

## The Antioxidative Properties of *Ganghwayakssuk* (*Artemisia princeps* Pamp.) Extracts Added to Refrigerated Raw Chicken Nugget Batter against Lipid Oxidation

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### Abstract

The efficiency of three concentrations (0.05, 0.1, and 0.2%) of *Ganghwayakssuk* (*Artemisia princeps* Pamp.) extract on the susceptibility of raw chicken nugget batter to lipid oxidation was investigated after 0, 3, 7, and 10 d of refrigerated storage at 4°C. The pH and yellowness values of all treatments were higher than those of the control ( $p < 0.05$ ). Additionally, the lightness and redness values of all treatments were lower than those of the control and as the amount of *Ganghwayakssuk* ethanolic extracts increased. At the end of the storage period (10 d), the peroxide values (POV), conjugated dienes (CD), and thiobarbituric acid reactive substances (TBARS) values were lower than those of the control. The results show that *Ganghwayakssuk* prevents lipid oxidation in raw chicken nugget batter.

**Key words:** antioxidants, *Ganghwayakssuk* (*Artemisia princeps* Pamp.), lipid oxidation

### Introduction

Chicken meat and products have been used widely around the world. Consumption of chicken has become popular and has increased in many countries due to the nutrients and health effects of chicken (Choi *et al.*, 2010). Chicken is chosen because of its comparatively low-fat content, high-nutritional value, and low-cost of manufacture. However, chicken meat products tend to oxidize because they include high levels of unsaturated fatty acids (Choi *et al.*, 2010). Lipid oxidation is one of the main factors used to estimate meat quality due to the susceptibility of meat and meat products to oxidative degeneration (Morrissey *et al.*, 1998). Lipid oxidation causes undesired odors and flavors and limits shelf-life. Oxidation reactions increase during cutting, cooking, salting, and refrigerated storage due to the interaction of unsaturated fatty acids and pro-oxidant substances such as non-

heme iron (Goulas and Kontominas, 2007). A common way to prevent lipid oxidation is to use antioxidants (Tang *et al.*, 2001).

Antioxidants are compounds that delay, retard, or prevent autoxidation processes (Shahidi and Wanasundara, 1992). Synthetic antioxidants such as butylated hydroxytoluene and butylated hydroxyanisole have excellent antioxidant effects on meat and meat products. For that reason, synthetic antioxidants are commonly used as food preservatives (Verhagen *et al.*, 1994). However, synthetic antioxidants pose the possibility of health risk, toxicity, and carcinogenic effects (Branen, 1975) and have been linked with potential health problems (Hettiarachchy *et al.*, 1996). Accordingly, meat and meat products are used to screen and select natural antioxidants as effective alternatives to prevent food deterioration (Kikuzaki and Nakatani, 1993). Natural antioxidants occur as plant phenolics in leaves, fruits, vegetables, roots, nuts, and seeds (Pratt and Hudson, 1990). Mathew and Abraham (2006) reported that plant phenolics scavenge free radicals and stop free radical chain reactions in meat and meat products.

Among the natural antioxidants, mugwort is widely used as a food or food additive. It contains eupatilin,

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acacetin, and eudesmane. Furthermore, it has been used to treat gastroenteritis, diarrhea, asthma, and many circulatory disorders (Ruy *et al.*, 2004). *Ganghwayakssuk* (*Artemisia princeps* Pamp.), which is distributed on Ganghwa Island in Korea, has more polyphenol, eupatillin, and flavonoids than plants in other regions (Ruy *et al.*, 2005). *Ganghwayakssuk* consists of bioactive compounds such as phenolics alkaloids, vitamins A, B<sub>1</sub>, B<sub>2</sub>, and C, as well as various minerals (Lee *et al.*, 1999). The protective effect of *Ganghwayakssuk* may be realized by adding it directly to meat or meat products during processing.

The objectives of this study were to determine the antioxidant activities of *Ganghwayakssuk* extracts, depending on various ethanol concentrations and the effects of *Ganghwayakssuk* ethanolic extracts in chicken nugget batter on pH, color, peroxide value (POV), conjugated dienes (CD), and thiobarbituric acid reactive substances (TBARS) values during 10 d at 4°C.

## Materials and Methods

### Determination of antioxidant properties

#### Preparation of *Ganghwayakssuk* extract (GYE)

Commercial samples of dried *Ganghwayakssuk* (*Artemisia princeps* Pamp.) were purchased from a local market at Ganghwa Island in Korea. After separating the leaves from the dried *Ganghwayakssuk*, they were ground using a blender (KA-2610, Jworld Tech, Korea) for a minute. Ground *Ganghwayakssuk* leaves (10 g) were extracted with 200 mL of distilled water, 50, 70, or 95% ethanol overnight in a shaker at room temperature. The extracts were filtered through filter paper (Ø110 mm, cat. no. 1001 110, Whatman International Ltd, UK) and evaporated with a rotary evaporator (EYELA N-1000, Rikakikai Co. Ltd., Japan) at < 50°C. After evaporation of each solvent, the *Ganghwayakssuk* extracts were dissolved in distilled water, 50, 70, or 95% ethanol (5%, v/w).

#### Extraction yields

Extraction yields for each solvent were calculated by subtracting the dried weight of plant material residue after extraction from the weight of the original plant material (Cha *et al.*, 2009).

#### Total phenol content

The amount of total phenolics was determined using Folin-Ciocalteu reagent (Slinkard and Singleton, 1977). Aliquots of extract (100 µL) were diluted with 4.5 mL of

distilled water. After vortexing for 1 min, 100 µL of Folin-Ciocalteu reagent was added and mixed using a vortex mixer. After 5 min, 300 µL of 2% Na<sub>2</sub>CO<sub>3</sub> was added and mixed, and the absorbance was measured at 760 nm. Gallic acid was used as the standard for the calibration curve. The total phenolic content was expressed as milligram gallic acid equivalents (GAE) per gram of sample (mg/g).

#### DPPH radical scavenging activity

The scavenging effects of GYE against DPPH radicals were determined according to the modified method of Brand-Williams *et al.* (1995). Briefly, 1 mL aliquot of each extract (0.1-1.0 mg/mL) was mixed with 4 mL of DPPH ethanolic solution (100 µM). The reaction mixture was shaken well and incubated for 30 min at room temperature. The absorbance of the resulting solution was read at 517 nm using a UV-Vis spectrophotometer (Libra S22, Biochrom Ltd., UK) against a blank. The inhibitory percentage of DPPH was calculated according to the following equation:

$$\text{Scavenging activity (\%)} = [1 - (\text{absorbance}_{\text{sample}} / \text{absorbance}_{\text{control}})] \times 100$$

#### Reducing power

GYE reducing power was determined according to the method of Oyaizu (1986). Briefly, 2.5 mL of extract with different GYE concentrations (0.1-10 mg/mL) was mixed with phosphate buffer (2.5 mL, 0.2 M, pH 6.6) and potassium ferricyanide [K<sub>3</sub>Fe(CN)<sub>6</sub>] (2.5 mL, 1%), and the mixture was incubated at 50°C for 20 min. An aliquot (2.5 mL) of trichloroacetic acid (10%) was added to the mixture, which was centrifuged at 650 g (MSE Mistral 2000, London UK) for 20 min. The supernatant (2.5 mL) was mixed with distilled water (2.5 mL) and FeCl<sub>3</sub> (0.5 mL, 0.1%), and the absorbance was measured at 700 nm against a spectrophotometer blank. Increased absorbance of the reaction mixture indicated increased reducing power.

#### Ferrous iron chelating ability

Ferrous iron-chelating activity was measured according to the method of Yen and Chung (1999). The reaction mixture, containing GYE in ethanol (0.1-1.0 mg/mL), ferrous chloride FeCl<sub>2</sub> (0.05 mL, 2 mM), and ferrozine (0.2 mL, 5 mM), was adjusted to 5 mL with distilled water. The mixture was shaken well and incubated for 10 min at room temperature. The absorbance of the mixture

was measured at 562 nm against a blank. The ability of the extracts to chelate ferrous iron was calculated using the following equation:

$$\text{Chelating activity (\%)} = [1 - (\text{absorbance}_{\text{sample}} / \text{absorbance}_{\text{control}})] \times 100$$

### Effects of *Ganghwayakssuk* extract on lipid oxidation in raw chicken nugget batter

#### Preparation of chicken nugget batter

Fresh chicken breast meat (*M. pectoralis major*) and chicken skin were purchased from a local market. The chicken materials were initially ground through an 8-mm plate. The ground tissue was then placed in polyethylene bags, vacuum packaged using a vacuum packaging system (FJ-500XL, Fujee Tech, Korea), and stored at 0°C until required for product manufacture. Suitable amounts of the muscle and chicken skin were tempered at 4°C for 24 h prior to preparing the chicken nugget batter. The first step for the chicken nugget batter was to prepare the binder meat. Chicken breast meat (17%) was homogenized and ground in a silent cutter (Cutter Nr-963009, Scharfen, Germany). 1.5% NaCl, 0.3% sodium tripolyphosphate, and 3% ice were mixed with the chicken breast meat and then added to the chicken skin. A temperature probe (Kane-May, KM330, Germany) was used to monitor the temperature of the emulsion, which was maintained at < 10°C during batter preparation. After emulsification of the binder meat, each portion of ground chicken breast meat was mixed with binder meat, and

50% GYE (pH: 6.06±0.02, L\*-value: 29.65±0.21, a\*-value: 2.06±0.24, b\*-value: 0.25±0.04) was added (w/w), according to the following formulation (Table 1): control (no antioxidant added); AC-0.05 (0.05% ascorbic acid); GYE-0.05 (0.05% *Ganghwayakssuk* ethanolic extract); GYE-0.1 (0.1% *Ganghwayakssuk* ethanolic extract); and GYE-0.2 (0.2% *Ganghwayakssuk* ethanolic extract). A portion of the raw chicken nugget batter was packaged as mentioned earlier, stored under refrigeration (4°C), and used for further analysis (0, 3, 7, and 10 d).

#### pH

The pH of 5 g samples blended with 20 mL distilled water for 60 s in a homogenizer (Ultra-Turrax T25, Janke and Kunkel, Germany) was determined with a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland).

#### Color

Color measurements were taken with a colorimeter (Chroma meter CR-210, Minolta, Japan; illuminate C, calibrated with a white standard plate L\* = 97.83, a\* = -0.43, b\* = +1.98) using an 8-mm diameter measuring area and a 50-mm diameter illumination area. Color values (CIE L\*, a\*, b\*) were measured on internal samples and were taken from three different spots on the surface of each ground sample and averaged.

#### Peroxide values (POV)

Lipid extraction was conducted according to the method of Folch (Folch *et al.*, 1957) using a chloroform:methanol solvent system (2:1). The lipid extracts were evaporated

**Table 1. Raw chicken nugget batter formulations with various *Ganghwayakssuk* ethanolic extracts (GYE) levels**

(Units: %)

Ingredients	Treatments				
	Control	AC-0.05	GYE-0.05	GYE-0.1	GYE-0.2
Chicken breast ground meat	70	70	70	70	70
Chicken binder meat	17	17	17	17	17
Chicken skin	10	10	10	10	10
Ice	3	3	3	3	3
Total	100	100	100	100	100
Salt	1.5	1.5	1.5	1.5	1.5
Sodium tripolyphosphate	0.3	0.3	0.3	0.3	0.3
Ascorbic acid	0	0.05	0	0	0
<i>Ganghwayakssuk</i> extracts	0	0	0.05	0.1	0.2

Control, no antioxidant; AC-0.05, raw chicken nugget containing ascorbic acid 0.05%; GYE-0.05, raw chicken nugget batters containing *Ganghwayakssuk* ethanolic extract 0.05%; GYE-0.1, raw chicken nugget batters containing *Ganghwayakssuk* ethanolic extract 0.1%; GYE-0.2, raw chicken nugget batters containing *Ganghwayakssuk* ethanolic extract 0.2%

and concentrated with a rotary evaporator (Rotary evaporator N-1000, Eyela, Japan), leaving the extracted lipids for POV analyses. Lipid extracted from the sample was determined by AOAC methods (1990). The lipid sample (0.5 g) was treated with 25 mL of solvent mixture (acetic acid:chloroform mixture, 3:2). The mixture was shaken thoroughly, and 1 mL of saturated potassium iodide solution was added. The mixture was kept in the dark for 10 min, 30 mL of distilled water was added, and the mixture was mixed. One mL of starch solution (1%, w/v) was added as an indicator. The peroxide value was determined by titrating the iodine liberated from potassium iodide with standardized 0.01 N sodium thiosulfate solutions. The POV was calculated as follows:

$$\text{POV (meq/kg)} = (S-B) \times F \times N \times 1000 / W$$

[S = titration amount of sample; B = titration amount of blank; F = titer of 0.01 N sodium thiosulfate; N = normality of sodium thiosulfate; W = sample weight (g)]. The results are expressed as milliequivalent peroxide O<sub>2</sub>/kg meat.

#### Conjugated dienes (CD)

Lipid extraction was determined according to the method of Folch (Folch *et al.*, 1957), using a chloroform:methanol solvent system (2:1). Conjugated diene formation was determined as described by Prasetyo *et al.* (2008). Extracted sample lipids (0.015 g) were massed into a 25 mL volumetric flask, brought to volume with isooctane, and mixed. The absorbance was read at 234 nm with isooctane used as the blank. The CD concentration was calculated using a 25200/M/cm molar extinction coefficient, and the results are expressed as μmol/mg meat lipid sample (Juntachote *et al.*, 2006).

#### Thiobarbituric acid reactive substances (TBARS) values

Lipid oxidation was assessed in triplicate using the TBARS method of Tarladgis *et al.* (22) with minor modifications. A 10 g sample was blended with 50 mL distilled water for 2 min and then transferred to a distillation tube. The cup used for blending was washed with an additional 47.5 mL of distilled water, which was added to the same distillation flask with 2.5 mL of 4 N HCl and a few drops of a silicone o/w antifoam agent (KMK-73, Shin-Etsu Silicone Co., Ltd., Korea). The mixture was distilled, and 50 mL of the distillate was collected. Five mL of 0.02 M 2-thiobarbituric acid in 90% acetic acid (TBA reagent) was added to a vial containing 5 mL of the

distillate and mixed well. The vials were capped and heated in a boiling water bath for 30 min to develop the chromogen and then cooled to room temperature. Absorbances were measured using a UV/VIS spectrophotometer (Optizen 2120 UV plus, Mecasys Co. Ltd., Korea) at 538 nm, against a blank prepared with 5 mL distilled water and 5 mL TBA-reagent. TBARS values were calculated from a standard curve (8-50 nmol) of malondialdehyde (MDA), freshly prepared by acidification of TEP (1,1,3,3-tetraethoxy propane). Reagents were obtained from Sigma. TBARS levels were calculated as mg MDA/kg samples.

#### Statistical analysis

An analysis of variance was performed on all the variables using the General Linear Model procedure of the SAS statistical package (SAS Institute, Inc., 2001). Duncan's multiple range tests ( $p < 0.05$ ) was used to determine differences between treatment means.

## Results and Discussion

### Antioxidant activity of the GYE depending on various ethanol concentrations

#### Extraction yields

Extraction yields of the *Ganghwayakssuk*, depending on the various ethanol concentrations were determined (Fig. 1). The extraction yields were 21.38, 26.07, 25.27, and 8.69% for the water, 50, 70 and 95% ethanol extracts,

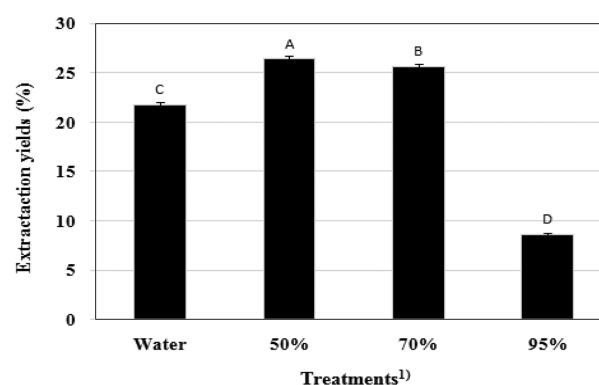


Fig. 1. Extraction yields (%) from the *Ganghwayakssuk* extracts depending on various ethanol concentrations.

<sup>A-D</sup> Means sharing different letters are significantly different ( $p < 0.05$ ).

<sup>1)</sup> Water, water extracts from *Ganghwayakssuk*; 50%, 50% ethanolic extracts from *Ganghwayakssuk*; 70%, 70% ethanolic extracts from *Ganghwayakssuk*; 95%, 95% ethanolic extracts from *Ganghwayakssuk*

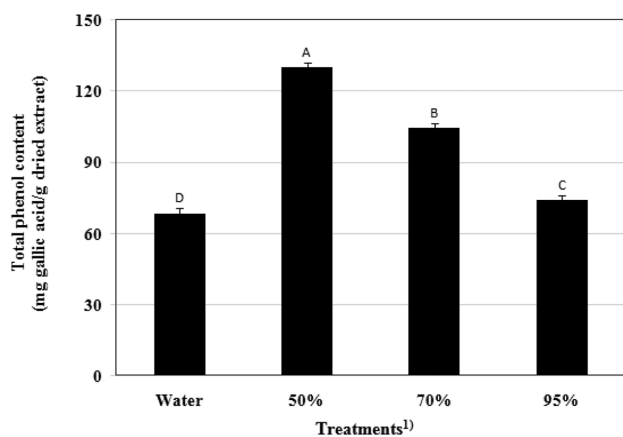


Fig. 2. Total phenol content (mg gallic acid/g dried extract) of *Ganghwayakssuk* extracts depending on various ethanol concentrations.

<sup>A-D</sup>Means sharing different letters are significantly different ( $p < 0.05$ ).

<sup>1)</sup>Water, water extracts from *Ganghwayakssuk*; 50%, 50% ethanolic extracts from *Ganghwayakssuk*; 70%, 70% ethanolic extracts from *Ganghwayakssuk*; 95%, 95% ethanolic extracts from *Ganghwayakssuk*

respectively. The highest extraction yield was recorded for the 50% GYE, whereas the lowest was for 95% GYE.

#### Total phenol content

Total phenol content of the GYE depending on the various ethanol concentrations are presented in Fig. 2. In this study, 50% aqueous ethanol was more efficient at extracting the polyphenolic compounds than other ethanol concentrations. The total phenol content was 68.60, 130.00, 105.17, and 74.23 mg gallic acid/g in water, 50, 70 and 95% GYE, respectively. Differences in the total phenol content of all samples were significant ( $p < 0.05$ ). The 50% GYE had the highest total phenolic content, followed by the 70 and 95% GYE, and water. Hong *et al.* (2007) showed that total polyphenol content of *Artemisia princeps* Pamp. was higher than the total flavonoid content, and that ethyl acetate extracts had higher total polyphenol content than other solvent extracts. Phenolic compounds are generally more soluble in polar organic solvents than in water. Phenolic compounds such as acid-phenols and their esters have antioxidative properties. They are secondary metabolites synthesized in plants and affect appearance, flavor, and oxidative stability (Cuvelier *et al.*, 1992). Phenol compounds readily bind with protein and prompt various physiological activities in microbes that delay microbial growth (Antonia *et al.*, 1990).

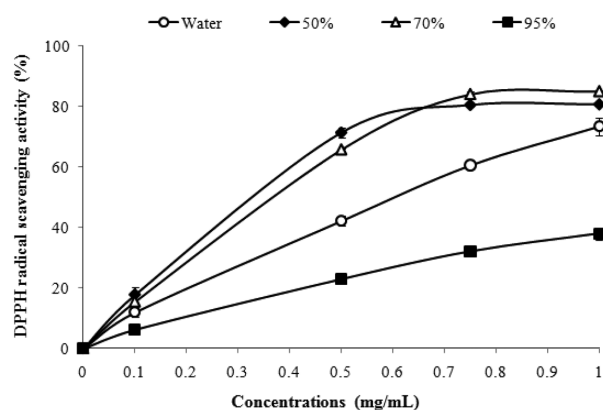


Fig. 3. DPPH free-radical scavenging activity of *Ganghwayakssuk* extracts depending on various ethanol concentrations.

Water, water extracts from *Ganghwayakssuk*; 50%, 50% ethanolic extracts from *Ganghwayakssuk*; 70%, 70% ethanolic extracts from *Ganghwayakssuk*; 95%, 95% ethanolic extracts from *Ganghwayakssuk*

#### DPPH radical scavenging activity and reducing power

The DPPH assay has been widely used to determine the free radical scavenging ability of potential antioxidants. The DPPH assay is most commonly used to evaluate the antioxidant activity of extracts, because this method is fast and easily available (Chang *et al.*, 2002). DPPH radical scavenging activities of GYE, depending on the various ethanol concentrations, are presented in Fig. 3. The results indicated that 50 and 70% GYE exhibited slightly greater DPPH radical scavenging activity than water and 95% GYE. Pack *et al.* (2002) showed that the electron donating abilities of mugwort are higher in ethanol extracts than water extracts by approximately 5-7%. Park and Kim (2006) reported that the DPPH radical scavenging of the 70% ethanol mugwort extract is higher than water extracts. The water extract (100-1,000 ppm) ranged from 73 to 81% and that of ethanol extracts ranged from 74 to 92%. Thus, the DPPH radical scavenging activity of GYE may be mostly related to their phenolic hydroxyl groups.

Reducing ability is the ability of a natural antioxidant to donate electrons. Reducing power is based on the ability of a solvent extract to reduce a  $\text{Fe}^{3+}$  ferricyanide complex to form a  $\text{Fe}^{2+}$  ferrous complex. The reducing power of the GYE, depending on the various ethanol concentrations are shown in Fig. 4. The reducing power of the treatments was ranked as follows: 50 (1.67) and 70% (1.60) GYE > water (1.42) > 95% GYE (0.60). Reducing properties are generally associated with reductions (Duh,

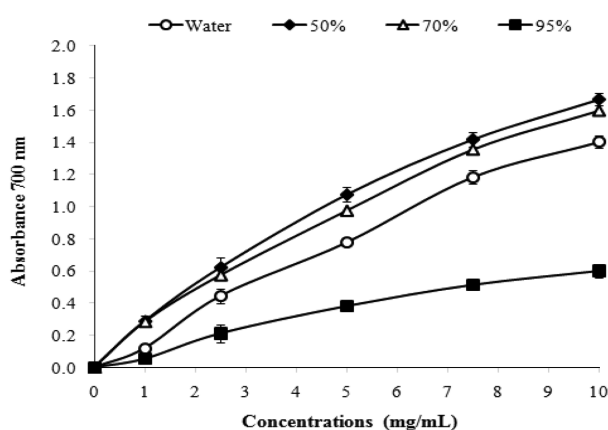


Fig. 4. Reducing power of *Ganghwayakssuk* extracts depending on various ethanol concentrations.

Water, water extracts from *Ganghwayakssuk*; 50%, 50% ethanolic extracts from *Ganghwayakssuk*; 70%, 70% ethanolic extracts from *Ganghwayakssuk*; 95%, 95% ethanolic extracts from *Ganghwayakssuk*

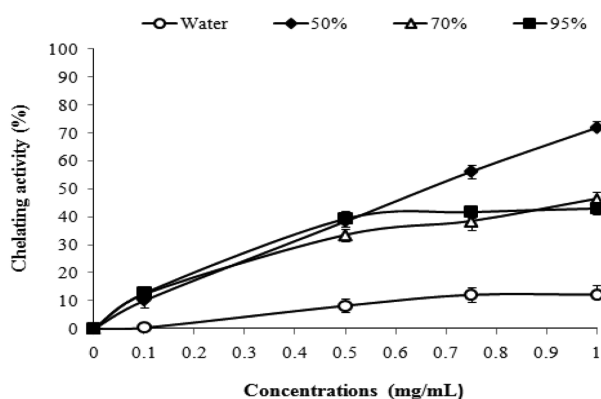


Fig. 5. Ferrous iron chelating ability of *Ganghwayakssuk* extracts depending on various ethanol concentrations.

Water: water extracts from *Ganghwayakssuk*; 50%: 50% ethanolic extracts from *Ganghwayakssuk*; 70%: 70% ethanolic extracts from *Ganghwayakssuk*; 95%: 95% ethanolic extracts from *Ganghwayakssuk*

1998). Shimada *et al.* (1992) reported that the antioxidative action of reductions is based on the breeding of free radical chains by donated hydrogen atoms.

#### Ferrous iron chelating activity

We measured  $\text{Fe}^{2+}$  chelating activity of the GYE at concentrations ranging from 0.1 to 1.0 mg/mL (Fig. 5). The 50% GYE had the highest chelating activity, and differences in chelating activity of all samples were significant ( $p < 0.05$ ). The chelating activity of 50% GYE was about 71.87% that of metal chelating activity. Other samples had metal chelating activity in the order of 70% GYE > 95% GYE > water extract, with rates of 46.29, 43.04, and 12.24%, respectively. Woo *et al.* (2010) showed that  $\text{Fe}^{2+}$

chelating effects were much higher in 80% ethanol *H. pilosella* flower extracts than water extracts. Generally,  $\text{Fe}^{2+}$  chelating activity is poorly correlated with phenol content (Graf and Eaton, 1990). However, DPPH radical scavenging increases with increasing phenol content and is positively correlated (Jeong *et al.*, 2007). The 50% GYE had the highest polyphenol content, DPPH radical scavenging, and chelating activity. Hence, 50% GYE showed an interrelationship among polyphenol content, DPPH radical scavenging, and chelating activity.

#### Effects of the GYE on lipid oxidation in chicken nugget batter during refrigerated storage

##### pH evaluation of chicken nugget batter

Table 2 shows the pH values of raw chicken nugget batter formulated with GYE and then subjected to refrigerated storage for 10 d. The pH of raw chicken nugget batter ranged from 6.08 to 6.25. At the end of storage, the pH values of the raw chicken nugget batter were higher in treatments with added GYE than in the control. Similar trends in pH were observed in studies by Kim (2006), who indicated that the pH values of dietary mugwort and sardine oil treatments increased significantly compared to those of the control during storage. The pH values of all treatments gradually decreased as storage progressed. Jung *et al.* (2004) noted that the pH values of pork patties with added mugwort powder decrease during storage. Park *et al.* (2006) reported that the decrease in pH during storage was due to lactic acid generation by microorganisms, which generally increase as storage temperature and time increase. pH was affected by the GYE because the pH of GYE was higher than that of the raw meat.

##### Color evaluations of chicken nugget batter

Osburn and Keeton (1994) reported that the color of meat and meat products was affected by additives and caramel reaction during manufacturing. Table 2 shows the lightness (CIE  $L^*$ ), redness (CIE  $a^*$ ), and yellowness (CIE  $b^*$ ) values of the raw chicken nugget batter formulated with GYE after refrigerated storage for 10 d. The lightness and redness values of the raw chicken nugget batter decreased with increasing GYE level ( $p < 0.05$ ), whereas the yellowness values increased significantly with increasing GYE content ( $p < 0.05$ ). Similar trends in color were observed in studies by Park *et al.* (2010) who investigated the quality characteristics of dried noodles with added lotus leaf powder. Gwon and Moon (2009) reported that adding green tea powder to *sulgidduk* results

**Table 2. Changes in pH and color values of raw chicken nugget batter containing *Ganghwayakssuk* ethanolic extracts (GYE) during refrigerated storage at 4°C**

	Storage periods (d)	Control	AC-0.05	GYE-0.05	GYE-0.1	GYE-0.2
pH	0	6.19±0.03 <sup>Aa</sup>	6.18±0.04 <sup>Aa</sup>	6.20±0.03 <sup>Aa</sup>	6.21±0.04 <sup>Aa</sup>	6.20±0.04 <sup>Aa</sup>
	3	6.16±0.02 <sup>BCb</sup>	6.14±0.03 <sup>Cb</sup>	6.18±0.02 <sup>ABb</sup>	6.19±0.03 <sup>Aab</sup>	6.19±0.03 <sup>Aa</sup>
	7	6.13±0.01 <sup>BC</sup>	6.10±0.02 <sup>Cc</sup>	6.15±0.02 <sup>Ac</sup>	6.16±0.03 <sup>Ab</sup>	6.16±0.02 <sup>Ab</sup>
	10	6.10±0.03 <sup>Bd</sup>	6.08±0.02 <sup>Cd</sup>	6.12±0.01 <sup>Ad</sup>	6.14±0.01 <sup>Ac</sup>	6.13±0.01 <sup>Ac</sup>
L* -value	0	62.88±0.32 <sup>Ba</sup>	63.58±0.46 <sup>Aa</sup>	61.03±0.27 <sup>Ca</sup>	59.99±0.20 <sup>Da</sup>	58.05±0.38 <sup>Ea</sup>
	3	62.49±0.19 <sup>Bb</sup>	63.40±0.22 <sup>Aa</sup>	60.48±0.30 <sup>Cb</sup>	59.87±0.42 <sup>Da</sup>	58.00±0.35 <sup>Eab</sup>
	7	62.00±0.40 <sup>Bc</sup>	63.17±0.58 <sup>Aa</sup>	60.46±0.27 <sup>Cb</sup>	59.31±0.54 <sup>Db</sup>	57.48±0.66 <sup>Eb</sup>
	10	60.76±0.17 <sup>Bd</sup>	62.50±0.22 <sup>Ab</sup>	60.03±0.27 <sup>Cb</sup>	58.68±0.30 <sup>Dc</sup>	56.78±0.43 <sup>Ec</sup>
a* -value	0	8.91±0.12 <sup>Ba</sup>	10.35±0.41 <sup>Aa</sup>	8.05±0.10 <sup>Ca</sup>	7.92±0.18 <sup>Ca</sup>	7.12±0.13 <sup>Da</sup>
	3	8.81±0.10 <sup>Bb</sup>	9.29±0.17 <sup>Ab</sup>	7.73±0.18 <sup>Cb</sup>	7.60±0.20 <sup>Cb</sup>	6.67±0.15 <sup>Db</sup>
	7	7.59±0.40 <sup>Bc</sup>	8.45±0.34 <sup>Ac</sup>	6.26±0.15 <sup>CDc</sup>	6.71±0.24 <sup>Cc</sup>	6.43±0.19 <sup>Dc</sup>
	10	5.19±0.29 <sup>Bd</sup>	7.86±0.44 <sup>Ad</sup>	6.06±0.18 <sup>Cd</sup>	5.34±0.23 <sup>Cd</sup>	5.15±0.21 <sup>Cd</sup>
b* -value	0	12.03±0.37 <sup>Ba</sup>	11.42±0.27 <sup>Ca</sup>	12.20±0.22 <sup>Ba</sup>	12.37±0.14 <sup>Ba</sup>	13.39±0.22 <sup>Aa</sup>
	3	11.64±0.15 <sup>Bb</sup>	11.05±0.20 <sup>Cb</sup>	11.79±0.38 <sup>Bb</sup>	11.74±0.20 <sup>Bb</sup>	13.36±0.29 <sup>Aa</sup>
	7	11.29±0.36 <sup>BCc</sup>	10.98±0.15 <sup>Cb</sup>	11.71±0.28 <sup>Bb</sup>	11.70±0.55 <sup>Bb</sup>	12.39±0.31 <sup>Ab</sup>
	10	10.63±0.12 <sup>Dd</sup>	10.87±0.21 <sup>DCb</sup>	11.50±0.10 <sup>Bb</sup>	11.18±0.42 <sup>Cc</sup>	12.06±0.47 <sup>Ab</sup>

All values are mean ± SD of the three replicates.

<sup>A-E</sup>Means sharing different letters in the same row are significantly different ( $p < 0.05$ ).

<sup>a-d</sup>Means sharing different letters in the same column are significantly different ( $p < 0.05$ ).

Control, no antioxidant; AC-0.05, raw chicken nugget containing ascorbic acid 0.05%, GYE-0.05, raw chicken nugget batters containing *Ganghwayakssuk* ethanolic extract 0.05%; GYE-0.1, raw chicken nugget batters containing *Ganghwayakssuk* ethanolic extract 0.1%; GYE-0.2, raw chicken nugget batters containing *Ganghwayakssuk* ethanolic extract 0.2%

in lower lightness and redness and higher yellowness values than the control. These results agree with those reported by Park and Kim (2006), who added mugwort powder to dried and cooked noodles. As a result, lightness and redness of the dried and cooked noodles decreased with increasing mugwort concentration ( $p < 0.05$ ). Han *et al.* (2001) also noted that the color of food with added mugwort had a lower lightness value and a higher yellowness value than that of the control. At the end of storage, raw chicken nugget batter samples with ascorbic acid showed the highest redness values ( $p < 0.05$ ). According to Ahn and Nam (2004), ascorbic acid combined with beef at a level of 0.1% (w/w) was very effective for maintaining redness of irradiated ground beef.

#### POV, CD, and TBARS values of chicken nugget batter

POV was assessed based on the quantity of hydroperoxides formed as primary oxidation products at the initial oxidation stage (Juntachote *et al.*, 2006). Differences in POV values can be caused by differences in meat and sample preparation such as the application of sodium

chloride and heat. Therefore, peroxides are very reactive and may actually decrease during storage of lipid-containing foods (Juntachote *et al.*, 2007). The POV values of raw chicken nugget batter stored for 0, 3, 7, and 10 d are illustrated in Table 3. The POV values for all samples, except GYE 0.1 and 0.2, increased until 7 d and decreased thereafter, suggesting that the hydroperoxide decomposition rate was faster than the production rate after the induction period. El-Alim *et al.* (1999) showed similar results that the POV of frozen stored salted pork patties increases and thereafter decreases as time passes. Applying ascorbic acid and GYE significantly delayed changes in the peroxide values compared to the control for all days of storage. Generally, raw samples containing 0.2% GYE exhibited lower peroxide values than samples with lower GYE content, samples with ascorbic acid, and the control.

CD was evaluated based on the hydroperoxides formed in the extracted lipids of the raw chicken nugget batter. As meat begins to oxidize, the fatty acid double bonds shift to create conjugated systems that can be measured spectrophotometrically (Teets and Were, 2008). Peroxida-

**Table 3.** Change in oxidative values of raw chicken nugget batter containing *Ganghwayakssuk* ethanolic extracts (GYE) during refrigerated storage at 4°C

	Storage periods (d)	Control	AC-0.05	GYE-0.05	GYE-0.1	GYE-0.2
POV (meq/kg)	0	23.565±0.43 <sup>Ad</sup>	18.416±0.42 <sup>Bd</sup>	17.587±0.44 <sup>Cd</sup>	14.886±0.23 <sup>Dd</sup>	12.431±0.39 <sup>Ed</sup>
	3	27.951±0.36 <sup>Ac</sup>	24.512±0.51 <sup>Bc</sup>	21.831±0.20 <sup>Cc</sup>	19.638±0.34 <sup>Dc</sup>	17.726±0.21 <sup>Ec</sup>
	7	38.476±0.41 <sup>Aa</sup>	33.143±0.32 <sup>Ba</sup>	33.093±0.28 <sup>Ba</sup>	29.593±0.17 <sup>Cb</sup>	27.019±0.38 <sup>Db</sup>
	10	31.382±0.41 <sup>Db</sup>	30.087±0.52 <sup>Eb</sup>	32.255±0.32 <sup>Cb</sup>	38.590±0.26 <sup>Aa</sup>	34.609±0.66 <sup>Ba</sup>
CD (µmol/mg)	0	0.714±0.005 <sup>Ad</sup>	0.685±0.005 <sup>Bd</sup>	0.663±0.003 <sup>Cd</sup>	0.630±0.012 <sup>Dd</sup>	0.597±0.006 <sup>Ed</sup>
	3	0.790±0.015 <sup>Ab</sup>	0.769±0.007 <sup>Bc</sup>	0.753±0.009 <sup>Cb</sup>	0.696±0.005 <sup>Dc</sup>	0.684±0.007 <sup>Dc</sup>
	7	0.956±0.007 <sup>Aa</sup>	0.841±0.007 <sup>Ba</sup>	0.796±0.010 <sup>Ca</sup>	0.741±0.009 <sup>Db</sup>	0.716±0.005 <sup>Eb</sup>
	10	0.766±0.003 <sup>Bc</sup>	0.794±0.005 <sup>Ab</sup>	0.682±0.005 <sup>Dc</sup>	0.794±0.007 <sup>Ca</sup>	0.754±0.006 <sup>Aa</sup>
TBA (MDA/kg)	0	0.14±0.03 <sup>Ad</sup>	0.12±0.10 <sup>Bd</sup>	0.11±0.16 <sup>Bd</sup>	0.09±0.07 <sup>Cd</sup>	0.08±0.04 <sup>Cd</sup>
	3	0.21±0.07 <sup>Ac</sup>	0.19±0.05 <sup>Bc</sup>	0.17±0.17 <sup>Cc</sup>	0.15±0.06 <sup>Cc</sup>	0.11±0.04 <sup>Ec</sup>
	7	0.28±0.07 <sup>Ab</sup>	0.24±0.07 <sup>Bb</sup>	0.21±0.16 <sup>Cb</sup>	0.19±0.06 <sup>Db</sup>	0.16±0.05 <sup>Eb</sup>
	10	0.37±0.15 <sup>Aa</sup>	0.32±0.12 <sup>Ba</sup>	0.31±0.16 <sup>Ca</sup>	0.28±0.11 <sup>Da</sup>	0.25±0.10 <sup>Ea</sup>

All values are mean ± SD of the three replicates.

<sup>A-E</sup>Means sharing different letters in the same row are significantly different ( $p<0.05$ ).

<sup>a-d</sup>Means sharing different letters in the same column are significantly different ( $p<0.05$ ).

Control, no antioxidant; AC-0.05: raw chicken nugget containing ascorbic acid 0.05%, GYE-0.05: raw chicken nugget batters containing *Ganghwayakssuk* ethanolic extract 0.05%; GYE-0.1, raw chicken nugget batters containing *Ganghwayakssuk* ethanolic extract 0.1%; GYE-0.2, raw chicken nugget batters containing *Ganghwayakssuk* ethanolic extract 0.2%

tion of unsaturated fatty acids is accompanied by a shift in the position of double bonds to form conjugated hydroperoxides, and the conjugated structure absorbs strongly at 232-234 nm (Kulas and Ackman, 2001). The CD values increased significantly ( $p<0.05$ ) in all samples, with the exception of the samples treated with GYE 0.1 and 0.2, during the 7 d of storage and then it peaked and later decreased until the end of storage (Table 3). This agrees with results obtained after adding several other natural antioxidants, including almond skin (Teets and Were, 2008). Peña-Ramos and Xiong (2003) also noted that the concentration of conjugated dienes in cooked pork patties treated with whey and soy protein hydrolysates increase significantly on the first day, followed by a decrease thereafter. A similar trend in CD values was observed in studies by Frankel (1998), in which the development of conjugated dienes, which parallels hydroperoxide production, exists in the early stages of lipid oxidation. Furthermore, Juntachote *et al.* (2006) reported that a decrease in CD values was followed by an increase in TBARS values in cooked ground pork.

The malondialdehyde (MDA) contents in raw chicken nugget batters stored for 0, 3, 7, and 10 d is shown in Table 3. TBARS is a measure of secondary oxidation products, mainly aldehydes and carbonyls of hydrocarbons that contribute to off-flavors and flavours in meat

(Cho and Rhee, 1997). TBARS values increased significantly in control raw chicken nugget batter ( $p<0.05$ ). However, when GYE was added, the raw chicken nugget batter resisted lipid oxidation, and the TBARS values of all treated samples were much lower ( $p<0.05$ ) than the control on all days. The GYE treatment (0.2%) suppressed lipid oxidation more than the ascorbic acid treatment ( $p<0.05$ ). This effect may be associated with GYE concentration because the highest concentration (0.2% GYE) delayed the oxidation process most efficiently by maintaining TBARS values during the 10 d of storage. Similar TBARS values were reported by Sayago-Ayerdi *et al.* (2009) in raw and cooked chicken hamburgers who investigated the effects of antioxidants on dietary fiber. Mugwort contains many ingredients with antioxidant and antimicrobial effects such as polyphenols (Yun *et al.*, 2008). Thus, the antioxidant effect of GYE may be related to its phenolic constituents. Several studies have noted a relationship between phenolic content and antioxidant activity (Velioglu *et al.*, 1998). Sheard *et al.* (2000) recommended 0.5 mg/kg TBARS as a threshold value for rancidity perception by consumers. The TBARS values of all raw chicken nugget batter samples did not exceed 0.5 mg/kg by the end of the storage period.

Adding GYE to raw chicken nugget batter inhibited lipid oxidation during 10 d of refrigerated storage. These



data strongly suggest that GYE has potential as a natural antioxidant source for meat and meat products. Due to concerns regarding the safety and toxicity of synthetic antioxidants, *Ganghwayakssuk* may prove useful as a safe, natural health promoting antioxidant for the meat industry. GYE showed potential as a good natural antioxidant source that can be used as a functional ingredient for chicken nugget batter. Chicken nugget batter with added GYE could be a commercially acceptable meat product and can be readily manufactured with high quality. The best results were obtained using raw chicken nugget batter with 0.2% of added GYE.

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