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Original Article

Effects of dried tomato waste powder levels on lycopene content, lipid oxidation, color, antioxidant activity, and sensory properties of frankfurter sausage made from Thai native beef

Sarong So[1], Suthipong Uriyapongson[1*], and Juntanee Uriyapongson[2]

[1] *Department of Animal Science, Faculty of Agriculture, Khon Kaen University, Mueang, Khon Kaen, 40002 Thailand*

[2] *Department of Food Technology, Faculty of Technology, Khon Kaen University, Mueang, Khon Kaen 40002, Thailand*

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Abstract

The influence of dried tomato waste powder (TWP) on lycopene content, lipid oxidation, antioxidant activity, color, and sensory properties of frankfurter sausage made from Thai native beef was studied. The levels of TWP and storage time were studied and assigned according to a 6x3 factorial arrangement in a completely randomized design. The frankfurter sausage was produced with six levels of TWP: 0%; 1%; 2%; 3%; 4%; and 5%. Data collection of all variances was performed at day 1, day 7, and day 14 of storage. The results showed that adding TWP significantly decreased lightness ($P<0.01$) but significantly increased redness, yellowness, hue angle, and chroma ($P<0.05$). Lycopene content increased significantly ($P<0.05$) as TWP increased. Lipid oxidation increased significantly ($P<0.05$) at a high amount of TWP; however, 1% TWP showed reduced lipid oxidation. Antioxidant activity reduced significantly ($P<0.05$) on day 7 and day 14. The addition of TWP promoted the sensory properties with a higher likeability score. In all, the addition of 2% of dried TWP in frankfurter sausage made from Thai native beef was recommended.

Keywords: tomato, antioxidant, lycopene content, color, sensory property

1. Introduction

Meat products, such as sausages, are a well-known, well-liked, and well-accepted product by consumers around the world. Consumers are recently looking for safe and nutritious meat products. This demand has driven meat processors to develop products that can meet consumer requirements using different techniques that include reducing chemical additives and supplementing the products with natural non-meat ingredients (Desmond, 2006; Guardia, Guerrero, Gelabert, Gou, & Arnau, 2006; Hayes, Desmond, Troy, Buckley, & Mehra, 2006; Resurreccion, 2004; Verbeke, Pérez-Cueto, Barcellos, Krystallis, & Grunert, 2010; Viuda-Martos *et al.*, 2009). Meat product quality is determined by different quality parameters. Since color is one of the main determiners to affect the purchasing decision of consumers (Deda, Bloukas, & Fista, 2007; Fletcher, 2002; Oztan, 2005), nitrite was the first additive to serve this purpose because it gives the meat product a red curing color (Feiner & Feiner, 2016; Govari & Pexara, 2015; Hayes, Canonico, & Allen, 2013; Honikel, 2008; Shimokomaki, Youssef Youssef, & Terra, 2003;). However, nitrite is known as a toxic additive, and a prolonged intake of nitrite in the diet was reported to be linked to different types of diseases (Agency for Toxic Substance and Disease Registry, 2005; New Hampshire Department of Environmental Service, 2006). Natural non-meat ingredients with health benefits have been introduced to replace additives (Bacus, 2006; Kim, Jin, Mandal, & Kang, 2011; Sebranek & Bacus, 2007). In addition, the group of cured meats was moderately recommended for consumption

*Corresponding author
Email address: suthipng@kku.ac.th

because it could be related to the risk of colon cancer and other diseases (Fung, Schulze, Manson, Willett, & Hu, 2004; Kiani, Knutsen, Singh, Ursin, & Fraser, 2006; Song, Buring, Manson, & Liu, 2004; Wolk, 2005; World Health Organization [WHO], 2003;). Lycopene is a red pigment substance in the carotenoid food groups. Lycopene is found in certain types of fruits and vegetables, such as tomatoes, grapes, guava, and watermelon, and may be effective in preventing several health problems (Cohen, 2002; Rao, Ray, & Rao, 2006; Story, Kopec, Schwartz, & Harris, 2010). To reduce the risk of chronic diseases from consuming cured meat in the diet, tomato products are being used to provide health benefits and improve the quality of meat products. Using tomato products to improve the quality of meat products was reported by Hayes *et al.* (2013) who used tomato pulp powder in pork luncheon roll. Calvo, Garcia, and Selgas (2008) added tomato peel powder in dry fermented sausage, Modzelewska-kapituła (2012) studied tomato powder in meatloaf, and Kim *et al.* (2011) added tomato powder in low fat pork sausage. The results showed significantly improved quality of the meat products. However, dried tomato waste powder (TWP) to improve the quality of frankfurter sausage made from Thai native beef has not been studied. Therefore, this study aimed to determine the influence of different levels of dried TWP on the lycopene content, thiobarbituric acid reactive substances (TBARS), color, antioxidant activity, and sensory properties of frankfurter sausage processed from Thai native beef.

2. Materials and Methods

2.1 Dried TWP preparation

Fresh tomato waste (pulp, seed and peel) was obtained from Rosa Agro-Industry located in Nongkhai Province, Thailand. The tomato waste was then cleaned through tap water to separate unclean particles and dried using a hot air oven at 80 °C. After drying, it was ground and passed through an 80 mesh shaking machine to obtain the powder. The dried TWP was vacuum-wrapped in polyethylene packaging and kept in a cool and clean place.

2.2 Frankfurter sausage manufacture

The whole process of frankfurter sausage manufacturing was slightly adapted from Department of Livestock Development (2003). Six treatments were randomly manufactured according to a 6x3 factorial arrangement in a completely randomized design (CRD) with 0%, 1%, 2%, 3%, 4%, and 5% TWP. After manufacturing, the sausages were vacuum-wrapped and kept in a chilled room at 4 °C. During storage, the quality analyses were performed on days 1, 7, and 14.

2.3 Proximate analysis

The chemical compositions of the TWP samples were separately analyzed according to AOAC (2000) for dry matter (DM), ash content, total dietary fiber (TDF), crude protein (CP), ether extract (EE) or fat, and lycopene content.

2.4 Lycopene analysis

The lycopene content analysis was performed according to Taungbodhitham, Jones, Wahlqvist, and Briggs (1998). The amount of lycopene is expressed as mg/100 g of sample and three replications were prepared for each sample.

2.5 Lipid oxidation analysis

TBARS were determined to represent lipid oxidation. The method was performed according to Pfalzgraf, Frigg, and Steinhart (1995) with minor modifications as cited and described by Hayes *et al.* (2006). The amount of malondialdehyde (MDA) was measured by spectrophotometry at 532 nm and calculated according to the formula of Sinnhuber and Yu (1958). The amount of MDA is expressed as mg/kg sample and three replications were performed for each sample according to this formula:

MDA = sample Abs_{532nm} × (1 M TBA chromagen/156000) × [(1 mol/L/M) × (0.0032/weight sample in g) × (72.07 g MDA/mol MDA) × 1000 mg/g) × 1000g/kg

2.6 Color analysis

The color of the frankfurter sausage was analyzed using Ultra Scan XE (Hunter Lab colorimeter *l**, *a**, and *b**). The procedure was modified from the American Meat Science Association (2012). The measurements were randomly performed at four locations on the sliced sausage, and the values of lightness (L*), redness (a*) and yellowness (b*) were recorded. The a* and b* values were used for further calculation of Hue angle (h^o) and Chroma (H) value.

2.7 Antioxidant activity analysis

The DPPH radical scavenging activity test was performed to measure the antioxidant capacity, and the procedure was modified as described by Leong and Shui (2002). The DPPH radical scavenging was expressed as mg of Trolox standard per 100 g of sample. The 2, 2`-azinobis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS) radical scavenging test was performed to validate the DPPH method according to the method of Stratil, Klejdus, and Kubáň (2006) with minor adaptations.

2.8 Sensory properties evaluation

Hedonic tests were performed to evaluate the sensory properties. The procedure and scoring scale were presented according to Eyiler and Oztan (2011) using 30 panelists. The test was performed during 1 day and the panelists were randomly served cooked sausage.

2.9 Statistical analysis

Statistical analyses were applied to the collected data for lycopene content, lipid oxidation, antioxidant activity, and color using the 6x3 factorial arrangement in CRD. An orthogonal polynomial was applied to study the trend effect of

the TWP level. One-way ANOVA in complete randomize block design was used to analyze the sensory evaluation data. Duncan's multiple range test was applied for different means of treatments using SAS version 9.

3. Results and Discussion

3.1 Proximate analysis

The chemical components of the dried TWP, that include DM, ash, TDF, CP, EE or fat percentage, and lycopene content, are shown in Table 1. The TWP sample had 8.08% DM, 2.39% ash, 57.53% TDF, 18.08% CP, 1.94% fat, and 113.2 mg/100g lycopene. Under this study, the TWP sample had low fat content (1.94%) and high TDF (57.53%), and lycopene content (113.2 mg/100g) which indicated healthy proportions in the sausage product as desired by consumers. Increased fiber food consumption contributes to a healthy life. Makki, Deehan, Walter and Backhed (2018) stated that fiber consumption helps preserve gut ecology and regulate macronutrients and host physiology. In addition, Jha, Singh and Prakash (2017) said that dietary fibers potentially affect the immune system, bacterial enzyme degradation, water retention capacity, organic materials absorption, and cation exchange ability. Furthermore, it is recommended that adults consume dietary fibers in the daily amounts of 25 g for women and 38 g for men. Furthermore, it has been widely reported that the intake of lycopene from tomato and tomato products has positive effects on human health (Costa-Rodrigues, Pinho, & Monteiro, 2018a; Costa-Rodrigues, Pinho, & Monteiro, 2018b). The data from the current study showed that the CP content in the TWP (18.08%) was about 62% higher compared to the findings of Salem (2013) who found 11.17% CP in tomato peel.

Table 1. Chemical composition of dried tomato waste powder samples.

Chemical composition (db)	Constituents					
	DM (%)	Ash (%)	TDF (%)	CP (%)	EE (%)	Lycopene (mg/100 g)
Dried tomato waste powder	8.08	2.39	57.53	18.08	1.94	113.2

db = dry weight basis, DM = dry matter, TDF = total dietary fiber, CP = crude protein, EE = ether extract (Fat)

3.2 Lycopene content

The results of the lycopene content in the frankfurter sausage are shown in Table 2. The interaction effect between TWP levels and storage time was not significant (P>0.05) which indicated that the lycopene content was independently influenced by the TWP levels and storage time. The frankfurter sausage contained 1.26–3.12 mg of lycopene. The concentration of lycopene increased significantly (P<0.01) as the levels of TWP increased. The storage time significantly decreased the lycopene concentration (P<0.01). The addition of TWP from 1% to 5% linearly and significantly increased the lycopene content of the sausage (P<0.01). Toor and Savage (2005) reported that 48% of the total lycopene of three cultivars was from the skin and pulp. Tomato products were the main sources of the lycopene compound (Toor & Savage, 2005). This present study agreed with Eyiler and Oztan (2011) who used different levels of tomato powder in frankfurters to increase the lycopene concentration. Wimontham and Rojanakorn (2016) indicated that the lycopene content increased as the amount of gac aril powder increased. Modzelewska-kapituła (2012) used tomato powder in meatloaf and García, Calvo, and Selgas (2009) studied beef hamburger enhanced with dry tomato peel. Under this current study, the lycopene content in the final product was lower by 1%–1.5% compared to the reported contents by the authors mentioned above. In Poland, the average lycopene consumption was 4.9 mg/day (Hamulka & Wawrzyniak, 2011) which indicated that an intake of 100 g of frankfurter sausage with 5% TWP would contribute approximately 4 mg of lycopene to the diet of the consumers. Rao and Shen (2002) stated that a daily intake of 5–7mg of lycopene could prevent oxidative stress and diseases. However, the lycopene content was significantly reduced during storage time (P<0.01). A similar result was found by Li *et al.* (2018). The lycopene loss was due to light and exposure to oxygen. Lee and Chen (2002) reported that 94% of the lycopene was lost when dissolved in hexane and exposed to illumination that ranged from 200 to 300 lux which caused loss of all trans-isomers and unstable cis-isomers.

3.3 Lipid oxidation

A non-significant difference in the interaction effect between the TWP levels and storage time on the TBARS value was found (P>0.05). The effect of TWP on lipid oxidation during storage is shown in Table 2. The TBARS values ranged from 0.18 to 0.20 mg MDA/kg. A non-significant effect of TWP on the TBARS values was found in the frankfurter sausages (P>0.05). However the TBARS values increased as the level of TWP increased. The TBARS values were higher in frankfurter sausage with TWP compared to the control. The results showed that the addition of more than 2% of TWP energized the oxidation reaction, but TWP at 2% was more effective against the oxidation process. The addition of TWP in the sausages containing curing salt (nitrite and nitrate as components) showed a pro-oxidant effect compared to the control sausages that contained only the curing salt. The increase of TBARS in meat products containing the natural antioxidant and nitrite was reported (Lin *et al.*, 2011; Hayes *et al.*, 2013; Uearreeloet & Konsue, 2016). Another reason for the negative effect of TWP on the increased TBARS values was due to the high amount of flavonoids and phenolic compounds presented in different fractions of the tomatoes (Toor & Savage, 2005). The fatty acid effect on increased lipid oxidation was studied (Buckley *et al.*, 1989). Lycopene (20 μg/mL) with triglyceride showed increased oxidation (Haila, Lievonen, & Heinonen, 1996). In meat products that contained MDA higher than 2 mg/kg, the samples had an unpleasant flavor (Greene & Cumuze, 1981). The frankfurter sausages had TBARS values that did not exceed 0.4 mg MDA/kg over 14 days of storage which indicated less rancidity of the product.

Table 2. Effects of dried tomato waste powder levels on TBARS, lycopene, DPPH, and ABTS of frankfurter sausage made from Thai native beef during storage at days 1, 7, and 14.

%TWP	Storage time	TBARS	Lycopene	DPPH	ABTS
0%	Mean	0.19	-	35.28^{A}	19.64^{B}
	1 day	0.19	-	44.15^{a}	20.11
	7 days	0.19	-	30.92^{b}	20.70
	14 days	0.20	-	30.76^{b}	18.10
	Contrast	ns	-	*l, q*	ns
1%	Mean	0.20	1.26^{C}	33.76^{BC}	20.85^{AB}
	1 day	0.19	2.36^{a}	43.67^{a}	22.06
	7 days	0.21	1.08^{b}	28.81^{b}	18.71
	14 days	0.20	0.35^{b}	28.81^{b}	21.80
	Contrast	ns	*l*	*l, q*	*q*
2%	Mean	0.18	1.23^{C}	35.94^{A}	22.73^{A}
	1 day	0.20	2.28	43.97^{a}	27.85^{a}
	7 days	0.15	1.15	31.81^{b}	21.61^{b}
	14 days	0.20	0.27	32.03^{b}	18.72^{b}
	Contrast	ns	ns	*l, q*	*l*
3%	Mean	0.20	1.88^{B}	34.95^{AB}	18.87^{B}
	1 day	0.20	3.41^{a}	42.55^{a}	18.61
	7 days	0.20	1.77^{b}	31.35^{b}	19.35
	14 days	0.20	0.45^{c}	30.96^{b}	18.64
	Contrast	ns	*l*	*l, q*	ns
4%	Mean	0.19	2.45^{B}	33.03^{C}	22.45^{A}
	1 day	0.19	4.23^{a}	40.34^{a}	19.80^{b}
	7 days	0.19	2.36^{b}	29.59^{b}	28.11^{a}
	14 days	0.20	0.77^{c}	29.16^{b}	19.43^{b}
	Contrast	ns	*l*	*l, q*	*q*
5%	Mean	0.20	3.12^{A}	33.69^{BC}	22.37^{A}
	1 day	0.19	4.70^{a}	41.25^{a}	20.06
	7 days	0.21	3.59^{a}	29.87^{b}	20.38
	14 days	0.21	1.06^{b}	29.94^{b}	26.69
	Contrast	ns	*l*	*l, q*	ns
SEM	%TWP	0.031	0.788	3.730	1.864
	d storage	0.031	0.527	0.855	1.975
	%TWP x days stored	0.034	0.283	0.605	0.969
P-value	%TWP	0.923	<0.001	0.001	0.002
	Days stored	0.869	<0.001	<0.001	0.349
	%TWP x days stored	0.992	0.178	0.262	<0.001

SEM: standard error of mean

^{abc} Means within column within dried tomato waste powder levels supplementation having superscript letter were different at P<0.05

^{ABC} Means within the same column for dried tomato waste level having different superscript letter were different at P<0.05

L, q: Within the column, the effect of dried tomato waste powder for each storage day was linear and quadratic, respectively, at P<0.05

3.4 Color

A non-significant interaction effect was found between the TWP levels and storage time on the color properties (P>0.05). The storage time and TWP levels independently influenced the color properties of the frankfurter sausage. A significant difference in color properties was influenced by the addition of TWP (P<0.01) (Table 3). The lightness of the sausage containing TWP was lower than the control. The addition of TWP significantly decreased the lightness of sausage (P<0.01). A reduction in the lightness of sausage containing TWP was previously reported by Kim *et al.* (2011) and Hayes *et al.* (2013). The reason was due to the carotenoid pigment in the TWP. The results agreed with Parsi, Ebrahim Hosseini, Mahdi Seyedein and Behmadi (2014) who studied the effect of rice starch and tomato peel powder and found that the lightness value had reduced about 5% in sausage containing the rice starch and tomato peel powder; however, the reported results were still lower than the results of the present study. The redness increased linearly as the TWP increased by 2% and 3% with an increase in storage time. The results were similar with previous findings that found an increase in redness for sausage containing tomato powder (Modzelewska-kapituła, 2012; Calvo, Garcia & Selgas, 2008). Also, the yellowness increased significantly as the addtion of TWP increased (P<0.01). Similar results were reported by Eyiler and Oztan (2011) and García, Calvo, and Selgas (2009). The increase in redness and yellowness along with reduced lightness of the processed meat containing tomato products could be explained by the addition of high amounts of TWP (Candogan, 2002; Martínez-Valverde, Periago, Chesson, & Provan, 2002; Periago *et al.*, 2009). The addition of TWP significantly increased the Hue angle and Chroma values of the sausage (P<0.01). The reasons were explained by Candogan (2002) and Deda *et al.* (2007). The study pointed out that the color properties of the sausage were improved with the addition of TWP.

Table 3. Effect of dried tomato waste powder (TWP) levels on color property (L*, lightness; a*, redness; b*, yellowness; h°, Hue angle; C*, Chroma) of frankfurter sausage made from Thai native beef during storage at days 1, 7, and 14.

%TWP	Storage time	L*	a*	b*	h°	C*
0%	Mean	67.19^{A}	15.84^{C}	15.94^{C}	1.74^{D}	23.12^{F}
	1 day	67.18	16.39	16.30	1.76	23.38
	7 days	67.42	15.86	15.86	1.70	23.03
	14 days	66.99	15.27	15.65	1.77	22.96
	Contrast	ns	ns	ns	ns	ns
1%	Mean	65.95^{B}	17.20^{B}	19.68^{B}	2.60^{D}	26.83^{E}
	1 day	66.34	17.73	19.85	2.56	26.77
	7 days	65.57	17.08	19.54	2.71	26.82
	14 days	65.93	16.78	19.67	2.52	26.90
	Contrast	ns	ns	ns	ns	ns
2%	Mean	64.44^{C}	17.42^{B}	21.59^{B}	3.91^{C}	28.82^{D}
	1 day	64.55	17.85^{a}	21.49	3.90	28.97
	7 days	64.71	17.36^{b}	21.54	3.63	28.82
	14 days	64.07	17.05^{b}	21.72	4.21	28.67
	Contrast	ns	*l*	ns	ns	ns
3%	Mean	64.36^{C}	18.20^{B}	24.38^{A}	6.04^{B}	31.69^{C}
	1 day	64.64	18.22	24.14	5.78	31.73
	7 days	64.49	18.31	24.65	6.29	31.74
	14 days	63.95	18.07	24.37	6.06	31.59
	Contrast	ns	*l*	ns	ns	ns
4%	Mean	61.73^{D}	19.49^{A}	25.46^{A}	4.13^{C}	33.63^{B}
	1 day	61.95	19.48	25.43	3.84	33.49
	7 days	61.83	19.46	25.24	4.51	34.33
	14 days	61.40	19.53	25.72	4.04	33.08
	Contrast	ns	ns	ns	ns	ns
5%	Mean	61.77^{D}	19.26^{A}	26.58^{A}	8.49^{A}	34.39^{A}
	1 day	61.89	19.62	26.44	9.61	34.44
	7 days	62.30	19.38	26.78	8.13	34.46
	14 days	61.12	18.77	26.51	7.73	34.28
	Contrast	ns	ns	ns	ns	ns
SEM	%TWP	0.747	5.569	1.222	0.564	0.321
	Storage days	1.388	0.915	2.479	1.437	2.369
	%TWP x storage days	0.834	0.617	1.405	0.594	0.331
P-value	%TWP	<0.001	<0.001	<0.001	<0.001	<0.001
	Storage days	0.499	0.217	0.999	0.867	0.300
	%TWP x storage days	0.999	0.997	1.000	0.728	0.752

SEM: standard error of mean
[ab] Means within column within dried tomato waste powder levels supplementation having superscript letter were different at P<0.05
[ABCDEF] Means within the same column for dried tomato waste level having different superscript letter were different at P<0.05
l: Within the column, the effect of dried tomato waste powder for each storage day was linear and quadratic, respectively, at P<0.05

3.5 Antioxidant activity

The antioxidant activities of TWP in the frankfurter sausage are shown in Table 2. A non-significant interaction was found between the main factors on DPPH radical scavenging (P>0.05). The storage time and TWP levels were independently affected by DPPH activity. The addition of TWP significantly reduced the DPPH activity and indicated a quadratic trend (P<0.01). A reduction of the DPPH activity showed an excellent ability of free radical trapping. The highest DPPH activity of 35.94 mg was found with the addition of 2% TWP. The results agreed with Kim *et al.* (2013) and Padayatty *et al.* (2003). A decrease in the antioxidant activity in meat products containing tomato product was reported (Ismail, Lee, Ko, & Ahn, 2008; Jia, Kong, Liu, Diao, & Xia, 2012; Radha krishnan *et al.*, 2014). The phenolic compounds could work on the inactivation of free radicals (Pokorny, 2001). Therefore, TWP could be used as an antioxidant to reduce cell and tissue damage by free radicals. The ABTS scavenging was associated with DPPH; however, the results were lower compared to DPPH scavenging and were lower as the amount of TWP increased (Table 2). Storage time and TWP levels dependently influenced ABTS activity (P<0.01). Increasing the levels of TWP from 1% to 4% produced a significant quadratic trend of the ABTS activity (P<0.01). The reasons for the decreased ABTS radical scavenging were not different from the DPPH radical scavenging. Hydrophilic antioxidant activity is related to the total phenolic compounds present in tomato fiber which serves as an antioxidant function when hydrolyzed with vitamin C (Garcia-Alonso *et al.*, 2009; Periago *et al.*, 2009).

3.6 Sensory evaluation

Significant differences were found in the mean values of color, taste, texture, appearance, and overall likeability scores of the frankfurter sausages (P<0.05) (Table 4). The color score was significant in both within and between

Table 4. Effect of dried tomato waste powder (TWP) levels on sensory properties of Frankfurter sausages (n=30).

%TWP	Likability score of sensory properties					
	Color[/1]	Taste[/1]	Texture[/1]	Appearance[/1]	Odor[/1]	Overall likability[/1]
0	2.80[b]	3.26[ab]	3.33[ab]	2.86[c]	2.96	3.30[b]
1	3.03[b]	3.46[ab]	3.56[a]	3.40[ab]	3.13	3.60[ab]
2	3.66[a]	3.56[a]	3.80[a]	3.76[a]	3.40	3.76[a]
3	3.56[a]	3.00[bc]	3.06[bc]	3.40[ab]	3.40	3.26[b]
4	3.10[b]	2.60[c]	2.46[d]	3.26[bc]	3.03	2.73[c]
5	3.56[a]	2.53[c]	2.80[cd]	3.63[ab]	3.16	3.16[b]
P-Value	<0.01	<0.01	<0.01	<0.01	0.26	<0.01

[abcd] Means within column of TWP levels addition having superscript letter were significant at P<0.05
[/1] Likability score: 1= dislike very much, 2= dislike moderately, 3= neither like nor dislike, 4= like moderately, 5= like very much

groups. As the addition of TWP increased, higher color likeability scores were obtained. The results showed that 2% TWP provided the highest likeability score for taste, texture, appearance, and overall likeability. The results agreed with a study by Eyiler and Oztan (2011) on higher color likeability scores of frankfurters; however, Hayes *et al.* (2013) showed lower color acceptability scores of pork luncheon roll with 3% tomato peel power. Kim *et al.* (2011) showed lower color acceptability scores of low fat pork sausage with 1.5% tomato powder which was similar to Modzelewska-kapituła (2012). This was possibly due to the color of carotenoid compounds, especially lycopene that affected the visual appeal. Odor was not significant with the addition of TWP in the same amounts. The author concludes that the addition of TWP at 2% obtained the highest likeable scores for all sensory attributes of the frankfurter sausage made from Thai native beef.

4. Conclusions

Adding TWP to frankfurter sausage made from Thai native beef affected lightness (L*), redness (a*), and yellowness (b*), Hue angle and Chroma, and antioxidant activity in terms of free radical scavenging, lipid oxidation, and lycopene content. The TWP reduced lightness, but increased redness, yellowness, Hue angle and Chroma, lycopene content, and lipid oxidation. Adding TWP at 1% reduced lipid oxidation. Antioxidant activity, DPPH, and ABTS scavenging were low with the addition of TWP. Sensory properties showed higher likeability scores in terms of color, taste, texture, appearance, and overall likeability. A level of TWP at 2% is recommended for frankfurter sausage made from Thai native beef.

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