Effects of Goldenrod (*Solidago virgaurea*) leaf and stem extracts on oxidative stability in cooked ground pork during chilled storage

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Abstract— **This study aimed to evaluate the oxidation stability of cooked ground pork containing 70% ethanolic goldenrod leaf (GL) and stem extracts (GS) during chilled storage for 12 days. Six treatments groups were as follows: Control (without antioxidant), GL-0.1 (with 0.1% GL), GL-0.5 (with 0.5% GL), GS-0.1 (with 0.1% GS), GS-0.5 addition (with 0.5% GS) and BHT-0.01 (with 0.01% buthyl -hydroxytoluene (BHT)). The pH of pork samples increased until day 7. Lower a* values were found in GL and GS relative to BHT-0.01 with increasing storage time (p<0.05). In pork samples with GL and GS, the increase in TBARS values was slow and was maintained at a lower (p<0.05) level than in the control. GL-0.05 and BHT treatments had the lowest CD (conjugated dienes) concentrations for all samples over the entire storage period. These results indicate that goldenrod leaf and stem have notable effects on meat products as a natural lipid oxidative inhibitor.**

Keywords— **oxidative stability, Goldenrod, ground pork**

I. INTRODUCTION

In meat products, oxidative quality inhibit is most important. Synthetic antioxidants had been used to inhibit lipid oxidation and prolong lag phase for microorganism in meat food industry. However synthetic antioxidants, such as butylated hydroxyl - toluene, tertiarybutyl hydroquinone and propyl gallate have begun to be restricted due to potential riskiness on health (Branen, 1975). Natural antioxidant came from plants, plums, fruits, spices instead of synthetic antioxidants came to the fore because of health benefits. The natural antioxidants have amount of phenolics and flavonoid contents inhibit oxidation on meat products.

These days, Goldenrod (*Solidago virgaurea*) is taken as traditional dishes in Korea. It is rich in protein, phytochemicals, calcium, potassium, iron, vitamin A, B_2, C, and niacin.

The objective of this study was to investigate the oxidation stability and color stability of cooked ground pork meat with 70% ethanolic goldenrod leaf (GL) and stem extracts (GS) during 12 days of refrigerated storage.

II. MATERIALS AND METHODS

1. Preparation of goldenrod leaf and stem extracts

The goldenrod was washed and cut to separate the leaves and stems. The leaves were cut into small pieces and dried by a hot air dryer (Enex-Co-600, Enex, Koyang, Korea) at 50 ℃ for 15 h, powdered (35 mesh). The dried pumpkin leaves powder (15 g) was extracted with 300 ml of 70% ethanol overnight in a shaker (VS-8480, Vison Scientific, Bucheon, Gyeonngi) at room temperature. The extract was filtered through Whatman No. 1 filter paper and the solvent was removed using a vacuum evaporator (CCA-1110, Rikakikai, Tokyo, Japan) at 45℃ to dryness. After evaporation of ethanol, goldenrod leaves and stems ethanolic extracts were dissolved in 70% ethanol (5% v/w).

2. Preparation of meat samples

Suitable amounts of the pork skin were tempered at Fresh pork hams and back fats were purchased from a pilot plant at Konkuk University, Korea, at 48 h postmortem. All subcutaneous and intramuscular fat and visible connective tissues were removed from the fresh ham muscles. The ground meat samples were produced by the following formulation: 73.5% lean

pork meat, 20% pork back fat, 5% Ice, and 1.5% salt. The lean pork meat and pork back fat were ground through a 3 mm grinding plate and then the ice and salt were added. The 50% ethanol extracts of goldenrod leaf and stem were added (w/w) according to the following formulation: Control (without antioxidant), GL-0.1 (with 0.1% GL extract), GL-0.5 (with 0.5% GL extract), GS-0.1 (with 0.1% GS extract), GS-0.5 addition (with 0.5% GS extract) and BHT-0.01 (with 0.01% buthyl -hydroxytoluene (BHT)). These percentages were based on formula weight of minced meat samples without antioxidant extract. Samples were hand mixed for 3 min. Then, the mixed meat was anaerobically packed in PE/nylon film bags, spread to a thickness of 2.5 cm, stored at 4±1 ℃ during 12 days (1, 4, 7, 10, and 12 day).

3. Analytical methods

3.1. Compositional properties

Compositional properties of the semi-dried jerky were performed using AOAC (2000). Moisture content was determined by weight loss after 12 h of drying at 105℃ in a drying oven (SW-90D, Sang Woo Scienctific Co., Bucheon, South Korea). Fat content was determined by Soxhlet method with a solvent extraction system (Soxtec® Avanti 2050 Auto System, Foss Tecator AB, Höganas, Sweden) and protein was determined by Kjeldahl method with an automatic Kjeldahl nitrogen analyzer (Kjeltec® 2300 Analyzer Unit, Foss Tecator AB, Höganas, Sweden). Ash was determined according to AOAC method 923.03.

3.2. pH values

The pH was determined, following grinding and homogenization of 5 g of sample with 20 ml of distilled water for 60 s (Ultra-Turrax® T25, Janke & Kunkel, Staufen, Germany) and the pH was then measured using a pH meter (Model 340, Mettler-Toledo GmbH Analytical, Schwerzenbach, Switzerland). All determinations were performed in triplicate.

3.3. Color measurement

The instrumental color analyses of raw meat samples were conducted as follows. The color measurements were taken with a colorimeter (Chroma meter CR-210, Minolta, Japan; illuminate C), calibrated with a white standard plate CIE L^* = 97.83, CIE a^* = -0.43, CIE b^* = +1.98), consisting of an 8 mm diameter measuring area and a 50 mm diameter illumination area. The color values (CIE L^*, a^*, and b^*) were measured on the sample surfaces and data were taken in triplicate for each sample.

3.4. Conjugated dienes (CD)

3.4.1. Lipid Extraction

Lipids from the meat samples were extracted by the method of Folch (Floch, Lee, & Stanley, 1957) using the chloroform:methanol solvent system (2:1). The lipid extracts were evaporated and concentrated with a rotary evaporator (Rotary evaporater N-1000, EYELA, Japan). The lipid extract of meat samples used for CD and FFA analyses.

3.4.2. Analysis of CD

Fifteen mg of extracted sample lipids were put into a 25 ml volumetric flask and massed up with isooctane. The samples were mixed and absorbance was read 234 nm against a blank of isooctane using a UV/VIS spectrophotometer (Libra S22, Biochrom Ltd., Cambridge, England). The CD concentration was calculated using a molar extinction coefficient of 25,200 M^{-1} cm^{-1} and expressed as µmol mg^{-1} meat lipid sample.

4. Thiobarbituric acid reaction substance (TBARS) values

Fifty ml of trichloroacetic acid was added to 10 g sample prior to homogenization (PT-MR 2100, Polytron Co., Littau-Lucerne, Switzerland) at 12,000 rpm for 1 min. The cup used for blending was washed with an additional 50 ml of distilled water. The mixture was filtered through filter paper (Whatman NO. 1). Five ml of 0.02 M 2-thiobarbituric acid in distilled water (TBA reagent) was added to a vial containing 5 ml of the filtered mixture and mixed well. The vials were capped and heated in a boiling water bath for 10 min to develop the chromogen and cooled to room temperature. The absorbance was measured at 532 nm (Libra S22, Biochrom Ltd., Cambridge, England), against a blank prepared with distilled water (5 ml) and TBA-reagent (5 ml). The K value

was calculated using 1,1,3,3,-tetraethoxypropane (Sigma) as the standard and TBARS values were calculated by multiplying the absorbance values by the K values. Also, the TBARS values were calculated as follows and expressed as MDA mg/kg meat.

5. Statistical analysis

Three batches of samples for each treatment and storage days were prepared. The proximate composition, pH, color, CD, and TBARS values were analyzed using two-way analysis of variance (ANOVA) with treatments and storage days. An analysis of variance was performed on all the variables measured using the General Linear Model (GLM) procedure of the SAS statistical package (SAS Institute, Inc., 1999). Duncan's multiple range test (p<0.05) was used to determine the differences among means of treatments.

III. RESULTS AND DICSUSSION

Composition properties of ground pork added various levels of goldenrod leaf extract (GL) and goldenrod stem extract (GS) are shown in Table 1. The water content was higher (p<0.05) in the treatments added GL and GS than the control. The addition of GL significantly increased (p<0.05) the protein content in ground pork meat. The pH values of ground pork samples added GL and GS ranged from 6.05 to 6.37 over 12 days of storage (Table2). The addition of GS resulted in decrease (p<0.05) of pH in ground pork samples. The pH values of all treatments increased until the 7 day of storage. The reduction in pH is probably due to formation of ammonia and amino sugar complex by decomposition of protein and lipid (Jay and Shelef, 1978). After day 7, pH decreased (p<0.05). In all samples, L^* values significantly increased (p<0.05) and a^* values decreased (p<0.05) over the 12 days of storage. The reduction rate of a^* values was the lowest in GL-0.5 treatment by increasing of storage. Amounts of lipid oxidation can be measured by CD concentrations. In samples, increase of GL and GS concentration resulted in decrease of CD concentration during 12 days. The control had the highest (p<0.05) TBARS values during the entire storage period. However, the GL-0.5 and BHT treatments had the lowest (p<0.05) TBARS on day 12.

Table 1
Proximate composition of ground pork added various levels of goldenrod leaf extract(GL) and goldenrod stem extract (GS)

Treatment[1)]	Properties (%)			
	Moisture	Protein	Fat	Ash
Con	58.91±0.35^{CD}	23.28±0.18^{AB}	15.15±0.90^{A}	2.58±0.11^{A}
GL-0.1	58.21±0.66^{D}	23.51±0.05^{A}	14.84±0.46^{A}	2.58±0.18^{A}
GL-0.5	62.16±0.94^{A}	23.67±0.06^{A}	12.61±0.54^{B}	2.55±0.10^{B}
GS-0.1	61.27±2.06^{AB}	22.61±0.10^{C}	13.07±1.02^{B}	2.55±0.07^{B}
GS-0.5	60.96±0.99^{AB}	22.97±0.45^{BC}	12.84±0.56^{B}	2.47±0.10^{B}
BHT	60.32±0.83^{BC}	23.25±0.09^{AB}	13.37±0.71^{B}	2.64±0.07^{B}

All values are mean ± standard deviation of three replicates.
$^{A-D}$ Means within columns with different superscript letters are significantly different (p<0.05).
[1)]control: ground pork without antioxidant powder, GL-0.1: ground pork meat with 0.1% goldenrod leaf extracts, GL-0.5: ground pork meat with 0.5% goldenrod leaf extracts, GS-0.1: ground pork meat with 0.1% goldenrod stem extracts, GS-0.5: ground pork meat with 0.5% goldenrod stem extracts, BHT : ground pork meat with 0.01% butylated hydroxyltoluene(BHT).

Table 2
The pH values in cooked ground pork added various levels of goldenrod leaf (GL) and stem extract (GS) during refrigerated storage for 12 days

Treatment[1)]	Storage days				
	1	4	7	10	12
Con	6.19±0.15^{Abe}	6.24±0.11^{Cc}	6.37±0.07^{ABa}	6.34±0.04 ^{Bb}	6.22±0.13^{Ad}
GL-0.1	6.07±0.16^{De}	6.17±0.05^{Dc}	6.29±0.12^{Ca}	6.21±0.02 ^{Eb}	6.13±0.02^{Dd}
GL-0.5	6.19±0.06^{Ae}	6.32±0.12^{Ac}	6.38±0.02^{Aa}	6.35±0.21^{Ab}	6.23±0.11^{Ad}
GS-0.1	6.13±0.14^{Ce}	6.22±0.12^{Cc}	6.37±0.02^{ABa}	6.28±0.07 ^{Db}	6.16±0.08^{Cd}
GS-0.5	6.05±0.21^{Ee}	6.18±0.24^{Dc}	6.36±0.02^{Ba}	6.20±0.09^{Eb}	6.13±0.07^{Dd}
BHT	6.18±0.12^{Bc}	6.27±0.25^{Bb}	6.31±0.02^{Ca}	6.31±0.02 ^{Ca}	6.19±0.04^{Bc}

All values are mean ± standard deviation of three replicates.
$^{A-E}$ Means within columns with different superscript letters are significantly different (p<0.05).
$^{a-e}$ Means within rows with different superscript letters are significantly different (p<0.05).
[1)]control: ground pork without antioxidant powder, GL-0.1: ground pork meat with 0.1% goldenrod leaf extracts, GL-0.5: ground pork meat with 0.5% goldenrod leaf extracts, GS-0.1: ground pork meat with 0.1% goldenrod stem extracts, GS-0.5: ground pork meat with 0.5% goldenrod stem extracts, BHT : ground pork meat with 0.01% butylated hydroxyltoluene(BHT).

Table 3
The color evaluation in cooked ground pork added various levels of goldenrod leaf (GL) and stem extract (GS) during refrigerated storage for 12 days

	Treatment[1)]	Storage days				
		1	4	7	10	12
L^*	Con	51.87±1.21^{Cc}	58.38±0.74^{Cb}	59.03±0.75^{Cb}	59.24±0.80^{Cb}	60.97±0.84^{Aa}
	GL-0.1	54.08±2.02^{ABb}	62.69±0.63^{Aa}	61.36±2.14^{ABa}	62.41±0.64^{Aa}	61.28±1.30^{Aa}
	GL-0.5	51.44±1.33^{Cb}	58.23±1.04^{Ca}	57.55±1.37^{Ca}	57.33±0.82^{Da}	57.61±0.96^{Ba}
	GS-0.1	53.72±1.50^{ABc}	59.34±1.03^{Cb}	62.41±2.07^{Aa}	61.15±0.44^{Ba}	61.66±1.37^{Aa}
	GS-0.5	54.17±0.44^{Ad}	60.72±1.82^{Bc}	61.33±0.86^{ABbc}	62.44±0.33^{Aa}	61.93±0.82^{Aab}
	BHT	52.72±0.73^{BCc}	59.37±0.70^{Cb}	60.61±1.17^{Ba}	60.66±0.51^{Ba}	61.40±1.19^{Aa}
a^*	Con	10.62±0.63^{Aa}	6.08±0.64^{Ab}	5.74±0.79^{Ab}	5.86±0.41^{Ab}	4.87±0.42^{Bc}
	GL-0.1	9.11±0.87^{Ba}	4.72±0.32^{Cbc}	5.14±1.20^{ABb}	4.18±0.42^{Bcd}	3.59±0.34^{CDd}
	GL-0.5	7.45±1.08^{Da}	4.09±0.52^{Db}	4.46±1.33^{Bb}	3.92±0.40^{BCbc}	3.09±0.60^{Dc}
	GS-0.1	9.28±0.51^{Ba}	5.39±0.50^{Bb}	4.41±0.48^{Bc}	3.80±0.30^{BCd}	3.22±0.40^{CDe}
	GS-0.5	8.30±0.75^{Ca}	4.87±0.46^{Cb}	4.40±0.66^{Bb}	3.71±0.36^{Cc}	3.69±0.62^{Cc}
	BHT	9.85±0.36^{Ba}	6.38±0.51^{Ab}	6.11±0.81^{Abc}	6.08±0.38^{Abc}	5.70±0.42^{Ac}
b^*	Con	14.30±0.75^{Bab}	12.44±0.63^{Ac}	13.64±0.29^{Ab}	14.72±0.65^{Aa}	14.22±0.79^{Aab}
	GL-0.1	14.69±0.34^{ABa}	11.75±0.71^{Bd}	12.27±0.76^{Ccd}	13.13±0.64^{Bb}	12.85±0.77^{Bbc}
	GL-0.5	14.94±0.32^{Aa}	12.42±0.44^{Ad}	13.12±0.45^{ABbc}	13.45±0.46^{Bb}	12.95±0.52^{Be}
	GS-0.1	14.28±0.45^{Ba}	12.78±0.71^{Acd}	12.43±0.50^{Cd}	13.23±0.31^{Bbc}	13.48±0.42^{Ab}
	GS-0.5	13.53±0.82^{Ca}	12.49±0.53^{Ac}	12.71±0.70^{BCbc}	13.34±0.38^{Bab}	13.79±0.63^{Aa}
	BHT	14.18±0.73^{Ba}	12.90±0.76^{Abc}	12.59±0.34^{BCc}	13.16±0.98^{Bbc}	13.56±0.87^{ABab}

All values are mean ± standard deviation of three replicates.
$^{A-D}$ Means within columns with different superscript letters are significantly different (p<0.05).
$^{a-e}$ Means within rows with different superscript letters are significantly different (p<0.05).
[1)]control: ground pork without antioxidant powder, GL-0.1: ground pork meat with 0.1% goldenrod leaf extracts, GL-0.5: ground pork meat with 0.5% goldenrod leaf extracts, GS-0.1: ground pork meat with 0.1% goldenrod stem extracts, GS-0.5: ground pork meat with 0.5% goldenrod stem extracts, BHT : ground pork meat with 0.01% butylated hydroxyltoluene(BHT).

IV. CONCLUSIONS

The addition of golden leaf and stem extracts can play a roles as a natural and safe antioxidant in meat products.

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Table 4
Thiobarbituric acid reaction substance (TBARS) values (mg of MDA/kg meat) in cooked ground pork added various levels of goldenrod leaf (GL) and stem extract (GS) during refrigerated storage for 12 days

Treatment[1)]	Storage days				
	1	4	7	10	12
Con	0.48 ± 0.06^{Ae}	0.75 ± 0.09^{Bd}	0.97 ± 0.24^{Ac}	1.34 ± 0.05^{Ab}	1.60 ± 0.16^{Aa}
GL-0.1	0.29 ± 0.01^{CDe}	0.63 ± 0.05^{CDd}	0.80 ± 0.05^{Bc}	1.13 ± 0.04^{Db}	1.26 ± 0.01^{Ba}
GL-0.5	0.27 ± 0.01^{De}	0.61 ± 0.01^{Dd}	0.69 ± 0.02^{CDc}	0.92 ± 0.02^{Eb}	1.16 ± 0.02^{Ca}
GS-0.1	0.41 ± 0.06^{Bd}	0.81 ± 0.10^{Ac}	0.89 ± 0.02^{Bc}	1.30 ± 0.02^{Bb}	1.36 ± 0.42^{Ba}
GS-0.5	0.31 ± 0.08^{Ce}	0.64 ± 0.01^{Cd}	0.88 ± 0.02^{Bc}	1.24 ± 0.07^{Cb}	1.31 ± 0.01^{Ba}
BHT	0.21 ± 0.01^{Ee}	0.56 ± 0.01^{Ed}	0.64 ± 0.05^{Dc}	0.91 ± 0.03^{Eb}	1.11 ± 0.01^{Ca}

All values are mean ± standard deviation of three replicates.
[A-E] Means within columns with different superscript letters are significantly different ($p<0.05$).
[a-e] Means within rows with different superscript letters are significantly different ($p<0.05$).
[1)]control: ground pork without antioxidant powder, GL-0.1: ground pork meat with 0.1% goldenrod leaf extracts, GL-0.5: ground pork meat with 0.5% goldenrod leaf extracts, GS-0.1: ground pork meat with 0.1% goldenrod stem extracts, GS-0.5: ground pork meat with 0.5% goldenrod stem extracts, BHT : ground pork meat with 0.01% butylated hydroxyltoluene(BHT).

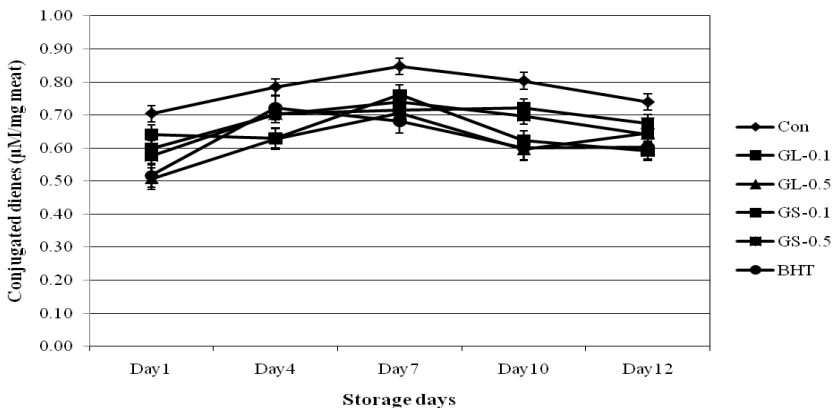

Fig. 1. Conjugated dienes (μM/mg meat) in cooked ground pork added various levels of goldenrod leaf (GL) and stem extract (GS) during refrigerated storage for 12 days.