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Evaluation of Selected Thai Herb and Spice Extracts as Natural Preservative on the Shelf Life of Chicken Nuggets

Wanangkarn, A.[1, 2*], Tan, F. J.[3], and Udaiy, T.[1]

[1]Department of Agricultural Science, Faculty of Agriculture, Natural Resources and Environment, Naresuan University, Phitsanuloke 65000, Thailand; [2]The Center for Agricultural Biotechnology (AGBIOTECH-NU), Naresuan University, Phitsanuloke 65000, Thailand; [3]Department of Animal Science, College of Agriculture and Natural Resources, National Chung Hsing University, Taichung 402, Taiwan.

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Abstract The effects of Thai herb and spice extracts on the physicochemical, microbial, and sensory characteristics of cooked chicken nuggets during storage at 4±1℃ for 21 days were investigated. Cooked chicken nuggets were treated with chemical food preservative (CFP), eugenol (Eu), galangal extract (Ga), sweet basil extract (Sw), and galangal and sweet basil extract (GS). The results were compared to those obtained for nugget without any food preservative (Con) and the addition of GS showed a lowest TBARS values and suppressed the growth of microbial thoughout the storage period. Regarding the standard for acceptable microbial counts of ≤ 6.0 log cfu/g sample, GS treatment could extend the shelf life up to 14 days with longer than Con sample. Moreover, GS samples revealed better color, textural and sensory scores than the other herb and spice samples. It was demonstrated that the combination of galangal and sweet basil extracts gave a potential as a natural preservative in processed meat products.

Keywords: Herb and spice extracts, natural preservative, shelf life, chicken nugget

Introduction

The shelf life of meat products is shortened by lipid oxidation and microbial spoilage, as these will reduce the quality and nutritional value of meat products (Ahn *et al*., 2007; Dave and Ghaly, 2011) and become unacceptable in term of sensory properties or harmful to the consumer. Thus, food preservatives have been used for centuries to extend shelf life via their antioxidant or antimicrobial activities (Barbosa-Pereira *et al*., 2015). For commercial meat processing widely used synthetic preservatives are sodium benzoate, benzoic acid, sodium sorbate, potassium sorbate, sodium nitrite, butylated hydroxyanisole (BHA) and butylated hydroxytoluene (BHT) (Karre *et al*.,

* **Coressponding Author:** Wanangkarn, A.; **E-mail:** Amornrat.w@nu.ac.th

2013; Tfouni and Toledo, 2002). These synthetic preservative have led to serious concern about consumer health, resulting from the long term consumption of them (Legesse *et al*., 2016). Hence, there is a need to search for a natural source of preservatives that can be used to replace the synthetic preservatives in the meat industry.

Herbs and spices have been used for centuries as culinary cooking ingredients in several tropical countries, including Thailand. One single plant can be classified as both herb and spice depending on the parts used. The leafy green or flowering parts of plants are referred to as herbs while spices are derived from other parts of plants, such as seeds, roots, bark, berries, and the stigma of a flower (Banchob, 2000; Kritsanapun, 1995). The use of herbs and spices as natural preservatives has become more popular in recent years for extending shelf life of meat and meat products by reducing or inhibiting lipid oxidation and microbial spoilage (Gramatina *et al*., 2017; Nugboon and Intarapichet, 2015) because the compounds of herbs and spices contain many bioactive components, including phenolic compounds, flavanoids, tannins, vitamins, minerals, carotenoids, and phytoestrogens (Dawidowicz *et al*., 2006; Hygreeva *et al*., 2014). All these compounds can be use in combination or independently action via a variety of mechanisms to exhibit strong antioxidant and antimicrobial activities. Many studies have reported that the major compound is usually considered to be one of the phenolic compounds (Hara-Kudo *et al*., 2004), which are more effective antioxidants than vitamins E or C (Rice-Evans *et al*., 1997)

Our previous experiment on antioxidant and antimicrobial activities of several herbs and spices grown domestically in Thailand, including sweet basil, holy basil, finger root, kaffir lime leaf, black pepper, galangal and lemongrass demonstrated that galangal had the highest antimicrobial activity, while the sweet basil showed the highest antioxidant activity (Wanangkarn *et al*., 2018). However, there is a need for research regarding the application of local Thai herb and spice extracts in order to prolong shelf life and improve the quality of meat and meat products. Therefore, the purpose of this study was to examine the possibility of applying different herbs and spices extracts as natural preservatives to chicken nuggets at refrigeration (4±1 ℃) in order to extend their shelf life.

Materials and methods

Dried galangal and sweet basil were ground and extracted according to the methods of Weerakkody *et al*. (2010) with some modifications. Dried plant powder (10 g) was mixed with 100 ml of 95% ethanol and stirred at ambient temperature for 24 h. The mixture was filtrated through Whatman filter paper

no. 1 and then centrifuged at 10,000 g for 10 min. The residue after centrifugation was repeated three times with similar procedure. Solvent extracts were concentrated using a rotary evaporator under vacuum at 70 °C and then were lyophilized and kept in sterilized cape vials at 4 °C until use. The chemical food preservative and eugenol were purchased from Chemipan Corporation Co., Ltd. (Bangkok, Thailand).

Chicken nugget preparation

Chicken nugget batter was prepared by mixing lean chicken (91% w/w), chicken fat (3.50% w/w), water (3% w/w), white soy sauce (0.80% w/w), table salt (0.50% w/w), black pepper (0.45% w/w), sodium tripolyphosphate (0.35% w/w), garlic powder (0.20% w/w) and seasoning (0.20% w/w). To prepare each treatment, six treatments of chicken nuggets were prepared with different herb and spice extracts (0.20 ml/100 g), singly or in combination; namely, Con (sterile saline water), CFP (Chemical food preservative), Eu (Eugenol), Ga (Galangal), Sw (Sweet basil), and GS (Galangal and Sweet basil [1:1]). All ingredients were mixed homogeneously and formulated in three separated batches. Each nugget mixture was formed into a specific shape (4x2x1 cm) and chilled at -18 °C for 1 h. The nuggets were coated with a layer of crumbs and cooked by deep fat frying at 180 °C in palm oil for 3 min with an internal temperature about 80 ± 2°C then packed in a polyethylene bag and stored at 4 ℃. Nuggets were selected randomly on day 0, 3, 7, 14 and 21 for analyses.

Physicochemical analysis

pH value was measured according to the method described by Trout *et al*. (1992), ten-gram samples were blended with 50 ml distilled water in a polyethylene bag for 1 min using a laboratory homogenizer, and then the pH value of the mixture was measured using a digital pH meter (Weilheim, Germany). Thiobarbituric acid-reactive substances (TBARS) assay was determined as described by Witte *et al*. (1970). TBARS were calculated from a standard curve of 1,1,3,3-tetraethoxypropane (TEP) at a concentration ranging from 8-50 nmol. TBARS values were calculated as mg of malondialdehyde (MDA) equivalent/kg sample.

Color parameters of samples were taken using a handy colorimeter (MiniScan EZ, Hunter Associates Laboratory, USA). The instrument was standardized with a calibration plate, including light trap/black glass and white tile. The colorimeter was directly put on the surface of the chicken nugget

samples at six different points, expressed as L* (lightness), a* (redness), and b* (yellowness) values.

In the texture profile analysis (TPA), a texture analyzer (QTS Texture analyzer, CNS Farnell, Essex, UK) was applied to determine texture parameters, including hardness, chewiness, springiness and cohesiveness of samples. Six pieces of nugget samples had the coating system removed and were cut into 2.0 cm in height and 2.0 cm in diameter pieces. A compression platform of 30 mm was used as a probe. The TPA was performed according to the procedure of Bourne (1978).

Microbiological analysis

Microbial qualities were determined according to APHA (2001). At a specified sampling time, a 25-gram sample was aseptically placed in a sterile bag, which contained 225 ml of 0.85% NaCl solution, and homogenized with a stomacher (Stomacher blender, Model 400, Seward) for 2 min. Serial dilutions were then made. Plate count agar (Merck, Dram Stadt, Germany) and potato dextrose agar (Merck, Dram Stadt, Germany) were used for enumeration of total plate counts, and yeast and mould counts, respectively, using the pour plate method. Total microflora was incubated at 35°C for 48 h. For yeast and mould counts, agar plates were incubated at 25°C for 5 days. The microbial counts were expressed as $\log_{10}$ colony forming units (CFU) per gram of sample.

Sensory evaluation

Sensory evaluation was carried out at different storage times (0, 7, 14, and 21 days). Cooked chicken nuggets were reheated in a microwave (800 W) for 30s and then served to a sensory panel, which consisted of 30 panelists. Sensory attributes, including appearance, flavor, taste, texture, and overall acceptability were evaluated using a 1 to 9-point hedonic scale, with 1 and 9 representing extremely dislike and extremely like, respectively. During the evaluation process, the panelists were provided unsalted crackers and water to neutralize their palates and taste receptors between different samples.

Statistical analysis

Analysis of variance (ANOVA) was performed to analyze the effect of treatment (Con, CFP, Eu, Ga, Sw and GS) and time of storage (0, 3, 7, 14, and 21 days). Mean comparisons were run by Duncan's multiple range test. Data analyses were performed using Statistical Analysis System's Procedures (Version 9.1, SAS Institute Inc., Cary, NC) with a 5% level of significance.

Results

Physicochemical analysis

The change of pH values in samples is given in Fig. 1. The initial mean pH value of cooked chicken nugget was 6.38-6.47, and the addition of preservative and plant extracts exhibited significantly lower pH values than the control samples. In control samples, pH values slightly increased throughout storage time and exhibited the highest final value as 6.52 at day 21, while herb and spice extract treatments remained at 6.43-6.47 throughout storage time. Additionally, Eu samples had significantly (P<0.05) lower pH values among all treatments.

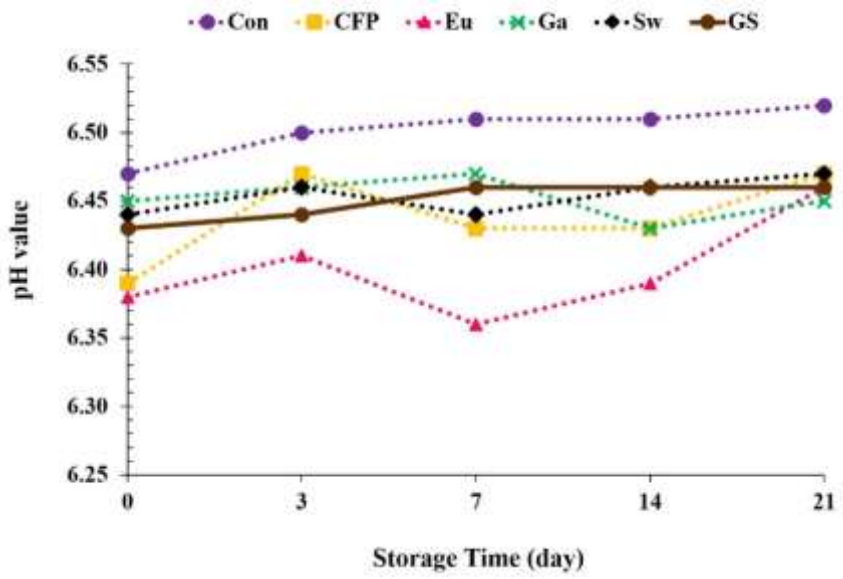

Figure 1. Changes in pH value of chicken nuggets with/without herb and spice extracts during storage at 4±1°C.

TBARS value, which is an indicator of lipid oxidation, is shown in Fig. 2. The TBARS values in chicken nuggets did not difference (P>0.05) among the treatment groups at day 0. The values of all samples increased throughout storage time as expected. The highest TBARS values occurred in control samples from 0.34 mg MDA/kg at day 0 (after cooking) and up to 1.25 mg MDA/kg at day 21 while chicken nuggets with herb and spice extracts increased from 0.33-0.35 mg MDA/kg at day 0 up to 0.58-0.61 mg MDA/kg at day 7, followed by a slight increase to 0.97-1.01 mg MDA/kg at day 21. In herb

and spice extract treatments, the GS samples exhibited significantly lower TBARS values (P<0.05). The inhibition effect was strongest (P<0.05) in the CFP samples, increasing from 0.32 mg MDA/kg at day 0 up to 0.47 mg MDA/kg at day 7, followed by a slight increase to 0.90 mg MDA/kg at day 21.

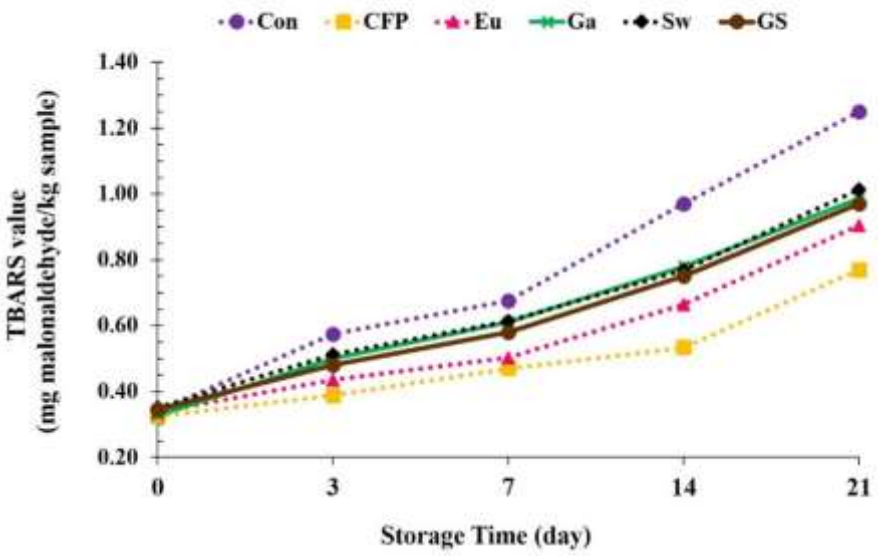

Figure 2. Changes in TBARS value of chicken nuggets with/without herb and spice extracts during storage at 4±1 °C.

The CIE color values of chicken nugget samples are shown in Table 1. L* and a* values of all samples continuously showed a significant decrease over the entire storage period. The initial L* and a*values were found to be 71.27-73.26 and 10.44-12.99, respectively, and decreased to 61.84-67.41 and 6.17-7.91 at day 21, respectively. The lowest values of L* and a* occurred in the control samples, while chicken nuggets with CFP exhibited higher values (P<0.05) than the other treatments throughout storage time (P>0.05). However, the samples with GS were slightly decreased and exhibited the highest L* and a* values among all herb and spice extract treatments.

In this study, the b* values of all treatments significantly increased (P<0.05), especially in the control sample as 25.02 at day 0 and 32.52 at day 21 of storage time. Samples treated with herb and spice extracts showed lower values than the control treatment but higher than CFP treatment in the range between 25.60-26.60 at day 0 and 29.30-30.58 at day 21 of storage time. Morover, the lowest b* values were observed in CFP samples.

Table 1. Changes in color parameters of chicken nuggets with/without herb and spice extracts during storage at 4±1 °C.

Treatment	Storage Time (day)				
	0	**3**	**7**	**14**	**21**
L* value					
Con	73.02 ±4.02 ^{A,a}	68.93 ±0.28 ^{A,b}	65.76 ±1.89 ^{B,c}	63.05 ±0.21 ^{B,d}	61.84 ±6.03 ^{C,e}
CFP	73.26 ±2.51 ^{A,a}	71.49 ±0.83 ^{A,a}	69.32 ±1.02 ^{A,b}	68.89 ±0.91 ^{A,b}	67.41 ±2.95 ^{A,c}
Eu	71.46 ±2.00 ^{A,a}	68.33 ±1.13 ^{A,b}	66.51 ±0.22 ^{B,b}	64.18 ±1.41 ^{B,c}	63.39 ±1.29 ^{B,c}
Ga	72.00 ±1.21 ^{A,a}	69.92 ±2.32 ^{A,a}	68.39 ±0.76 ^{A,b}	67.50 ±0.68 ^{A,c}	64.06 ±0.90 ^{B,d}
Sw	71.27 ±3.78 ^{A,a}	69.50 ±0.51 ^{A,a}	67.09 ±1.86 ^{B,b}	66.94 ±1.90 ^{A,b}	64.79 ±0.85 ^{B,c}
GS	72.83 ±0.97 ^{A,a}	70.81 ±0.51 ^{A,a}	69.10 ±0.32 ^{A,b}	66.30 ±0.31 ^{A,c}	65.07 ±0.05 ^{AB,c}
a* value					
Con	12.89 ±0.15 ^{A,a}	10.28 ±0.38 ^{A,ab}	8.47 ±1.08 ^{A,b}	7.21 ±0.69 ^{A,b}	6.17 ±0.57 ^{A,c}
CFP	12.99 ±0.30 ^{A,a}	11.39 ±1.19 ^{A,a}	9.29 ±0.79 ^{A,b}	8.67 ±1.51 ^{A,b}	7.91 ±0.94 ^{A,b}
Eu	10.58 ±2.77 ^{A,a}	9.49 ±0.63 ^{A,a}	8.37 ±0.19 ^{A,a}	6.91 ±0.82 ^{B,b}	6.67 ±0.57 ^{A,b}
Ga	10.44 ±0.15 ^{A,a}	9.08 ±1.06 ^{A,a}	8.81 ±0.19 ^{A,ab}	7.63 ±1.05 ^{A,b}	7.17 ±0.45 ^{A,b}
Sw	11.69 ±0.74 ^{A,a}	10.44 ±0.91 ^{A,a}	8.83 ±1.50 ^{A,ab}	7.54 ±1.41 ^{A,b}	6.92 ±0.96 ^{A,b}
GS	11.62 ±1.31 ^{A,a}	10.68 ±0.66 ^{A,a}	8.94 ±0.91 ^{A,ab}	8.15 ±1.46 ^{A,ab}	7.36 ±0.12 ^{A,b}
b* value					
Con	25.02 ±0.52 ^{B,b}	26.99 ±0.95 ^{AB,b}	28.40 ±0.25 ^{A,ab}	30.49 ±0.45 ^{A,a}	32.52 ±1.31 ^{A,a}
CFP	25.44 ±0.52 ^{B,b}	26.50 ±0.62 ^{AB,ab}	27.21 ±1.30 ^{B,a}	27.98 ±0.12 ^{B,a}	28.76 ±0.60 ^{B,a}
Eu	24.41 ±1.85 ^{B,b}	25.37 ±0.88 ^{B,b}	26.60 ±0.05 ^{B,b}	27.58 ±1.29 ^{B,a}	29.05 ±3.19 ^{A,a}
Ga	25.60 ±1.72 ^{B,b}	27.54 ±1.90 ^{A,a}	28.04 ±3.63 ^{A,a}	28.12 ±0.71 ^{AB,a}	29.30 ±0.72 ^{A,a}
Sw	28.46 ±0.45 ^{A,a}	28.90 ±1.19 ^{A,a}	29.06 ±1.68 ^{A,a}	29.42 ±0.83 ^{A,a}	30.58 ±0.16 ^{AB,a}
GS	26.60 ±0.74 ^{AB,b}	27.24 ±1.19 ^{A,b}	27.27 ±1.48 ^{B,ab}	27.94 ±1.13 ^{B,a}	28.25 ±0.21 ^{B,a}

$^{a–e}$ Means within the same row with different superscripts are significantly different ($P < 0.05$).
$^{A–B}$ Means within the same column with different superscripts are significantly different ($P < 0.05$).

The results of the texture profile analysis are presented in Table 2. A continuous increase in hardness was observed in all samples from 12.30-14.97 N on day 0 (after cooking) up to 23.57-25.57 on day 21. Similar change patterns were also observed in chewiness with a significant increased from 4.18-5.19 N on day 0 up to 5.89-6.38 N on day 21. The addition of GS had the lowest values of hardness and chewiness on day 14 to 21 ($P<0.05$). On the other hand, springiness and cohesiveness of all samples tended to decrease from 5.01-5.04 mm and 0.39-0.46 at day 0 to 4.61-4.88 mm and 0.31-0.39 at day 21, respectively.

Microbial analysis

Microbial changes in samples during storage are shown in Fig. 3. The total plate counts (TPC) of all samples increased throughout storage time from 1.13-1.58 log CFU/g at day 0 up to 5.32-7.92 log CFU/g at day 21. The highest

TPC occurred in control samples, whereas chicken nuggets with CFP showed the lowest count during storage time. In the batch with herb and spice extracts added, the GS samples exhibited a lower TPC with an initial count at 1.25 log CFU/g, and significantly increased to 6.12 log CFU/g at day 21.

Table 2. Changes in texture profile of chicken nuggets with/without herb and spice extracts during storage at 4±1 °C.

Treatment	Storage Time (day)				
	0	**3**	**7**	**14**	**21**
Hardness (N)					
Con	12.30 ±0.44^{A,e}	17.43 ±0.49^{B,d}	20.28 ±0.35^{B,c}	22.94 ±0.37^{B,b}	24.65 ±0.58^{B,a}
CFP	13.30 ±0.83^{A,d}	18.46 ±0.36^{A,c}	20.29 ±0.83^{B,b}	22.83 ±0.24^{B,ab}	23.80 ±0.04^{C,a}
Eu	13.88 ±0.43^{A,d}	18.29 ±0.30^{A,c}	21.00 ±0.32^{AB,b}	23.71 ±0.33^{A,ab}	24.87 ±0.14^{B,a}
Ga	14.42 ±0.29^{A,d}	17.79 ±0.46^{AB,c}	22.00 ±0.24^{A,b}	23.26 ±0.36^{AB,b}	25.57 ±0.31^{A,a}
Sw	14.97 ±0.14^{A,d}	19.41 ±0.38^{A,cd}	21.00 ±0.34^{AB,c}	24.09 ±0.68^{A,b}	25.46 ±0.15^{A,a}
GS	13.16 ±1.05^{A,d}	17.34 ±0.35^{B,c}	20.01 ±0.46^{B,b}	22.49 ±0.99^{B,ab}	23.57 ±0.47^{C,a}
Chewiness (N mm)					
Con	4.84 ±0.13^{A,b}	4.92 ±0.04^{A,b}	5.61 ±0.25^{A,a}	5.82 ±0.15^{A,a}	6.17 ±0.13^{A,a}
CFP	5.19 ±0.11^{A,b}	5.36 ±0.19^{A,b}	5.70 ±0.43^{A,a}	6.17 ±0.19^{A,a}	6.38 ±0.03^{A,a}
Eu	4.59 ±0.17^{A,c}	5.32 ±0.48^{A,b}	5.59 ±0.12^{A,a}	5.97 ±0.15^{AB,a}	6.12 ±0.15^{A,a}
Ga	4.90 ±0.35^{A,c}	5.07 ±0.23^{A,b}	5.34 ±0.15^{A,b}	5.82 ±0.29^{A,a}	6.15 ±0.14^{A,a}
Sw	4.79 ±0.26^{A,b}	4.98 ±0.11^{A,b}	5.11 ±0.11^{A,b}	5.47 ±0.10^{B,a}	6.13 ±0.21^{A,a}
GS	4.18 ±0.16^{A,b}	4.61 ±0.12^{A,b}	5.30 ±0.16^{A,a}	5.59 ±0.06^{B,a}	5.89 ±0.12^{B,a}
Springiness (mm)					
Con	5.03 ±0.01	4.87 ±0.03	4.90 ±0.00	4.85 ±0.02	4.76 ±0.02
CFP	5.01 ±0.01	4.99 ±0.03	4.83 ±0.01	4.63 ±0.07	4.61 ±0.04
Eu	5.00 ±0.02	4.97 ±0.02	4.93 ±0.01	4.85 ±0.01	4.67 ±0.09
Ga	5.04 ±0.05	4.94 ±0.02	4.97 ±0.05	4.93 ±0.01	4.82 ±0.01
Sw	5.02 ±0.05	4.90 ±0.05	4.86 ±0.01	4.79 ±0.02	4.74 ±0.02
GS	5.04 ±0.02	4.95 ±0.02	4.94 ±0.03	4.90 ±0.01	4.88 ±0.03
Cohesiveness (ratio)					
Con	0.41 ±0.02	0.38 ±0.02	0.36 ±0.01	0.33 ±0.01	0.31 ±0.03
CFP	0.41 ±0.03	0.39 ±0.01	0.37 ±0.01	0.34 ±0.02	0.32 ±0.03
Eu	0.42 ±0.01	0.41 ±0.02	0.38 ±0.03	0.37 ±0.02	0.35 ±0.02
Ga	0.40 ±0.02	0.38 ±0.01	0.35 ±0.01	0.32 ±0.02	0.32 ±0.03
Sw	0.46 ±0.02	0.44 ±0.02	0.43 ±0.02	0.41 ±0.02	0.39 ±0.03
GS	0.39 ±0.03	0.39 ±0.01	0.37 ±0.02	0.34 ±0.04	0.32 ±0.02

$^{a–e}$ Means within the same row with different superscripts are significantly different ($P < 0.05$).
$^{A–B}$ Means within the same column with different superscripts are significantly different ($P < 0.05$).

Similarly, the highest yeast and mold counts were found in control samples, which a significant increase from 0.49 log CFU/g at day 0 up to 3.64 log CFU/g at day 21. The strong inhibition effect was shown in CFP and Eu samples with a range between 0.38-2.97 and 0.41-3.16 log CFU/g, respectively.

Additionly, the yeast and mold counts of GS samples were lower than the other herb and spice extract treatments.

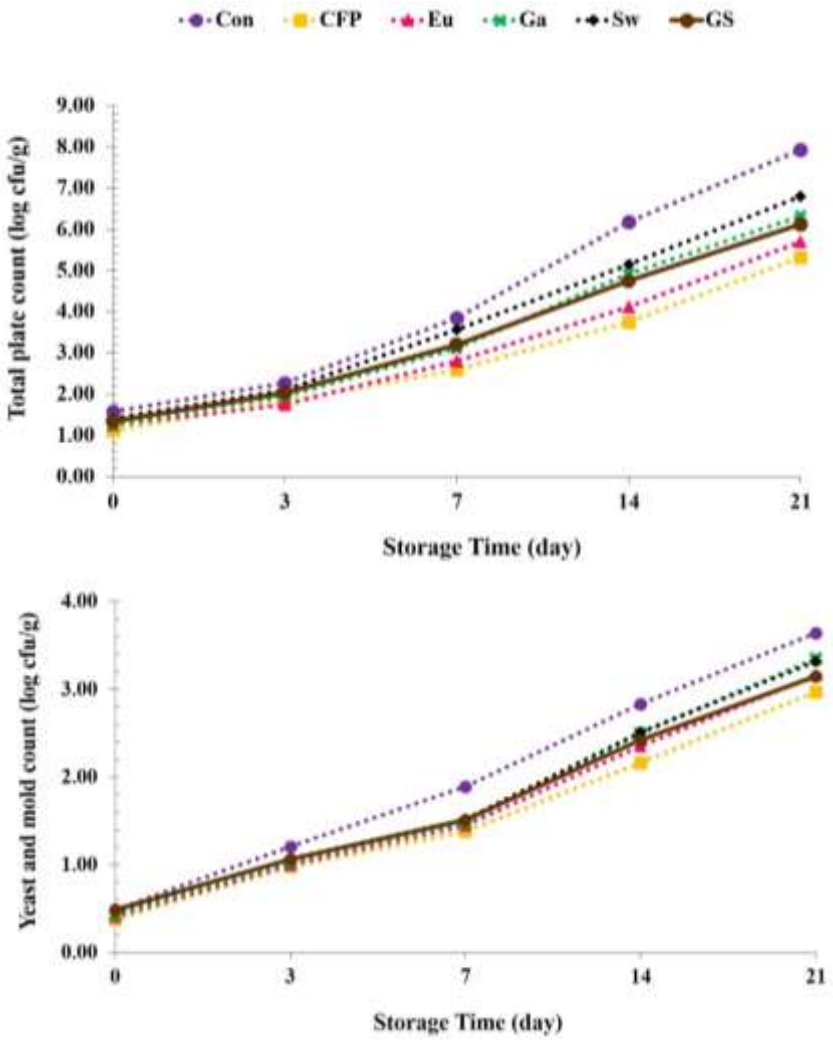

Figure 3. Changes in total plate count and yeast and mold count of chicken nuggets with/without herb and spice extracts during storage at 4±1 °C.

Sensory analysis

Fig. 4 illustrates the sensory evaluation results. In this study, appearance, flavor, taste, texture, and overall acceptability tended to decrease with storage time increased. The treatments with CFP had higher acceptability for all sensory attributes than other treatments at all storage times (i.e., day 3, 7, 14

and 21), whereas the Eu samples showed the lowest scores in flavor, taste, texture, and overall acceptability. However, herb and spice extract treatments exhibited higher scores in appearance, flavor, taste, and overall acceptability than control samples at day 14 and 21, and the GS samples showed the highest score among these treatments.

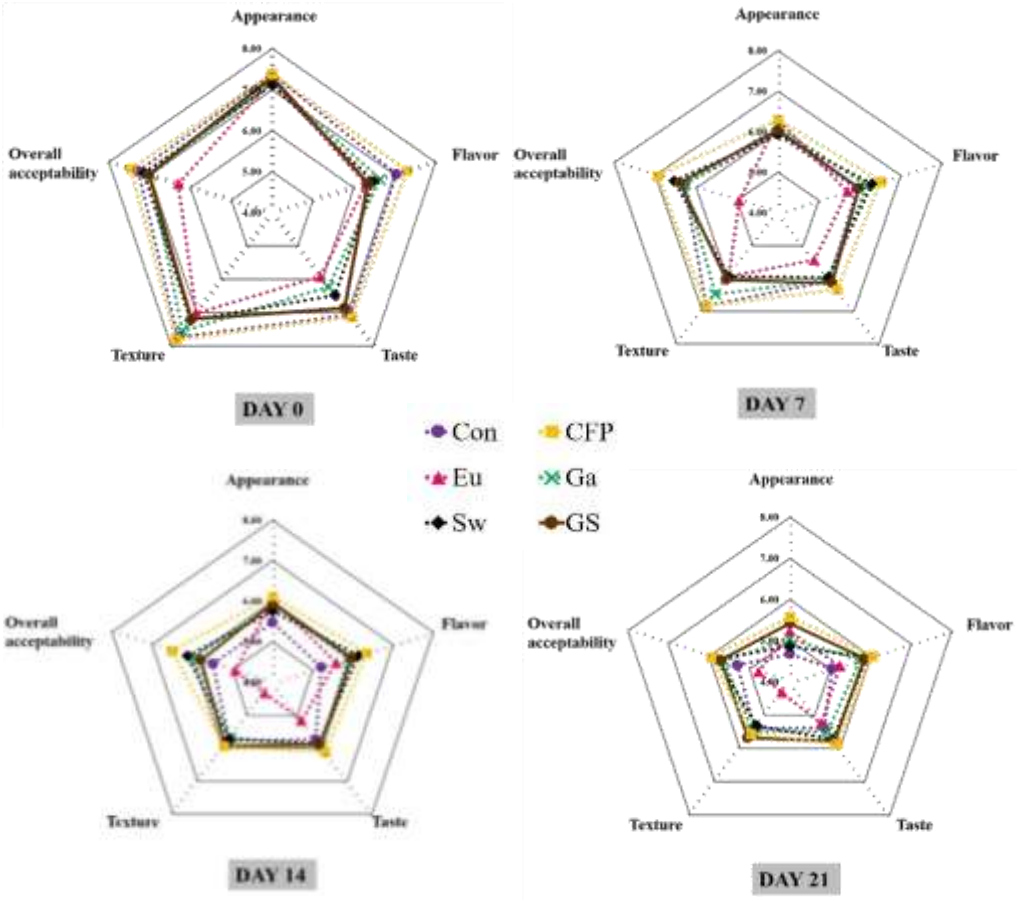

Figure 4. Changes in sensory evaluation of chicken nuggets with/without herb and spice extracts during storage at 4±1 °C.

Discussion

The results demonstrate that the herb and spice extracts used in this study provided antioxidant and antimicrobial benefit, which could be used to extend the shelf-life of cooked chicken nuggets during cold storage. Several studies have investigated the effect of herb and spice extracts, including clove,

garlic, ginger, oregano, rosemary, and thyme on quality attributes of meat products (Babatunde and Adewumi, 2015; Rodriguez-Vaquero *et al*., 2010). These studies stated that the plant extracts could be used to improve the sensory quality and prolong the shelf-life of meat products. Previous studies reported that herb and spice extracts have potential as natural preservatives due to the presence of several compounds, such as polyphenolics, flavanoids, lignans, and terpenoids (Dawidowicz *et al*., 2006; Karre *et al*., 2013; Wu *et al*., 2006). Zhang *et al*. (2016) reported that the addition of two spice extracts (rosemary extract 0.5% + clove extract 0.5%) was effect to increase the shelf-life from 6 to 12 days of raw chicken meat during storage at 4◦C.

Galangal and sweet basil, which are commercially cultivated in Thailand, are generally used to enhance the sensory quality of Thai foods. In a previous study (Wanangkarn *et al*., 2018), the ethanol extracts from galangal and sweet basil were found to possess great antioxidant and antimicrobial activity. It was observed that sweet basil extract consists of a high level of linalool and eugenol (Juliani and Simon, 2002). Moreover, eucalyptol, methyl eugenol, and methyl chavicol were also founded as the components in Thai sweet basil leaf oil (Lawtrakul *et al.*, 2014). For galangal, it was found to contain flavonoids, alkaloids, terpenoids, glycosides, coumarins, and tannins (Youssef *et al*., 2015). The galangal extract displayed strong antimicrobial, including *Bacillus cereus*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Escherichia coli* (Basri *et al*., 2017; Mayachiew and Devahastin, 2008).

In this study, TBARS and pH values in all samples were increased throughout storage time, and control treatment exhibited a higher value than herb and spice extract treatments. The results showed pH values in agreement with the study of Kumar and Tanwar (2011) and Zhang *et al*. (2016); they also reported that the pH values of both control and plant extract treated batches significantly increased with storage time. The increase in pH values of samples could be due to denaturation of protein and releases of free amino acid groups by the growth of bacteria, which is leading to possible spoilage (Masniyom *et al*., 2002). Moreover, the addition of plants or vegetables could exhibit low pH values due to the type of plant or vegetable, which more acidic (Bhosale *et al.*, 2011). The stronger antioxidant activity of the mixed galangal and sweet basil extracts was noticed when compared with the individual extract or control treatment. The finding is in accordance with the study of Zhang *et al*. (2016) who also documented that the combination of clove and rosemary extracts significantly delayed lipid oxidation more than those of a single extract. This might be due to the result of synergistic actions of phenolic and other compounds in the mixed herbs and spices. However, TBARS values were well below the acceptable limits of 1-2 mg MDA/kg meat, indicating the good

quality of meat products (Iheagwara and Okonkwo, 2016; Mir and Masoodi, 2017).

In this study, the values of TBARS for chicken nuggets with herb and spice extracts were lower than 1 mg MDA/kg throughout the storage period, while control samples exhibited TBARS values higher than 1 mg MDA/kg on day 21. The phenolic compounds are secondary metabolites derived from plants and considered as the major active group for antioxidant activity (Aksoy *et al*., 2013; Juliani and Simon, 2002; Roohinejad *et al*., 2017), which categorized into 4 groups: phenolic acids, flavonoids, volatile oils, and phenolic diterpenes (Barba *et al*., 2014; Sahin *et al*., 2018). It was reported that the strong antioxidant activity of phenolic compounds are multifunctional, including reducing agents, chelate formation, and free radical scavenging resulting in the formation of a stable end product (Aksoy *et al*., 2013; Zhang *et al*., 2016).

The microbiological safety of processed meat products is essential and the use of natural antimicrobials are been given more attention due to the consumers' increasing concerns with chemical preservatives. Antimicrobial agents are used in food to control natural spoilage processes and prevent growth of micro-organisms during processing and strorage period (Babatunde and Adewumi, 2015; Naidu, 2000). This study demonstrated that the use of the ethanolic extract of galangal and sweet basil extract could retard microbial growth by maintaining a bacteria count lower than 6 log cfu/g sample until day 14, which is the acceptable microbial count (Nugboon and Intarapichet, 2015). This antimicrobial activity is related to the extract's chemical compounds; galangal ethanol extracts produce lipophilic compounds (Natta *et al*., 2008). Among the Zingiberaceae genus (galangal, ginger, turmeric, and krachai), the extracts of galangal exhibit the strongest inhibitory effect against *S. aureus* (Mayachiew and Devahastin, 2008; Oonmetta-Aree *et al*., 2006). Several studies have reported a high positive correlation between antimicrobial efficacy and the level of phenolic components in herb and spice extracts (Nitiema *et al*., 2012; Alves *et al*., 2013). In addition, methyl eugenol and methyl chavicol present in sweet basil has bactericidal properties (Joshi, 2014). However, the ability to inhibit bacteria growth may involve multiple active compounds (Sunayana *et al*., 2003) and multiple functions, including breaking down the cell wall, disrupting the cytoplasmic membrane, leakage of intracellular components, coagulation of cytoplasm, and reduction in the proton motive force (Burt, 2004).

Lipid oxidation and protein degradation affect sensory properties and cause unpleasant flavor, taste, color and texture changes (Yerlikaya and Gokoglu, 2010). In the sensory evaluation of this study, the samples treated with herb and spice extracts were given lower scores than the control treatment

on day 0. This might be due to the herb and spice flavor detected by the panelists, not from microbiological causes (Kong *et al*., 2007). After day 7, nuggets with mixed galangal and sweet basil showed the highest sensory scores among those herb and spice treaments, wheareas control samples exhibited lower scores, caused by the increase in lipid oxidation and microbial counts during storage time. Therefore, these results indicated that the mixed galangal and sweet basil extracts were more effective than the individual extracts alone.

Conclusion

This research demonstrate the effectiveness of Thai herb and spice extracts in inhibiting microbial growth, reducing lipid oxidation, and extending the shelf-life of cooked chicken nuggets during storage at 4±1◦C. According to the acceptable microbial counts, the addition of galangal and sweet basil extracts could be used to extend the shelf life up to 14 days while only 7 days shelf life was observed for control nuggets. However, the strongest preservative effect was exhibited by the combination of galangal and sweet basil extracts, which could be a result of synergistic actions of specific compounds in the mixed herb and spices. Thus, Thai herb and spice extracts have a great potential for used as a natural preservative substitute for chemical preservatives in the processed meat industry besides the several health benefits for consumers.

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