Effects of Dietary *Rhus verniciflua* Stokes Supplementation on Meat Quality Characteristics of Hanwoo (Korean Cattle) Beef during Refrigerated Storage*

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ABSTRACT : The effects of dietary *Rhus verniciflua* Stokes supplementation (0%, 2%, 4% and 6%/feed) on meat color, water-holding capacity (WHC), lipid oxidation and fatty acid composition in *m. longissimus* from Hanwoo (Korean cattle) beef during refrigerated storage were investigated. The *L**, *a**, *b** and *C** values of 4% group were significantly ($p<0.05$) higher than those of the other groups for 7 days of storage. The *a**, *b** and *C** values declined gradually during storage in all of the groups and the decline was more rapid in control group. The metmyoglobin (%) was significantly ($p<0.05$) increased during storage time in all of the groups, but the 4% group had a lower rate of metmyoglobin accumulation during storage. WHC was significantly ($p<0.05$) higher in the 2% and 4% groups than in the other groups. The TBARS (thiobarbituric acid reactive substances) value of day 0 was not significantly ($p>0.05$) different among 4 diet conditions, but the TBARS value after 5 days of storage was significantly ($p<0.05$) higher in the control group than in other groups. The proportions of C18:1, MUFA, UFA and MUFA/SFA ratio were significantly ($p<0.05$) higher in the meat from *Rhus verniciflua* Stokes-supplemented Hanwoo than in the control group. Consequently, the meat from *Rhus verniciflua* Stokes-supplemented Hanwoo showed higher color stability, WHC, unsaturated fatty acids and retarded lipid oxidation compared to the control meat. In particular, dietary *Rhus verniciflua* Stokes supplementation with 4% extended storage life compared to the other groups. ***(Asian-Aust. J. Anim. Sci. 2006. Vol 19, No. 1 : 113-118)***

Key Words : *Rhus verniciflua* Stokes, Color, WHC, TBARS, Fatty Acid Composition, Hanwoo

INTRODUCTION

In recent years, there has been a global trend toward the use of natural substances present in fruits, vegetables, and herbs as antioxidants and functional foods (Farr, 1997; Wang et al., 1997; Kitts et al., 2000; Muramoto et al., 2005). The natural antioxidants recently have been expected to replace the synthetic antioxidants which are widely used at present time (Sun et al., 1999; Hong et al., 2001; Lin and Chen, 2005). Greene (1969) was one of the first investigators to report on the potential color-preserving effect of antioxidants in meat.

Rhus verniciflua Stokes (RVS) belongs to Anacardiaceae and has been used traditionally for medicinal purposes and for the protection of antiquities in Korea for a long time (Kim, 1996). For example, it has been used as Korean herbal medicine to treat gastritis, stomach cancer, and arteriosclerosis (Jung, 1998).

Recently, it was shown that *Rhus verniciflua* Stokes has various biological activities (Lee et al., 1999; Lee et al., 2001). Antioxidant activity of *Rhus verniciflua* Stokes has been reported to correspond to well known enzymatic and non-enzymatic antioxidants in model linoleic emulsion experiments (Lim and Shim, 1997). Lee et al. (2001) reported that the ethanol extract from RVS showed antioxidant effect against hydroxyl radicals. The stem bark of *Rhus verniciflua* contains a high level of urushiols, which are polymerized formation of a lacquer film by the radical-chain reaction (Hirota et al., 1998). The exudate was previously found to have anti-AIDS, a strong antioxidant and immune-enhancing activities (Miller et al., 1996). However, urushiol was the main irritating component of exudate constituents of *Rhus verniciflua*. The heartwood of *Rhus verniciflua* dose not cause this type of allergenic action, which implies that it dose not contain urushiols (Park et al., 2004). However, information on the application of *Rhus verniciflua* Stokes is still limited.

The objective of this study was to determine the effects of feeding levels (0, 2, 4 and 6%/feed) of dietary *Rhus verniciflua* Stokes on meat color, water-holding capacity, lipid oxidation and fatty acid composition in *m. longissimus* from Hanwoo (Korean cattle) beef during refrigerated storage.

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MATERIALS AND METHODS

Animals and diets

Rhus verniciflua Stokes of 8 years was obtained from Wonju, Kwangwon province, Korea in 2003. The stem bark and heartwood of *Rhus verniciflua* Stokes were naturally dried and reduced to sawdust by an electrical mill (Premco Co., Korea). Hanwoo (Korean cattle) steers aged 22 months were divided into four groups (n = 5/group). Control group (0%) was fed a common basal diet for 4 months prior to slaughter. The other groups were fed a supplemented concentrate diet with a *Rhus verniciflua* Stokes supplement of 2, 4 and 6%/feed for 4 months prior to slaughter.

The formulation of the common basal diet consisted of approximately 27.99% fresh corn grain, 18.50% corn grain, 4% wheat grain, 10% wheat bran, 4% wheat flour, 10% corn gluten feed, 2% soybean meal, 2% distiller grain, 2% cotton seeds meal, 5% palm meal, 5.78% coconut meal, 6% molasses, 1.34% limestone, 0.5% salt dehydrated, 0.1% vitamin mixture, 0.1% mineral premix and other additives. Each group was held in separate pens and each animal was fed individually.

Sample preparation

All animals were conventionally slaughtered on day of transport at one location. The *longissimus* muscles were sliced (1.2 cm thickness) about 48 h after slaughter, then overwrapped in polyethylene wrap film (oxygen transmission rate 35,273 cc/m^2/24 h/tm, thickness 0.01 mm). Samples were then stored at 3±1°C for 7 days.

Proximate composition, pH and water-holding capacity measurement

Moisture, protein, fat, and ash contents of fresh meat were determined according to AOAC methods (1995). pH was determined by homogenizing a 10 g sample of muscle with 100 ml distilled water for 1 min using a homogenizer at the 8,000 rpm (AM-7, Nihonseiki kaisha Ltd., Japan). The pH of the resultant suspension was measured with a pH meter (F-12, Horiba, Japan) equipped with a combination pH electrode calibrated to pH 4.0 and 7.0. The pH of the distilled water was pH 5.86. Water-holding capacity (WHC) was measured by the press method (Grau and Hamm, 1953; Wierbicki and Deatherage, 1958). Approximately 0.5 g of homogenized sample was weighed onto a Whatman No. 1 filter paper and pressed between two stainless steel sheets for 1 min. The area was measured using a planimeter (Planix 5000, Tamaya Technics Inc., Tokyo, Japan).

Surface color measurement

CIE (Commission Internationale de l'Eclairage) L^* (lightness), a^* (redness), and b^* (yellowness) values for Illuminant C were measured by a color difference meter (CR-310, Minolta Co., Tokyo, Japan). A white ceramic tile with a specification of $Y = 93.7$, $x = 0.3129$, $y = 0.3194$ was used to standardize the colorimeter. Also, chroma (C^*) value and hue-angle (h^0) were calculated as $C^* = (a^{*2}+b^{*2})^{1/2}$, and $h^0 = \tan^{-1}(b^*/a^*)$, respectively (CIE, 1986). The samples of day 0 was measured at 40 min after cutting a fresh surface.

Surface metmyoglobin percent measurement

The relative content of metmyoglobin at the meat surface was measured by the method of Kryzwicki (1979) using reflectance at 525, 572, and 730 nm. Reflectance readings were converted to absorbance [2-log (% reflectance)] and used in the following equation (Demos et al., 1996).

$$\text{Metmyoglobin (\%)} = 1.395-[(A572-A730)/(A525 - A730)]\times 100$$

Reflectance at selected wavelengths was measured by a dual beam spectrophotometer (UV-2401PC, Shimadzu, Kyoto, Japan) provided with a diffuse reflectance attachment adjusted to 100% reflectance with a $BaSO_4$ block.

Lipid oxidation measurement

The level of thiobarbituric acid reactive substances (TBARS) was used as an index of lipid oxidation in meat. TBARS was measured according to the method of Sinnhuber and Yu (1977). TBARS were expressed as milligrams of malonaldehyde per kilogram of meat.

Fatty acid composition measurement

Total lipids for fatty acid analysis were extracted from fresh muscle using the method of Folch et al. (1957). Fatty acid methyl esters were prepared according to the procedure of Sukhija and Palmquist (1988). Analysis was carried out using a gas chromatograph ACME 6000 (Younglin Instrument Co., Ltd, Seoul, Korea) with flam ionization detector and HP-FFAP capillary column (30 m×0.25 mm i.d., film thickness 0.25 μm). The carrier gas was nitrogen at a flow rate of 1 ml/min. The oven temperature was programmed from 180°C to 250°C at 0.5°C/min. The injector and detector temperature was 250°C.

Statistical analysis

Data were analyzed as a 4 (diet conditions) by 4 (storage days) factorial design using the General Linear Model (SAS Institute, Inc., 1993). Least square means were used, and when F-values were significant, least square mean differences were compared by using PDIFF at $p<0.05$. No interactions were detected.

RESULTS AND DISCUSSION

Proximate composition

The results for proximate composition of fresh meat are shown in Table 1. The moisture, protein and ash contents of *m. longissimus* were not significantly affected by diet conditions. But the lipid content was significantly ($p<0.05$) lower in 6% group and control group had the highest

Table 1. Effects of dietary *Rhus verniciflua* Stokes supplementation on proximate composition (%) in *m. longissimus* from Hanwoo (Korean cattle) beef

Diet condition	Moisture	Lipid	Protein	Ash
Control	69.40	9.04[a]	20.58	0.98
2%	69.58	8.92[ab]	20.51	0.99
4%	69.65	8.86[ab]	20.50	0.99
6%	69.71	8.58[b]	20.72	0.99
SEM[c]	0.10	0.13	0.10	0.003

[a-b] Least square mean values within the same column with different superscripts are significantly different ($p<0.05$).
[c] Standard error of the least square mean.

($p<0.05$) lipid content. The lipid contents of the samples decreased with more *Rhus verniciflua* Stokes supplementation.

pH and water-holding capacity

Effects of dietary *Rhus verniciflua* Stokes supplementation on pH and water-holding capacity in Hanwoo beef were compared (Table 2). The pH was not significantly ($p>0.05$) different among 4 diet conditions. Water-holding capacity was significantly ($p<0.05$) higher in 2% and 4% groups than in the other groups, but there was not significantly ($p>0.05$) different between control and 6% groups.

As shown in Table 3, the pH of 2% and 6% groups were little affected by storage days, but control and 4% groups were significantly ($p<0.05$) changed during refrigerated storage. In particular, pH of day 2 decreased more rapidly in the control group than in the other groups. As a whole, water-holding capacity (Table 3) was significantly increased during refrigerated storage except 6% group. The water-holding capacity of day 0 was significantly ($p<0.05$) lower in control group than in the other groups.

Surface color and metmyoglobin

Effects of dietary *Rhus verniciflua* Stokes supplementation on meat color in Hanwoo beef were compared (Table 2). The CIE *L**, *a**, *b** and *C** values of 4% group were significantly ($p<0.05$) higher than those of the other groups. In contrast, metmyoglobin (%) were lower in 4% group than in the other groups.

As shown in Table 4, the *L** value of 4% group was significantly ($p<0.05$) higher than that of the other groups over time. The *L** values of control and 4% groups was little affected by storage time. Murray (1989) reported that CIE *L** values of beef were inversely and linearly related to the darkness of the meat surface. Zhu and Brewer (1998) reported that *L** value was the best instrumental color indicator of sensory redness.

The *a** value gradually decreased ($p<0.05$) over time. In

Table 2. Effects of dietary *Rhus verniciflua* Stokes supplementation on meat quality characteristics in *m. longissimus* from Hanwoo (Korean cattle) beef[e]

Diet condition	pH	*L**	*a**	*b**	*C**	h^0	MetMb[f]	WHC[g]	TBARS[h]
Control	5.39	41.44[b]	19.39[c]	10.65[b]	22.11[b]	28.83[a]	27.72[a]	46.79[b]	0.39[a]
2%	5.42	38.62[d]	20.86[b]	9.62[c]	22.97[b]	24.67[c]	25.67[ab]	54.15[a]	0.29[b]
4%	5.42	43.52[a]	23.11[a]	12.04[a]	26.06[a]	27.43[b]	23.98[b]	53.12[a]	0.28[b]
6%	5.41	40.58[c]	20.63[b]	10.42[b]	23.11[b]	26.87[b]	27.22[a]	49.23[b]	0.27[b]
SEM[i]	0.01	0.27	0.37	0.19	0.41	0.25	0.80	0.89	0.02

[a-d] Least square mean values within the same column with different superscripts are significantly different ($p<0.05$).
[e] Least square means are pooled over diet condition and storage day.
[f] Metmyoglobin, [g] water-holding capacity, [h] thiobarbituric acid reactive substances.
[I] Standard error of the least square mean.

Table 3. Effect of dietary *Rhus verniciflua* Stokes supplementation on pH and water-holding capacity (WHC) in *m. longissimus* from Hanwoo (Korean cattle) beef during refrigerated storage

Items	Storage days	Diet condition				SEM[d]
		Control	2%	4%	6%	
pH	0	5.44[a]	5.40	5.44[a]	5.40	0.02
	2	5.36[b]	5.42	5.43[a]	5.43	0.03
	5	5.38[ab]	5.41	5.43[a]	5.42	0.04
	7	5.38[ab]	5.42	5.38[b]	5.40	0.04
	SEM[e]	0.02	0.03	0.02	0.04	
WHC	0	43.34[cz]	52.99[abx]	49.75[by]	50.35[abxy]	1.12
	2	46.64[by]	53.99[abx]	52.06[abx]	52.72[ax]	1.37
	5	47.67[aby]	50.07[bxy]	55.06[ax]	46.96[by]	1.92
	7	49.51[ay]	59.56[ax]	55.61[ax]	46.89[by]	1.84
	SEM[e]	0.79	2.29	1.52	1.20	

[a-c] Least square mean values within the same column with different superscripts are significantly different ($p<0.05$).
[d] Standard error of the least square mean among different diet conditions within the same storage day.
[e] Standard error of the least square mean among different storage days within the same diet condition.
[x-z] Least square mean values within the same row with different superscripts are significantly different ($p<0.05$).

Table 4. Effect of dietary *Rhus verniciflua* Stokes supplementation on meat color in *m. longissimus* from Hanwoo (Korean cattle) beef during refrigerated storage

Items	Storage days	Diet condition				SEM^{e}
		Control	2%	4%	6%	
*L**	0	40.80^{y}	38.04^{bz}	43.46^{x}	40.14^{by}	0.56
	2	41.28^{y}	38.09^{bz}	43.39^{x}	40.61^{aby}	0.59
	5	41.40^{y}	39.28^{az}	42.84^{x}	40.26^{bz}	0.40
	7	42.26^{y}	39.05^{az}	44.40^{x}	41.32^{ay}	0.58
	SEM^{f}	0.65	0.28	0.77	0.32	
*a**	0	21.76^{ayz}	21.21^{abz}	24.86^{ax}	22.87^{ay}	0.64
	2	20.68^{az}	21.53^{ayz}	24.00^{ax}	21.98^{abyz}	0.50
	5	18.41^{bz}	20.73^{by}	22.66^{bx}	20.43^{by}	0.44
	7	16.70^{by}	19.97^{cx}	20.91^{cx}	17.23^{cy}	0.49
	SEM^{f}	0.63	0.26	0.43	0.56	
*b**	0	11.03^{aby}	9.84^{z}	13.00^{ax}	10.93^{ay}	0.38
	2	11.19^{ax}	9.80^{y}	12.06^{abx}	11.12^{ax}	0.37
	5	10.51^{aby}	9.42^{z}	11.87^{abx}	10.27^{ayz}	0.35
	7	9.86^{by}	9.42^{y}	11.24^{bx}	9.34^{by}	0.24
	SEM^{f}	0.41	0.16	0.41	0.30	
*C**	0	24.33^{ayz}	23.38^{az}	28.05^{ax}	25.35^{ay}	0.73
	2	23.51^{ay}	23.38^{ay}	26.86^{abx}	24.63^{ay}	0.61
	5	21.20^{bz}	22.76^{aby}	25.58^{bx}	22.86^{by}	0.54
	7	19.39^{bz}	22.08^{by}	23.75^{cx}	19.61^{cz}	0.51
	SEM^{f}	0.74	0.29	0.56	0.62	
h^{0}	0	26.90^{cx}	24.65^{cz}	27.51^{abx}	25.41^{cy}	0.24
	2	28.31^{bx}	24.73^{cz}	26.53^{by}	26.76^{by}	0.32
	5	29.62^{ax}	25.08^{bz}	27.53^{aby}	26.62^{bcy}	0.37
	7	30.50^{ax}	25.52^{az}	28.16^{ay}	28.68^{ay}	0.59
	SEM^{f}	0.36	0.19	0.43	0.45	

[a-d] Least square mean values within the same column with different superscripts are significantly different (p<0.05).
[e] Standard error of the least square mean among different diet conditions within the same storage day.
[f] Standard error of the least square mean among different storage days within the same diet condition.
[x-z] Least square mean values within the same row with different superscripts are significantly different (p<0.05).

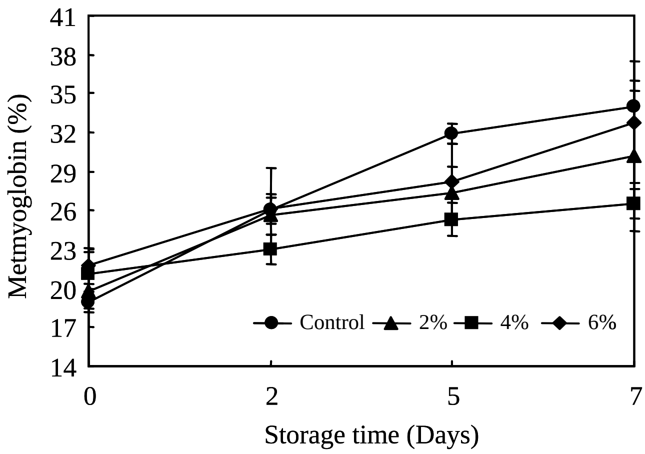

Figure 1. Effect of dietary *Rhus verniciflua* Stokes supplementation on metmyoglobin (%) in *m. longissimus* from Hanwoo (Korean cattle) beef during refrigerated storage.

particular, control group was more accelerated compared to the other groups. The *a** value of day 7 was significantly (p<0.05) higher in 2% and 4% groups than in the other groups. The trend for *C** value was similar to that for *a** value.

The *a** value is a measure of redness, however the *a** value alone has limited meaning (Howe et al., 1982). Hue angle specifically defines the hue of the color; in meat the lager the hue angle, the less red color. Hue angle increased (p<0.05) as storage time increased. And control group at day 7 had higher (p<0.05) hue angle than the other groups. In particular, hue angle increased more rapidly in the control group.

As shown in Figure 1, the metmyoglobin (%) of day 0 (before storage) was significantly (p<0.05) higher in 4% and 6% groups than in the other groups. It was significantly (p<0.05) increased during storage time in all of the groups, but 4% group had a lower rate of metmyoglobin accumulation during storage. In general, when brown metmyoglobin reaches 30-40% of total pigments on the surface of fresh retail beef, consumers make a no-purchase decision (Greene at al., 1971).

Lipid oxidation

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). As shown in Figure 2, thiobarbituric acid reactive substances (TBARS)

Table 5. Effect of dietary *Rhus verniciflua* Stokes supplementation on fatty acid composition in *m. longissimus* from Hanwoo (Korean cattle) beef

Fatty acids	Diet condition				SEM[g]
	Control	2%	3%	4%	
C14:0	3.38[ab]	2.62[b]	3.45[a]	3.54[ab]	0.20
C16:0	27.25[a]	20.98[b]	24.13[ab]	24.37[b]	1.32
C16:1	5.63	5.76	6.34	6.48	0.48
C18:0	12.52[ab]	15.46[a]	10.67[b]	10.74[b]	0.94
C18:1	45.37[b]	49.84[a]	50.76[a]	49.94[a]	1.11
C18:2	3.71	3.94	3.27	3.55	0.39
C18:3	0.37[a]	0.21[ab]	0.33[ab]	0.19[b]	0.06
C20:1	0.42	0.41	0.26	0.33	0.11
C20:4	1.19[a]	0.78[b]	0.71[b]	0.79[b]	0.14
C22:4	0.16[a]	0.00[b]	0.08[ab]	0.07[b]	0.04
SFA[c]	43.15[a]	39.06[b]	38.25[b]	38.65[b]	0.94
MUFA[d]	51.41[b]	56.01[a]	57.36[a]	56.75[a]	1.20
PUFA[e]	5.44	4.93	4.39	4.60	0.51
UFA[f]	56.85[b]	60.94[a]	61.75[a]	61.35[a]	0.94
MUFA/SFA	1.19[b]	1.47[a]	1.50[a]	1.47[a]	0.06

[a-b] Least square mean values within the same row with different superscripts are significantly different ($p<0.05$).
[c] Saturated fatty acids, [d] monounsaturated fatty acids, [e] polyunsaturated fatty acids, [f] unsaturated fatty acids.
[g] Standard error of the least square mean.

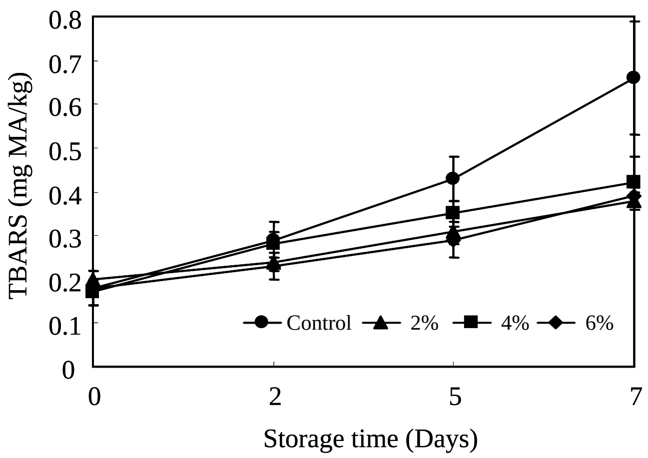

Figure 2. Effect of dietary *Rhus verniciflua* Stokes supplementation on TBARS (thiobarbituric acid reactive substances) in *m. longissimus* from Hanwoo (Korean cattle) beef during refrigerated storage.

value which represent fat rancidity tended to increase as storage time increased in all of the groups. The TBARS value of day 0 was not significantly ($p>0.05$) different among 4 diet conditions, but the TBARS value after 5 days of storage was significantly ($p<0.05$) higher in control group than in other groups. Consequently, *Rhus verniciflua* Stokes supplementation significantly delayed lipid oxidation, whatever the feeding level. Andersen et al. (1990) provided evidence for supporting the pigment oxidation process as an initiator of lipid oxidation.

Fatty acid composition

There were significant differences in the percentages of many of the fatty acids (Table 5). Oleic acid (C18:1) usually was the major unsaturated fatty acid, and palmitic acid (C16:0) and stearic acid (C18:0) were the major saturated fatty acids. From a flavor standpoint, the short- to medium-chain fatty acids are the most important contributors (Brennand, 1989). Bovine fat is typically rich in saturated fatty acids, particularly palmitic acid, which is considered a hypercholesterolemic factor whereas certain unsaturated fatty acids are stated to show antiatherogenic or even anticarcinogenic properties in humans (Decker and Shantha, 1994). However, stearic acid has been shown not to raise plasma cholesterol as much as other saturated fatty acids (Bonanome and Grundy, 1988). The proportions of C18:1, monounsaturated fatty acids (MUFA), unsaturated fatty acids (UFA) and MUFA/SFA ratio were significantly ($p<0.05$) higher in the meat from *Rhus verniciflua* Stokes-supplemented Hanwoo (Korean cattle) than in the control group. But, the proportions of saturated fatty acids (SFA) was significantly ($p<0.05$) highest in control group. A desirable beef product have an adequate amount of marbling and a high ratio of monounsaturated fatty acids to saturated fatty acids (MUFA/SFA) (NRC, 1988).

CONCLUSIONS

The meat from *Rhus verniciflua* Stokes-supplemented Hanwoo (Korean cattle) was effective in increasing color stability, water-holding capacity, unsaturated fatty acids and retarding lipid oxidation than was the control meat. In particular, dietary *Rhus verniciflua* Stokes supplementation with 4% extended storage life compared to the other groups.

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