The Physico-Chemical Qualities Characteristics and Lipid Oxidation Properties of Thai-Semi Dried Pork with Four Herbs Extract during Storage

C. Taewtatam[1,2], N. Koomkrong[3], P. Huanarom[4], T. Tubboonmee[4] and A. Kayan[1,2,*]

[1] Department of Animal Science, Faculty of Agriculture, Kasetsart University, Bangkok 10900 Thailand
[2] Center for Advanced Studies for Agriculture and Food (CASAF), KU Institute for Advanced Studies, Kasetsart University, Bangkok 10900 Thailand
[3] Department of Animal Science, Faculty of Science and Technology, Suratthani Rajabhat University, Suratthani 84100 Thailand
[4] Division of Livestock Product Research and Development Center, Development of Livestock Development, Pathum Thani 12000 Thailand
[*] Corresponding author: fagrark@ku.ac.th
Submission: 5 April 2019 Revised: 6 August 2019 Accepted: 16 August 2019

ABSTRACT

The objective of the study was to evaluate the physio-chemical qualities quality characteristics and lipid oxidation properties of Thai-semi dried pork with four herbs extract during storage. The pork muscles (*longissimus dorsi*) were sliced, marinated, and dried using a convection oven at 55°C for 3 h. Nine different treatments were prepared: 1) non-added control, 2) added 0.5% turmeric extract, 3) added 1.0% turmeric extract, 4) added 0.5% galangal extract, 5) added 1.0% galangal extract, 6) added 0.5% lemongrass extract, 7) added 1.0% lemongrass extract, 8) added 0.5% black sesame extract, and 9) added 1.0% black sesame extract. Determination of pH at day 0 and day 7, T1 was significant lowest than other groups ($P < 0.05$). After storage of 14 days, T1, T2 and T5 showed significantly lower than other groups ($P < 0.05$). Water activity of (a_w) T2 was lower than others at Day 0 ($P < 0.05$). In day 7, T7 was lower than T1, T2, T3, T6 and T9 ($P < 0.05$). However, T6 was the lowest among treatment groups ($P < 0.05$). Changes in TBARS values revealed that TBARS values were increased during storage time. T1 showed significantly lower TBARS value than other groups in day 0, 7 and 14 ($P < 0.05$). Total plate count were detected in all treatment groups. However, there was no evidence of *Salmonella* contamination in all treatment groups. The concentration of four herbs extract in this study will not suitable for using as lipid oxidation properties and improve the physio-chemical qualities characteristics of Thai-semi dried pork. The further study should be increased the concentration of herbs extract.

Keywords: Physio-chemical qualities, antioxidant properties, Thai-semi dried pork, herbs extract

Thai J. Agric. Sci. (2019) Vol. 52(3): 161−171

INTRODUCTION

Jerky is a traditional meat product preserved by marinating and drying to reduce water activity (a_w), and its easy preparation, light weight, rich nutrient content, and stability without refrigeration (Choi *et al*., 2008). Jerky products also can be made with various marinade techniques, meats from different species and drying conditions (Yang *et al*., 2009). The final product reaches the a_w of 0.70-0.75 when it is ready for consumption, and is normally shelf stable for 6 months if left packed to inhibit microbial activity (Torres *et al*., 1994). However, a_w values were influenced by storage time. The a_w of jerky increased over the first 15 d of storage, but it was not change thereafter (Lee *et al*., 2017). Thai-semi dried pork is a tradition way to preserve pork. Pork is needed to marinate and dry by hot sun for a few hours which should be cook before consume.

Pork is the most widely eaten meat in the world, but it a high polyunsaturated fatty acid content (Dugan *et al*., 2015) which made it more susceptible to oxidation and hydrolytic reactions (Wójciak *et al*., 2015), giving rise to the formation of lipid hydroperoxides and other secondary products such as aldehydes, responsible for the development of rancidity and food deterioration (Shahidi and Zhong, 2010). Moreover, cooking promotes pork meat oxidation. Raw ground pork meat had low the thiobarbituric acid reactive substrates (TBARS) content, and its value increased after cooking at 90˚C for 45 min (Alvarez-Parrilla *et al*., 2014). Previous study indicated that pork jerky prepared under drying condition at 80˚C for 210 min had the highest TBARS values compared with various drying conditions (55˚C/60 min → 65˚C/60 min → 72˚C/90 min, 72˚C/90 min → 65˚C/60 min → 55˚C/60 min) (Han *et al*., 2007). Lipid oxidation can have negative effects on meat quality, causing changes in sensory attributes (color, texture, odor and flavor) and nutritional quality (Nam *et al*., 2016). Recently, there has been a considerable interest in finding natural antioxidant from plant materials to improvement of the quality and flavour of pork jerky (Zhao *et al*., 2016).

Herbs have been used in meat and meat products for both antioxidative and antimicrobial properties (Cheah and Gan, 2000; Hussein *et al*., 2015; Nigam *et al*., 2015; Zhang *et al*., 2015). Galangal (*Alpinia galanga*) is a rhizome closely related to the ginger family. It has been reported to have anti-oxidative activity, antibacterial effects and extending the shelf life of meat (Cheah and Gan, 2000). Turmeric, the rhizomes of the plant *Curcuma longa* Linn., is the major source of the polyphenol curcumin (Hewlings and Kalman, 2017). It has been reported curcumin, as a potential antioxidant, improved meat quality and oxidant stability of meat (Zhang *et al*., 2015). Lemongrass (*Cymbopogon citratus*) is a perennial, aromatic tall tropical grass that is commonly used as an aromatic herb (Ozer *et al*., 1995). It was effective in reducing lipid oxidation in meat product and can be used replace synthetic antioxidant (Olorunsanya *et al*., 2010). Moreover, increased the level of lemongrass improved the physical properties and sensory evaluation of meat product (Zaki *et al*., 2018). Sesame (*Sesamum indicum* L.) is one of the oldest cultivated plants in the world, mainly grown for extraction of oil from seeds. It has been reported that seed extract of black sesame contained varied types of pharmacologically active compounds with antioxidant and antimicrobial activities (Nigam *et al*., 2015). However, the effects of four herbs extract on the physio-chemical qualities characteristics and lipid oxidation properties of Thai-semi dried pork have not been extensively studied. Therefore, the purpose of this study was to evaluate the properties of the four herbs extract as natural preservatives to improve the physio-chemical qualities quality characteristics and lipid oxidation properties of Thai-semi dried pork.

MATERIALS AND METHODS

Meat and Curing Solution Preparation

The muscles (*longissimus dorsi*) (n = 20) of fresh pork [Duroc × (Large White × Landrace)] were randomly obtained from 150 animals in a commercial slaughterhouse in Thailand. After slaughter according to the standard slaughtering,

all subcutaneous, intermuscular fat and visible connective tissue were removed from the fresh muscles. After dissection, all muscles were frozen and stored at -20°C until use. The frozen pork was thawed at 4°C overnight, sliced into pieces of 1.0 cm thickness. Sliced muscles were cut parallel in direction to muscle fibers. Curing ingredients (based on raw meat weight) were included sugar, fish sauce, soy sauce, pepper, sodium nitrite, monosodium glutamate, sodium erythorbate, phosphate and natural antioxidant extract from galangal, turmeric, lemongrass and black sesame. Samples (10 kg. per group) were cured with 150 g sugar, 150 g fish sauce, 80 g soy sauce, 50 g pepper, 4 g sodium nitrate, 30 g monosodium glutamate, 1 g sodium erythorbate, 10 g phosphate, added with natural antioxidant extract at levels of 0.5 or 1.0% (v/wt). Nine different treatments were prepared (SK Herb Co., Ltd, Thailand): 1) non-added control, 2) added 0.5% turmeric extract, 3) added 1.0% turmeric extract, 4) added 0.5% galangal extract, 5) added 1.0% galangal extract, 6) added 0.5% lemongrass extract, 7) added 1.0% lemongrass extract, 8) added 0.5% black sesame extract, and 9) added 1.0% black sesame extract. For each batch of muscle samples and other ingredients were cured thoroughly at 4°C overnight. All cured muscle samples were dried using a convection oven at 55°C for 3 h. This product is need to be cooked before consume. After drying and cooling to ambient temperature the Thai-semi dried pork samples were vacuum packed and placed at 4°C for 0, 7 and 14 d for further analysis.

pH and Water Activity (a_w) Evaluation

The pH of sample (n = 5 per group) was determined with a pH meter (pH Spear, Eutech Instruments, Singapore). pH values were measured by blending a 3 g sample with 27 ml distilled water for 60 s in a homogenizer. Samples (n = 5 per group) for a_w were minced into pieces approximately 1 mm × 1 mm × 1 mm in size. The a_w of each sample was determined with a water activity meter.

Thiobarbituric Acid Reactive Substances (TBARS) Evaluation

The lipid peroxidation products TBARS levels were measured using a commercially available TBARS Assay Kit (STA-330, Cell Biolabs, Inc., CA, USA) according to the manufacturer's instructions. Jerky samples (n = 5 per group) were homogenized with 500 µl of phosphate buffer saline containing 3 µl of 100 × butylated hydroxytoluene. Homogenized samples were centrifuged at 10,000 ×g and 4°C for 5 min. The sample lysate supernatant was collected, reacted with thiobarbituric acid at 95°C for 60 min. After all sample tubes were cooled on ice, they were centrifuged at 1,000 ×g for 15 minutes. Then, 300 µl supernatant was collected and added 300 µl of n-Butanol, centrifuge at 10,000 ×g for 5 min. Absorbance of the solution was read at 532 nm with a PowerWave™XS microplate spectrophotometer (Bio Tek). Values are expressed as µmol/L.

Total Plate Count Evaluation

To measure the total plate count of the samples, 25 g samples (n = 5 per group) were aseptically transferred into a plastic bag and 225 ml of sterile 0.1% buffer peptone water (Oxoid, England) was added to each sample and shaking for 1 min. A decimal serial dilution in 0.1% buffer peptone water was prepared. Microorganisms were determined using Plate Count Agar at 37 °C for 48 h. Microbial colonies were counted and expressed as colony forming units (log CFU) per gram (AOAC, 2006).

***Salmonella* spp. Evaluation**

Thai-semi dried pork samples total 25 g (n = 5 per group) were put into a plastic bag containing 225 ml of buffer peptone water (BPW) (Oxoid, England), shaking for 1 minute and transferred to laboratory bottle, incubated at 37 °C for 20–24 h. After pre-enrichment 0.1 ml of inoculum was transferred into 10 ml of Rappaport-Vassiliadis soya peptone (RVS) broth (Oxoid, England) and then, incubated at 42ºC for 20–24 h. The Rappaport-Vassiliadis soya peptone broth was streaked onto Xylose lysine deoxycholate (XLD) agar (Oxoid, England), incubated at 37ºC for 20–24 h.

DNA Extraction

DNA extraction was using DNA extraction kits (Favorgen, Taiwan). Bacterial cells were pelleted from 1 ml of Rappaport-Vassiliadis soya peptone broth, centrifuge 14,000 rpm for 2 min, and the supernatant discarded. Add 200 µl FATG1 buffer and mixed together. Proteinase K (10 mg/ml) 20 µl were added and incubated at 60ºC for 30 min, centrifuge 14,000 rpm for 30 s. Add 4 µl RNase A and incubated at room temperature for 2 min. FATG2 buffer were added 200 µl, incubated at 70ºC for 10 min, centrifuge 14,000 rpm for 30 s. Add 200 µl Ethanol, centrifuge 14,000 rpm for 30 s. Transferred all samples into FATG mini column and centrifuge 14,000 rpm for 1 min and transferred FATG mini column into a new collection tube. Wash the column by 500 µl wash buffer, centrifuge 14,000 rpm for 1 min and solution discarded. Wash the column again by 750 µl wash buffer, centrifuge 14,000 rpm for 1 min and solution discarded. Centrifuge for 3 min to drying the column. The FATG Mini Column was transferred into elution tube. Then 100 µl elution buffer were added and leaved the column for 3 min and centrifuge 14,000 rpm for 2 min. Storage DNA at 4ºC or -20ºC for further analysis.

Polymerase Chain Reaction

The PCR primer was used specific for *invA* gene, primer forward: 5´-GCT GCG CGC GAA CGG CGA AG-3´ and primer reward: 5´-TCC CGG CAG AGT TCC CAT T-3´ (Ramya *et al*., 2012). Polymerase chain reactions (PCR) were performed in a 20 µl volume containing 2 µl of genomic DNA, 1 × PCR buffer (with 1.5 mM $MgCl_2$), 0.25 mM of dNTP, 5 pM of each primer and 0.1 U of Taq DNA polymerase (Thermo Scientific, USA). Amplifications were carried out in PCR machine (Applied Biosystems, USA) and performed under the following condition: initial denaturing at 95ºC for 5 min, followed by 35 cycles of 1 min at 95ºC, 1 min 20 s at 59ºC and 45 sec at 72ºC and elongation of 7 min at 72ºC. PCR products were detected by gel electrophoresis on 1.5% agarose gel for 15 min and used voltage 100 V, stained with ethedium bromide and visualized under UV light by using Gel Doc XR system (Bio-Rad, USA).

Statistical Analysis

Data were subjected to ANOVA by the GLM procedure considering drip loss and storage time as fixed effects using SAS (SAS Inst. Inc., Cary, NC). The model was as follows:

$$Y_{ij} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + e_{ij}$$

where Y_{ij} is the observation of the traits (pH, aw, total plate count and TBARS); µ is the overall mean; α_i is the effect of the treatment (i = T1, T2, T3, T4, T5, T6, T7, T8, T9); β_j is the effect of the storage time (j = 0, 7, 14 days); $\alpha\beta_{ij}$ is the effect of the interaction between treatment and storage time, and e_{ij} is the random error. Significant differences of values among groups were detected by the probability difference (PDIFF), and the mean values were separated at the level of 5%. The results for the groups are presented as least square means (LSM) with the standard errors.

RESULTS AND DISCUSSION

pH and Water Activity

pH of Thai-semi dried pork at day 0 and day 7, T1 was significant lowest than other groups ($P < 0.05$) (Table 1). After storage of 14 days, T1, T2 and T5 showed significantly lower than other groups ($P < 0.05$). Post-mortem metabolism continues, glycogen and ATP levels decline, and lactic acid accumulates with consequently lowering the muscle pH. This process results in an overall pH decline to an ultimate pH (pHu) of about 5.4 to 5.7 at 24 h in pig *longissimus dorsi* muscle (Bowker *et al.*, 2002). After processing, the average of meat pH in this study was 5.9–6.2 in day 0 and lower than 5.9 both in day 7 for T1, T3 and T4 groups and day 14 for T1, T2, T3, T5 and T6 groups. The decreasing of pH in pork jerky from day 0 to day 14 might be due to lactic acid bacteria (LAB) constitute a part of the initial microflora which develops easily after meat is processed (Hugas, 1998). pH of all treatments in this study was higher with the previous study in day 0 and 7 excepted day 14 in T1, T2, T5 and T6 (Bower *et al*., 2003). Decreasing meat pH significantly increased the efficacy of potassium sorbate and temperature to reduce levels of the pathogen (Juneja *et al*., 2016).

Table 1 Effect of four herbs extract on pH and moisture of Thai-semi dried pork during storage

Parameter	Treatment	Storage time (days)		
		0	7	14
pH	T1	5.93 ± 0.04^{aE}	5.57 ± 0.02^{bD}	5.37 ± 0.02^{cG}
	T2	6.19 ± 0.02^{bC}	6.32 ± 0.05^{aB}	5.38 ± 0.01^{cG}
	T3	5.92 ± 0.03^{aE}	5.87 ± 0.02^{abE}	5.83 ± 0.03^{bE}
	T4	6.12 ± 0.02^{aD}	5.78 ± 0.00^{bF}	6.15 ± 0.02^{aB}
	T5	6.15 ± 0.03^{aCD}	6.18 ± 0.07^{aC}	5.39 ± 0.01^{bFG}
	T6	6.21 ± 0.02^{bBC}	6.48 ± 0.01^{aA}	5.44 ± 0.02^{cF}
	T7	6.21 ± 0.01^{bBC}	6.36 ± 0.05^{aB}	6.08 ± 0.02^{cC}
	T8	6.28 ± 0.01^{aA}	6.11 ± 0.08^{bD}	5.97 ± 0.03^{cD}
	T9	6.22 ± 0.02^{bBC}	6.16 ± 0.03^{cCD}	6.49 ± 0.02^{aA}
a_w	T1	0.9434 ± 0.0009^{bA}	0.9479 ± 0.0009^{abA}	0.9505 ± 0.0019^{aA}
	T2	0.9269 ± 0.0198^{bB}	0.9431 ± 0.0014^{aA}	0.9471 ± 0.0033^{aA}
	T3	0.9427 ± 0.0014^{A}	0.9447 ± 0.0003^{A}	0.9464 ± 0.0007^{A}
	T4	0.9388 ± 0.0006^{bA}	0.9387 ± 0.0017^{bAB}	0.9490 ± 0.0014^{aA}
	T5	0.9434 ± 0.0008^{A}	0.9412 ± 0.0014^{AB}	0.9477 ± 0.0006^{A}
	T6	0.9407 ± 0.0015^{A}	0.9423 ± 0.0008^{A}	0.9434 ± 0.0005^{B}
	T7	0.9374 ± 0.0005^{bA}	0.9363 ± 0.0009^{bB}	0.9444 ± 0.0010^{aA}
	T8	0.9398 ± 0.0007^{A}	0.9406 ± 0.0004^{AB}	0.9462 ± 0.0005^{A}
	T9	0.9437 ± 0.0001^{A}	0.9418 ± 0.0009^{A}	0.9465 ± 0.0014^{A}

Note: Letter (s) in each row indicated least significant differences at probability $P < 0.05$.
Letter (s) in each column indicated least significant differences at probability $P < 0.05$.
$^{A-G}$ Means without same case letters within the same column differ significantly at $P < 0.05$.
T1, non-added control; T2, added 0.5% turmeric extract; T3, added 1.0% turmeric extract; T4, added 0.5% galangal extract; T5, added 1.0% galangal extract; T6, added 0.5% lemongrass extract; T7, added 1.0% lemongrass extract; T8, added 0.5% black sesame extract; T9, added 1.0% black sesame extract

In present study, the drying process of Thai-semi dried pork have finished by reaching below 0.95 a_w in all treatment groups during storage. Water activity in this study were below 1.0 and safe for consumption. The high residual sugar concentration in the ingredients contributes to increased osmotic pressure and decreased water activity in any product that incorporates them. Low a_w jerky will be microbiologically safer; however, these meats tend to be unacceptably tough and chewy (Bower *et al*., 2003). Water activity (a_w) of T2 was lower than others at day 0 ($P < 0.05$) (Table 1). In day 7, T7 was lower than T1, T2, T3, T6 and T9 ($P < 0.05$). However, T6 was the lowest among treatment groups in day 14 ($P < 0.05$). Pork jerky samples (control and samples with 0.5% and 1.0% leek extract) with EB technology. Water activity was 0.73 to 0.77 in non-irradiated samples, and no significant difference in the water activity was observed between the samples treated

with leek and the control (Kim *et al*., 2013). Meat slices dried rapidly, reaching an a_w of 0.86 and a shelf-stable moisture-protein ratio of ≤ 1.6 within the first 2.5–3 h of drying (Holley, 1985). Jerky processed at 82°C, pH 5.5, with 0.25% PS to a final a_w of 0.7 resulted in a maximum *Salmonella* (Juneja *et al*., 2016). It was found that ready-to-eat commercially available jerky type snack foods exhibited protein contents of over 50%, a low fat content (approximately 3.6%) and relatively high contents of table salt (approximately 6.0%). Due to a lowered water content (approximately 20%) and a_w below 0.8, they are classified as intermediate moisture foods (Konieczny *et al*., 2007). This study might be showed that these four herbs extract in 0.5 and 1% concentration have not affected on pH value and water activity of Thai-semi dried pork.

Table 2 Effect of four herbs extract on TBARS of Thai-semi dried pork during storage

Treatment	TBARS (µmol/L)		
	Day 0	Day 7	Day 14
T1	2.22 ± 0.06^{bCD}	2.83 ± 0.24^{bC}	4.42 ± 0.03^{aD}
T2	3.12 ± 0.06^{bABC}	3.48 ± 0.53^{bBC}	4.95 ± 0.15^{aCD}
T3	2.49 ± 0.51^{bCD}	3.96 ± 0.54^{aAB}	4.48 ± 0.03^{aD}
T4	2.88 ± 0.00^{cBC}	4.96 ± 0.24^{bA}	8.48 ± 0.48^{aA}
T5	3.03 ± 0.27^{cABC}	4.31 ± 0.18^{bAB}	5.78 ± 0.86^{aBC}
T6	1.53 ± 0.15^{cD}	4.72 ± 0.12^{bA}	8.68 ± 0.15^{aA}
T7	2.49 ± 0.33^{cCD}	4.07 ± 0.18^{bAB}	6.49 ± 0.15^{aB}
T8	3.96 ± 1.02^{bA}	4.31 ± 0.30^{bAB}	9.10 ± 0.09^{aA}
T9	3.57 ± 0.09^{bAB}	4.10 ± 0.15^{bAB}	9.48 ± 0.24^{aA}

Note: Letter (s) in each row indicated least significant differences at probability P < 0.05.
Letter (s) in each column indicated least significant differences at probability P < 0.05.
^{abc} Means without same case letters within the same row differ significantly at P < 0.05.
$^{A-D}$ Means without same case letters within the same column differ significantly at P < 0.05.
T1, non-added control; T2, added 0.5% turmeric extract; T3, added 1.0% turmeric extract; T4, added 0.5% galangal extract; T5, added 1.0% galangal extract; T6, added 0.5% lemongrass extract; T7, added 1.0% lemongrass extract; T8, added 0.5% black sesame extract; T9, added 1.0% black sesame extract

TBARS

Changes in TBARS values of Thai-semi dried pork with four herbs extract during storage are presented in Table 2. There was revealed that TBARS values were increased during storage time. T1 showed significantly lower TBARS value than other groups in day 0, 7 and 14 (P < 0.05). In the present study, four herbs extract could not suppress the lipid oxidation in all treatment groups during storage. Four herbs have been used in meat and meat products for both antioxidative (Cheah and Gan, 2000; Hussein *et al*., 2015; Nigam *et al*., 2015; Zhang *et al*., 2015). Herbs were effective in reducing lipid oxidation in meat product and can be used replace synthetic antioxidant (Olorunsanya *et al*., 2010). Moreover, Herbs contained varied types of pharmacologically active compounds with antioxidant and antimicrobial activities (Nigam *et al*., 2015). Incorporating natural antioxidants (Shirazi thyme, cinnamon, and rosemary extracts) led to a significant reduction in TBARS (36.58–46.34%) in meat product (Gahruie *et al*., 2017). Thiobarbituric

acid reactive substances (TBARS) values increased after storage for 12 days, whereas samples formulated with green tea powder showed lower TBARS values compared to control groups (Cho and Chung, 2010). Prunus mume jerky showed significantly lower TBARS value than Citrus junos seib after 20 d. The extracts of Prunus mume will be used in sun-dried Hanwoo beef jerky as a natural agent to retard lipid oxidation (Lim *et al*., 2012). This study was difference from the previous studies. This might be due to the concentration of herbs extract in all treatments groups. The future study should increase the concentration of herbs extract for effective as an antioxidant in the meat products.

Total Plate Count and *Salmonella* spp.

Total plate count in day 0 revealed that T5 (1% galangal extract) was the lowest in total plate count ($P < 0.05$) (Table 3). Day 7, T3 (0.5% turmeric extract) was the lowest among the treatments. T8 (1.0% lemongrass extract) during storage of 14 day showed lower total plate count than other treatments ($P < 0.05$). Thai-herbs have potent antimicrobial activity (Jarriyawattanachaikul *et al*., 2016). There has previous study revealed the potential using herb and irradiation to protect the microbial growth. The total aerobic bacterial count was significantly decreased with an increase in the irradiation dose and leek extract addition when compared to that of the control (4.54 ± 0.05 Log CFU/g). Electron-beam irradiation in combination with leek extract to improve the microbiological safety of pork jerky (Kim *et al*., 2013). However, bacterial populations decreased below the detection limit as early as 7 h during drying or remained detectable even after 60 days of storage, depending on acid adaptation, pre-drying treatment, and agar media (Calicioglu *et al*., 2003). In this study, the concentration of Thai herbs extract might be involved on antimicrobial activity. Using herbs extract in Thai-semi dried pork, the concentration will need to be validate in further study. Moreover, the total plate count can be observed the growing of microbial. This might be depend on a_W value of this product. A_W value was quite higher than the standard of Thai industrial standards institute (less than 0.85).

Table 3 Effect of four herbs extract on total plate count of Thai-semi dried pork during storage

Treatment	Total plate count (log CFU/g)		
	Day 0	Day 7	Day 14
T1	5.58 ± 0.00^{AB}	5.41 ± 0.10	5.64 ± 0.08^{A}
T2	5.39 ± 0.55^{AB}	5.64 ± 0.02	5.58 ± 0.06^{A}
T3	5.75 ± 0.03^{A}	5.40 ± 0.23	5.78 ± 0.05^{A}
T4	4.78 ± 0.06^{B}	5.61 ± 0.05	5.72 ± 0.00^{A}
T5	4.73 ± 1.00^{bB}	5.46 ± 0.02^{ab}	5.77 ± 0.01^{aA}
T6	5.74 ± 0.10^{A}	5.69 ± 0.03	5.85 ± 0.02^{A}
T7	5.51 ± 0.07^{AB}	5.46 ± 0.13	5.61 ± 0.00^{A}
T8	5.64 ± 0.05^{aAB}	5.77 ± 0.05^{a}	4.59 ± 1.17^{bB}
T9	5.95 ± 0.14^{A}	5.65 ± 0.06	5.68 ± 0.01^{A}

Note: Letter (s) in each row indicated least significant differences at probability $P < 0.05$.
Letter (s) in each column indicated least significant differences at probability $P < 0.05$.
^{ab} Means without same case letters within the same row differ significantly at $P < 0.05$.
^{AB} Means without same case letters within the same column differ significantly at $P < 0.05$.
T1, non-added control; T2, added 0.5% turmeric extract; T3, added 1.0% turmeric extract; T4, added 0.5% galangal extract; T5, added 1.0% galangal extract; T6, added 0.5% lemongrass extract; T7, added 1.0% lemongrass extract; T8, added 0.5% black sesame extract; T9, added 1.0% black sesame extract

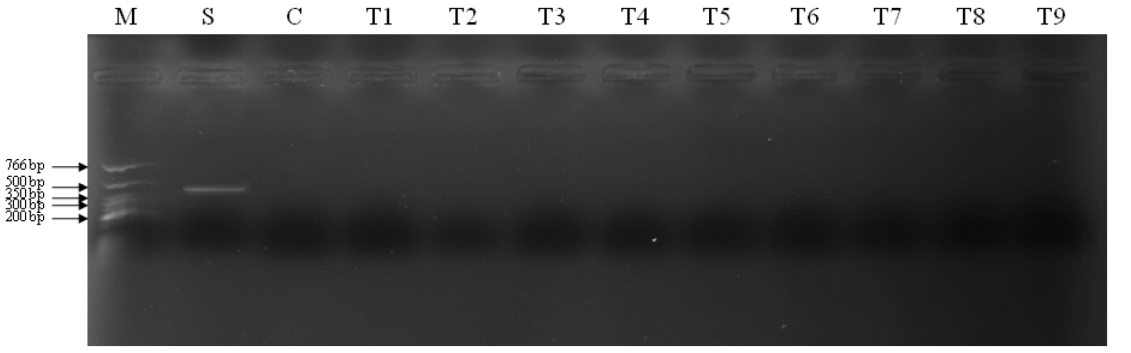

Figure 1 Conventional PCR detection of *Salmonella* spp. in Thai-semi dried pork. M, marker; S, *Salmonella* spp. 389 bp (Positive control); C, negative control; T1, non-added control; T2, added 0.5% turmeric extract; T3, added 1.0% turmeric extract; T4, added 0.5% galangal extract; T5, added 1.0% galangal extract; T6, added 0.5% lemongrass extract; T7, added 1.0% lemongrass extract; T8, added 0.5% black sesame extract; T9, added 1.0% black sesame extract

Analysis of *Salmonella* contamination with PCR detection of Thai-semi dried pork during storage. The result indicated that there was no evidence of *Salmonella* contamination in all treatment groups (Figure 1). In comparison with the control (0% leek extract), samples with 1.0% leek extract showed significant reduction in the numbers of *Escherichia coli*, *Listeria monocytogenes*, and *Salmonella Typhimurium*. No viable counts were detected for *Salmonella Typhimurium* in both control and leek-extract samples (Kang *et al*., 2012). Decreasing meat pH significantly increased the efficacy of Potassium sorbate and temperature to reduce levels of the levels of *Salmonella* spp. Beef jerky processed at 82°C, pH 5.5, with 0.25% PS to a final a_w of 0.7 resulted in a maximum *Salmonella* logarithmic reduction of 5.0 Log CFU/g (Juneja *et al*., 2016). There has a previous study reported that oregano essential oil in meat was effective in inhibiting *Salmonella enteritidis* and *Escherichia coli* (Hernández *et al*., 2017). Irradiation treatment can be combined with the use of natural antibacterial compounds, such as extracts of spices and herbs, or various packaging systems (Szczawińska, 2017). In this study, there have no detected *Salmonella* contamination, these might be according to the standard control for *Salmonella* contamination of Thai agricultural commodity and food standard should not detected in pork meat per 25 grams.

CONCLUSION

The concentration of four herbs extract not suitable for using as lipid oxidation properties and improve the quality characteristics of Thai-semi dried pork. These results might be contributed to studies in further by preliminary the concentration of Thai herbs extract for Thai-semi dried pork.

ACKNOWLEDGEMENTS

This work was partially supported by the Center for Advanced Studies for Agriculture and Food, Institute for Advanced Studies, Kasetsart University Under the Higher Education Research Promotion and National Research University Project of Thailand, Office of the Higher Education Commission, Ministry of Education, Thailand.

REFERENCES

Alvarez-Parrilla, E., G. Mercado-Mercado, L.A.D.L. Rosa, J.A.L. Díaz, A. Wall-Medrano and G.A. González-Aguilar. 2014. Antioxidant activity and prevention of pork meat lipid oxidation using traditional Mexican condiments (pasilla dry pepper, *achiote*, and *mole* sauce). Food Sci. Technol. (Campinas) 34: 371–378.

AOAC. 2006. Official Methods of Analysis of AOAC International. 18th Edition, Gaithersberg, MD, USA.

Bower, C., K. Schilke and M. Daeschel. 2003. Antimicrobial properties of raisins in beef jerky preservation. J. Food Sci. 68: 1484–1489.

Bowker, B.C., A.L. Grant, J.C. Forrest and D.E. Gerrard. 2002. Muscle metabolism and PSE pork. J. Anim. Sci. 79: 1–8.

Calicioglu, M., J.N. Sofos, J. Samelis, P.A. Kendall and G.C. Smith. 2003. Effect of acid adaptation on inactivation of *Salmonella* during drying and storage of beef jerky treated with marinades. Int. J. Food Microbiol. 89: 51–65.

Cheah, P.B. and S.P. Gan. 2000. Antioxidative/antimicrobial effects of galangal and a-tocopherol in minced beef. J. Food Prot. 63: 404–407.

Cho, S.H. and C.H. Chung. 2010. Quality characteristics of pork meat patties formulated with either steam-dried green tea powder or freeze-dried raw tea leaf powder. Korean J. Food Cook. Sci. 26: 567–574.

Choi, J.H., J.Y. Jeong, D.J. Han, Y.S. Choi, H.Y. Kim, M.A. Lee, E.S. Lee, H.D. Paik and C.J. Kim. 2008. Effects of pork/beef levels and various casings on quality properties of semi-dried jerky. Meat Sci. 80: 278–286.

Dugan, M., P. Vahmani, T. Turner, C. Mapiye, M. Juárez, N. Prieto, A. Beaulieu, R. Zijlstra, J. Patience and J. Aalhus. 2015. Pork as a source of omega-3 (n-3) fatty acids. J. Clin. Med. 4: 1999–2011.

Gahruie, H.H., S.M. Hosseini, M.H. Taghavifard, M.H. Eskandari, M.T. Golmakani and E. Shad. 2017. Lipid oxidation, color changes, and microbiological quality of frozen beef burgers incorporated with shirazi thyme, cinnamon, and rosemary extracts. J. Food Qual. 2017: 1–9.

Han, D.J., J.Y. Jeong, J.H. Choi, Y.S.Choi, H.Y. Kim, M.A. Lee, E.S. Lee, H.D. Paik and C.J. Kim. 2007. Effects of drying conditions on quality properties of pork jerky. Korean J. Food Sci. Ani. Resour. 27: 29–34.

Hernández, H., A. Fraňková, T. Sýkora, P. Klouček, L. Kouřimská, I. Kučerová and J. Banout. 2017. The effect of oregano essential oil on microbial load and sensory attributes of dried meat. J. Sci. Food Agric. 97: 82–87.

Hewlings, S.J. and D.S. Kalman. 2017. Curcumin: a review of its' effects on human health. Foods 6: E92.

Holley, R.A. 1985. Beef jerky: viability of food-poisoning microorganisms on jerky during its manufacture and storage. J. Food Prot. 48: 100–106.

Hugas, M. 1998. Bacteriocinogenic lactic acid bacteria for the biopreservation of meat and meat products. Meat Sci. 49: S139–S150.

Hussein, S.A., M.S.A. Shahin and M.R.M. Masoud. 2015. Effect of using lemongrass and thyme on some beef burger characteristics. Egypt. J. Agric. Res. 93: 133–145.

Jarriyawattanachaikul, W., P. Chaveerach and N. Chokesajjawatee. 2016. Antimicrobial Activity of Thai-herbal Plants against Food-borne Pathogens *E. Coli*, *S. Aureus* and *C. Jejuni*. Agric. Sci. Procedia 11: 20–24.

Juneja, V.K., M. Valenzuela-Melendres, D. Heperkan, D. Bautista, D. Anderson, C.-A. Hwang, A. Peña-Ramos, J.P. Camou and N. Torrentera-Olivera. 2016. Development of a predictive model for *Salmonella* spp. reduction in meat jerky product with temperature, potassium sorbate, pH, and water activity as controlling factors. Int. J. Food Microbiol. 236: 1–8.

Kang, M., H.-J. Kim, D. Jayasena, Y. Bae, H. Yong, M. Lee and C. Jo. 2012. Effects of combined treatments of electron-beam irradiation and addition of Leek (*Allium tuberosum*) extract on reduction of pathogens in pork jerky. Foodborne Pathog. Dis. 9: 1083–1087.

Kim, H.J., M. Kang, H.I. Yong, Y.S. Bae, S. Jung and C. Jo. 2013. Synergistic effects of electron-beam irradiation and leek extract on the quality of pork jerky during ambient storage. Asian-Australas. J. Anim. Sci. 26: 596–602.

Konieczny, P., J. Stangierski and J. Kijowski. 2007. Physical and chemical characteristics and acceptability of home style beef jerky. Meat Sci. 76: 253–257.

Lee, J.H., L. Alford, G. Kannan and B. Kouakou. 2017. Curing properties of sodium nitrite in restructured goat meat (chevon) jerky. Int. J. Food Prop. 20: 526–537.

Lim, D.G., J.J Kim, K.S. Seo and K.C. Nam. 2012. Effect of natural antioxidant extracted from *Citrus junosseib*. or *Prunus mume*. on the quality traits of sun-dried Hanwoo beef jerky. Korean J. Agric. Sci. 39: 243–253.

Nam, K.C., H.C. Kim, J. Cha and D.G. Yim. 2016. The quality characteristics and antioxidant properties of sun-dried venison jerky with green tea powder during storage. Korean J. Food Sci. An. 36: 626–634.

Nigam, D., C. Singh and U. Tiwari. 2015. Evaluation of *in vitro* study of antioxidant and antibacterial activities of methanolic seed extract of *Sesamum indicum.* J. Pharmacogn. Phytochem. 3: 88–92.

Olorunsanya, A.O., E.O. Olorunsanya, S.A.O. Bolu, C.T. Adejumobi and R.M.O. Kayode. 2010. Effect of graded levels of lemongrass (*cymbopogon citratus*) on oxidative stability of raw or cooked pork patties. Pakistan J. Nutr. 9: 467–470.

Ozer, N.K., D. Boscoboinik and A. Azzi. 1995. New roles of low density lipoproteins and vitamin E in the pathogenesis of atherosclerosis. Biochem. Mol. Biol. Int. 35: 117–124.

Ramya, P., T. Madhavarao and L.V. Rao. 2012. Study on the incidence of *Salmonella enteritidis* in poultry and meat samples by cultural and PCR methods. Vet. World. 5(9): 541–545.

Shahidi, F. and Y. Zhong. 2010. Lipid oxidation and improving the oxidative stability. Chem. Soc. Rev. 39: 4067–4079.

Szczawińska, M.E. 2017. Application of Ionizing radiation for control of *salmonella* in food, pp. 253–274. *In:* M. Mares, (Ed.), Current Topics in *Salmonella* and Salmonellosis. IntechOpen.

Torres, E.A.F.S., M. Shimokomaki, B.D.G.M. Franco, M. Landgraf, B.C. Carvalho Jr. and J.C. Santos. 1994. Parameters determining the quality of charqui, an intermediate moisture meat product. Meat Sci. 38: 229–234.

Wójciak, K.M., M. Karwowska and Z.J. Dolatowski. 2015. Fatty acid profile, color and lipid oxidation of organic fermented sausage during chilling storage as influenced by acid whey and probiotic strains addition. Sci. Agric. 72: 124–131.

Yang, H.S., S.W. Kang, J.Y. Jeong, J.Y. Chun, S.T. Joo, G.B. Park and S.G. Choi. 2009. Optimization of drying temperature and time for pork jerky using response surface methodology. Food Sci. Biotechnol. 18: 985–990.

Zaki, E.F., A.A Nadir, I.M.F. Helmy and N.M.A. Maguid. 2018. Antioxidant and antimicrobial effects of lemongrass (*cymbopogon citrates*) oil on the quality characteristics of camel burger "camburger" under refrigerated storage. Int. J. Curr. Microbiol. App. Sci. 7: 3623–3631.

Zhang, J., Z. Hu, C. Lu, K. Bai, L. Zhang and T. Wang. 2015. Effect of various levels of dietary curcumin on meat quality and antioxidant profile of breast muscle in broilers. J. Agric. Food Chem. 63: 3880–3886.

Zhao, X., J. Zhang, H. Ming, W. Zou, Y. Wang, C. Zhao, S. Mu, H. Zhang and L. Qiu. 2016. Research on pork jerky obtained through fermentation with *Pediococcus acidilactici*. Pol. J. Food Nutr. Sci. 66: 25–29.