Journal of Animal Science and Technology 53(6) 541~548, 2011
http://dx.doi.org/10.5187/JAST.2011.53.6.541

Effect of Dietary Kocetin™ on Meat Quality of Hanwoo Loin

Mingu Kang[1], Hyun Joo Kim[1], Hyun Jung Lee[1], Aera Jang[2], Gwan Sik Yun[3] and Cheorun Jo[1]*
[1]Department of Animal Science and Biotechnology, Chungnam National University, Daejeon 305-764, Korea,
[2]Quality Control and Utilization Division, National Institute of Animal Science, RDA, Suwon, 441-706, Korea,
[3]Synergen Inc., Bucheon, 420-020, Korea

ABSTRACT

This study was performed to determine the effects of dietary Kocetin™ on meat quality of Hanwoo (Korean native cattle) beef. Samples were divided into 3 groups; dietary supplementation of Kocetin™ (KC) at 21 and 42 ppm (n=4), and non-supplemented control (n=3) for 75 days. The KC composed of 10% of quercetin which was a bioactive compound. After slaughtering the Hanwoo, each loin from 10 Hanwoos were obtained and analyzed. Dietary supplementation of KC did not affect the final pH, water holding capacity, drip loss, cooking loss, surface color, total phenolics content, radical scavenging activity, and sensory scores. Dietary quercetin also showed no difference in both TBARS and VBN values. Textural profile analysis results also showed no difference, except for adhesiveness and springness. Springness was significantly higher in loin from Hanwoo treated by dietary KC at 42 ppm when compared to control. Results revealed that the loin from Hanwoo fed dietary KC up to 42 ppm (approximately 4.2 ppm of quercetin) was not sufficient to have clear positive effects on meat quality of loin.
(**Key words :** Hanwoo, Loin, Quercetin, Quality)

INTRODUCTION

Meat and meat products are important sources for protein, fat, essential amino acids, minerals and vitamins and other nutrients (Biesalski, 2005). In recent years, the consumer demands for high quality beef, such as from Korean native cattle (Hanwoo) (Zhang et al., 2010). However, oxidation in meat and meat products is a main problem for the meat industry. This problem brings to the deterioration of lipids and proteins that affect the degradation in flavor, texture and color of displayed fresh meat (Decker et al., 1995).

To prevent oxidative process, retard occurrence of off-odors, and improve color stability, antioxidants are added to fresh and extra processed meats (Xiong et al., 1993). Synthetic antioxidants, such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT) and propyl gallate (PG) can be used to minimize lipid oxidation in meat effectively. However, their potential health risk limited their expansive use and increased the popularity in using natural antioxidants (Han and Rhee, 2005; Ito et al., 1983). Consequently, natural antioxidants have been recommended as an alternative to synthetic antioxidants to retard oxidative processes and to enhance the quality of meat. Natural antioxidants like vitamins, fatty acids, and polyphenols has been studied (Zhang et al., 2010).

Quercetin is a typical catechol-type flavonoid with high antioxidant ability, present in most edible parts of food and feed plants (Hertog et al., 1993; Hollman and Arts, 2000) and thus is existed at various concentrations in most human and animal diets such as fruits, vegetables, flowers and tea. Currently, the possible mechanisms of antioxidant activity of quercetin *in vitro* have been researched in several studies, explaining direct scavenging of reactive oxygen (ROS) or nitrogen species (RNS), chelating of redox active transition metal ions and inhibition of enzymes entailed in ROS production (Middleton et al., 2000; Mira et al., 2002; Zhu et al., 2000). Previous studies suggest that the ingestion of supplemented flavonoids is connected with a decreased risk of some cancers and cardiovascular disease (Ross and Kasum, 2002; Sesso et al., 2003).

The effectiveness of dietary supplementation of quercetin on oxidative stability of chicken during storage has been reported (Jang et al., 2010). Cho et al. (2010) demonstrated the effect of dietary quercetin on meat quality of goat. Also,

* Corresponding author : Cheorun Jo, Department of Animal Science and Biotechnology, Chungnam National University, Daejeon 305-764, Korea, Tel: +82-42-821-5774, Fax: +82-42-825-9754, E-mail: cheorun@cnu.ac.kr

other studies were done with rats and pigs (Ameho et al., 2008; de Boer et al., 2005; Luehring et al., 2011).

The objective of this study was to investigate the effect of dietary supplementation of KC, including quercetin, on physical characteristics, antioxidative activity, and quality of Hanwoo beef loin meat during storage.

MATERIALS AND METHODS

1. Sample preparation

A total of 11 Hanwoos were divided into 3 groups; 1) 21 ppm of dietary Kocetin™ (KC) (n = 4), 2) 42 ppm of dietary KC (n = 4), and 3) non-treated control (n = 3) in an experimental farm (CJ Co., Ltd., Seoul, Korea). The amount of KC was decided for the possibility to replace 50 and 100% of vitamin E on the basis of the feeding practice in the farm studied (42 ppm). The KC was mixed with feed for the designated concentrations and fed for 75 days. The prepared feed was provided at 10 kg/day. KC was obtained from Synergen Co. (Bucheon, Korea) which consisted of 10% of quercetin and 90% of $CaCO_3$. Ten fresh loin meats of Hanwoo beef were obtained from a commercial abattoir 24 h postmortem and transported to a laboratory using a cold container. All samples were stored in a refrigerator at 4℃ for 7 days and quality characteristics were analyzed.

2. Proximate analysis

Approximately 200 g of the samples were used to measure collagen, fat, moisture, and protein contents using a FoodScan Lab Meat Analyzer (FoodScan Lab, Type 78800, FOSS, Hilleroed, Denmark).

3. Physical characteristics

(1) pH

The samples (1 g) were homogenized (T25b, Ika Works (Asia)., Sdn, Bhd, Malaysia) with distilled water (9 mL) at 16,000 rpm for 20 s. pH of the loin meat was measured by pH meter (SevenGo, Mettler-Toledo Inti, Inc, Schwerzenbach, Switzerland).

(2) Water holding capacity (WHC)

The sample (1 g) of minced loin meat was placed into conical tube and centrifuged at 3,000 rpm for 10 min. The released water was weighed and calculated as a percentage of the initial moisture content of meat.

(3) Color measurement

Color measurements of the surface of the loin were performed using a spectrophotometer CM 3500d (Konica Minolta Censing Inc., Japan) and Hunter color L* − (lightness), a* − (redness) and b* − (yellowness) value were determined. Sample was placed on a quartz cell (8 mm diameter) and the instrument was calibrated to standard black and white plate before analysis. A small size aperture was used, and the measurement was carried out in triplicate.

(4) Texture profile analysis

For texture analysis, the loin meat samples were cut into 30 mm × 20 mm × 15 mm. The experiment was carried out with a Texture Analyzer (Model TA-XT 2i, Stable Micro systems Ltd., Surrey, UK). A round needle type probe (75 mm diameter) was set and moved perpendicularly to the sample with a speed of 1.00 mm/s, and trigger force of 0.005 kg. Texture analysis was performed by the texture expert software (version 4,0,12,0. Stable Micro system Ltd.), and the following parameters like hardness, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience were recorded (Bourne, 1978). Each measurement was replicated at three times.

4. Antioxidative activity

Loin meats (3 g) were homogenized (T25b, Ika Works (Asia) in 15 mL of distilled water at 16,000 rpm for 20 s. The samples were centrifuged at 3,000 rpm for 10 min and filtered with a filter paper (Whatman No. 1, Whatman Ltd., Maidstone, England). Chloroform (10 mL) was added to remove fat. The mixture of the samples was shaken 2 - 3 times. The samples were divided into lipids and the aqueous supernatant by centrifuging at 3,000 rpm for 10 min and then the supernatant used for the analysis of the total phenolic contents and DPPH radical scavenging activity.

Total phenolic contents were measured by the Folin-Ciocalteu's method (Subramanian et al., 1965). The prepared sample solution (0.1 mL) was added to the Folin-Ciocalteu reagent (0.2 mL) and kept to reaction for 1 min. Sodium carbonate (5%, 3 mL) was added and vortexed. The mixture was kept in incubator for 2 h at 23℃. The absorbance was measured with a spectrophotometer (DU 530, Beckman

Instruments Inc., Fullerton, CA, USA) at 765 nm. Quantification was done based on a standard curve generated with gallic acid.

The DPPH radical scavenging effect was estimated according to the method of Blois (1958) with slight modification. The samples (0.2 mL) were added to distilled water (0.8 mL) and 0.2 mM methanolic DPPH solution (1 mL). For the control, distilled water (1 mL) was added to 0.2 mM methanolic DPPH solution (1 mL). The mixture was left to stand for 30 min at room temperature. The absorbance was measured with a spectrophotometer (Beckman Instruments Inc.) at 517 nm. The percentage of DPPH radical scavenging was obtained from the following equation.

DPPH radical scavenging activity = [1 − (absorbance of sample / absorbance of control)] × 100.

5. 2-thiobarbituric acid reactive substances (TBARS)

TBARS values of the loin meat were measured during storage and done according to method by Jung et al. (2011). Each sample (3 g) was added to distilled water (9 mL) and BHT (7.2% in ethanol, 50 μL) in centrifuge tube (50 mL). The samples were homogenized at 16,000 rpm for 20 s. The homogenate (1 mL) was transferred to a centrifuge tube (15 mL) and added to 20 mM TBA/TCA solution (in 15% TCA, 2 mL). Tubes were heated in a water bath at 90℃ for 30 min, cooled in cold water and then centrifuged at 3,000 rpm for 10 min. Absorbance was measured at 532 nm with a spectrophotometer (Beckman Instrument Inc.). TBARS value was reported as mg malondialdehyde per kg meat.

6. Volatile basic nitrogen (VBN)

Measurement of VBN was done according to Conway (1950). Samples (3 g) were homogenized at 16,000 rpm for 10 min with distilled water (3 g) and TCA (10%, 6 mL). The samples were centrifuged at 3,000 rpm for 10 min and filtered with a filter paper (Whatman No. 1). Homogenized mixture was added to TCA (5%, 18 mL). The mixture was centrifuged at 3,000 rpm for 10 min, and then made up to a final volume 30 mL with TCA (5%). 0.01 N boric acid was used as a VBN absorber and placed in the inner section of a Conway micro-diffusion cell (Sibata Ltd., Tokyo, Japan). The sample solution (1 mL) was placed into the outer section. TCA (5%) was used as control. K_2CO_3 solution (1 mL) was placed into the outer section on the opposite side of the sample solution and the lid was closed immediately. Conway micro-diffusion cell was stirred smoothly and then incubated at 37℃ for 60 min. The samples were titrated against 0.01 N sulfuric acid. The concentration of VBN was calculated as ammonia equivalent using the following equation:

VBN value (mg%) = [0.14 × (titration volume of sample solution-titration volume of control) × 10] × 100

7. Sensory evaluation

Sensory evaluation was performed by a ten-member of panelist who has experience of meat quality analysis for at least 1 year. Different sessions were carried out in 3 consecutive days. The samples were sliced into 15 mm thick portions. Samples were grilled on both sides for 45 s to reach an interior temperature of 75℃. The grilled meat samples were scored on a 9-point hedonic scale by sensory panelists to assess meat quality attributes. Sensory parameters evaluated were meat color, odor, taste, tenderness, juiciness, flavor and overall acceptance (extremely dislike = 1 to extremely like = 9).

8. Statistical analysis

Statistical analysis was performed by one-way analysis of variance (ANOVA). When significant differences were detected, the differences among the mean values were identified by Duncan's multiple range tests using SAS software (2004) at a confidence level of $P < 0.05$. Mean values and standard errors of the mean are reported.

RESULTS AND DISCUSSION

1. Proximate composition

The proximate composition of the three treatment groups is presented in Table 1. Crude fat content was significantly higher in the loin of Hanwoo fed KC 21 ppm (21.07%) than other treatments. The KC 21 ppm sample was also higher in collagen contentthan other treatments. On the other hand, moisture and crude protein content was the least in KC 21 ppm samples compared to other treatments. Generally, proportions of intramuscular fat and moisture have inverse relationship. Fat content of beef muscle had a negative correlation with moisture content (Rhee et al., 1982).

Table 1. Proximate composition (%) of the loin meat from Hanwoo fed Kocetin™

Supplementation	Collagen	Fat	Moisture	Protein
Control	2.17[b]	15.09[b]	63.42[a]	19.46[a]
21 ppm	2.66[a]	21.07[a]	58.61[b]	17.85[b]
42 ppm	2.12[b]	14.39[b]	63.94[a]	19.73[a]
SEM[1)]	0.120	1.724	1.423	0.441

[1)] Standard error of the means (n = 11).

[a-b]Different letters within the same column differ significantly ($p < 0.05$).

2. Physical characteristics

Table 2 shows the physical characteristics of samples from the Hanwoo loin fed KC. In previous study, there was an association between pH and water holding capacity (Bee et al., 2007). The change of meat pH to near isoelectric point decreases water holding capacity (Swatland, 2008). However, the present experiment had no significant difference on the final pH of the samples. In addition, there were no significant differences on the water holding capacity, drip loss, cooking loss and surface color of sample. These results mean that the dietary quercetin treatments did not change the physical meat quality characteristics, which is in agreement with Kremer et al. (2000).

The texture profile analysis (TPA) of the loin of Hanwoo fed KC is shown in Table 3. Our results showed that all TPA values had no significant difference, except for springness and adhesiveness. Springness was higherin the loin of Hanwoo fed KC at 42 ppm level, compared with control. In the previous study, it was revealed that hardness was the most important factor in texture analysis (Chambers and Bowers, 1993). Jung et al. (2011) reported that high springiness is one of the characteristic meat quality traits of Korean native chicken when compared with commercial broilers. Overall, the feeding of quercetin did not influence thetexture of the Hanwoo loin.

3. Antioxidant activity and volatile basic nitrogen content

Several investigators have found phenolic and flavonoid compounds in quercetin (Hertog et al., 1993; Hollman and Arts, 2000; Pratt and Watts, 1964). Total phenolics content of the loin fed KC ranged from 1.93 to 1.96 mg/g (Table 4). However, among the samples from Hanwoo fed KC, there was no significant difference. The role of antioxidant properties is associated mainly to their phenolic compounds, hence the antioxidant ability of quercetin has been related with the existence of several phenolic compounds such as resveratrol, carnosine and rutin, which break free radical chain reactions by electron donation and metal ion chelation (Bekhik et al., 2003).

The antioxidant activity of the Hanwoo loin fed KC was measured by radical scavenging activity, according to the DPPH method. DPPH is a widely used method for estimating the antioxidative activity. However, in this case, no difference was found. These results may be associated with rapid metabolism of quercetin (de Boer et al., 2005; van der Woude et al., 2004). Similar results were shown in previous study (Cho et al., 2010). Bekhit et al. (2004)

Table 2. Physical characteristics of the loin meat from Hanwoo fed Kocetin™

		Supplementation			SEM[1)]
		Control	21 ppm	42 ppm	
Final pH		5.54	5.60	5.58	0.023
Water holding capacity (%)		98.52	99.23	98.76	0.283
Drip loss (%)		0.92	1.18	1.59	0.399
Cooking loss (%)		17.32	16.92	18.87	0.955
Surface color	L*	33.63	29.01	32.94	1.708
	a*	18.31	17.62	18.07	0.670
	b*	14.97	13.08	14.80	0.505

[1)] Standard error of the means (n = 11).

Table 3. Texture profile analysis of the loin meat from Hanwoo fed Kocetin™

Supplementation	Hardness (kg)	Adhesiveness (g/sec)	Springness (mm)	Cohesiveness (%)	Gumminess (kg)	Chewiness (kg*mm)	Resilience
Control	28.44	−2.37[a]	0.52[b]	0.46	13.34	7.01	0.22
21 ppm	32.62	−2.73[ab]	0.54[ab]	0.47	15.86	8.63	0.22
42 ppm	30.37	−3.96[b]	0.58[a]	0.50	15.35	8.86	0.23
SEM[1)]	3.012	0.378	0.014	0.038	2.527	1.458	0.024

[1)] Standard error of means (n=11).

[a, b] Different letters within the same column differ significantly ($P < 0.05$).

Table 4. Antioxidative activity of the loin meat from Hanwoo fed Kocetin™

Supplementation	Total phenolic content (mg/g)	DPPH radical scavenging activity (%)
Control	1.93	37.80
21 ppm	1.96	35.84
42 ppm	1.95	30.88
SEM[1)]	0.039	4.489

[1)] Standard error of the means (n = 11).

reported that the stronger antioxidative capacity of quercetin may explain the lower negative effect exerted on the oxidative stress.

Lipid oxidation is a major cause of deterioration in the quality of muscle foods and can directly affect many quality characteristics such as flavor, color, texture, nutritive value, and safety of the food (Buckley et al., 1995). The effect on TBARS values of the loin from Hanwoo fed KC during storage for 7 days at 4℃ is shown in Table 5. TBARS values increased significantly during storage time but there was no increase found in the samples supplemented with KC. The increase of TBARS value is explained by auto-oxidation of fat in the presence of oxygen and the dietary KC may inhibit the development of lipid oxidation during storage. However, there was no difference found among the treatments significantly. Similarly, dietary supplementary of quercetin to goats did not show the effect on lipid oxidation in goat meat (Cho et al., 2010). In contrast, other studies using rats, chickens, and pigs showed the effect of dietary quercetin on suppressing lipid oxidation (Ameho et al., 2008; Jang et al., 2010; Luehring et al., 2011). This difference in results may be due to difference in structure of the digestive system and the amount of feeding quercetin because of the unique role of the rumen volatile fatty acids (VFA) in ruminants. The previous studies revealed that quercetin has exhibited high antioxidative capacity against hydroxyl and peroxyl radicals and superoxide anions (Afanasev et al., 1989; Robak and Gryglewski, 1988). Chen et al. (1999) demonstrated that quercetin inhibited lipid peroxidation in irradiated raw pork patties.

Table 5 shows the VBN content in the loin meat of Hanwoo that were fed KC. Total VBN concentration has been considered as an indicator of freshness and spoilage (Kruk et al., 2011). In this study, there was no significant difference according to treatments and during the storage time. Increase of VBN content in meat can be caused by either microorganisms or enzymatic degradation of protein (Field and Chang, 1969; Jo et al., 2004). In a previous study, dietary supplementation of quercetin to chickens has

Table 5. 2-thiobarbituric acid reactive substances (TBARS) and volatile basic nitrogen (VBN) of the loin meat from Hanwoo fed Kocetin™

Supplementation	Storage (day)		SEM
	0	7	
TBARS (mg malondialdehyde/kg meat)			
Control	0.39[y]	0.65[x]	0.035[2)]
21 ppm	0.39	0.47	0.049[3)]
42 ppm	0.35	0.50	0.068[3)]
SEM[1)]	0.053	0.059	
VBN (mg %)			
Control	5.27	5.37	0.219[2)]
21 ppm	5.18	5.25	0.187[3)]
42 ppm	5.25	5.00	0.207[3)]
SEM[1)]	0.194	0.217	

[1)] Standard error of means (n=11), [2)] (n=6), [3)] (n=8).

[x, y] Different letters within the same row differ significantly ($p < 0.05$).

Table 6. Sensory evaluation of the loin meat from Hanwoo fed Kocetin™

Supplementation	Color	Odor	Taste	Tenderness	Juiciness	Flavor	Overall acceptance
Control	5.83	5.63	5.98	4.52	6.07	5.88	6.17
21 ppm	5.75	5.60	6.48	4.86	6.31	5.98	5.98
42 ppm	5.83	5.79	6.21	4.06	6.15	6.09	6.15
SEM[1)]	0.168	0.199	0.232	0.283	0.229	0.245	0.267

The score was evaluated by 10 semi-trained panelists (1, extremely dislike; 5, neither dislike nor like; 9, extremely like).
[1)] Standard error of means (n=11).

highly inhibited protein decomposition (Jang et al., 2010).

4. Sensory evaluation

Eating quality, a combination of tenderness, flavor, and juiciness, is one of the most important characteristics by which consumer's judge meat quality (Grunert et al., 2004). Sensory evaluation of the loin from Hanwoo fed with KC was carried out to measure effects on color, odor, taste, tenderness, juiciness, flavor and overall acceptance (Table 6). According to the sensory score, there were no significant differences among the samples. The current study reveals that the dietary quercetin was not stored in muscle directly (de Boer et al., 2005; Graf et al., 2006). In this regard, quercetin does not work directly in the meat, but, it is metabolized in other organs or digestive tract after absorption, and these are considered having an effect on sensory parameters of meat (Cho et al., 2010). On the other hand, KC consists of only 10% of quercetin, which may be difficult to show any effect at this level of feeding. Therefore, further study using a higher dose of quercetin is needed.

In conclusion, this study indicate that feeding KC did not alter final pH, water holding capacity, drip loss, cooking loss, color, total phenolics, and radical scavenging activity significantly. These results showed that quercetin does not affect the quality characteristics of meat. It might be associated with the different digestive system of rumen from monogastric animaland limited amount of feeding the active compound (10% of quercetin in KC). Therefore, further studies on the effect of dietary quercetin at higher concentrations are required to see effect on meat quality.

ACKNOWLEDGMENT

This study was financially supported by research fund of Chungnam National University in 2011.

REFERENCES

Afanasev, I. B., Dorozhko, A. I., Brodskii, A. V., Kostyuk, V. A. and Potapovitch, A. I. 1989. Chelating and Free-Radical Scavenging Mechanisms of Inhibitory-Action of Rutin and Quercetin in Lipid-Peroxidation. Biochem. Pharmacol. 38:1763-1769.

Ameho, C. K., Chen, C. Y. O., Smith, D., Sanchez-Moreno, C., Milbury, P. E. and Blumberg, J. B. 2008. Antioxidant activity and metabolite profile of quercetin in vitamin-E-depleted rats. J.Nutr. Biochem. 19:467-474.

Bee, G., Anderson, A. L., Lonergan, S. M. and Huff-Lonergan, E. 2007. Rate and extent of pH decline affect proteolysis of cytoskeletal proteins and water-holding capacity in pork. Meat Sci. 76:359-365.

Bekhik, A. E. D., Geesink, G. H., Ilian, M. A., Morton, J. D. and Bickerstaffe, R. 2003. The effects of natural antioxidants on oxidative processes and metmyoglobin reducing activity in beef patties. Food Chem 81:175-187.

Bekhik, A. E. D., Geesink, G. H., Ilian, M. A. Morton, J. D. and Sedcole, J. R. and Bickerstaffe, R. 2004. Pro-oxidant activities of carnosine, rutin and quercetin in a beef model system and their effects on the metmyoglobin-reducing activity. Eur. Food Res. Technol. 218:507-514.

Biesalski, H. K. 2005. Meat as a component of healthy diet - Are there any risks or benefits if meat is avoided in the diet? Meat Sci. 70:509-524.

Blois, M. S. 1958. Antioxidant Determinations by the Use of a Stable Free Radical. Nature, 181:1199-1200.

Bourne, M. C. 1978. Texture profile analysis. Food Technol. 33:62-66.

Buckley, D. J., Morrissey, P. A. and Gray, J. I. 1995. Influence of dietary vitamin E on the oxidative stability and quality of pig meat. J. Anim. Sci. 71:3122-3130.

Chambers, E. and Bowers, J. R. 1993. Consumer Perception of Sensory Qualities in Muscle Foods - Sensory Characteristics of Meat Influence Consumer Decisions. Food Technol. 47:116.

Chen, X., Jo, C., Lee, J. I. and Ahn, D. U. 1999. Lipid oxidation, volatiles and color changes of irradiated pork patties as affected by antioxidants. J. Food Sci. 64:16-19.

Cho, S. K., Jo, C., Jung, S., Kim, M. K., Oh, H. M., Lee, B. D. and Lee, S. K. 2010. Effects of dietary quercetin on the feed utilization, blood parameters, and meat quality in Korean native goats. J. Anim. Sci. Technol. 52:297-304.

Conway, E. J. 1950. Microdiffusion analysis and volumetric error, 3rd ed, London:Crosby Lockwood and Son Ltd. pp. 87-107.

de Boer, V. C. J., Dihal, A. A., van der Woude, H., Arts, I. C. W., Wolffram, S., Alink, G. M., Rietjens, I. M. C. M., Keijer, J. and Hollman, P. C. H. 2005. Tissue distribution of quercetin in rats and pigs. J. Nutr. 135:1718-1725.

Decker, E. A., Chan, W. K. M., Livisay, S. A., Butterfield, D. A. and Faustman, C. 1995. Interactions between carnosine and the different redox states of myoglobin. J. Food Sci. 60:1201-1204.

Field, R. A. and Chang, Y. D. 1969. Free amino acids in bovine muscles and their relationship to tenderness. J. Food Sci. 34:329-331.

Graf, B. A., Ameho, C., Dolnikowski, G. G., Milbury, P. E., Chen, C. Y. and Blumberg, J. B. 2006. Rat gastrointestinal tissues metabolize quercetin. J. Nutr. 136:39-44.

Grunert, K. G., Bredahl, L. and Brunso, K. 2004. Consumer perception of meat quality and implications for product development in the meat sector - A review. Meat Sci. 66: 259-272.

Han, J. and Rhee, K. S. 2005. Antioxidant properties of selected Oriental non-culinary/nutraceutical herb extracts as evaluated in raw and cooked meat. Meat Sci. 70: 25-33.

Hertog, M. G. L., Hollman, P. C. H., Katan, M. B. and Kromhout, D. 1993. Intake of Potentially Anticarcinogenic Flavonoids and Their Determinants in Adults in the Netherlands. Nutr. Cancer Int. J. 20:21-29.

Hollman, P. C. H. and Arts, I. C. W. 2000. Flavonols, flavones and flavanols - nature, occurrence and dietary burden. J. Sci. Food Agric. 80:1081-1093.

Ito, N., Fukushima, S., Hagiwara, A., Shibata, M., and Ogiso, T. 1983. Carcinogenicity of butylated hydroxyanisole in F344 rats. J. Natl. Cancer Inst. 70:343-352.

Jang, A., Park, J. E., Kim, S. H., Chae, H. S., Ham, J. S., Oh, M. H., Kim, K. H., Cho, S. H. and Kim, D. H. 2010. Effect of Dietary Supplementation of Quercetin on Oxidative Stability of Chicken Thigh. Korean J. Poultry Sci. 37:405-413.

Jo, C., Kim, D. H., Kim, H. Y., Lee, W. D., Lee, H. K. and Byun, M. W. 2004. Studies on the development of low-salted, fermented, and seasoned *Changran Jeotkal* using the intestines of Therage chalcogramma. Radiat. Phys. Chem. 71:123-126.

Jung, Y., Jeon, H. J.., Jung, S., Choe, J. H., Lee, J. H., Heo, K. N., Kang, B. S. and Jo, C. 2011. Comparison of quality traits of thigh meat from Korean native chickens and broilers. Korean J. Food Sci. Ani. Resour. 31:684-692.

Kremer, B. T., Stahly, T. S. and Sebranek, J. G. 2000. Effect of dietary quercetin on pork quality. Iowa State University, ASL, 1621.

Kruk, Z. A., Yun, H., Rutley, D. L., Lee, E. J., Kim, Y. J. and Jo, C. 2011. The effect of high pressure on microbial population, meat quality and sensory characteristics of chicken breast fillet. Food Control. 22:6-12.

Luehring, M., Blank, R. and Wolffram, S. 2011. Vitamin E-sparing and vitamin E-independent antioxidative effects of the flavonol quercetin in growing pigs. Anim. Feed Sci. Technol. 169:199-207.

Middleton, E., Kandaswami, C. and Theoharides, T. C. 2000. The effects of plant flavonoids on mammalian cells: Implications for inflammation, heart disease, and cancer. Pharmacol. Rev. 52:673-751.

Mira, L., Fernandez, M. T., Santos, M., Rocha, R., Florencio, M. H. and Jennings, K. R. 2002. Interactions of flavonoids with iron and copper ions: A mechanism for their antioxidant activity. Free Radical Res. 36:1199-1208.

Pratt, D. E. and Watts, B. M. 1964. The Antioxidant Activity of Vegetable Extracts I. Flavone Aglyconesa. J. Food Sci. 29: 27-33.

Rhee, K. S., Dutson, T. R., Smith, G. C., Hostetler, R. L. and Reiser, R. 1982. Cholesterol content of raw and cooked beef longissimus muscles with different degrees of marbling. J. Food Sci. 47:716-719.

Robak, J. and Gryglewski, R. J. 1988. Flavonoids Are Scavengers of Superoxide Anions. Biochem. Pharmacol. 37:837-841.

Ross, J. A. and Kasum, C. M. 2002. Dietary flavonoids: Bioavailability, metabolic effects, and safety. Annu. Rev. Nutr. 22:19-34.

SAS Institute Inc. 2004. SAS User's Guide. Cary, NC : SAS Institute Inc.

Sesso, H. D., Gaziano, J. M., Liu, S. and Buring, J. E. 2003. Flavonoid intake and the risk of cardiovascular disease in women. Am. J. Clin. Nutr. 77:1400-1408.

Subramanian, K. N., Padmanaban, G. and Sarma, P. S. 1965.

Folin-Ciocalteu reagent for the estimation of siderochromes. Anal. Biochem. 12:106-112.

Swatland, H. J. 2008. How pH causes paleness or darkness in chicken breast meat. Meat Sci. 80:396-400.

van der Woude, H., Boersma, M. G., Vervoort, J. and Rietjens, I. M. C. M. 2004. Identification of 14 quercetin phase II mono- and mixed conjugates and their formation by rat and human phase II *in vitro* model systems. Chem. Res. Toxicol. 17: 1520-1530.

Xiong, Y. L., Decker, E. A., Robe, G. H. and Moody, W. G. 1993. Gelation of Crude Myofibrillar Protein Isolated from Beef-Heart under Antioxidative Conditions. J. Food Sci. 58:1241-1244.

Zhang, W., Xiao, S., Samaraweera, H., Lee, E. J. and Ahn, D. U. 2010. Improving functional value of meat products. Meat Sci. 86:15-31.

Zhu, Q. Y., Huang, Y. and Chen, Z. Y. 2000. Interaction between flavonoids and alpha-tocopherol in human low density lipoprotein. J. Nutr. Biochem. 11:14-21.

(Received Nov. 28, 2011; Revised Dec. 15, 2011; Accepted Dec. 16, 2011)