many previous researches (e.g., Chiang et al., 2003). For the above reasons, IgG level was significantly increased with addition HC level. Moreover, coral mineral supplied enough trace mineral, such as selenium and zinc, which have positive effect on immunity, is another explanation to improve the IgG level in pig. In the current study, HC did not affect lymphocyte level in blood. Our data are different from other research, which has shown, that porcine immune cell with cortisol suppresses lymphocyte proliferation (Salak et al., 1993). This may be due to cortisol level just showed a slight different, which is not enough to cause the lymphocyte proliferation reducing, among the treatments in our experiment.

In the current study, HC did not affect colour, drip loss, pH and WHC. Our data were consistent with the results by Peeters et al. (2006), who reported no effect of herb-supplemented group in the diet of pigs on pH and WHC in *longissimus* muscle. No more comparisons with other studies could be made because investigations about the use of herbal products in relation to meat quality are not reported yet. The TBARS was decreased numerically in HC treatments compared with CON treatment in current study. Anti-oxidative effect of pollen pini in herb mix may be causing this numerical decline of TBARS. Bao et al. (2006) reported that the active antioxidant components of the pollen pini are known for vitamin E, carotene and Se, which were widely known for inhibiting the lipid *in vitro* and protein peroxidation. They suggested the further mechanism may be due to pollen pini could improve the activity of SOD and free radical scavenging effect. Similarly, Guo et al. (2006) suggested that high level of vitamin E supplementation had a beneficial effect on the oxidative stability of pork as indicated by TBARS values. Surprisingly, marbling and firmness of sensory evaluation were linearly decreased with the increase of HC level. The decline of marbling scale may be caused by the reduction of physical activity have some negative effect on intramuscular fat deposition. The exact mechanisms underlying these abnormalities reduction of firmness are not known from current experiment. Understanding these mechanisms should prove useful in the quest for unraveling the complex machinery controlling pork quality development.

IMPLICATIONS

Under the conditions of present experiment, the benefit on cortisol and IgG level in serum and the greater gain/feed have been obtained with the supplement of HC in diets. However, unexpected negative effect of meat quality was detected, which is necessary to be further investigated to explain the underlying mechanism. The

further research should be continued with testing single herbs or coral minerals effects. Also ethological research should be conducted to investigate whether sedative and tranquilizing herbs supplementation in pig diets can lead to a decline of spontaneous motor activity. It may be explain some underlying mechanism in this experiment.

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