

## Effect of *Gaeddongssuk* (*Artemisia annua* L.) Powder on Quality and Shelf Stability of Emulsion Sausages during Refrigerated Storage

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### Abstract

The objective of this study was to evaluate effects of *Gaeddongssuk* powder (GP) on quality characteristics and shelf stability of emulsion sausages during storage. Proximate composition properties showed no significant differences in all treatment ( $p>0.05$ ). Control showed the highest cooking loss while the treatment with GP showed decreased cooking loss depending on increasing GP content ( $p<0.05$ ). Apparent viscosity of batter was increased as the amount of GP increased, whereas hardness of emulsion sausages was decreased with increasing GP level. In sensory evaluation, emulsion sausage with 0.1% GP resulted in the highest score in overall acceptability. The pH values of all treatments decreased at the early storage stage, followed by gradual increase. The lightness and redness of treatments were decreased when the level of GP was increased. However, the yellowness of sausages with GP were higher than that of control ( $p<0.05$ ). The addition of GP inhibited lipid oxidation of emulsion sausages during storage depending on its level. The aerobic bacteria population and VBN was unaffected by addition of GP during the storage ( $p>0.05$ ). Therefore, *Gaeddongssuk* powder up to 0.1% has a potential as a natural antioxidant for meat products because it can inhibit lipid oxidation of sausages without decreasing their sensory properties.

**Keywords:** *Gaeddongssuk* (*Artemisia annua* L.), emulsion sausage, quality characteristics, shelf stability

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### Introduction

Recently, improvement in the economic status and educational level of consumers has led to healthy food choices. Consumers will consider the impact of food on their health as well as the nutritional value of food. Consumers have been avoided synthetic additives that could potentially be harmful to health. So the physiological activity of natural products and their derivatives as functional materials have been intensively studied (Lee and An, 2010; Lee *et al.*, 2002; Ryu and Kwon, 2012).

Most meat products contain lipid and lipid oxidation causes loss of its nutritional value. Various oxidation products can be produced by peroxide oxidation, including aldehydes, hydrogen peroxide. They are potentially toxic to humans and animals (Horton *et al.*, 1987). They can

damage DNA and cause cancer. In addition, oxidation products are associated with aging (Zanardi *et al.*, 2004). Synthetic antioxidants butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) have been used to prevent lipid oxidation. However, these are known that cause of disease such as liver hepatomegaly with increased microsomal enzyme activity has been reported to be toxic or carcinogenic (Branen, 1975). Therefore, it is very important to develop safe and healthy natural antioxidants.

*Gaeddongssuk* (*Artemisia annua* L.) is an annual plant belonging to family of Chrysanthemum (*Compositae*). This plant is mostly distributed in Asia at roadside and riverside (Räth *et al.*, 2004). This plant has been used as traditional herbal medicine. *Gaeddongssuk* contains various bioactive compounds. It is especially rich in artemisinin (Räth *et al.*, 2004; Towler and Weathers, 2015). In addition, *Gaeddongssuk* contains flavonoids, phenolics, and purines (Iqbal *et al.*, 2012; Weathers *et al.*, 2011). The antioxidant activity of phenolic compounds in *Gaeddongssuk* has been reported (Brisibe *et al.*, 2009). It can

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protect lipid against peroxidation by inhibiting oxidizing chain reactions (Laguerre *et al.*, 2007). Some studies have reported the effect of *Gaeddongssuk* added to food and feed (Kang *et al.*, 2012; Lee *et al.*, 2014). However, *Gaeddongssuk* powder (GP) was not used as natural antioxidants to inhibit lipid oxidation in meat products.

Therefore, the objective of this study was to determine the effect of GP on quality characteristics during refrigerated storage of emulsion sausages as well as to provide effective uses of GP as a natural and functional ingredient in meat products.

## Materials and Methods

### Preparation of raw materials

Commercial samples of hot air-dried *Gaeddongssuk* powder (GP) ( $L^* = 47.23 \pm 1.33$ ,  $a^* = -6.82 \pm 0.11$ ,  $b^* = 24.52 \pm 0.34$ ) were purchased from a local market (Jirisan honghwain, Korea). Fresh pork ham, chicken breast and pork back-fat were obtained from a local commercial processor (Korea) 24 h after slaughter.

### Manufacturing of emulsion sausage

All subcutaneous, intramuscular fat and visible connective tissues were removed from the fresh ham muscles. Lean meat and pork back fat were ground through a 3 mm plate (Model 7548, Biro MFG. Co, USA). Pork ham, chicken meat, and pork back fat were mixed with curing ingredients (salt, sugar, phosphate) and stored at 4°C overnight (Fig. 1). Five formulations of emulsion sausages; control, one with 0.02% butylated hydroxytoluene (BHT) and three with different GP levels (0.1, 0.3 and 0.5%) and were prepared. Pork ham, chicken meat, water and other ingredients were emulsified by using a silent cutter (CR-40, Spain). After emulsification, the meat batter was stuffed into PVDC casings (Ø 65 mm) using a stuffer, and then were heated until the core temperature reached 71°C for 30 min in smoke house (IT-90404, Intertek, Korea). The cooked sausages were cooled with cold water. The produced samples were aerobically packed in polyethylene bags, and stored at 4°C until testing.

### Quality characteristics of emulsion sausage

#### Proximate composition

The moisture, protein and fat contents of emulsion sausage samples were analyzed using a Food Scan™ Lab 78810 (Foss Tecator Co., Ltd., DK), according to the method of Anderson *et al.* (2007).

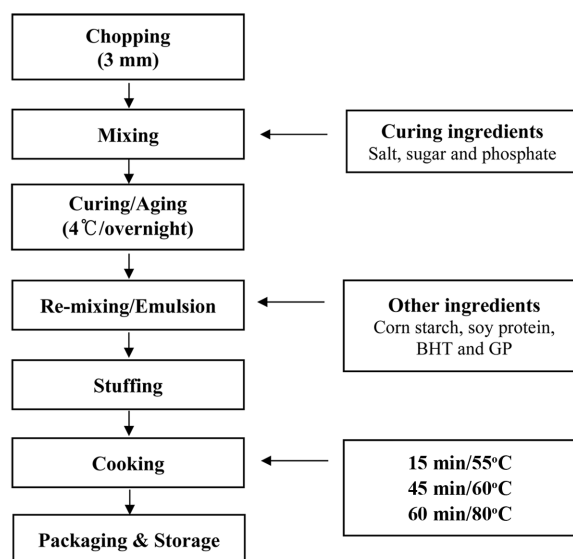


Fig. 1. Manufacturing procedure of emulsion sausage.

#### Cooking loss

As mentioned above, all emulsion sausages were cooked using water bath at  $75 \pm 2^\circ\text{C}$  for 30 min. The cooking loss of emulsion sausages were determined by calculating the difference in weight after and before cooking as follows:

$$\text{Cooking loss (\%)} = \left[ \frac{\text{the weight before cooking (g)} - \text{the weight after cooking (g)}}{\text{the weight before cooking (g)}} \right] \times 100$$

#### Apparent viscosity

The meat batter viscosity was measured in triplicate with a rotational viscometer (HAKKE Viscotester® 500, Thermo Electron Corporation, Germany) set at 10 rpm. The standard cylinder sensor (SV-2) was positioned in a 25 mL metal cup filled with batter and allowed to rotate under a constant shear rate at ( $\text{s}^{-1}$ ) for 30 s before each reading was taken. Apparent viscosity values in centipoises were obtained. The temperature of each sample at the time ( $18 \pm 1^\circ\text{C}$ ) of viscosity testing was also recorded.

#### Texture profile analysis (TPA)

The texture properties of the emulsion sausages were analyzed using a puncture probe (7 mm diameter) attached to a texture analyzer (Model 4465, Instron Corp, UK) (Seo *et al.*, 2015). For texture analysis, the samples were taken from the central portion of each treatment and cut into 2.54 cm long pieces in cylinder shape. The samples were axially compressed twice until reaching each time 80% of its initial height. The speed of load cell was set at 120

mm/min and the following parameters were calculated: hardness (kg), springiness (mm), and cohesiveness (kg\*mm), gumminess (kg) and chewiness (kg\*mm).

### Sensory evaluation

The sensory evaluations were performed on each evaluation of emulsion sausages by panelist. The panels consisted of 7 trained members (3 females, 4 males; ages 27-32) from Animal Products Processing Division of the National Institute of Animal Science, Suwon, Korea. The samples were cut into 1.5 cm and served to the panels when samples were at room temperature (about 25°C). The emulsion sausages were evaluated for color (1=extremely undesirable, 9=extremely desirable), *Gaeddongssuk* flavor (1=extremely undesirable, 9=extremely desirable), flavor (1=extremely undesirable, 9=extremely desirable), texture (1=extremely undesirable, 9=extremely desirable) and overall acceptability (1=extremely undesirable, 9=extremely desirable) using a 9-point scales. After evaluation of each sample, the panelists were asked to rinse their mouth with the distilled drinking water and salt-free crackers.

### Shelf life of emulsion sausages during storage for 4 weeks at 4°C

#### pH measurement

The pH values of emulsion sausages samples were determined in triplicates using a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland). The pH was measured after homogenizing 3 g of each sample with 27 mL of distilled water for 30 s using a homogenizer.

#### Color measurement

Color was determined at 4 defined areas on the cut surface of each emulsion sausages sample using a Minolta Chroma Meter CR-400 (Minolta Camera Co., Ltd., Japan) that was standardized with a white plate ( $Y = 93.5$ ,  $X = 0.3132$  and  $y = 0.3198$ ). Color was expressed according to the Commission International d'Eclairage (CIE) system and reported as CIE L\* (lightness), CIE a\* (redness), CIE b\* (yellowness).

#### Thiobarbituric acid reactive substances (TBARS)

Lipid oxidation was investigated in the emulsion sausages samples by measuring TBARS value using the distillation method, with slight modifications (Pikul *et al.*, 1989). A 10 g sample was blended with 35 mL of trichloroacetic acid (5%) and 1 mL of butylated hydroxytoluene

(0.5%) and then transferred to a round-bottom flask. After addition of 100 mL of distilled water, the mixture was distilled using a distillation column and 50 mL of distillate was collected. Five milliliters of distillate was added to a tube containing 5 mL of 2-thiobarbituric acid (0.02 M) and vortexed. The tubes were capped and heated in a boiling water bath for 60 min to develop the pink color and then cooled to room temperature. The absorbance was measured at 532 nm against a blank containing 5 mL of water and 5 mL of TBA (0.02 M) solution. The TBARS values were expressed as milligram malondialdehyde (MDA) per kilo-gram of sample. TEP (1,1,3,3-tetraethoxypropane, Merck) was used for the preparation of standard curve and calculation of TBARS value.

#### Volatile basic nitrogen (VBN)

Volatile basic nitrogen was determined by the micro-diffusion method according to Conway and Byrne (1933), and was express as mg% of the sample using the following steps: 10 g of samples were mixed with 90 mL of distilled water for 1 min by filtering through Whatman paper No. 1 (Ø150mm, Cat. No. 1001 150, Whatman International Ltd., England). One mL of filtrate was placed in outer space of Conway unit, and 1 mL of 0.01 N H<sub>3</sub>BO<sub>3</sub> and 200 µL of Conway reagent (0.066% methyl red in ethanol : 0.066% bromocresol green in ethanol = 1:1) were added in inner space. The Conway unit was sealed immediately after adding 1 mL of 50% K<sub>2</sub>CO<sub>3</sub> to the outer space. The sealed Conway unit was shaken slowly and incubated at 37°C for 2 h. The 0.02 N H<sub>2</sub>SO<sub>4</sub> was added to inner space for titration. The VBN was calculated using the following equation.

$$\text{VBN (mg\%)} = (a - b) \times (f \times 0.02 \times N \times 14.007 \times 100 \times 100) / S$$

a = titer for sample, b = titer for blank, f = factor of reagent, N = normality, S = sample weight (g).

#### Microbial analysis

Emulsion sausages (25 g) were taken aseptically from each batch in each treatment, transferred to sterile plastic pouches and homogenized for 1 min at room temperature with 225 mL of 1% peptone water using a stomacher Lab-Blender 400 (Seward Medical, London). Serial dilutions were made in sterilized diluted solution and aerobic mesophilic bacteria were determined by spreading 1 mL of appropriate dilutions on to 3M Petrifilm Aerobic Count Plate (3M Health Care., USA) incubated for 48 h at 35°C. Each

sample was done in duplicates and total aerobic mesophilic bacteria were expressed as  $\log_{10}$  numbers of colony forming units/gram (CFU/g).

### Statistical analysis

All tests were done at three times for each experimental condition and mean values were reported. The statistical analysis of all data was performed by SPSS Ver. 18.0 (SPSS Inc., USA). One-way analysis of variance (ANOVA) tests were carried out on quality characteristics. Two-way analysis of variance (ANOVA) tests were carried out on each variable of treatments and weeks. Duncan's multiple range comparison were used to find the level of significant differences ( $p < 0.05$ ).

## Results and Discussion

### Quality characteristics of emulsion sausage

#### Proximate composition

Proximate composition of emulsion sausages with GP is shown in Table 2. Moisture content of emulsion sausages of control and treatments were, 58.95-59.53%, showing no significant differences among control and treatments ( $p > 0.05$ ). Fat and protein contents of emulsion

sausages did not shown significantly different at all treatments ( $p > 0.05$ ). Moon *et al.*, (2003) showed no differences on proximate composition of pork patty among treatment groups within/without addition mugwort powder, as a similar result. This study indicated that addition of GP had no effect on proximate composition.

#### Cooking loss

Cooking loss of emulsion sausages with GP additive is summarized in Table 3. Cooking loss of the control was higher than T4 ( $p < 0.05$ ). It has been reported that a large amount of dietary fiber (dry 40.09%, wet 6.87%) is contained in mugwort (Hwang *et al.*, 1996). Generally, cooking loss is affected by the types of dietary fiber added to the meat product. Cooking loss of meat products with dietary fiber can be decreased when its contents are increased (Choi *et al.*, 2010a). Jeon *et al.* (2012) reported that cooking loss of pork patties was decreased when the content of seaweed powder (sea mustard, sea lettuce, and hijikia) was increased, resulting from increased water holding capacity due to dietary fiber in seaweeds. And addition of louts root or louts leaf powder to pork patties result in the low cooking loss compared with control. (Choi *et al.*, 2012). Therefore, dietary fiber in GP added to the sausages might have increased the water absorption ability of

**Table 1. The formulation of emulsion sausages with different levels of GP**

Ingredients	Treatments				
	Control	T1	T2	T3	T4
Pork meat	50	50	50	50	50
Chicken meat	10	10	10	10	10
Corn starch	5	5	5	5	5
Soy protein	5	5	5	5	5
Pork fat	18	18	18	18	18
Ice	10	10	10	10	10
Phosphate	0.2	0.2	0.2	0.2	0.2
Salt	1.3	1.3	1.3	1.3	1.3
Sugar	0.5	0.5	0.5	0.5	0.5
Total	100	100	100	100	100
BHT <sup>1)</sup>		0.02			
<i>Gaeddongssuk</i> powder			0.1	0.3	0.5

<sup>1)</sup>BHT: Butylated hydroxytoluene.

**Table 2. Comparison on proximate composition of emulsion sausages with different levels of GP**

Traits	Treatments <sup>1)</sup>				
	Control	T1	T2	T3	T4
Moisture (%)	59.42±0.07	59.14±0.06	58.95±0.12	59.52±0.06	59.53±0.13
Fat (%)	16.77±0.10	17.05±0.30	17.13±0.40	16.84±0.80	17.03±0.05
Protein (%)	17.16±0.08	17.06±0.02	17.02±0.10	17.18±0.06	17.15±0.11

All values are mean±standard deviation.

<sup>1)</sup>Treatments: Control, no added ingredient; T1, sausage with 0.02% BHT(butylated hydroxytoluene); T2, sausage with 0.1% *Gaeddongssuk* powder; T3, sausage with 0.3% *Gaeddongssuk* powder; T4, sausage with 0.5% *Gaeddongssuk* powder.

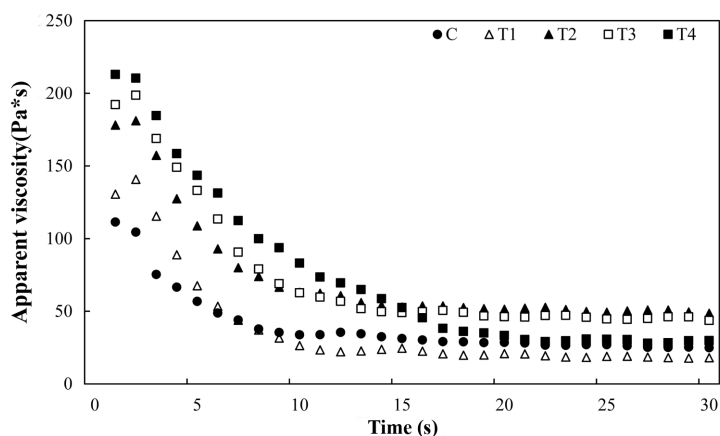
**Table 3. Comparison cooking loss on emulsion sausages with different GP levels**

Traits	Treatments <sup>1)</sup>				
	Control	T1	T2	T3	T4
Cooking loss (%)	1.31±0.25 <sup>A</sup>	1.14±0.15 <sup>AB</sup>	1.12±0.14 <sup>AB</sup>	0.84±0.52 <sup>AB</sup>	0.75±0.17 <sup>B</sup>

All values are mean±standard deviation.

<sup>1)</sup>Treatments: Control, no added ingredient; T1, sausage with 0.02% BHT(butylated hydroxytoluene); T2, sausage with 0.1% *Gaeddongssuk* powder; T3, sausage with 0.3% *Gaeddongssuk* powder; T4, sausage with 0.5% *Gaeddongssuk* powder.

<sup>A,B</sup>Means within a row with different letters are significantly different ( $p<0.05$ ).



**Fig. 2. Comparison of apparent viscosity on emulsion sausage with different levels of GP. (●)Control: no added ingredient, (Δ)T1: sausage with 0.02% BHT(butylated hydroxytoluene), (▲)T2: sausage with 0.1% *Gaeddongssuk* powder, (□)T3: sausage with 0.3% *Gaeddongssuk* powder, (■)T4: sausage with 0.5% *Gaeddongssuk* powder.**

emulsion sausages, leading to the reduction in cooking loss.

#### Apparent viscosity

Apparent viscosity of meat batter with GP is shown in Fig. 2. The control and treatments with GP showed reduction in apparent viscosity as turning time was increased, which is a characteristic of thixotropic material. Initial viscosity of the control had the lowest value at 111 Pa\*s while that of the treatment with 0.5% GP (T4) had the highest value at 213 Pa\*s. This is thought to be due to the effect of GP on increased viscosity of the emulsion. Nuria *et al.* (1999) reported that dietary fiber, fat, and water contents can affect the viscosity of meat emulsions. This study showed that decreased fat and high dietary fiber content in batter increased viscosity. Dogan *et al.* (2005) reported that viscosity of emulsions can exert the largest effect on water absorption of additives. Akras and Gencelep (2006) reported that increased emulsion viscosity is related to increased emulsion stability. Such relationship can serve as a useful standard for manufacturing high-quality emulsion sausages.

#### Texture profile analysis (TPA)

Changes in texture properties of emulsion sausages with GP are shown in Table 4. Hardness was decreased as the amount of GP was increased ( $p<0.05$ ). The springiness value was the highest (18.41 mm) in the control ( $p<0.05$ ). Han (2010) reported that the hardness of meat products is decreased as the added amount of salted bamboo shoot powder is increased, similar to the results of this study. However, cohesiveness, gumminess, and chewiness showed no significant ( $p>0.05$ ) differences among treatments. The quality of raw meat and types of additives as well as differences in the extent of protein denaturation based on differences in heating temperature during processing process can lead to changes in histological characteristics (Moon *et al.*, 2003). In addition, dietary fiber in the GP may have effect on hardness and springiness of emulsion sausages by retaining more moisture due to its high water holding capacity as reported in previous studies (Choi *et al.*, 2010a; Jeon *et al.*, 2012).

#### Sensory evaluation

Sensory characteristics (color, *Gaeddongssuk* flavor, flavor, texture, and overall acceptability) of emulsion sau-

**Table 4. Comparison on texture properties of emulsion sausages with different levels of GP**

Traits	Treatments <sup>1)</sup>				
	Control	T1	T2	T3	T4
Hardness (kg)	1.04±0.10 <sup>A</sup>	1.06±0.08 <sup>A</sup>	1.05±0.08 <sup>A</sup>	0.92±0.06 <sup>B</sup>	0.86±0.04 <sup>C</sup>
Springiness (mm)	18.41±1.24 <sup>A</sup>	17.00±0.71 <sup>B</sup>	17.72±0.30 <sup>AB</sup>	17.61±0.29 <sup>B</sup>	17.15±0.71 <sup>B</sup>
Cohesiveness	1.42±0.55	1.26±0.72	1.25±0.78	1.59±0.68	1.54±0.64
Gumminess (kg)	1.47±0.53	1.36±0.79	1.35±0.86	1.49±0.62	1.33±0.56
Chewiness (kg*mm)	26.80±0.91	23.21±3.70	23.83±5.17	26.42±0.97	22.91±0.84

All values are mean±standard deviation.

<sup>1)</sup>Treatments: Control, no added ingredient; T1, sausage with 0.02% BHT(butylated hydroxytoluene); T2, sausage with 0.1% *Gaeddongssuk* powder; T3, sausage with 0.3% *Gaeddongssuk* powder; T4, sausage with 0.5% *Gaeddongssuk* powder.

<sup>A-C</sup>Means within a row with different letters are significantly different ( $p<0.05$ ).

**Table 5. Sensory evaluation of emulsion sausages with different levels of GP**

Traits <sup>2)</sup>	Treatments <sup>1)</sup>				
	Control	T1	T2	T3	T4
Color	4.43±1.39 <sup>C</sup>	4.57±0.97 <sup>C</sup>	5.86±1.06 <sup>B</sup>	7.43±0.78 <sup>A</sup>	8.29±0.75 <sup>A</sup>
<i>Gaeddongssuk</i> flavor	1.29±0.48 <sup>C</sup>	1.14±0.37 <sup>C</sup>	4.71±1.70 <sup>B</sup>	6.43±1.51 <sup>A</sup>	7.43±1.13 <sup>A</sup>
Flavor	5.57±1.71	5.29±1.70	4.71±1.89	4.00±1.91	3.71±1.89
Texture	4.86±1.77	4.57±1.61	4.86±1.06	5.14±1.34	5.14±1.57
Overall acceptability	6.14±1.06 <sup>AB</sup>	6.14±0.69 <sup>AB</sup>	6.29±1.25 <sup>A</sup>	5.00±1.15 <sup>BC</sup>	4.71±1.49 <sup>C</sup>

All values are mean±standard deviation.

<sup>1)</sup>Treatments: Control, no added ingredient; T1, sausage with 0.02% BHT(butylated hydroxytoluene); T2, sausage with 0.1% *Gaeddongssuk* powder; T3, sausage with 0.3% *Gaeddongssuk* powder; T4, sausage with 0.5% *Gaeddongssuk* powder.

<sup>2)</sup>Traits: color (1=extremely undesirable, 9=extremely desirable), *Gaeddongssuk* flavor (1=extremely undesirable, 9=extremely desirable), flavor (1=extremely undesirable, 10=extremely desirable), texture (1=extremely undesirable, 9=extremely desirable), and overall acceptability (1=extremely undesirable, 9=extremely desirable)

<sup>A-C</sup>Means within a row with different letters are significantly different ( $p<0.05$ ).

sages with various GP levels are summarized in Table 5. There was significant ( $p<0.05$ ) difference in color, *Gaeddongssuk* flavor, and overall acceptability among treatments. However, there was no significant ( $p<0.05$ ) difference in flavor or texture among treatments. The color and *Gaeddongssuk* flavor of emulsion sausages were increased as the GP concentration increased. Overall acceptability of treatment with 0.1% GP showed the highest score while the treatment with 0.5% GP (T4) had the lowest score ( $p<0.05$ ). Kim *et al.* (2009) reported that excessive dietary fiber may cause a decrease in the quality attributes of meat products such as physicochemical, rheological, and sensory properties. Therefore, during manufacture of

the sausage, it is preferable to adding GP to less than 0.3% without negative effects.

### Shelf life of emulsion sausages during storage for 4 weeks at 4°C

#### pH measurement

The pH of emulsion sausages with GP added under different storage durations are shown in Table 6. As the storage duration was increased, significant ( $p<0.05$ ) decrease in pH was found in all treatments. After 4 weeks of storage, the treatments without GP (Control) had significantly the lowest pH value at 6.62 while the treatment

**Table 6. Change in pH values of emulsion sausages with different levels of GP during refrigerated storage time**

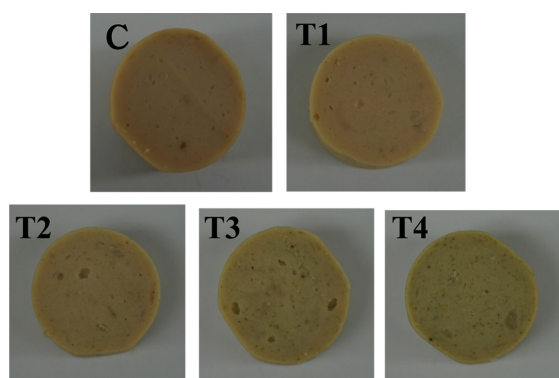
Storage time (wk)	Treatments <sup>1)</sup>				
	Control	T1	T2	T3	T4
1	6.78±0.01 <sup>ABa</sup>	6.77±0.01 <sup>Cb</sup>	6.79±0.01 <sup>Ba</sup>	6.81±0.01 <sup>Aa</sup>	6.82±0.01 <sup>Aa</sup>
2	6.78±0.01 <sup>ABa</sup>	6.77±0.01 <sup>Cb</sup>	6.79±0.01 <sup>Ba</sup>	6.81±0.01 <sup>Aa</sup>	6.81±0.01 <sup>Aa</sup>
3	6.66±0.01 <sup>Bb</sup>	6.65±0.02 <sup>Bc</sup>	6.65±0.02 <sup>Bb</sup>	6.70±0.01 <sup>Ab</sup>	6.71±0.01 <sup>Ab</sup>
4	6.62±0.01 <sup>Cc</sup>	6.65±0.01 <sup>Bc</sup>	6.66±0.02 <sup>Bb</sup>	6.71±0.01 <sup>Ab</sup>	6.70±0.01 <sup>Ac</sup>

All values are mean±standard deviation.

<sup>1)</sup>Treatments: Control, no added ingredient; T1, sausage with 0.02% BHT(butylated hydroxytoluene); T2, sausage with 0.1% *Gaeddongssuk* powder; T3, sausage with 0.3% *Gaeddongssuk* powder; T4, sausage with 0.5% *Gaeddongssuk* powder.

<sup>A-C</sup>Means within a row with different letters are significantly different ( $p<0.05$ ).

<sup>a-c</sup>Means within a column with different letters are significantly different ( $p<0.05$ ).



**Fig. 3. Cross section of emulsion sausages with different levels of GP.** C: no added ingredient, T1: sausage with 0.02% BHT(butylated hydroxytoluene), T2: sausage with 0.1% *Gaeddongssuk* powder, T3: sausage with 0.3% *Gaeddongssuk* powder, T4: sausage with 0.5% *Gaeddongssuk* powder.

with 0.5% GP (T4) had significantly the highest pH value at 6.82 ( $p<0.05$ ). These higher pH of treatment with GP resulted from higher pH value of GP than raw meat. Okonkwo *et al.* (1992) reported a decreasing trend of pH with an increase in storage duration for meat products. It has been reported that the decrease in pH with increase in storage duration is due to the effect of salt concentration on ionic strength (Bower *et al.*, 2003). Choi *et al.* (2007) reported that pH of meat products is generally decreased as the storage duration is increased, similar to the results of this study. Affected by manufacture and storage conditions, the pH values of meat products during storage are decreased due to lactic acid produced during the growth

of microorganisms (Langlois and Kemp, 1974).

#### Color evaluations

The additives added to sausage products have been shown to play important roles in meat color during storage (Choi *et al.*, 2010b). Colors of emulsion sausages with GP during storage are shown in Table 7. The CIE L\* value indicating the lightness of emulsion sausages in the control was significantly ( $p<0.05$ ) higher than that of treatments with GP added. As the amount of GP in sausages was increased, the lightness was significantly decreased ( $p<0.05$ ). The CIE a\* value indicating the redness was also higher in the control compared to that in the treatments with GP added. As GP content increased, redness of sausages was significantly decreased ( $p<0.05$ ). The CIE b\* value indicating the yellowness was higher in the treatments with GP compared to that of the control. Lee *et al.* (2004) reported that lightness and redness values of sausages showed significantly decreasing tendency, when increasing amount of Wormwood (*Artemisia absinthium L.*) powder added during manufacture of sausages, similar to the results of this study. This was in contrast to the report of Moon *et al.* (2003) that the addition of 0.3% mugwort powder to patties failed to affect meat product color. The changes in lightness and redness observed in sausages with different amounts of GP in this study could be due to color of GP itself.

#### Thiobarbituric acid reactive substances (TBARS)

To measure the lipid oxidation of emulsion sausages

**Table 7. Change in color values of emulsion sausages with different levels of GP during refrigerated storage time**

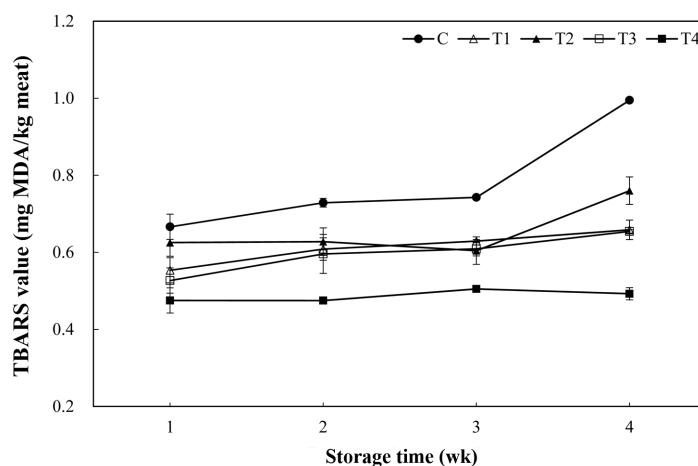
Traits	Storage time (wk)	Treatments <sup>1)</sup>				
		Control	T1	T2	T3	T4
CIE L* (Lightness)	1	82.90±0.85 <sup>Ab</sup>	83.23±0.88 <sup>Ab</sup>	80.94±0.78 <sup>Bc</sup>	77.06±0.59 <sup>Cc</sup>	73.04±0.59 <sup>Dc</sup>
	2	83.94±0.82 <sup>ABa</sup>	84.43±0.58 <sup>Aa</sup>	82.27±0.53 <sup>Cb</sup>	78.36±0.80 <sup>Db</sup>	75.65±0.61 <sup>Ea</sup>
	3	83.64±0.57 <sup>Aa</sup>	80.75±1.21 <sup>Bc</sup>	84.01±0.70 <sup>Aa</sup>	77.13±1.00 <sup>Ca</sup>	74.16±0.84 <sup>Db</sup>
	4	83.50±0.62 <sup>Ab</sup>	84.17±0.47 <sup>Aa</sup>	80.68±0.57 <sup>Bc</sup>	76.50±0.96 <sup>Ca</sup>	74.60±1.39 <sup>Db</sup>
CIE a* (Redness)	1	6.21±0.37 <sup>Aa</sup>	6.17±0.22 <sup>Abc</sup>	3.57±0.26 <sup>Bab</sup>	0.66±0.29 <sup>Ca</sup>	-1.42±0.27 <sup>Da</sup>
	2	6.22±0.16 <sup>Aa</sup>	6.32±0.09 <sup>Ab</sup>	3.80±0.37 <sup>Bab</sup>	0.82±0.44 <sup>Ca</sup>	-1.40±0.06 <sup>Da</sup>
	3	6.35±0.38 <sup>Aa</sup>	6.11±0.21 <sup>Ad</sup>	3.58±0.21 <sup>Bab</sup>	0.75±0.57 <sup>Ca</sup>	-1.46±0.14 <sup>Da</sup>
	4	6.51±0.21 <sup>Aa</sup>	6.56±0.21 <sup>Aa</sup>	3.29±0.22 <sup>Bb</sup>	0.55±0.15 <sup>Cab</sup>	-1.24±0.13 <sup>Da</sup>
CIE b* (Yellowness)	1	14.75±0.45 <sup>Db</sup>	14.57±0.47 <sup>Db</sup>	15.45±0.49 <sup>Ca</sup>	16.10±0.28 <sup>Bc</sup>	16.99±0.26 <sup>Ac</sup>
	2	14.68±0.36 <sup>Db</sup>	14.38±0.45 <sup>Db</sup>	15.64±0.46 <sup>Ca</sup>	16.97±0.17 <sup>Ba</sup>	18.18±0.33 <sup>Aa</sup>
	3	15.14±0.46 <sup>Da</sup>	15.59±0.41 <sup>Ca</sup>	14.80±0.44 <sup>Db</sup>	16.48±0.61 <sup>Bb</sup>	17.37±0.23 <sup>Ab</sup>
	4	14.41±0.24 <sup>Db</sup>	14.39±0.51 <sup>Db</sup>	15.77±0.59 <sup>Ca</sup>	17.04±0.34 <sup>Ba</sup>	18.34±0.48 <sup>Aa</sup>

All values are mean±standard deviation.

<sup>1)</sup>Treatments: Control, no added ingredient; T1, sausage with 0.02% BHT(butylated hydroxytoluene); T2, sausage with 0.1% *Gaeddongssuk* powder; T3, sausage with 0.3% *Gaeddongssuk* powder; T4, sausage with 0.5% *Gaeddongssuk* powder.

<sup>A-E</sup>Means within a row with different letters are significantly different ( $p<0.05$ ).

<sup>a-d</sup>Means within a column with different letters are significantly different ( $p<0.05$ ).



**Fig. 4.** Changes in TBARS on emulsion sausages containing different levels of GP during storage time. (●)Control: no added ingredient, (Δ)T1: sausage with 0.02% BHT(butylated hydroxytoluene), (▲)T2: sausage with 0.1% *Gaeddongssuk* powder, (□)T3: sausage with 0.3% *Gaeddongssuk* powder, (■)T4: sausage with 0.5% *Gaeddongssuk* powder.

with GP added during storage, TBARS values were measured (Fig. 4). During storage, TBARS value of the control was the highest ( $p < 0.05$ ) at 0.99 mg MDA/kg, while the treatment with 0.5% GP (T4) had the lowest TBARS value at 0.32 mg MDA/kg. It has been reported that mugwort contains large amounts of caffeic acid, catechol, and protocatechic acid, all of which have strong antioxidant properties, allowing for the delay in lipid oxidation (Lee *et al.*, 1992). As storage duration was increased, lipid oxidation of all treatments was significantly increased ( $p < 0.05$ ). Turner (1954) have stated that meat with TBARS value of 1.2 mg/kg or higher is generally considered as rotten. In this study, no treatments showed TBARS value over 1.2 mg/kg during storage. GP might have suppressed lipid oxidation since the TBARS value of the control was higher than that of the treatments GP added. Jung *et al.* (2003) reported that large amount of antioxidants such as polyphenol in mugwort can lower the TBARS values of sausages when mugwort powder added. Heating of mug-

wort extracts can contribute to the generation of antioxidants and the conversion of bound polyphenol into free polyphenol, leading to its increased antioxidant activity (Kang and Lee, 2013).

#### Volatile basic nitrogen (VBN)

VBN is commonly used to evaluate the freshness of meat. Biochemical changes in meat can occur due to enzymes present in muscles and those produced by microorganisms that induce catabolism of proteins into peptides or free amino acids and further breakdown into ammonia, amines, mercaptan, and hydrogen sulfide, causing unpleasant odor (Huang *et al.*, 2015). Such changes in inorganic nitrogen level can reflect the freshness of meat products. In terms of the relationship between VBN formation and food edibility limit, 5-10 mg% indicates fresh state whereas 30-40 mg% indicates early decomposition state (Witte *et al.*, 1970). VBN values of emulsion sausages with GP during storage are shown in Table 8. As storage duration

**Table 8.** Change in VBN values of emulsion sausages with different levels of GP during refrigerated storage time

Storage time (wk)	Treatments <sup>1)</sup>				
	Control	T1	T2	T3	T4
1	11.62±0.16 <sup>Dc</sup>	12.81±0.32 <sup>Cc</sup>	13.09±0.41 <sup>BBc</sup>	13.82±0.16 <sup>Bc</sup>	14.65±0.31 <sup>Ac</sup>
2	12.62±0.47 <sup>Cc</sup>	12.08±0.72 <sup>Cc</sup>	13.54±0.16 <sup>Bc</sup>	14.09±0.16 <sup>Bc</sup>	16.02±0.31 <sup>Ab</sup>
3	14.55±0.28 <sup>Bb</sup>	15.01±0.79 <sup>Bb</sup>	15.92±0.27 <sup>Ab</sup>	16.29±0.15 <sup>Ab</sup>	16.38±0.15 <sup>Ab</sup>
4	18.21±0.73 <sup>ABa</sup>	16.29±1.19 <sup>Ca</sup>	17.94±0.99 <sup>Ba</sup>	18.12±0.16 <sup>ABa</sup>	19.49±0.16 <sup>Aa</sup>

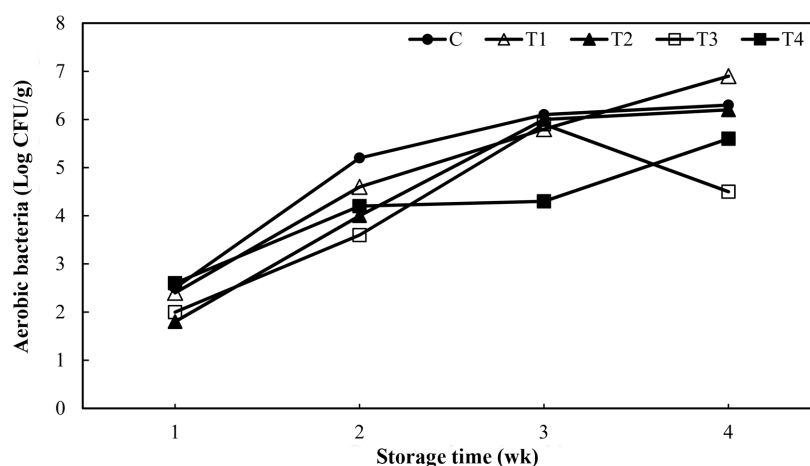
All values are mean±standard deviation.

<sup>1)</sup>Treatments: Control, no added ingredient; T1, sausage with 0.02% BHT(butylated hydroxytoluene); T2, sausage with 0.1% *Gaeddongssuk* powder; T3, sausage with 0.3% *Gaeddongssuk* powder; T4, sausage with 0.5% *Gaeddongssuk* powder.

<sup>A-D</sup>Means within a row with different letters are significantly different ( $p < 0.05$ ).

<sup>a-c</sup>Means within a column with different letters are significantly different ( $p < 0.05$ ).





**Fig. 5.** Effect of GP on the population of aerobic bacteria of emulsion sausages during refrigerated storage (Log CFU/g). (●)Control: no added ingredient, (Δ)T1: sausage with 0.02% BHT(butylated hydroxytoluene), (▲)T2: sausage with 0.1 *Gaeddongssuk*, (□)T3: sausage with 0.3% *Gaeddongssuk* powder, (■)T4: sausage with 0.5% *Gaeddongssuk* powder.

was increased, VBN values of all treatments were significantly increased ( $p < 0.05$ ), in agreement with results of a previous study showing increased VBN concentration with increased storage duration of meat (Terasaki *et al.*, 1965; Jung *et al.*, 2003). During storage, VBN values of all treatments fell into the range of 11.62 to 19.49 mg%, all of which were below 20 mg%, the edible limit, suggesting that sausages can be kept for up to 4 wk of refrigeration storage.

#### Microbial analysis

The count of aerobic bacteria (AB) of emulsion sausages refrigerated for 4 wk is summarized in Fig. 5. As expected, the number of AB of all treatment groups were constantly increased when storage days were increased. The initial AB in emulsion sausages ranged from 1.8-2.6 Log CFU/g. It was increased to 4.5-6.9 Log CFU/g after 28 d. The maximal recommended limit of microbial content is 7 Log CFU/g in meat (Nottingham, 1982). None of the treatments exceeded the permitted limit of AB at 7 Log CFU/g at the end of storage. Result that AB of emulsion sausage containing GP was slightly lower compared with the control. Jung *et al.*, (1989) observed terpinen-4-ol in essential oils of mugwort is a leaded food microbiology *S. cerevisiae*, *L. mesenteroides*, *L. plantarum*, *A. oryzae* and *B. subtilis* and the count of *E. coli*, the indicator of food contamination also inhibited by far 1000 ppm, so that demonstrated great antimicrobial effect of mugwort. Also, Kim (2011) reported similar result that AB of emulsified sausage containing mugwort was slightly lower compared with the control.

#### Conclusion

In this study, the addition of GP increased pH and yellowness but decreased lightness, redness and cooking loss on emulsion sausages. In sensory evaluation, the addition of 0.1% GP to emulsion sausage obtained the highest score. Also, emulsion sausage with GP added inhibited lipid oxidation during refrigerated storage. These effects were dependent on the amount of GP added. The AB population and VBN was not significantly different among treatments ( $p > 0.05$ ). In addition, GP in emulsion sausages could retard lipid oxidation. GP has the potential to increase shelf stability of meat products. Thus, GP could be used as a natural antioxidant to prevent oxidative damage and improve the sensory properties of meat products.

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