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ARTICLE

Effect of *Gleditsia sinensis* Lam. Extract on Physico-Chemical Properties of Emulsion-Type Pork Sausages

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Abstract

This study was performed to investigate the effect of *Gleditsia sinensis* Lam. extract on the physicochemical properties of emulsion-type pork sausages during storage at 10°C for 4 wk. Treatments were as follows: (C, control; T1, sodium ascorbate 0.05%; T2, *Gleditsia sinensis* Lam. 0.05%; T3, *Gleditsia sinensis* Lam. 0.1%; T4, *Gleditsia sinensis* Lam. 0.2%; T5, *Gleditsia sinensis* Lam. 0.1% + sodium ascorbate 0.05%). The values of pH, moisture content, lightness, redness, and sensory attributes were all significantly decreased, while the yellowness, chroma, hue angle, and texture properties were increased during storage with increase of the *Gleditsia sinensis* Lam. extract added. In addition, the antioxidant activity and antimicrobial activity in the sausages displayed significant increases ($p<0.05$). Therefore, although it was concluded that the addition of *Gleditsia sinensis* Lam. extract is not effective for improvement of the physical properties compared to chemical additives in sausages, it could be applied to meat products as a natural preservatives.

Keywords *Gleditsia sinensis* Lam., physical properties, DPPH radical scavenging activity, anti-microbial activity

Introduction

Consumer demand for meat and meat products is constantly changing due to the increased concerns regarding diet, health, changing life style, and increased convenience of food (Resurreccion, 2004). In recent years, meat production and consumption have suffered from a lot of negative publicity, due to issues such as bovine spongiform encephalopathy (BSE), foot and mouth disease, use of chemical additives, etc. (Coffey *et al.,* 2005; Marsh *et al.,* 2004; Winter and Davis, 2006). However, the total global meat consumption increased by almost 60% between 1990 and 2009, from 175,665 thousand tons to 278,863 thousand tons - a trend which is expected to continue (Henchion *et al.,* 2014). Meat and meat products are excellent sources of high quality protein, vitamin B12, B6, niacin, iron, zinc, phosphorus and other important nutrients in the human diet (Tobin *et al.,* 2014).

Nowadays, there is high consumer demand for safe and healthy food with high quality (Andrée *et al.,* 2010). In food industry, in order to increase quality and shelf-life of foods, food manufacturers have used cheap and effective synthetic additives such as butylated hydroxytoluene (BHT), butylated hydroxyanisole

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(BHA), potassium sorbate, sodium ascorbate, and sodidum nitrite, etc. However, since it was revealed that synthetic additives are toxic and can have side effects in the human body (Branen, 1975; Sebranek *et al.,* 2005; Shahidi and Wanasundara, 1992), food products which contain minimal or no chemical preservatives have become increasingly preferred among consumers (Gupta and Abu-Ghannam, 2011). For these reasons, much research has been carried out to determine natural additives which can be added to meat products, thus, the derivatives from plant materials such as herbs, fruits, vegetables, seed, and seaweeds have now replaced many synthetic additives (Biswas *et al.,* 2015; Hayes *et al.,* 2011; Hygreeva *et al.,* 2014; López-López *et al.,* 2009). To date, however, it has not been easy to find a suitable or remarkable natural material for the economic and efficient replacement of synthetic materials.

Gleditsia sinensis Lam. (Leguminosae) is a perennial shrub with wide distribution throughout Korea and China. Its thorns, called "Jo Gak Ja" in Korea, can be gathered regardless of the season, and have been used in traditional herbal medicine for the treatment of various diseases (Park *et al.,* 2011). Previous studies reported the various biological effects of *Gleditsia sinensis* Lam., including anti-diabetic, anti-hyperglycemic, antioxidant activity, anti-inflammatory, anticancer, anticoagulant activities (Ha *et al.,* 2008; Ko *et al.,* 2007; Lee *et al.,* 2011; Yoo *et al.,* 2010). However, no studies have yet investigated the effects of *Gleditsia sinensis* Lam. extract on the quality characteristics of meat products. In the present study, the effects of *Gleditsia sinensis* Lam. extract on the physicochemical characteristics of emulsion-type pork sausage were examined, confirming the possibility of a novel raw material for addition to meat products.

Materials and Methods

Preparation of *Gleditsia sinensis* Lam. extract

The dried *Gleditsia sinensis* Lam. which cultivated in Korea were purchased from Kumho herbal medicine market, Seoul, Korea. The plant material was air dried at room temperature (26°C) and in darkness, and was then powdered with a mill (IKAM20, IKA, Germany). The dried sample was extracted with distilled water (1:10) at 80°C, and was then refluxed for 6 h to give an initial extract (fraction I). The residues were extracted with distilled water (1:5) at 80°C for 2 h to give fraction II. After cooling to room temperature and then filtering (Whatman No 2), the two fractions were combined and dried under vacuum below 40°C. Extract of *Gleditsia sinensis* Lam. was completely dried in a freeze-drier and stored at -20°C until further use.

Preparation of emulsion-type pork sausages

Fresh lean pork (*Biceps femoris*, moisture 75%, protein 20%, fat level 5%) and backfat (fat 82%, moisture 18%) from male and female LYD (Landrace × Yorkshire × Duroc) pigs was purchased from a local slaughtering house. Subcutaneous and excessive connective tissues were removed from pork meat and ground twice through a 9-mm plate. Each of the six treatment groups used in this study were prepared three replications and a treatment group (1 batch) was prepared by 10 kg respectively for analysis. Six batches (60 kg) for experiment were prepared three replications and the basic recipe consisted of 72.2% meat, 11.2% back fat and 14% iced water. Minced meat was ground for 1 min using a bowl cutter (Talsa K30, DSL Food Machinery Ltd, Spain). NPS ($NaCl:NaNO_2$=99:1) (1.4%), sodium tripolyphosphate (0.2%), and half of ice were subsequently added and mixed for 2 min. As experiment design (C, control; T1, sodium ascorbate 0.05%; T2, *Gleditsia sinensis* Lam. 0.05%; T3, *Gleditsia sinensis* Lam. 0.10%; T4, *Gleditsia sinensis* Lam. 0.20%; T5, *Gleditsia sinensis* Lam. 0.1% + sodium ascorbate 0.05%), respective batches were then treated. After 1 min, fat and spices were added and emulsified for 1 min and the remaining ice was added to the batter. The final emulsified batter was obtained by applying additional 3 min mixing under high speed (bowl speed: 24 rpm, knife shaft speed: 2840 rpm). The temperature of the batter was maintained below 11.5°C. The batter was then stuffed into fibrous casings (Nalo Top, Kalle GmbH, Germany; 70-mm diameter) using a stuffer (IS-8, Sirman, Italy). The stuffed samples were cooked in a heating chamber (Thematec Food Industry Co., Korea) to the internal temperature of 75°C. The emulsified sausages were then cooled and stored at 10°C for 4 wk. The formulation for emulsion-type pork sausages are presented in Table 1.

Physico-chemical analysis methods

pH

The pH was measured in triplicate using a digital pH meter (8603, Metrohm, Switzerland). About 10 g of sample were cut into small pieces to which 90 mL of distilled water was added, and slurry was made using a homoge-

Table 1. Experimental design for emulsion-type pork sausage (unit: %)

Items	C	T1	T2	T3	T4	T5
Lean meat	72.24	72.24	72.24	72.24	72.24	72.24
Backfat	11.2	11.2	11.2	11.2	11.2	11.2
Ice	14	14	14	14	14	14
NPS[1]	1.4	1.4	1.4	1.4	1.4	1.4
Sodium tripolyphosphate	0.2	0.2	0.2	0.2	0.2	0.2
Sugar	0.5	0.5	0.5	0.5	0.5	0.5
MSG	0.06	0.06	0.06	0.06	0.06	0.06
Seasoning-A	0.4	0.4	0.4	0.4	0.4	0.4
Total	100	100	100	100	100	100
Sodium ascorbate	-	0.05	-	-	-	0.05
Extract (dry base)	-	-	0.05	0.1	0.2	0.1

[1]NPS(NaCl:$NaNO_2$=99:1).
Treatments: C = control, T1 = sodium ascorbate 0.05%, T2 = *Gleditsia sinensis* Lam. 0.05%, T3 = *Gleditsia sinensis* Lam. 0.10%, T4 = *Gleditsia sinensis* Lam. 0.20%, T5 = *Gleditsia sinensis* Lam. 0.1% + sodium ascorbate 0.05%.

nizer (T25B, IKA Sdn, Bhd., Malaysia) and the pH was measured using a pH meter. The pH meter was calibrated daily with standard buffers of pH 4.0 (9863 pH buffer solution, Mettler Toledo, Switzerland) and 7.0 (9865 pH buffer solution, Mettler Toledo, Switzerland) at 25°C.

Moisture content

Moisture content was determined according to AOAC (2000). The samples were dried in an air oven at 102°C for 24 h, cooled down for 30 min and the total moisture content of individual sample was determined from their dry weights expressed as the percentage of gram water per gram of dry weight.

Cooking loss

A 3-cm-thick slice cut from sausage was placed into a polypropylene bag, cooked for 40 min at 70ºC in a water-bath, and cooled down to room temperature for 30 min. Cooking loss was calculated by the weight difference of samples before and after cooking. Cooking loss was done in triplicates.

Analysis of texture properties

The shear force of the sausages was estimated using an Instron 3343 (US/MX50, A&D Co., USA) attached to a Warner Bratzler shearing device, providing a 100 mm/min crosshead speed. Five cores (2×2×1 cm) of each sausage were analyzed at room temperature, with a crosshead speed of 100 mm/min. The average shear force value was calculated for each treatment and was expressed in N/cm^2. The textural properties of the sausages were analyzed using the EZ Test-500N texture analyzer (TA-XTZ-5, Shimadzu Co., Japan) attached to a cylindrical plunger (5 mm diameter, depression speed = 60 mm/min) and a 500 N load cell. Texture profile parameters that were measured included hardness, brittleness, cohesiveness, springiness, gumminess, chewiness, and adhesiveness.

Color

The CIE lightness (L*), redness (a*), and yellowness (b*) of sausage were measured using a Minolta colorimeter (CR-400, Japan) using a 8 mm aperture size, illuminant D65, a 2 ° Closely matches CIE 1931 Standard Observer and measurement / illumination area Φ8 mm/ Φ11 mm. The instrument was standardized using a white plate (Y=93.5, X= 0.3132, y=0.3198) and D65 illuminant source before the measurements. The chroma (C*) and hue angle were calculated as (a*2+b*2)1/2 and Tan-1 (b*/a*), respectively (Fernández-López *et al.,* 2000). The color variables were measured at five points on the central part of the cut surface of the slices of the samples. Thickness of sample was a 12 to 15 mm that does not absorb the reflected light from the bottom.

Volatile basic nitrogen (VBN)

Volatile basic nitrogen, as a measure of protein degradation, as was measured described previously with some modifications (Pearson, 1976). Briefly, 10 mL of sample and a few drops of phenolphthalein indicator (0.5 wt% solution in 50 wt% ethanol) were placed in a distillation flask, and then 3.5 mL of 20% sodium hydroxide solution was added. The apparatus was then immediately sealed, and the end of the steam distillate was collected in a flask containing 20 mL of 4% boric acid and a few drops of

Tashiro indicator (methyl red-methylene blue = 2:1). The steam distillation procedure was continued until 250 mL of distillate had been collected. Next, the obtained basic solution was titrated against 0.01-M hydrochloric acid to the end point, which was indicated by a green to gray color change. The VBN content was determined after blank correction that was determined by the steam distillation of 6% perchloric acid.

2,2-diphenyl-1-picryhydrazla hydrate (DPPH) radical scavenging activity

The DPPH radical scavenging activity measurement was modified according to the method of Bersuder *et al*. (1998). The 500 μL of each peptide fraction was mixed with 500 μL of ethanol and 250 μL of a DPPH solution (0.5 mM 1,1-diphenyl-2-picrylhydrazyl/ethanol). The mixtures were incubated for 30 min in the dark at room temperature and the reduction of DPPH radicals was measured at 517 nm. The DPPH radical scavenging activity was calculated as: DPPH radical scavenging activity (%) = ([absorption of control-absorption of sample]/absorption of control) × 100. The control was conducted in the same manner, with the exception that distilled water was used instead of sample.

Microorganism

Microorganism was analyzed for total plate count colonies according to standard procedures (Speck, 1992). The total plate count (TPC) was incubated for 72 h at 37°C. The relevant colonies on the plates were counted, and the results are expressed as colony-forming units (CFU) per gram of meat sample. The TPC counts were then normalized with logarithm on base 10.

Sensory evaluation

Sensory evaluation was performed by a panel of 16 semi trained tasters by method of Meilgaard *et al.* (2006). The panel consisted of 10 researchers and 6 technicians at the Gyeongnam National University of science and technology in Korea (40% male/ 60% females, age range between 25 and 45). All samples were given a random numbers and served randomly. One slice, 1 cm thick and 1.8 cm in diameter, was cut into six pie-shaped wedges and presented to each panelist. The panelists chose three of the most characteristic wedges in order to avoid a sample containing large pieces of connective tissue. The panelists rinsed their mouths with water and some neutral crackers between the samples. The sausage color, aroma and flavor (1 = extremely undesirable, 9 = extremely desirable), springiness (1 = extremely nonelastic, 9 = extremely elastic), juiciness (1 = extremely dry, 9 = extremely juicy), and overall acceptability (1 = extremely undesirable, 9 = extremely desirable) were evaluated using nine-point scale. The samples were evaluated at every test weeks.

Statistical analysis

The experiment was composed by a total of 90 observations used for statistical analysis (6 treatments × 3 batches × 5 storage times from each batch). The entire experiment was performed at different times in the same place, and a completely randomized design was used. The data in the physico-chemical properties during storage were analyzed by an analysis of variance (one-way ANOVA) using the GLM procedure of SAS program, which performed on the observations by the addition level of additives and storage wk respectively. Duncan's multiple range test was used to determine the statistical significance among the means at a 95% significance level. Mean values and standard error of the means (SEM) were reported. All data analysis was performed using SAS for Windows 7.0, version 9.1.3 (SAS, 2003).

Results and Discussion

pH, moisture and cooking loss

The effects of *Gleditsia sinensis* Lam. extract on the quality properties of emulsion-type pork sausages during 4 wk of storage at 10°C are summarized in Table 2. Control and T1 samples showed higher pH values than the groups containing *Gleditsia sinensis* Lam. extract, whereas the pH value of T4 was the lowest among the treatments ($p<0.05$). During the 4-wk storage, as the level of *Gleditsia sinensis* Lam. extract increased, the pH values tended to decrease. Except for the examination carried out at 3 wk, the lowest moisture content was observed in T5 ($p<0.05$), while significant reduction in the moisture content occurred with increase in the amount of *Gleditsia sinensis* Lam. extract added. For cooking loss, significant differences were observed at 0 wk, but no consistent tendency between the level of *Gleditsia sinensis* Lam. extract and cooking loss values was observed. After 2 wk, all cooking loss values significantly began to increase. According to the report of Zhou *et al.* (2007), *Gleditsia sinensis* Lam. extract contains a lot of phenolic compounds and flavonoids, including ethyl gallate, caffeic acid, dihydrokaempferol, eriodictyol, quercetin, 3,3',5',5,7-pentahydrofla-

Table 2. Effect of *Gleditsia sinensis* Lam. extract on quality properties of emulsion-type pork sausages during 4 wk at 10°C

Items	Treatments[2]	Storage (wk)					SEM[1]
		0	1	2	3	4	
pH	C	6.05^{Ab}	5.92^{Be}	5.96^{d}	5.98^{Ac}	6.08^{Aa}	0.015
	T1	6.04^{Bab}	5.93^{Ac}	5.91^{c}	5.96^{Bbc}	6.07^{ABa}	0.020
	T2	6.01^{Cb}	5.91^{Cd}	5.95c	5.96^{Bc}	6.07^{Ba}	0.014
	T3	6.01^{Cb}	5.92^{Bd}	5.94c	5.94^{Cc}	6.04^{Ca}	0.012
	T4	5.97^{Db}	5.88^{De}	5.92c	5.90^{Ed}	6.01^{Da}	0.013
	T5	6.01^{Cb}	5.92^{Be}	5.94c	5.93^{Dd}	6.04^{Ca}	0.013
	SEM[1]	0.006	0.004	0.010	0.006	0.005	
Moisture (%)	C	68.40^{Aa}	68.26^{Ab}	68.21^{Cb}	68.37^{a}	68.09^{Ac}	0.032
	T1	67.80^{Bd}	67.04^{BCc}	67.96^{Bbc}	68.04^{ab}	68.05^{Aa}	0.026
	T2	67.89^{Bab}	68.04^{Ba}	68.02^{Ba}	67.69^{b}	67.87^{Bab}	0.041
	T3	67.56^{Cc}	67.74^{CDb}	67.98^{Ba}	68.00^{a}	67.91^{Ba}	0.045
	T4	67.52^{CDb}	67.66^{Da}	67.67^{Ca}	67.68^{a}	67.62^{Cab}	0.021
	T5	67.40^{D}	67.21^{E}	67.48^{D}	68.82	67.42^{D}	0.256
	SEM[1]	0.081	0.082	0.059	0.193	0.058	
Cooking loss (%)	C	12.50^{Bb}	13.78^{b}	18.94^{a}	17.64^{a}	18.26^{a}	0.708
	T1	13.79^{Ab}	14.58^{b}	18.89^{a}	18.22^{a}	19.26^{a}	0.627
	T2	13.80^{Ac}	14.26^{c}	20.28^{a}	18.67^{b}	19.08^{ab}	0.773
	T3	12.37^{Bc}	13.92^{b}	19.62^{a}	18.61^{a}	18.91^{a}	0.844
	T4	13.28^{ABd}	14.65^{c}	19.87^{a}	18.49^{b}	18.65^{ab}	0.698
	T5	12.18^{Bd}	14.09^{c}	20.24^{a}	17.40^{b}	18.67^{ab}	0.816
	SEM[1]	0.206	0.121	0.234	0.181	0.170	

$^{A-E}$Means with different superscription within the same column differ (p<0.05).
$^{a-e}$Means with different superscription within the same row differ (p<0.05).
[1]Standard error of the means. [2]Treatments: C = control, T1 = sodium ascorbate 0.05%, T2 = *Gleditsia sinensis* Lam. 0.05%, T3 = *Gleditsia sinensis* Lam. 0.10%, T4 = *Gleditsia sinensis* Lam. 0.20%, T5 = *Gleditsia sinensis* Lam. 0.1% + sodium ascorbate 0.05%.

vanone and (-)-epicatechin. Lee *et al.* (2011) also determined the total phenol content of *Gleditsia sinensis* Lam. extract to be 1.12 g / 100 g for methanol extraction and 0.60 g/100 g after ethanol extraction. This was considered to be the reason for the pH decrease of the sausages containing *Gleditsia sinensis* Lam. extract compared to untreated groups. According to the study of Han and Rhee (2005), they reported that the extracts of plants containing a lot of phenolic compounds (49-791 mg/g) were acidic and ranged from 3.05 to 3.88. In addition, in the processing of emulsion-type meat products, the pH of emulsion is highly related to the binding capacity of the raw meat (Puolanne *et al.,* 2001). A reduction of the pH to the isoelectric point causes equalization of the positive and negative charges of the proteins. These positive and negative groups are attracted to each other, causing the water in the emulsion to be exuded out (Huff-Lonergan and Lonergan, 2005). Therefore, owing to the addition of *Gleditsia sinensis* Lam. extract, containing phenolic substances, the pH was decreased, causing a subsequent reduction in the water content of the emulsion-type pork sausages. In addition, significant increases of pH at week 4 compared to other week in our study have been reported to be due to microbial growth and protein degradation (Benito *et al.,* 2004).

Sausage color

The effect of the *Gleditsia sinensis* Lam. extract on the CIE* color of emulsion-type pork sausages during 4 wk of storage at 10°C is presented in Table 3 and Fig. 1. The lightness value of the control was the highest among the treatments during 4 wk (p<0.05). The treatment groups containing *Gleditsia sinensis* Lam. extract exhibited significantly lower lightness values than the untreated groups, with a trend of decreasing lightness upon increase of the amount of *Gleditsia sinensis* Lam. extract added (p<0.05). For the redness values, T1 displayed the highest value, whereas T3 was the lowest among the treatments during the 4-wk storage (p<0.05). The yellowness values gradually increased with the addition of *Gleditsia sinensis* Lam. extract (p<0.05). In particular, the addition of 0.2% *Gleditsia sinensis* Lam. extract showed the highest yellowness value among the treatments during all storage periods (p< 0.05). The chroma (C) and hue (h) values also showed

Table 3. Effect of *Gleditsia sinensis* Lam. extract on CIE* color of emulsion-type pork sausages during 4 wk at 10°C

Items	Treatments[2]	Storage (wk)					SEM[1]
		0	1	2	3	4	
L*	C	81.69^{A}	81.94^{A}	81.97^{A}	81.89^{A}	81.94^{A}	0.044
	T1	81.60^{A}	81.43^{A}	81.29^{B}	81.34^{B}	81.44^{B}	0.046
	T2	78.70c	78.87^{B}	78.55^{C}	78.83^{C}	78.90^{C}	0.054
	T3	77.34^{Cabc}	77.56^{Ca}	77.13^{Dc}	77.24^{Ebc}	77.45^{Dab}	0.053
	T4	72.34^{D}	72.79^{D}	72.66^{E}	72.61^{F}	72.78^{E}	0.079
	T5	77.20^{C}	77.41^{C}	77.11^{D}	77.50^{D}	77.43^{D}	0.076
	SEM[1]	0.767	0.737	0.747	0.744	0.738	
a*	C	6.17^{Cb}	5.87^{Dc}	6.19^{Dab}	6.39^{Ca}	6.31^{Cab}	0.053
	T1	7.43^{Ac}	7.58^{Abc}	7.83^{Aa}	7.80^{Aab}	7.76^{Aab}	0.048
	T2	6.22^{Cb}	6.04^{Cc}	6.50^{Ca}	6.24^{CDb}	6.29^{CDb}	0.044
	T3	5.68^{Dbc}	5.63^{Ec}	5.86^{Ea}	5.79^{Eab}	5.81^{Eab}	0.027
	T4	6.21^{Ca}	6.05^{Cb}	6.28^{Da}	6.18^{Da}	6.18^{Da}	0.025
	T5	6.94^{Bab}	6.95^{Bab}	7.03^{Ba}	6.80^{Bc}	6.94^{Bb}	0.022
	SEM[1]	0.140	0.166	0.158	0.157	0.154	
b*	C	7.34^{Da}	7.42^{Ea}	7.34^{Ea}	7.13^{Db}	7.07^{Eb}	0.039
	T1	7.22^{Da}	7.15^{Fa}	7.05^{Fab}	6.91^{Ebc}	6.80^{Fc}	0.046
	T2	10.09^{Ca}	10.18^{Da}	10.13^{Da}	9.98^{Cab}	9.85^{Db}	0.040
	T3	11.69^{Ba}	11.59^{Cab}	11.67^{Ca}	11.66^{Ba}	11.43^{Cb}	0.031
	T4	14.08^{Aa}	13.93^{Aab}	13.84^{Aab}	13.75^{Ab}	11.70^{Ab}	0.049
	T5	11.80^{Bcd}	11.99^{Ba}	11.93^{Bab}	11.84^{Bbc}	13.70^{Bd}	0.030
	SEM[1]	0.600	0.593	0.597	0.608	0.606	
C*	C	9.59^{F}	9.46^{F}	9.61^{F}	9.58^{F}	9.47^{F}	0.024
	T1	10.36^{E}	10.42^{E}	10.54^{E}	10.43^{E}	10.32^{E}	0.037
	T2	11.86^{Dab}	11.84^{Dab}	12.03^{Da}	11.77^{Db}	11.68^{Db}	0.042
	T3	13.00^{Cab}	12.89^{Cab}	13.06^{Ca}	13.01^{Ca}	12.82^{Cb}	0.031
	T4	15.39^{Aa}	15.19^{Aab}	15.20^{Aab}	15.07^{Ab}	15.03^{Ab}	0.048
	T5	13.69^{Bb}	13.86^{Ba}	13.85^{Ba}	13.66^{Bb}	13.60^{Bb}	0.030
	SEM[1]	0.478	0.474	0.462	0.457	0.461	
h*	C	49.97^{Eb}	51.62^{Da}	49.86^{Eb}	48.13^{Ec}	48.26^{Ec}	0.369
	T1	44.18^{Fa}	43.31^{Eb}	42.00^{Fc}	41.53^{Fcd}	41.21^{Fd}	0.310
	T2	58.32^{Db}	59.32^{Ca}	57.34^{Dc}	57.99^{Dbc}	57.45^{Dc}	0.206
	T3	64.07^{Ba}	64.10^{Ba}	63.36^{Bbc}	63.57^{Bb}	63.06^{Bc}	0.121
	T4	66.20^{Aa}	66.51^{Aa}	65.57^{Ab}	65.78^{Ab}	65.69^{Ab}	0.105
	T5	59.54^{Cbc}	59.88^{Cab}	59.47^{Cc}	60.12^{Ca}	59.32^{Cc}	0.090
	SEM[1]	1.871	1.904	1.965	2.088	2.067	

$^{A-E}$Means with different superscription within the same column differ (p<0.05).
$^{a-d}$Means with different superscription within the same row differ (p<0.05).
[1]Standard error of the means. [2]Treatments: C = control, T1 = sodium ascorbate 0.05%, T2 = *Gleditsia sinensis* Lam. 0.05%, T3 = *Gleditsia sinensis* Lam. 0.10%, T4 = *Gleditsia sinensis* Lam. 0.20%, T5 = *Gleditsia sinensis* Lam. 0.1% + sodium ascorbate 0.05%.
*L: lightness, a: redness, b: yellowness, C: chroma, h: hue value.

dose-dependent trends upon the addition of *Gleditsia sinensis* Lam. extract (p<0.05). Overall, the addition of *Gleditsia sinensis* Lam. extract considerably affected the color of the emulsion-type pork sausages, because *Gleditsia sinensis* Lam. has its own color such as reddish purple or reddish brown. Further, the extract contained a number of phenolic compounds. Mathew and Parpia (1971) reported that phenolic compounds took part in both enzymatic and non-enzymatic browning reactions in food. Additionally, plant extracts containing polyphenols are susceptible to oxidation, and the oxidized polyphenols form a dark color (Liu *et al.,* 2009). Thus, the lightness and redness values were decreased, whereas values in the yellowness, chroma and hue angle were increased upon the addition of *Gleditsia sinensis* Lam. extract.

DPPH, VBN and TPC

The effects of the *Gleditsia sinensis* Lam. extract on the

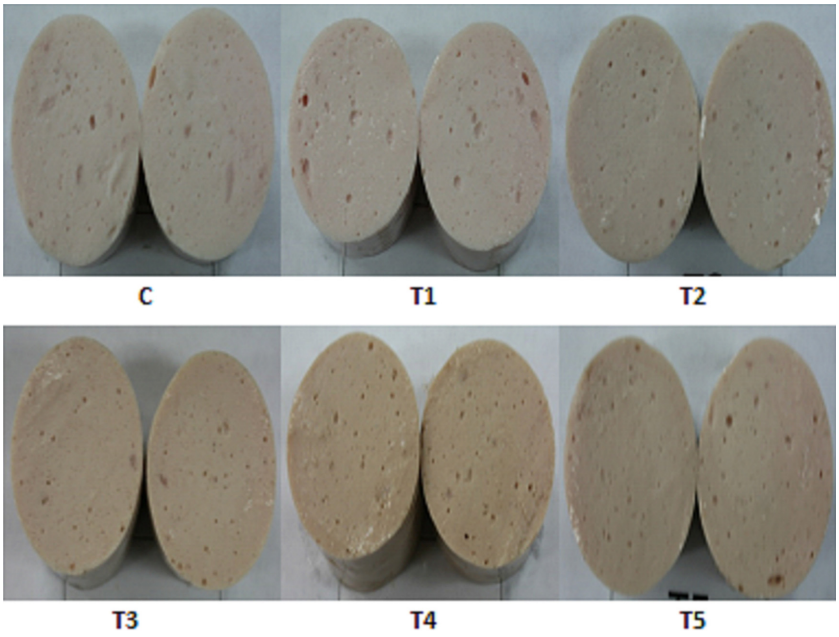

Fig. 1. Representative image of the emulsion-type pork sausages with added *Gleditsia sinensis* Lam. extract at 0 wk.

storage characteristics of emulsion-type pork sausages during 4 wk at 10°C are described in Table 4. During 4 wk of storage, the DPPH free radical scavenging activity maintained the highest values in T5, whereas the lowest values in the control. The treatment (T4) containing 0.2% *Gleditsia sinensis* Lam. extract displayed similar or higher values compared to the 0.05% sodium ascorbate treatment (T1) during storage. The VBN value of the control was also lower than the other treatment groups during all storage periods. Meanwhile, all treatment samples maintained low VBN values until 3 wk, after which significant increase was observed. A significant difference in the total microbial count of emulsion-type pork sausage according to *Gleditsia sinensis* Lam. extract content was observed in wk 1 and 2 of storage. At 1 wk, T1 had significantly higher total microbial count than the control and T3 groups ($p<0.05$), while the other treatment groups were not detected. In addition, the total microbial counts in the T3 and T4 groups were significantly lower than the treatment group containing 0.05% ascorbic acid (T1) at 2 wk. The total microbial counts of treatment groups containing *Gleditsia sinensis* Lam. extract were also lower than those of the untreated groups numerically, or were not detected at wk of 3 and 4 of storage ($p>0.05$). The DPPH free radical scavenging activity observed for samples including *Gleditsia sinensis* Lam. extract indicates anti-oxidative activity was present in the sausages, while the addition of 0.2% *Gleditsia sinensis* Lam. extract showed higher values than the addition of 0.05% sodium ascorbate. According to Lee *et al.* (2011), the DPPH radical scavenging activities of 0.1% *Gleditsia sinensis* Lam. extract were 68.8% (extracted with methanol) and 70.4% (extracted with ethanol), respectively. These results were similar with the results of the present study, in which the extract was obtained with an aqueous method. To achieve anti-oxidative activity in meat products, many natural plant extracts have been examined (Shah *et al.,* 2014). The phytochemicals in plants, such as polyphenol and flavonoids, are largely good for the protection of lipids and proteins against reactive oxygen species (Qwele *et al.,* 2013; Vuorela *et al.,* 2005). According to a study investigating correlations between phenolic content and antioxidant activity (Thitilertdecha *et al.,* 2008), there was a substantial correlation between the phenolic content and free radical scavenging activity (R^2=0.96). Thus, it was concluded that the anti-oxidant properties of *Gleditsia sinensis* Lam. extract could be attributed to the phenolic components. In this study, the addition of *Gleditsia sinensis* Lam. extract and sodium ascorbate was the most effective on antioxidant, because sodium ascorbate is an electron donor that is a chemical traditionally used as an antioxidant in meat processing (Bendich *et al.,* 1986). Based on the antioxidant results of this study, it seems to have a synergistic effect with the *Gleditsia sinensis* Lam. extract. In general, the creation of volatile basic nitrogen

Table 4. Effect of *Gleditsia sinensis* Lam. extract on storage characteristics of emulsion-type pork sausages during 4 wk at 10°C

Items	Treatments[2]	Storage (wk)					SEM[1]
		0	1	2	3	4	
DPPH[3] (%)	C	15.64^{Fb}	20.40^{Da}	13.47^{Ec}	16.61^{Eb}	15.44^{Dbc}	0.657
	T1	69.57^{Cc}	45.48^{Aa}	67.34^{Cd}	81.79^{Bb}	88.74^{Aa}	2.415
	T2	39.79^{Ec}	62.40^{Cb}	50.47^{Da}	26.51^{Dd}	41.68^{Cc}	2.154
	T3	55.44^{Dc}	62.40^{Bb}	70.42^{Ba}	48.53^{Cd}	60.66^{Bb}	1.967
	T4	88.46^{Ba}	87.29^{Aa}	84.71^{Ab}	83.49^{Bb}	89.46^{Aa}	0.650
	T5	91.33^{Aa}	87.49^{Ab}	84.46^{Ac}	90.54^{Aa}	89.48^{Aa}	0.697
	SEM[1]	6.481	6.186	5.952	7.052	6.846	
Volatile basic nitrogen (mg%)	C	7.98^{Bc}	8.82^{Cbc}	9.24^{Cb}	9.24^{Cb}	17.64^{a}	0.319
	T1	8.02^{Bb}	11.34^{Aa}	11.48^{ABa}	11.43^{Aa}	18.22^{a}	0.387
	T2	8.19^{ABb}	11.15^{Aa}	9.98^{BCa}	10.08^{ABCa}	18.64^{a}	0.316
	T3	8.40^{ABc}	9.75^{BCab}	10.82^{ABCab}	11.62^{Aa}	18.61^{ab}	0.323
	T4	8.54^{Ac}	9.66^{BCbc}	12.04^{Aa}	10.99^{ABab}	18.49^{a}	0.465
	T5	8.40^{ABc}	10.26^{ABab}	10.45^{ABCab}	9.38^{BCbc}	17.40^{a}	0.316
	SEM[1]	0.067	0.250	0.277	0.309	0.172	
Total plate count[4] (Log CFU/g)	C	-	0.38^{B}	1.00^{AB}	1.22	1.18	0.307
	T1	-	0.95^{A}	1.97^{A}	1.30	1.16	0.318
	T2	-	-	1.55^{AB}	-	-	0.243
	T3	-	0.34^{B}	0.30^{B}	0.23	-	0.080
	T4	-	-	0.34^{B}	0.30	-	0.087
	T5	-	-	-	0.30	-	0.060
	SEM[1]	-	0.112	0.253	0.255	0.263	

[A-F]Means with different superscription within the same column differ ($p<0.05$).
[a-d]Means with different superscription within the same row differ ($p<0.05$).
[1]Standard error of the means. [2]Treatments: C = control, T1 = sodium ascorbate 0.05%, T2 = *Gleditsia sinensis* Lam. 0.05%, T3 = *Gleditsia sinensis* Lam. 0.10%, T4 = *Gleditsia sinensis* Lam. 0.20%, T5 = *Gleditsia sinensis* Lam. 0.1% + sodium ascorbate 0.05%. [3]2,2-diphenyl-1-picryhydrazla hydrate radical scavenging activity. [4]Values are expressed in Log_{10} CFU/g.

is the result of degradation, such as the conversion of proteins to free-amino acids and non-protein nitrogen compounds by microorganisms and enzymes during storage (Liu *et al.,* 2009). According to Liu *et al.* (2009), chicken sausage with plant extracts from rosemary or Chinese mahogany had significantly lowered VBN values compared to the control sample, because the anti-microbial compounds present in the extracts inhibited the growth of microbes in the chicken sausages. However, in the present study, a significant relationship between the microbial count and VBN content was not observed. In this study, the VBN values of treatment groups with *Gleditsia sinensis* Lam. extract were higher than those of the control during storage periods. This result is believed to be due to the fact that *Gleditsia sinensis* Lam. extract has strong bioactivities such as anti-inflammation, anti-allergic, anti-tumor, anti-angiogenesis, antibacterial and antifungal activity, etc. (Gao *et al*., 2008; Lee *et al*., 2009; Yi *et al*., 2012; Yi *et al*., 2015; Zhang *et al*., 2016; Zhou *et al*., 2007). In other words, it is considered that the volatile substances in the treatment groups were increased because the main components of *Gleditsia sinensis* Lam. extract exhibiting bioactivities affected the protein of sausages electrically or enzymatically. Zhou *et al.* (2007) reported that the phenolic compounds in *Gleditsia sinensis* Lam. showed antibacterial activities on the Gram-positive bacterium *Xanthomonas vesicatoria* and the Gram-negative bacterium *Bacillus subtilis*. The study also revealed the major phenolic compounds in *Gleditsia sinensis* Lam. to be ethyl gallate and caffeic acid. According to other researchers (Harrison *et al.,* 2003; Nakayama *et al.,* 2013), of the phenolics in plants, gallate and caffeic acid show particularly high growth inhibition of microbes. Our results revealed that the treatment groups containing *Gleditsia sinensis* Lam. extract maintained lower total microbial counts during the storage period than the untreated groups. During the entire storage period, at 0 wk, it was judged that no microorganisms were detected immediately after the sausage production, at 1 and 2 wk, strong antimicrobial was shown by the antimicrobial effect of the *Gleditsia sinensis* Lam.

extract, and no studies on the disappearance of sculpture extracts during storage were found, but at 3 and 4 wk, the main components of the *Gleditsia sinensis* Lam. extract seemed to be somewhat lost and the antimicrobial effect seems to be somewhat reduced. In general, the mechanism of anti-microbial activity involves a reaction with the cell membrane, inactivation of essential cellular enzymes, or a combination of the two principles (Davidson and Branden, 1981).

Texture properties

The texture properties of the emulsion-type pork sausages containing *Gleditsia sinensis* Lam. extract are presented in Table 5. The highest shear force was observed in the mixed treatment (T5) group with 0.1% *Gleditsia sinensis* Lam. extract and 0.05% ascorbate during 1 to 4 wk ($p<0.05$). While the addition of 0.05% *Gleditsia sinensis* Lam. extract showed lower shear force value than the addition of 0.1 and 0.2% extract, the value was higher than for the 0.05% ascorbate treatment group during the 4-wk storage. However, all the shear force values exhibited a significant increase during the 4th wk of storage compared to the 3rd wk. The hardness value of the control was the highest among the groups tested at weeks 0 and 4, displaying a significant difference. The initial brittleness value of T4 (addition of 0.2% *Gleditsia sinensis* Lam. extract) was higher than all treatment groups except for T5 ($p<0.05$) at week 0. Over the 4-wk storage period, gradual increase of the brittleness was observed, with increase of the *Gleditsia sinensis* Lam. extract. Significant differences among the treatments and storage periods were detected in most of the measurements, including cohesiveness, springiness, gumminess, chewiness, and adhesiveness. However, notable differences were not detected between the control and treatment groups containing *Gleditsia sinensis* Lam. extract, as well as among the treated groups during the storage periods. No studies related to emulsion-type pork sausage with added *Gleditsia sinensis* Lam. extract were conducted previously. Regarding the study of plant extracts containing phenolic compounds, Jongberg *et al.* (2015) found that when 100, 500, and 1,500 ppm green tea extract was added to meat emulsion, the high concentrations of phenolic compounds reacted with the protein thiols, preventing the protein disulfide bonds. Thus, poor protein networks were formed in the emulsion, consequently leading to deterioration of the texture. Similar results were obtained herein: as the amount of the extract added increased, the shear force, hardness and brittleness values in the emulsion sausages significantly increased, even if the other measurement parameters such as springiness, cohesiveness, gumminess, adhesiveness, and chewiness did not show a notable effect. On the other hand, Hayes *et al.* (2011) reported that because the phenolic compounds present in plant extract protect the protein from oxidative damage, the textural properties of meat products may be maintained well during storage. Furthermore, such results have been also found in other studies (Estévez *et al.,* 2005; Estévez *et al.,* 2006). Therefore, addition of a suitable amount of *Gleditsia sinensis* Lam. extract was determined to be helpful to the stability of the texture properties of the emulsion-type pork sausage.

Sensory evaluation

The results of the sensory evaluation of emulsion-type pork sausages added with *Gleditsia sinensis* Lam. extract are shown in Table 6. The subjective color scores were significantly decreased by addition of *Gleditsia sinensis* Lam. extract during all storage periods ($p<0.05$). The aroma

Table 5. Effect of *Gleditsia sinensis* Lam. extract on texture profile analysis of emulsion-type pork sausages during 4 wk at 10°C

Items	Treatments[2]	Storage (wk)					SEM[1]
		0	1	2	3	4	
Shear force (N/cm^2)	C	8.99^{Cd}	9.59^{Cc}	11.14^{Cb}	10.82^{Bb}	17.50^{Ea}	0.815
	T1	9.08^{Cc}	9.03^{Cc}	10.75^{Cb}	9.22^{Dc}	18.76^{Da}	1.002
	T2	9.53^{BCc}	9.33^{Cc}	11.59^{Bb}	9.86^{Cc}	20.87^{Ba}	1.174
	T3	10.95^{Ac}	10.27^{Bd}	12.19^{Ab}	10.51^{Bcd}	19.67^{Ca}	0.947
	T4	11.40^{Ac}	10.67^{Bd}	12.12^{Ab}	10.88^{Bd}	21.56^{Aa}	1.110
	T5	10.05^{Bc}	11.88^{Ab}	12.29^{Ab}	12.53^{Ab}	21.76^{Aa}	1.107
	SEM[1]	0.230	0.242	0.148	0.255	0.376	

[a-d]Means with different superscription within the same column differ ($p<0.05$).
[A-D]Means with different superscription within the same row differ ($p<0.05$).
[1]Standard error of the means. [2]Treatments: C = control, T1 = sodium ascorbate 0.05%, T2 = *Gleditsia sinensis* Lam. 0.05%, T3 = *Gleditsia sinensis* Lam. 0.10%, T4 = *Gleditsia sinensis* Lam. 0.20%, T5 = *Gleditsia sinensis* Lam. 0.1% + sodium ascorbate 0.05%.

Table 5. Effect of *Gleditsia sinensis* Lam. extract on texture profile analysis of emulsion-type pork sausages during 4 wk at 10°C (Continued)

Items	Treatments[2]	Storage (wk)					SEM[1]
		0	1	2	3	4	
Hardness (N)	C	3.36^{Aab}	3.16^{b}	3.20^{b}	3.20^{b}	3.49^{Aa}	0.043
	T1	3.00^{C}	3.00	3.03	3.10	3.13^{C}	0.030
	T2	3.07^{BC}	3.00	3.13	3.13	2.87^{D}	0.045
	T3	3.26^{ABa}	3.07^{c}	3.20^{ab}	3.13^{bc}	3.20^{BCab}	0.023
	T4	3.07^{BC}	2.94	3.20	3.16	3.20^{BC}	0.042
	T5	3.13^{BCab}	3.07^{b}	3.20^{ab}	3.29^{ab}	3.00^{ABa}	0.038
	SEM[1]	0.038	0.038	0.030	0.029	0.049	
Brittleness (N)	C	2.26^{BCc}	2.94^{b}	3.20^{ab}	3.20^{ab}	3.49^{Aa}	0.119
	T1	1.79^{Cb}	3.00^{a}	3.03^{a}	3.10^{a}	3.13^{Ba}	0.139
	T2	2.22^{BCb}	3.00^{a}	3.13^{a}	3.07^{a}	2.87^{Ca}	0.102
	T3	2.25^{BCb}	3.07^{a}	3.16^{a}	3.13^{a}	3.16^{Ba}	0.097
	T4	3.07^{A}	2.90	3.20	3.16	3.20^{B}	0.045
	T5	2.54^{ABb}	3.07^{ab}	3.20^{a}	3.26^{a}	3.33^{ABa}	0.101
	SEM[1]	0.113	0.046	0.031	0.030	0.050	
Cohesiveness (%)	C	0.60	0.60	0.60	0.60^{AB}	0.61	0.008
	T1	0.61	0.58	0.59	0.56^{B}	0.58	0.007
	T2	0.62^{a}	0.57^{b}	0.60^{ab}	0.62^{Aa}	0.57^{b}	0.007
	T3	0.59	0.54	0.60	0.61^{AB}	0.58	0.010
	T4	0.61	0.56	0.60	0.63^{A}	0.58	0.009
	T5	0.59^{ab}	0.58^{ab}	0.55^{b}	0.58^{ABab}	0.61^{a}	0.008
	SEM[1]	0.019	0.007	0.007	0.008	0.006	
Springiness (mm)	C	1.02	1.03^{A}	1.00	1.00	1.04^{A}	0.006
	T1	1.00	1.00^{B}	1.00	1.00	1.00^{B}	0.001
	T2	1.00	1.00^{B}	1.00	1.02	1.00^{B}	0.004
	T3	1.01	1.00^{B}	1.01	1.02	1.00^{B}	0.004
	T4	1.00	1.00^{B}	0.99	1.03	1.00^{B}	0.007
	T5	1.02	1.02^{AB}	1.00	1.00	1.00^{B}	0.005
	SEM[1]	0.004	0.004	0.002	0.007	0.004	
Gumminess (N)	C	2.02^{ab}	1.86^{b}	1.92^{b}	1.96^{ABb}	2.15^{Aa}	0.033
	T1	1.82	1.76	1.76	1.76^{B}	1.79^{C}	0.022
	T2	1.89^{ab}	1.69^{bc}	1.89^{ab}	1.96^{ABa}	1.63^{Dc}	0.042
	T3	1.96	1.66	1.96	1.92^{AB}	1.86^{BC}	0.044
	T4	1.89^{ab}	1.66^{b}	1.96^{a}	2.02^{Aa}	1.86^{BCab}	0.042
	T5	1.86	1.79	1.76	1.92^{AB}	2.02^{AB}	0.042
	SEM[1]	0.037	0.029	0.031	0.030	0.043	
Chewiness (N*mm)	C	2.09^{ab}	1.96^{ab}	1.92^{b}	1.96^{ABab}	2.22^{Aa}	0.043
	T1	1.86	1.76	1.79	1.76^{B}	1.79^{CD}	0.026
	T2	1.92^{a}	1.73^{ab}	1.89^{a}	1.99^{ABa}	1.63^{Db}	0.046
	T3	1.99	1.66	1.96	1.99^{AB}	1.86^{BC}	0.050
	T4	1.89^{ab}	1.66^{b}	1.92^{ab}	2.09^{Aa}	1.89^{BCab}	0.050
	T5	1.89	1.82	1.76	1.92^{AB}	2.02^{BB}	0.045
	SEM[1]	0.044	0.039	0.030	0.038	0.048	
Adhesiveness (N s)	C	1.50	1.43^{AB}	1.53	1.53^{AB}	1.53^{A}	0.018
	T1	1.37	1.40^{AB}	1.47	1.40^{BC}	1.37^{ABC}	0.020
	T2	1.43^{ab}	1.24^{Bc}	1.56^{a}	1.37^{Cbc}	1.24^{Cc}	0.037
	T3	1.43^{ab}	1.47^{Aab}	1.60^{a}	1.40^{BCb}	1.33^{BCb}	0.030
	T4	1.40	1.40^{AB}	1.53	1.47^{ABC}	1.37^{ABC}	0.034
	T5	1.30^{c}	1.37^{ABbc}	1.53^{ab}	1.60^{Aa}	1.50^{ABabc}	0.037
	SEM[1]	0.025	0.028	0.020	0.024	0.031	

$^{a-d}$Means with different superscription within the same column differ (p<0.05).
$^{A-D}$Means with different superscription within the same row differ (p<0.05).
[1]Standard error of the means. [2]Treatments: C = control, T1 = sodium ascorbate 0.05%, T2 = *Gleditsia sinensis* Lam. 0.05%, T3 = *Gleditsia sinensis* Lam. 0.10%, T4 = *Gleditsia sinensis* Lam. 0.20%, T5 = *Gleditsia sinensis* Lam. 0.1% + sodium ascorbate 0.05%.

Table 6. Effect of *Gleditsia sinensis* Lam. extract on sensory quality attributes of emulsion-type pork sausages during 4 wk at 10°C

Items	Treatments[1)]	Storage (wk)					SEM[1]
		0	1	2	3	4	
Color	C	7.75^{A}	7.68^{A}	7.50^{A}	7.37^{A}	7.31^{A}	0.066
	T1	7.93^{A}	7.93^{A}	7.87^{A}	7.50^{A}	7.56^{A}	0.075
	T2	7.06^{B}	7.06^{B}	6.97^{B}	6.75^{B}	6.62^{B}	0.068
	T3	6.81^{Ba}	6.68^{BCab}	6.56^{BCab}	6.31^{Cb}	6.25^{BCb}	0.071
	T4	6.37^{Ca}	6.37^{Ca}	6.12^{Cab}	5.87^{Db}	5.75^{Cb}	0.078
	T5	6.87^{Ba}	6.81^{BCa}	6.81^{Bab}	6.62^{BCb}	6.37^{Bab}	0.079
	SEM[1]	0.096	0.103	0.107	0.092	0.113	
Aroma	C	7.37a	7.31^{ab}	7.06^{ABab}	6.87^{ABb}	7.12^{ab}	0.072
	T1	7.50	7.50	7.31^{A}	7.12^{A}	7.12	0.079
	T2	7.12^{ab}	7.18^{a}	6.87^{ABab}	6.62^{ABb}	6.81^{ab}	0.081
	T3	7.31^{a}	7.06^{ab}	6.62^{Bb}	6.62^{ABb}	6.75^{ab}	0.092
	T4	7.06^{a}	6.93^{ab}	6.75^{Bab}	6.37^{Bbc}	6.12c	0.101
	T5	7.25^{a}	7.50^{a}	7.06^{ABab}	6.56^{ABb}	6.87^{ab}	0.104
	SEM[1]	0.088	0.080	0.073	0.083	0.074	
Flavor	C	7.75^{Aa}	7.68^{ABab}	7.28^{ABb}	7.31^{Aab}	6.75^{ABc}	0.085
	T1	7.68^{Aa}	7.73^{Aa}	7.43^{Aab}	7.31^{Aab}	7.06^{Ab}	0.086
	T2	7.25^{ABa}	7.00^{Ca}	7.00^{BCa}	6.93^{ABa}	6.31^{BCb}	0.084
	T3	7.43^{ABa}	7.06^{Cab}	6.81^{Cb}	6.75^{ABbc}	6.31^{BCc}	0.090
	T4	6.87^{Ba}	6.68^{Cab}	6.25^{Dab}	6.37^{Bab}	6.12^{Cb}	0.097
	T5	7.06^{Ba}	7.18B^{Ca}	6.81^{Cab}	6.50^{Bb}	6.68^{ABab}	0.086
	SEM[1]	0.087	0.087	0.077	0.091	0.078	
Springiness	C	7.56	7.37^{A}	7.47^{A}	7.25^{A}	7.12^{A}	0.077
	T1	7.31^{a}	7.06^{ABab}	7.18^{ABab}	6.93^{ABab}	6.62^{Bb}	0.091
	T2	7.03	6.75^{AB}	6.78^{C}	6.62^{BC}	6.50^{B}	0.084
	T3	7.37^{a}	6.85^{ABb}	6.62^{CDb}	6.75^{ABCb}	6.50^{Bb}	0.088
	T4	7.00^{a}	6.56^{Bab}	6.37^{Db}	6.37^{Cb}	6.31^{Bb}	0.081
	T5	7.18^{a}	7.06^{ABa}	6.83^{BCab}	6.93^{ABab}	6.50^{Bb}	0.082
	SEM[1]	0.092	0.088	0.071	0.078	0.066	
Juiciness	C	7.62^{a}	7.31^{ab}	7.41^{Aab}	7.18^{ab}	7.00^{Ab}	0.072
	T1	7.47^{a}	7.31^{a}	7.18^{ABab}	7.06^{ab}	6.75^{ABb}	0.078
	T2	7.50^{a}	6.97^{b}	6.97^{ABCb}	6.91^{b}	6.75^{ABb}	0.081
	T3	7.62^{a}	7.03^{b}	6.85^{BCb}	6.93^{b}	6.62^{ABb}	0.091
	T4	7.28^{a}	7.00^{a}	6.68^{Cab}	6.75^{ab}	6.25^{Bb}	0.104
	T5	7.25^{a}	7.25^{a}	6.75^{BCab}	6.96^{ab}	6.62^{ABb}	0.081
	SEM[1]	0.067	0.072	0.068	0.063	0.085	
Overall acceptability	C	7.77^{Aa}	7.62^{Aab}	7.53^{Aab}	7.35^{Ab}	6.85^{Ac}	0.076
	T1	7.68^{Aa}	7.56^{Aa}	7.50^{Aa}	7.31^{Aab}	6.93^{Ab}	0.084
	T2	7.31^{ABa}	7.00^{Bab}	6.97^{Bab}	6.68^{Bbc}	6.41^{Bc}	0.072
	T3	7.25^{ABa}	7.08^{Ba}	6.62^{Cb}	6.50^{BCbc}	6.22^{BCc}	0.074
	T4	6.87^{Ba}	6.75^{Bab}	6.27^{Dbc}	6.18^{Cc}	5.93^{Cc}	0.094
	T5	7.15^{ABa}	7.22^{ABa}	6.78^{BCab}	6.62^{Bb}	6.60^{ABb}	0.079
	SEM[1]	0.091	0.074	0.076	0.080	0.070	

$^{a-d}$Means±SD with different superscription within the same column differ (p<0.05).
$^{A-C}$Means±SD with different superscription within the same row differ (p<0.05).
1: very bad or poor, 9: very good or superb.
[1]Standard error of the means.

score of T4 (0.2% *Gleditsia sinensis* Lam. extract) was lower than that of T2 (0.05% sodium ascorbate) at wk 2 and 3 (p<0.05). The flavor score of T4 was also the lowest among all treatment groups tested during the 4 wk (p<0.05). For springiness, the T4 group was also scored significantly lower than the control during the 4 wk, excluding

week 0. The juiciness score of T4 was also significantly lower than the control at wk 2 and 4. Finally, considering all aspects, the overall acceptability score of the T4 treatment group was the lowest, with significant differences compared with the other treatment groups during the 4 wk. In addition, all treatment groups containing *Gleditsia sinensis* Lam. extract showed lower overall acceptability than the control and T1 group from wk 1 to 4 ($p<0.05$). In this study, the addition of 0.2% *Gleditsia sinensis* Lam. extract negatively influenced the sensory evaluation during the storage periods. Particularly, the scores of color, flavor and overall acceptability were significantly reduced. *Gleditsia sinensis* Lam. is an oriental herbal medicine which has unique color and flavor. When oriental herbal medicine extracts are applied to food, the consumer acceptability may generally be decreased (Lee *et al*., 1997). However, the addition of less than 0.2% *Gleditsia sinensis* Lam. extract did not have a significant negative influence on the sensory evaluation of the emulsion-type pork sausage during storage periods.

Conclusion

It was concluded that the addition of *Gleditsia sinensis* Lam. extract is not effective for improving the physical properties of the emulsion-type pork sausage compared to chemical additives, but the antioxidant and antimicrobial activities in the pork sausage were found to be excellent. Therefore, it is considered that more research is needed to effectively apply *Gleditsia sinensis* Lam. extract to meat products without adversely affecting the physicochemical properties of meat products. In addition, given the results of present study, the appropriate amount of *Gleditsia sinensis* Lam. extract was less than 0.2% for emulsion-type pork sausage.

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