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Effect of glycerol on improving quality of ready to eat Nham jerky, an innovation of Thai fermented meat product

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Abstract Different concentrations of glycerol were investigated for improving qualities of ready to eat pork Nham jerky, an innovation of Thai fermented meat product. Three concentrations at 0 (control), 5 and 10% of glycerol were applied in pork Nham. Microbiologica and physicochemical qualities were recorded during fermentation period and after drying. The results showed that addition of 10% glycerol displayed higher pH particularly on the third day of fermentation ($p<0.05$), causing lower total acidity and purge loss in pork Nham during fermentation process. However, lactic acid bacteria population were not different in all treatments. Greater red color (a*) and lower lightness (L*) was observed in Nham with 5% and 10% glycerol adding ($p<0.05$). After 3 days of fermentation process, pork Nham was cooked and dehydrated until the internal temperature reached 72˚C and water activity (a_w) < 0.75. This product, ready to eat Nham jerky is a novel meat product as normally Nham consume as raw product. Percentage of drying yield, a_w, shear force, color and sensory evaluation were compared among treatments. The results demonstrated that drying yield percentage of jerky Nham containing 5% and 10% glycerol was significantly higher than that of the control ($p<0.05$), while a_w and shear force obtained the lower value than control ($p<0.05$). Sensory evaluation indicated that the highest score in overall acceptance was observed in Nham jerky containing 10% glycerol. In conclusion, adding glycerol in Nham jerky improved qualities and sensory acceptance.

Keywords glycerol, Nham, Thai fermented meat product

Introduction

As our research focus on develop innovation product, therefore, the favourite product in Thailand was concerned. Nham is the most favourite traditional fermented pork product in Thailand (Luxananil *et al*., 2009; Kingcha *et al*., 2012). The ingredients of Nham composed of minced pork (60% w/w), cooked pork ride (35% w/w), fresh garlic (4.3%), cooked rice (4.3%), salt (1.9%

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w/w), sugar (0.3% w/w), sodium tripolyphosphate (0.2%), erythobate (0.25% w/w), potassium nitrite (0.01%) and monosodium glutamate (0.2% w/w). After all ingredients were mixed well, Nham was packed in an air-tight casing which reacted in oxygen-limited but still maintains the water activity throughout the process. The fermentation process occur a room temperature (30-37°C) for 3-5 days which is carried out by lactic acid bacteria (Visessanguan *et al*., 2005; Chokesajjawatee *et al*., 2009; Pringsulaka *et al*., 2011; Swetwiwathana and Visessanguan, 2015). As Nham is consumed as raw product without heating (Swetwiwathana and Visessanguan, 2015). The incidence of pathogenic bacteria is currently concerned for consumer safety (Chokesajjawatee *et al*., 2009). Even though the pH of Nham is lower than 4.6 (According to standard TIS 1219-2547, 2004 issue by the Thai industrial standard institute, Ministry of industry) which this pH is useful to inhibit the growth of pathogenic bacteria. However, there have been reported on pathogens during the fermentation of pork products as well (Zhao *et al*., 2016). Pathogenic bacteria can be observed during early phase of Nham fermentation (Chokesajjawatee *et al*., 2009). Therefore, to overcome this problem, raw Nham was cooked and dried for ready-to-eat Nham jerky. Subsequently, Nham jerky is an innovation Thai fermented meat product.

Nowadays, the market for meat snack has rapidly grown and those meat snack, meat jerky is very popular because it has high protein content and can be purchased easily in retail shops worldwide and has shelf stability. (Church *et al*., 2013; Kim and Kim, 2017). Jerky is one of the typical intermediate-moisture food which is favourite for ready to eat meat product in the world. There are different type of jerky which made from slice hole muscle meat and formed from ground meat, follow by marinated or mixed with spice, and then dried (Choi *et al*., 2008; Sorapukdee *et al*., 2016). This product was dried by reduction in water a_w to 0.70-0.75 to preserve the content.This properties resulted in prolong shelf-life of jerky without refrigerate during storage (Yang *et al*., 2009; Jang *et al*., 2015; Zhao *et al*., 2016). However, disadvantages of semi-dried meat product were undesirable of color, a tough texture and reduction chewibility of product (Yang *et al*., 2009). Generally, consumers prefer products with a softer texture (Chen *et al*., 2000). To overcome this problem, humectant is used in semi-dried meat product particularly 5-10% concentration of glycerol (Chen *et al*., 2000; Jang *et al*., 2015; Sorapukdee *et al*., 2016). The properties of humectant improve water holding capacity, texture and appearance of dry meat products. It has been reported that adding 5 to 10% glycerol was effective in reduction a_w and improved texture (Kim *et al*., 2010; Sorapukdee *et al*., 2016). Another research reported that adding glycerol 3, 6 and 9% in chinese-style pork jerky improved texture as shear force value decreased (Chen *et al*., 2000).

Therefore, the objectives of this research was to investigate the effect of glycerol on improving qualities and sensory of ready to eat semi-dried Nham (Nham jerky), an innovation of Thai fermented meat product.

Materials and Methods

Nham Jerky preparation samples

The ingredient of Nham composed of ground pork from ham portion, cooked pork ride, cooked rice, fresh garlic, salt, sugar, sodium tripolyphosphate, sodium erythobate, potassium nitrite and monosodium glutamate. Salt and Sodium tripolyphosphate were added into ground pork and mixed well, then followed by other ingredients. The mixture divided into 3 groups: 1) control (without glycerol), 2) adding 5% and 3) adding 10% glycerol. The mixture was formed into strip ($3\times10\times0.5$ cm^2) and subsequently packed in vacuum pack and kept at 30 ^oC for 3 days. After 3 days, Nham was dried in an oven at temperature 85 ^oC for 2 hours (h) until the internal temperature reached to 72 ^oC and continued at 60 ^oC for 1 hr to reduce a_w

Determination of Nham quality during fermentation process

Microbiological determination

Lactic acid bacteria, *Staphylococcus aureus* and yeast/mold in pork Nham were counted. Twenty- five grams of each treatment was homogenized and diluted to 10-fold serial dilution with 225 ml of 0.1% (w/v) peptone solution. Appropriate dilution was used for bacterial enumeration. 100 µl of dilution was spreaded on to media. Lactic acid bacteria was analyzed by MRS agar (de Man-Rogosa-Sharp; Merck, Germany) containing 0.5% calcium carbonate (AOAC, 2006). *S. aureus* was carried out by Baird-parker agar (Merck, Germany) adding egg yolk tellurite emulsion and the plate was incubated at 37 ^oC for 24-48 hr. The black colonies were selected for continue biochemical test as described by BAM (2001). For yeast/mold investigation, method of AOAC (2005) was followed using Malt agar (Merck, Germany) acidified with lactic acid and subsequently the plates were incubated at 26 ^oC for 3-5 days. Yield of bacteria expressed as log CFU/g.In addition, total plate count using plate count agar (Merck, Germany), *s. aureus* and yeat/mold were detected after drying.

Determination of pH and total acidity

Two grams of sample was blended and homogenized (Ultra tarrax model IKA T 25 digital, Germany) with 20 ml of distilled water. The mrat suspension was directly applied for pH measurement using a pH meter (Mettler Toledo, Switzerland) (AOAC, 1984). Total acidity of pork Nham determination was described by Friedrich (2001). Two gram of pork Nham was homogenized with 20 ml distilled water. The homogenate was centrifuged at 4000 g (4 ^{o}C). The supernatant was filter through filter paper (Whatman No. 1) and the filtrate was titrated subsequently with standardized 0.1 N NaOH with phenolphthalein as indicator.

Determination of purge loss

Purge loss was performed as modified by Nakao *et al.*, (1998). Twenty-five gram of pork Nham before fermentation at day 0 (A) was weight. Then, Nham was packed in vacuum pack during fermentation process for 1, 2 and 3 days. During fermentation period, pork Nham was removed from package, the exudate was dried with paper towels and consequently weight again (B). The purge loss was calculated by weight difference and expressed as a percentage of the initial weight as following

$$\text{Purge loss (\%)} = \frac{(A-B)}{A} \times 100$$

Determination of Nham jerky quality after dried

Percentage of drying yield

Drying yield was evaluated by calculating the weight differences from jerky Nham before and after drying as follows:

$$\text{Drying yield (\%)} = \frac{\text{Weight of dried sample (g)}}{\text{Weight of raw sample before dry (g)}} \times 100$$

Measurement of a_w

Water activity was recorded in triplicate on 2 gram of sample using a water activity meter (Novasina® Labmaster aw, Axair Ltd, Switzerland).

Shear force measurement

Sample size of Nham jerky 1×3×0.5 cm was applied to texture analyzer with Warner-Bratzler shear blade (Instron, 1011, USA). The shear force was express in Newton (N).

Color measurement

Three random area of surface sample (size of sample around 3x8x0.5 cm) were measured by the lightness (L*), redness (a*), and yellowness (b*) system mode of CIE, using a Hunterlab Mini Scan Ez (Germany).

Sensory evaluation

Ready to eat Nham jerky samples were served to 30 undergraduate and graduate students of Department of Animal Production Technology and Fisheries, KMITL as panelists. The hedonic test was used to evaluate the color, appearance, texture, flavor, sourness and overall acceptability. A score ranged from 1 to 7 indicating as the following: 1= undesirable, 2= moderately undesirable, 3= slightly undesirable, 4= indifferent, 5= slightly desirable, 6= moderately desirable and 7= extremely desirable.

Statistic analysis

All data were analyzed using the analysis of variance (ANOVA). Comparison of treatment means was based on a Duncan's Multiple Range Test. The statistical analyzed were carried out by using the Statistical Package for Social Science (SPSS for windows version 11.5, SPSS Inc., USA).

Results

Effect of glycerol on microbial counts in pork Nham during fermentation process

Lactic acid bacteria, total plate count, *S. aureus* and yeast/mold during fermentation process (0 and 3 days) in control, 5% and 10% glycerol treatments were detected. There were no significant differences in number of lactic acid bacteria among 3 treatments ($p>0.05$) as shown in Table 1 This indicated that glycerol at 5% and 10% had no effect on lactic acid bacteria growth. Although, the initial lactic acid bacteria count that analyzed on the first day of fermentation in control, 5% and 10% glycerol trails were 4.89, 4.70 and 4.42 log cfu/g respectively ($p>0.05$). Lactic acid bacteria population in all treatments after 3 days of fermentation increased with significant difference ($p<0.05$) at 7.63, 7.48 and 7.39, respectively. The initial number of *S. aureus* in pork Nham was 3.04, 2.74 and 1.85 log cfu/g, while initial number of yeast/mold was 3.97, 3.95 and 4.09 log cfu/g in control, 5% and 10% glycerol treated, respectively. However, both *S. aureus* and yeast/mold decreased less than 1 log cfu/g which were undetectable after 3 days of fermentation and oven-dried.

Table 1. Effect of glycerol on microbial in pork Nham during fermentation process and after dried

Microorganisms	Fermentation period (day)	Microbial counts (log cfu/g)		
		Control	5% Glycerol	10% Glycerol
Lactic acid bacteria	0	$4.89 \pm 0.99^{a,B}$	$4.70 \pm 0.71^{a,B}$	$4.42 \pm 0.21^{a,B}$
	3	$7.63 \pm 0.32^{a,A}$	$7.48 \pm 0.11^{a,A}$	$7.39 \pm 0.06^{a,A}$
	After dried	<1	<1	<1
Total plate count	0	$5.10 \pm 0.18^{a,A}$	$4.71 \pm 0.39^{a,A}$	$4.57 \pm 0.63^{a,A}$
	3	$4.26 \pm 0.20^{a,A}$	$4.92 \pm 0.21^{a,A}$	$5.24 \pm 0.69^{a,A}$
	After dried	<1	<1	<1
S. aureus	0	3.04 ± 0.54^{a}	2.74 ± 0.25^{a}	1.85 ± 0.72^{a}
	3	<1	<1	<1
	After dried	<1	<1	<1
Yeast/mold	0	3.97 ± 0.93^{a}	3.95 ± 0.75^{a}	4.09 ± 0.21^{a}
	3	<1	<1	<1
	After dried	<1	<1	<1

^{ab} different letters in the same row with different letters are significant different among glycerol treatment (p<0.05)
^{AB} different letters in the same column with different letters are significant different among fermentation period (p<0.05)

The Effect of glycerol on physicochemical properties of pork Nham during fermentation process

Effect of glycerol on pH and total acidity

The studies of pH value in pork Nham with 3 various concentrations of glycerol at 0, 5 and 10% on 1 and 3 days of fermentation process were carried out. The pH value of the product increased with significant difference (p<0.05) along on more glycerol adding. At the beginning, pH values of pork Nham without glycerol (control), 5 and 10% glycerol were not different (5.98, 6.11, and 6.0, respectively). After fermentation process for 3 days, the highest pH values were observed in pork Nham containing 10% glycerol (p<0.05). The pH of the control group was the lowest (<4.6), whereas pH of pork Nham with 0 and 5% glycerol were not different (4.51 and 4.65, respectively). The total acidity was not significant difference (p>0.05) in all treatments during pork Nham fermentation. After fermentation for 3 days, the lowest pH value was corresponding to the highest total acidity in control group. As pork Nham adding glycerol 5 and 10% revealed higher pH than control, resulting in lower total acidity (Table 2).

Table 2. Effect of glycerol on pH value and total acidity during fermentation process of pork Nham

Parameters	Fermentation period (days)	Control	5% Glycerol	10% Glycerol
pH	0	5.98 ± 0.08 [a,A]	6.11 ± 0.25 [a,A]	6.00 ± 0.10 [a,A]
	1	4.70 ± 0.26 [c,B]	5.13 ± 0.34 [ab,B]	5.62 ± 0.18 [a,A]
	2	4.60 ± 0.05 [b,B]	4.68 ± 0.08 [b,C]	4.96 ± 0.12 [a,B]
	3	4.51 ± 0.08 [b,B]	4.65 ± 0.09 [b,C]	4.89 ± 0.07 [a,B]
Total acidity	0	0.82 ± 0.30 [a,B]	0.83 ± 0.23 [a,B]	0.85 ± 0.25 [a,B]
	1	1.28 ± 0.18 [a,A]	1.19 ± 0.16 [a,AB]	1.08 ± 0.22 [a,AB]
	2	1.51 ± 0.27 [a,A]	1.28 ± 0.23 [a,A]	1.17 ± 0.26 [a,AB]
	3	1.69 ± 0.18 [a,A]	1.49 ± 0.17 [a,A]	1.38 ± 0.27 [a,A]

[ab] different letters in the same row with different letters are significant different (p<0.05)
[ABC] different letters in the same column with different letters are significant different (p<0.05)

Effect of glycerol on purge loss

The results revealed that the higher concentration of glycerol reduced purge loss during fermentation as shown in Table 3. Pork Nham with 10% glycerol released the lowest purge loss when compared to control and 5% glycerol treatments with significant difference (p<0.05). The purge loss percentage on the third day of fermentation was 9.46, 5.07 and 2.55 in control, 5 and 10% glycerol treated, respectively. In addition, the longer fermentation period, the higher of purge loss percentage were found.

Table 3. Effect of glycerol on purge loss during fermentation process of pork Nham

Fermentation peroid (day)	% Purge loss		
	control	5% Glycerol	10% Glycerol
1	1.54[a,C] ± 0.12	1.25[ab,B] ± 0.25	1.07[b,B] ± 0.16
2	4.64[a,B] ± 0.49	3.77[a,B] ± 0.52	2.13[b,A] ± 0.62
3	9.46[a,A] ± 0.39	5.07[b,A] ± 0.20	2.55[c,A] ± 0.23

[abc] different letters in the same row are significant different among treatments (p<0.05)
[ABC] different letters in the same column with different letters are significant different among fermentation peroids (p<0.05)

Effect of glycerol on color

There were not differenes in lighteness (L*), redness (a*) and yellowness (b*) on Nham with glycerol on the first day of fermentation. However, at 2 and 3 days, L* value of glycerol group was lower than control which was not different in yellowness. On the contrary, a* values were higher in glycerol adding than control with significant difference (p<0.05) as shown in Table 4. However, fermentation time increasing, L* and a* values also increased (Table 4).

Table 4. Effect of glycerol on color of pork Nham during fermentation process

Parameters	Fermentation peroid (day)	Control	5% Glycerol	10% Glycerol
Lightness (L*)	0	23.74 ± 0.60 ^{a,x}	24.06 ± 1.19 ^{a,D}	25.15 ± 0.84 ^{a,A}
	1	33.40 ± 0.39 ^{a,C}	30.36 ± 1.15 ^{b,C}	31.05 ± 1.06 ^{a,C}
	2	41.04 ± 0.23 ^{a,B}	37.05 ± 1.23 ^{b,B}	34.19 ±0.98 ^{c,B}
	3	44.03 ± 0.53 ^{a,A}	41.19 ± 0.78 ^{ab,A}	38.59 ± 0.92 ^{c,A}
Redness (a*)	0	12.91 ± 0.79 ^{b,B}	15.07 ± 0.21 ^{a,C}	15.84 ± 0.13 ^{b,B}
	1	14.23 ± 1.03 ^{a,AB}	15.30 ± 0.33 ^{a,C}	16.06 ± 0.17 ^{a,B}
	2	15.12 ± 0.58 ^{b,A}	16.20 ± 0.08 ^{ab,B}	16.91 ± 0.06 ^{a,A}
	3	16.04 ± 0.45 ^{c,A}	17.00 ± 0.42 ^{ab,A}	17.56 ± 0.12 ^{a,A}
Yellowness (b*)	0	17.29 ± 0.69 ^{a,A}	15.81 ± 0.24 ^{a,A}	16.50 ± 0.18 ^{a,A}
	1	14.24 ± 0.42 ^{a,A}	13.67 ± 0.01 ^{a,A}	14.66 ± 0.29 ^{a,A}
	2	13.48 ± 0.28 ^{a,A}	12.16 ± 0.06 ^{a,A}	13.66 ± 0.85 ^{a,A}
	3	12.26 ± 0.59 ^{a,A}	11.98 ± 0.24 ^{a,A}	13.52 ± 0.33 ^{a,A}

^{abc} different letters in the same row are significant different among treatments (p<0.05)
^{ABC} different letters in the same column are significant different among fermentation peroid (p<0.05)

Effect of glycerol on physicochemical characteristic of ready-to-eat Nham jerky after drying

The percentage of drying yield for all treatments was 35-40% and higher drying yield was observed in Nham jerky adding 5 and 10% glycerol compared to control (p<0.05). The a_w of ready-to-eat Nham jerky after oven-dried in all treatments was lower than 0.85 with the figures of 0.68, 0.70 and 0.73 in control, 5% and 10% glycerol groups, respectively. The a_w in 5 and 10% glycerol was lower than control with significant difference (p<0.05). The a_w of 10% glycerol adding was the lowest with significant difference (p<0.05) comparing to 5% glycerol and control (Table 5).The shear force value of Nham jerky decreased significantly (p<0.05) with increasing levels of glycerol. Shear force value was 45.53, 42.53 and 35.87 N in control, glycerol 5% and 10 %, adding respectively (Table 5). The glycerol in the product demonstrated the higher L* value with significant difference compared to control (p<0.05). In contrast to the a* value that was lower with significant difference to control (p<0.05). Sensory evaluation was performed on the effect of color, appearance, texture, flavor, sourness and overall acceptance. As Nham is fermented meat product, the important parameter to detect was sourness.The color, appearance, texture, flavor and overall acceptance in Nham jerky with 10% glycerol exhibited the highest acceptance to other groups (p<0.05) with liking score of 5 (slightly desirable) to 6 (moderately desirable).

In addition, the analysis of total count, *S. aureus*, yeast and mold in the product were under detectable level (<1 log cfu/g) as data has not shown.

Table 5. Effect of glycerol on physicochemical characteristics and sensory attributes of Nham jerky from pork

Parameters	Control	5% Glycerol	10% Glycerol
Drying yield (%)	35.14 ± 0.38^{c}	37.70 ± 0.73^{b}	40.77 ± 0.10^{a}
water activity	0.749±0.05^{a}	0.684±0.07^{b}	0.602±0.04^{b}
Shear force (N)	45.53 ± 0.25^{a}	42.53 ± 0.17^{b}	35.87 ± 0.25^{c}
Color			
- Lightness (L*)	21.89 ± 0.40^{b}	23.87 ± 0.23^{ab}	24.89 ± 0.33^{a}
- Redness (a*)	5.38 ± 0.0^{a}	4.09 ± 0.03^{b}	3.72 ± 0.03^{c}
- Yellowness (b*)	4.45 ± 0.10^{c}	5.31 ± 0.05^{b}	6.19 ± 0.11^{a}
Sensory attributes			
- Color	4.63^{a}	4.79^{a}	4.85^{a}
- Appearance	4.67^{b}	4.49^{b}	5.10^{a}
- Texture	4.46^{b}	4.48^{b}	5.46^{a}
- Flavor	4.82^{b}	4.88^{b}	5.19^{a}
- Sourness	5.06^{a}	4.81^{ab}	4.65^{b}
- Overall acceptability	4.53^{b}	4.82^{a}	5.06^{a}

^{abc} different letters superscripts in the same row indicate significances differences among treatments
(p<0.05)

Discussion

Microbiological and physicochemical characteristic of pork Nham with glycerol 5 and 10% compared to pork Nham without glycerol (control) were studied during fermentation process. It was found that lactic acid bacteria in pork Nham during fermentation for 3 days were not different in all treatments. Even though number of lactic acid bacteria were not different, pH value of pork

Nham adding glycerol was higher than the control, resulting in lower total acidity and lower purge loss percentage. Lactic acid bacteria increased during longer fermentation time. After fermentation period 3 days, *S. aureus* and yeast/mold did not observed. Lactic acid bacteria are usually present in raw meat in small amount (10^2-10^3 cfu/g), but propogate rapidly in the fermented meat products under vauum-packed with NaCl and nitrite (Pringsulaka *et al*., 2011; Rantsiou and Cocolin, 2008). Lactic acid bacteria are the major producers of organic acid which respond to decrease in pH and increase in acidity during fermentation (Valyasevi and Rolle, 2002; Zhao *et al*., 2016; Thongruck *et al*., 2017). The pH value of Nham was gradually decreased during fermentation because organic acid was produced from carbohydrate by lactic acid bacteria, contributing of the inhibition of undesirable microorganisms (Visessanguan *et al*., 2004a; Komprda *et al*., 2004; Bozkurt and Bayram, 2006; Zhao *et al*., 2016). The pH of uncooked Nham should lower than 4.6 after fermentation according to standard TIS 1219-2547 issued by Thai Industrial Standard Institute, Ministry of Industry. This pH value is useful to inhibit the growth of pathogenic bacteria (Chokesajjawatee *et al*., 2009). Previous mentioned pH in Nham adding glycerol showed higer value. However, there was no report on effect of glycerol on pH in fermented meat product before. This could be explained that after adding glycerol in Nham formulation, they attract water to itself, resulting in lower concentration of acidity and high pH. Even though, pork Nham adding glycerol displayed higher pH, indicating delay fermentation period but this product was oven-dried (internal temperature reached to 72 ˚C) after fermentation to overcome the incidence of undesirable microorganisms. Therefore, this product named ready to eat Nham jerky, an innovation Thai fermented meat product.

Percentage of purge loss of pork Nham was higher during fermentation period. In addition, purge loss percentage was lower in Nham adding glycerol. Smilar result had been reported by Visessanguan *et al*. (2004b). Increasing in weight loss and released water were found as the fermentation proceeded. This could be the accumulation of lactic acid resulting in lower pH, an increasing in releasing water caused by denaturation of Nham protein. As the Nham adding glycerol displayed higher pH, leading to lower releasing water. Adding glycerol in Nham showed lower L* and higher a* value. Visessanguan *et al.* (2005) explained that characteristic color of meat is a function of meat pigments and light-scattering properties. Nitric oxide myoglobin (NOMb) was spontaneously formed in Nham during the mixing process and accounted for approximately 90% of total heme pigment. However, L* and a*value in Nham increased with longer fermentation period. Visessanguan *et al.* (2005) also explained that acidification of meat proteins affectes color by increasing the light-scattering properties, thus meat becomes opaque and paler.

Physicochemical, microbiological and sensory were performed after pork Nham was dried. The percentage of drying yield was higher after adding glycerol in Nham jerky. This results agreed with Seol *et al.* (2003), Han *et al*. (2011) and Sorapukdee *et al.* (2016) who reported that humectant including glycerol, sorbitol, konjac, egg albumin, rice syrup enchanced in higher drying yield in meat jerky comparing to jerky meat without humectant. However, Jang *et al*. (2015) found that drying yield was not different after added 0, 2.5 and 5% sorbitol, glycerol and xylitol in semi-dried jerky. In this studied, a_w of Nham jerky decreased with high level of glycerol. Similarly, several previous studied such as Chen *et al.* (2000); Kim *et al.* (2010), Jang *et al.* (2015) and Sorapukdee *et al.* (2016) reported that adding humectant, glycerol, sorbitol ect., could reduce water activity in jerky meat. Kim *et al.* (2010) explained that glycerol is an effective additive for water activity control. The water activity of Nham with glycerol 5 and 10% were 0.684 and 0.602, respectively. The use of glycerol in Nham jerky corresponded to safety standard of recommendation of semi-dried meat product from American Food Safety and Inspection Service, FSIS, Ministry of Agriculture, USA (FSIS<2012) that water activity of jerky product should be at ≤ 0.70 in order to inhibit yeast and mold growth. The shear force of Nham jerky decreased with higher level of glycerol, indicated tenderness improvement of product. This finding supported by Chen *et al.* (2000); Sorapukdee *et al*. (2016); Kim *et al*. (2010) and Jang *et al.* (2015) who demonstrated that adding humectant such as glycerol, sorbitol and xylitol ect. improved tenderness of jerky meat as their experiment had showed lower shear force value in jerky meat. Chen *et al.* (2000), Mori *et al*. (2016) and Kim *et al*. (2010) also explained that tenderness is the main factor which contributed to overall eating quality of meat as consumer preferred products with a softer texture. In addition, Chen *et al*. (2000) and Sorapukdee *et al.* (2016) reported that humectants were a substance that attracted water to it self, they could retain water in food stuff, reduced water activity and improving food softness. Flavor scores were increased by the addition of glycerol. There has been a similar finding by Chen *et al.* (2000) and Kim *et al.* (2010), indicated that the glycerol addition increased acceptance score. In conclusion, adding glycerol in Nham jerky improved qualities including yield, a_w, texture and leading sensory acceptance.

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References

AOAC (1984). Official Methods of Analysis. 14th ed. Association of Official Analytical Chemists. Washington DC.

AOAC (2005). Chapter 17 AOAC Official Method 940. 36B. p. 2. In Horwitz, W. and Latimer, G.W. Official methods of analysis of AOAC international. USA: AOAC international.

AOAC (2006). Chapter 17 AOAC Official Method 966.23c-24. P. 5-6 *In* Horwitz, W. and Latimer, W. Official methods of analysis of AOAC international. Maryland: AOAC international.

BAM (2001). Bacteriological Analytical Manual online, Chapter 12 *Staphylococcus aureus*. [Online].Available:https://www.fda.gov/Food/FoodScienceResearch/LaboratoryMethods/ucm071429.htm. [15/09/2014].

Bozkurt, H., and Bayram, M. (2006). Colour and textural attributes of sucuk during ripening. Meat Science. 73:344-350.

Chen, W. S., Liu, D. C., Chen, M. T. and Ockerman, H. W. (2000). Improving texture and storage stability of Chinese-sytle pork jerky by the addition of humectants. Animal Science. 13:1455-1460.

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

Chokesajjawatee, N., Pornaem, S., Zo, Y. G., Kamdee, S., Luxananil, P., Wanasen, S. and Valyasevi, R. (2009). Incidence of *Staphylococcus aureus* and associated risk factors in Nham, a Thai fermented pork product. Food Microbiology. 26:547-551.

Church, J. S., MacIntyre, C. M., Archambault, W. R., Moote, P. E., Cochran, J. L., Durance, T. D., and Van Hamme, J. D. (2013). Effect of radiant energy vacuum on physical and microbial properties of beef jerky. Journal of Food Science and Engineering. 3:33-36.

Friedrich, J. E. (2001). Tritratable activity of acid tastants. Current Protocols in Food Analytical Chemistry. John Wiley and sons, Tnc, Cargill Incorporated Minneapolis, Minesota.

Han, D. J., Choi, J. H., Choi, Y. S., Kim, H. Y., Kim, S. Y., Kim, H. W. and Kim, C. J. (2011). Effects of konjac, isolated soy protein, and egg albumin on quality properties of semi-dried chicken jerky. Korean Journal for Food Science of Animal Resources. 31:183-190.

Jang, S. J., Kim, H. W., Hwang, K. E., Song, D. H., Kim, Y. J., Ham, Y. K. and Kim, C. J. (2015). Effects of replacing sucrose with various sugar alcohols on quality properties of semi-dried jerky. Korean Journal for Food Science of Animal Resources. 35:622-629

Kim, G. D., Jung, E. Y., Seo, H. W., Joo, S. T. and Yang, H. S. (2010). Textural and sensory properties of pork jerky adjusted with tenderizers or humectant. Korean Journal for Food Science of Animal Resources. 30:930-937.

Kim, M. J. and Kim, H. Y. (2017). Species identification of commercial jerky products in food and feed using direct pentaplex PCR assay. Food Control. 78:1-6.

Kingcha, Y., Tosukhowong, A., Zendo, T., Roytrakul, S., Luxananil, P., Chareonpornsook, K. and Visessanguan, W. (2012). Anti-listeria activity of *Pediococcus pentosaceus* BCC 3772 and application as starter culture for Nham, a traditional fermented pork sausage. Food Control. 25:190-196.

Komprda, T., Smelá, D., Pechová, P., Kalhotka, L., Štencl, J. and Klejdus, B. (2004). Effect of starter culture, spice mix and storage time and temperature on biogenic amine content of dry fermented sausages. Meat Science. 67:607-616.

Luxananil, P., Promchai, R., Wanasen, S., Kamdee, S., Thepkasikul, P., Plengvidhya, V. and Valyasevi, R. (2009). Monitoring *Lactobacillus plantarum* BCC 9546 starter culture during fermentation of Nham, a traditional Thai pork sausage. International Journal of Food Microbiology. 129:312-315.

Mori, K., Nishimura, T., Yasukawa, T. and Takahashi, K. (2016). Tenderization of heated sliced beef by succinylated glycerol monostearate, a novel meat tenderizer. Journal of Food Science. 54:524-529.

Nakao, Y., Konno, A., Taguchi, T., Tawada, T., Kasai, H., Toda, J. and Terasaki, M. (1998). Curd land: properties and application to foods. International Journal of Food Microbiology. 56:769-772.

Pringsulaka, O., Patarasinpaiboon, N., Suwannasai, N., Atthakor, W. and Rangsiruji, A. (2011). Isolation and characterisation of a novel Podoviridae-phage infecting Weissella cibaria N 22 from Nham, a Thai fermented pork sausage. Food Microbiology. 28:518-525.

Rantsiou, K. and Cocolin, L. (2008). Fermented meat products. *In* Cocolin, L. And Ercolini, D. (Ed.). Molecular Techniques in the Microbial Ecology of Fermented Foods. Italy. Springer New York. pp. 91-118.

Seol, J. S., Lee, S. Y., Lee, J. C., Nam, H. D. and Kim, K. H. (2003). Electrical and optical properties of Cu_2ZnSnS_4 thin films prepared by rf magnetron sputtering process. Solar Energy Materials and Solar Cells. 75:155-162.

Sorapukdee, S., Uesakulrungrueng, C. and Pilasombut, K. (2016). Effects of humectant and roasting on physicochemical and sensory properties of jerky made from spent hen meat. Korean journal for food science of animal resources. 36:326.

Swetwiwathana, A. and Visessanguan, W. (2015). Potential of bacteriocin-producing lactic acid bacteria for safety improvements of traditional Thai fermented meat and human health. Meat science. 109:101-105.

Thongruck, K., Saelao, S., Sumpavapol, P., Benjakul, S. and Maneerat, S. (2017). Monitoring of changes in lactic acid bacteria during production of Thai traditional fermented shrimp (Kung-Som) by culturing method and PCR-DGGE technique. Songklanakarin Journal of Science and Technology. 39:41-47.

Valyasevi, R. and Rolle, R. S. (2002). An overview of small-scale food fermentation technologies in developing countries with special reference to Thailand: scope for their improvement. International Journal of Food Microbiology. 75:231-239.

Visessanguan, W., Benjakul, S., Panya, A., Kittikun, C. and Assavanig, A. (2005). Influence of minced pork and rind ratios on physico-chemical and sensory quality of Nham–a Thai fermented pork sausage. Meat science. 69:355-362.

Visessanguan, W., Benjakul, S., Riebroy, S. and Thepkasikul, P. (2004a). Change in composition and functional properties of proteins and their contributions to Nham Characteristics. Meat Science. 66:579-588.

Visessanguan, W., Benjakul, S., Smitinont, T. Kittikun, C. and Panya, A. (2004b). Influence of minced pork and rind ratios on physico-chemical and sensory quality of Nham – a Thai fermented pork sausage. Meat Science. 69:355-362.

Yang, H. S., Hwang, Y. H., Joo, S. T. and Park, G. B. (2009). The physicochemical and microbiological characteristics of pork jerky in comparison to beef jerky. Meat science. 82:289-294.

Zhao, C., Zhao, X., Lu, Z., Huang, J., He, S., Tan, H. and Liu, D. (2016). Production of fermented pork jerky using *Lactobacillus bulgaricus*. LWT-Food Science and Technology. 72:377-382.

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