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Research and development of the healthy ready-to-eat strip Chinese sausage

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Abstract The development of healthy ready-to-eat strip Chinese sausage products was investigated. The results showed that the cellulose gel with 25 % w/w of fat and glycerine with 60 % w/w of sucrose has no significant differences in redness (a^*), yellowness (b^*), texture (firmness and toughness), and sensory score (appearance, color, taste, flavor and overall liking) compared to the control sample ($p \geq 0.05$). However, the product texture score was lower than the control sample ($p < 0.05$). Secondly, the product shelf life in the vacuum-packed was studied with accelerated shelf-life testing (AST) at 35 and 45 ℃ for four weeks. Throughout the storage period, the water activity was 0.66-0.68, and the TBARS value was 0.13-0.21 mg malonaldehyde/kg sample. The results suggested that the product with 25 % cellulose gel (w/w of fat) and 60 % (w/w of sucrose) glycerine, vacuum packed in a nylon bag (per piece) and topped with a polyethylene bag (5 pieces/pack) stored at room temperature (28±2 ℃) for two months form Q10 calculation. Finally, the final product had shown high sensory scores in all attributes. In addition, 76.47 % of a consumer decided to purchase the product.

Keywords: Accelerated shelf life testing, Chinese sausage, Fat replacer, Humectant, TBARS

Introduction

Chinese dry sausage is a coarsely ground traditional meat product that has gained widespread popularity among customers due to its distinct flavor and taste. That, on the other hand, cannot be consumed right once; it must be cooked first, either by frying or grilling. Fat oxidation is caused by more than 30% of the fat in the formula, which is one of the major causes of bad odor in the product. Lipid oxidation and hydrolysis are the main causes of flavoring in Chinese dry sausage, producing more than 80% of the volatile flavoring agent. Because animal fats contain saturated fatty acids and high cholesterol, consumers are at risk for obesity-related conditions such as hypertension, coronary heart disease, and coronary artery disease. (Ozvural and Vural, 2008). More than 41 million people die each year from non-communicable diseases

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(NCDs), accounting for 71 percent of all deaths worldwide, with 15 million individuals dying prematurely between the ages of 30 and 69 years; over 85 % of these "premature" deaths occur in low- and middle-income countries. Furthermore, the amount of free water in the product (water activity: a_w) is a significant element in food deterioration caused by microbes. As a result, compounds that lower water content in food or humidifiers (a material added to products to bond with water and control the product's independent water content) have been introduced. Furthermore, rising consumer demand for meat products has motivated researchers to look for novel ways to improve the quality of these items, using both functional substances and technology (Dom ńguez *et al.*, 2017). In general, appearance affects consumers' purchasing decisions first due to study the effects of product changes during storage. One of the most widely accepted models for predicting shelf life using Q_{10} that study accelerated shelf life testing in various temperature conditions.

Human existence has changed dramatically in recent years as a result of ongoing societal development that has influenced daily living, such as the size of smaller families and the presence of more individuals working outside the home. Moreover, technological advancements have had an immediate impact on customer behavior due to the simplicity with which food innovation may be developed, making ready-to-eat meals feature indistinguishable from freshly made meals. There are a range of novelty items available, which provide greater convenience for consumers in a hurry, causing them to consume more ready-to-eat meals. Ready-to-eat meals (RTE) have made it relatively easy to obtain food, resulting in a continually rising market throughout time (Olsen *et al.*, 2010). In today's society, the term "quick" can refer to a person's lifestyle shift toward a faster pace of living, therefore food preparation must be more convenient as well. (Costa *et al.*, 2007).

The goal of this study was to develop a ready-to-eat strip of healthy Chinese sausage that uses fat alternatives and an independent water lowering agent (humectant) to minimize fat and sugar content while maintaining the unique texture and taste of Chinese sausage products.

Materials and methods

Chinese sausage preparation

Pork hip and back fat were obtained from local meat vendors (Talaad Thai market, Pathum Thani, Thailand) and transported to Thammasat University's meat science laboratory on ice. Connective tissue and external fat were removed from the lean tissue before it was chopped into appropriate size pieces and ground through a 5 mm plate. Before making Chinese sausage, it was placed the product in the freezer at -18 ℃ until the temperature reaches to -2 to -4 ℃. Cellulose powder (DKSH Limited, Thailand) is mixed with canola oil and cold water in a ratio of 2:20:78, then blended for 1 minute with a Kitchen Aid until all ingredients were homogeneous, then chilled for an hour at 4 ±2 ℃ before making Chinese sausage.

Processing of Chinese sausage

The chinese sausage were prepared with mined pork hip of 59.834%, the mined back fat of 16.750 %, sugar 20.757 %, prague powder (salt with sodium nitrite) 1.220 %, erythorbic acid 0.170 % and mixed spices 1.269%. There were five formulations of back fat partly which is substituted by cellulose gel and sugar partly is substituted by glycerine, including control (non substitutes), cellulose gel, and glycerine (25% and 50% w/w), cellulose gel and glycerine (25% and 60% w/w), cellulose gel and glycerine (50% and 50% w/w) and cellulose gel and glycerine (50% and 60% w/w) as shown in Table 1. The meat is mixed from each treatment pour into a drying height tray 0.7 cm at 60 ℃ for 12 hours, then dried in tray at 85 ℃ for 2 hours. It brought to desiccate and cut to dimension of 4.3x8.5 cm (width x length), then vacuum packed in a nylon bag (per piece).

Accelerated shelf life test

The products vacuum is packed in a nylon bag (per piece) and topped with a polyethylene bag (5 pieces/pack), as shown in Figure 3, with accelerated shelf life testing (ALST) at 35 ℃ and 45 ℃ (50% Relative Humidity) for 4 weeks. The products were selected for the analyses of texture, water activity and color sensory microbial properties. Then sensory characteristics after the designated storage periods were week 1, 2, 3 and 4) which calculated the shelf life at lower temperatures for prediction using Q_{10} values (Plahar *et al.*, 2003).

$$Q_{10} = \frac{\text{shelf life at temperature } T_1}{\text{shelf life at temperature } T_1 + 10^{O}C}$$

$$Q_{10}^{\triangle/10} = \frac{\text{shelf life at temperature } T_1}{\text{shelf life at temperature } T_2}$$

$\triangle$ = Difference Between T_1 and T_2

Texture-profile analysis

The texture-profile analysis (TPA) of the product was used TA-XT Plus Texture Analyser (Stable Micro System, English). Texture analysis was performed under the following the methods of cutting force of hot dogs using a Warner-Bratzler Blade Blade Set (HDP/BS) using 25kg load cell Heavy Duty Latform (HDP/90) conditions: pre-test speed 2.0 mm/s, test-speed 2.0 mm/s, post-test speed 10.0 mm/s and distance 30 mm. Values of firmness (kgf) and toughness (kgf.sec) were determined for the sample 4.3 cm width x 8.5 cm length.

Colour measurement, water activity (a_w) and Analysis of thiobarbituric acid reactive substances value (TBARS)

Color of the product was measured by Color Flex (Hunter Lab, CX2687, U.S.A) following the methods of Chen *et al.* (2019). Sampling were cut into diameter (3.0 cm width x 3.0 cm length). Water activity (aw) was measured with a water activity meter (Aqua Lab, CX2, U.S.A.). TBARS sent for inspection with the Foundation for Industrial Development National Food Institute (Bangkok, Thailand).

Microorganism

The product sent for inspection with the Asia Medical and Agricultural Laboratory and Research Center (Bangkok, Thailand), including Total Plate Count, *Clostridium botulinum*, *Escherichia coli*, Mesophilic Aerobic Sporeformers, Mesophilic Anaerobic Sporeformers, *Staphylococcus aureus*, *Salmonella* spp., and Yeast and Mold (Borch *et al.*,1996).

Sensory

Sensory evaluation was conducted on chinese sausages at room temperature on a 9-point hedonic scale (1 = the least , and 9 = the most), Just about right (JAR) scale (1 = too little, and 5 = too much), 5-point purchase scale (1 = definitely will not buy, 5 = definitely will buy, and eyes sensory (1 = accepted, and 2 = non accepted).

Statistical analysis

The experimental data are shown as the mean ± standard errors (SE), Analysis of variance (ANOVA) with Duncan's Multiple Range test was used to assess the significance of the treatment effects (P < .05) and five formulations batches of chinese sausages using Principal Component Analysis (PCA) by XLSTAT.

Table 1. Formulation of Chinese sausage

Ingredients	**Formulation (%)**				
	Control	**CS1**	**CS2**	**CS 3**	**CS 4**
pork hip mined	59.834	59.834	59.834	59.834	59.834
back fat mined	16.750	12.563	12.563	8.375	8.375
cellulose gel	-	4.187	4.187	8.375	8.375
sugar	20.757	10.379	8.303	10.379	8.303
glycerine	-	10.378	12.454	10.378	12.454
prague powder	1.220	1.220	1.220	1.220	1.220
erythorbic acid	0.170	0.170	0.170	0.170	0.170
mixed spices	1.269	1.269	1.269	1.269	1.269
Total	100.000	100.000	100.000	100.000	100.000

Control = non cellulose gel and non glycerine, CS1 = cellulose gel 25%, glycerine 50%,
CS 2 = cellulose gel 25%, glycerine 60%
CS 3 = cellulose gel 50%, glycerine 50%
CS 4 = cellulose gel 50%, glycerine 60%

Results

Development the healthy ready-to-eat strip Chinese sausage

There were no significant differences in redness (a^*), yellowness (b^*), texture (firmness and toughness) as indicated in Table 2 and Figure 1 when the cellulose gel content was increased by 25 % and the glycerine content was increased by 60 % as indicated in Table 3 and Figure 2, all six attributes were employed to analyze Principal Component Analysis (PCA). Principal component 1 (F1), which includes lightness (L^*), redness (a^*), yellowness (b^*), firmness, and toughness, has a variance of 80.74 %, indicating that the element is associated to sensory qualities. Water activity (a_w) is the second principal component (F2), and it explains 16.62 % of the variance. As illustrated in Figure 2, these two components accounted for 97.37 % of the total variation. Through Varimix rotation of major components between physical and chemical quality ratings, this relationship can be depicted in a biplot diagram. The redness (a^*) of CS1 and CS2 is measured on an average of 13.84 and 14.08, respectively. The fact that Chinese sausage products are red is a desirable characteristic. With an average of 0.72, the control recipe has an impressive attribute of free water content. Firmness and hardness are the most prominent texture features in CS4, with mean values of 10.19 and 66.92, respectively. When the formula is dried, the amount of cellulose in it increases, causing the non-crystalline component to crystallize. Replacement of fat with gel in bigger quantities has an influence on hardness. Similarly, JAR score the consumer had a need for a decreased hardness net score of 51.67 %, as shown in Table 4. Improvements in the formula Pork hip minced 57.970 %, back fat mined 12.560 %, cellulose gel 4.190 %, sugar 8.307 %, glycerine 12.450 %, cool water 1.864 %, prague powder (salt with sodium nitrite) 1.220 %, erythorbic acid 0.170 %, and mixed spices 1.269 % were included in the final product. Pour the meat from each treatment into a 0.7-cm-high drying tray at 60 ℃ for 10 hours, then into a second drying tray at 85 ℃ for 2 hours.

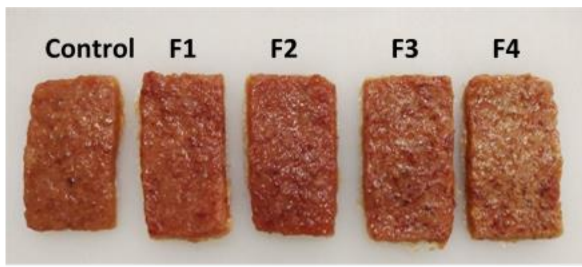


Figure 1. Five formuation of Chinese sausage products

Table 2. Mean and standard deviation of parameters of five formulations of Chinese sausage

Parameters	Formulation				
	Control	**CS1**	**CS 2**	**CS 3**	**CS 4**
a_w	0.722 ±0.01[a]	0.635 ±0.01[b]	0.632 ±0.01[b]	0.627 ±0.00[c]	0.625 ±0.00[c]
Rightness ($L*$)	35.84 ±0.47[e]	37.92 ±0.66[d]	36.96 ±0.95[c]	42.55 ±0.49[b]	43.76 ±0.31[a]
Redness ($a*$)	13.61 ±0.86[a]	13.84 ±0.36[a]	14.08 ±0.52[a]	11.93 ±0.74[b]	10.76 ±0.78[c]
Yellowness ($b*$)	14.19 ±0.77[b]	14.16 ±0.33[b]	14.08 ±0.52[b]	16.05 ±0.34[a]	15.91 ±0.46[a]
Firmness (kgf)	8.82 ±0.33[b]	8.55 ±0.54[b]	8.68 ±0.32[b]	9.79 ±0.70[a]	10.19 ±0.89[a]
Toughness (kgf .sec)	60.01 ±5.26[bc]	51.23 ±6.63[d]	57.04 ±5.40[cd]	64.07 ±6.43[ab]	66.92 ±9.20[a]

[a–d] Different superscripts within a column denote significant differences ($P \leq 0.05$)

Table 3. Factor loadings of physical and chemical properties of Chinese sausage samples after Varimax rotation on principal component analysis (PCA)

Parameters	Formulation			
	F1	F2	F3	F4
a_w	0.249	0.733	0.015	0.003
Rightness (*L**)	0.950	0.037	0.013	0.000
Redness (*a**)	0.954	0.012	0.021	0.013
Yellowness (*b**)	0.962	0.000	0.000	0.038
Firmness (kgf)	0.981	0.018	0.000	0.001
Toughness (kgf .sec)	0.749	0.198	0.051	0.002
% Variance	80.742	16.624	1.680	0.953

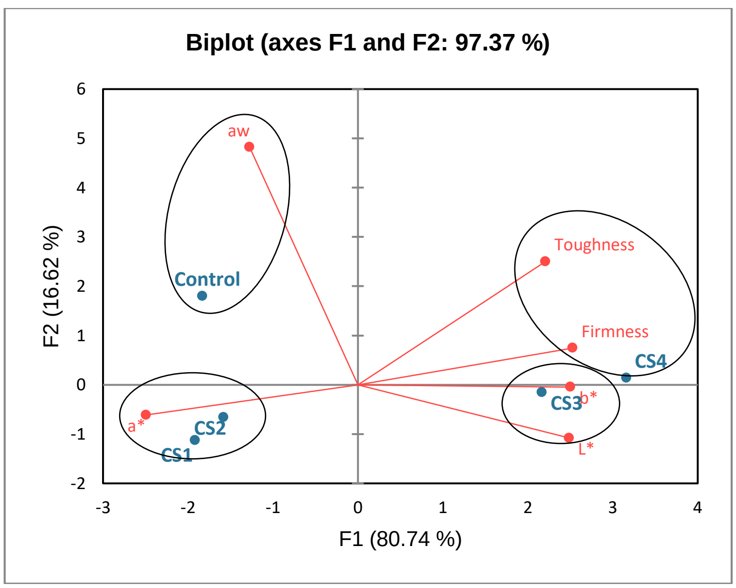


Figure 2. Biplots after Varimax rotation of physical and chemical properties for Chinese sausage

Table 4. Mean and standard deviation of consumer acceptance score of three formulations of Chinese sausage (n=60)

Formulation	Attribute					
	appearance[ns]	**colour**[ns]	**texture**	**taste**[ns]	**flavour**[ns]	**overall**[ns]
Control	13±1.55	6.25±1.59	6.12±1.74[a]	5.82±1.94	5.78±1.85	6.10±1.69
CS2	5.93±1.81	5.93±1.77	5.45±1.81[b]	5.58±1.62	5.58±1.83	5.68±1.76
p-value	0.269	0.133	0.008	0.356	0.467	0.073

Significant difference was considered at $p \leq 0.05$

Table 5. Degree of change scale (just about right scale) of the CS2

Parameters	Decrease itvery much	Decrease it	Leave it as it is (JAR)	Increase it	Increase it very much	Net effect
Texture	1.67	58.33	31.67	8.33	-	-51.67
Saltness	1.67	13.33	66.67	18.33	-	-3.33
Sweetness	-	8.33	65.00	25.00	1.67	-18.34
Flavour	1.67	30.00	38.33	30.00	16.67	-15.00

Accelerated shelf life test, Analysis of thiobarbituric acid reactive substances value (TBARS)**, **Microorganism, Sensory and purchase decision

Firstly, throughout the storage period under both 35^{O}C and 45^{O}C for 4 weeks that water activity in range 0.666 to 0.688 and had a TBARS value in the range was 0.13-0.21 mg malonaldehyde/kg per sample including textures were similar throughout the storage period at both temperatures as shown in Table 6. Secondly, every week there is a color acceptance test with 35 consumers which 35^{O}C the color of the chicnese sausage in the 4th week is also accepted by 3 consumers while at 45^{O}C 8 consumers only accepted the color of the product for a week as shown in Table 7. Then, the predicted shelf-life of the product at the different temperatures, based on the calculated Q_{10} values for both 2 temperature the date consumer accepts the color of the product; Shelf life at 28^{O}C = Shelf life 35^{O}C X $Q_{10}^{(\triangle/10)}$ by $T_{(35^{o}C)}$ = 28 days, $T_{(45^{o}C)}$ = 7 days, $\triangle T$ = 35-28 = 7 and Q_{10} = 28/7 = 4 equals 74 days. This is for food safety from the uncertainty of the results of commercial experiments. The shelf life must be reduced by 20 percent of the total number of days. The product could be stored at room temperature (28±2 ℃) for at 2 months from calculation Q_{10}. In addition, storage at ambient temperature for 1 month found that the microorganisms were within the Thai Community Product Standard Dried Pork Sausages as shown in Table 8. Finally, the healthy ready-to-eat strip Chinese sausage products has sensory scores higher in all attribute and consumer who made the decision to purchase the product 76.47 percent as shown in Table 9.

Figure 3. Packaging of the strip Chinese sausage products during storage

Table 6. Changes in physical and chemical properties during at storage at 35^{O}C and 45^{O}C for 4 weeks

Week	Temperatures (^{O}C)	a_w	TBARS (mg/kg)	Firmness (kg_f)	Toughness (kg_f.sec)
0		0.666±0.00	0.13	7.169±0.12	52.057±0.51
1		0.672±0.01	0.14	7.290±0.09	49.735±1.51
2	35	0.669±0.00	0.21	7.337±0.13	50.290±0.10
3		0.671±0.00	0.18	7.207±0.15	48.526±1.06
4		0.686±0.00	0.18	7.204±0.00	45.099±0.83
0		0.666±0.00	0.13	7.169±0.12	52.057±0.51
1		0.676±0.00	0.14	7.287±0.08	51.343±0.57
2	45	0.671±0.00	0.19	7.342±0.01	50.827±0.53
3		0.676±0.00	0.20	7.308±0.18	47.622±1.46
4		0.688±0.01	0.18	7.380±0.83	46.0.46±0.43

The results were expressed as mean values ± standard error.

Table 7. Changes in colour during at storage at 35^{O}C and 45^{O}C for 4 weeks

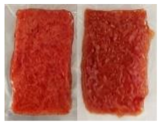
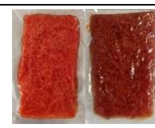
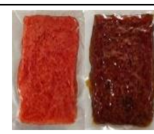
Week	Storage (35^{O}C)	Answer		Storage (45^{O}C)	Answer	
1	 Control Sample	Accepted	32	 Control Sample	Accepted	8
		Non accepted	3		Non accepted	27
2	 Control Sample	Accepted	23	 Control Sample	Accepted	0
		Non accepted	12		Non accepted	35
3	 Control Sample	Accepted	3	 Control Sample	Accepted	0
		Non accepted	32		Non accepted	35
4	 Control Sample	Accepted	3	 Control Sample	Accepted	0
		Non accepted	32		Non accepted	35

Table 8. Changes in microorganisms during at storage at ambient temperature for 30 days

Microorganism	0 Day	30 Days
Total Plant Count (CFU/g)	3.7 X 10^{2}	<10
*Clostridium botulinum** (per g)	Not Detected	Not Detected
Escherichia coli (MPN/g)	<3	<3
Mesophilic Aerobic Sporeformers* (CFU/g)	<10	<1
Mesophilic Anaerobic Sporeformers* (CFU/g)	<10	<10
Staphylococcus aureus (CFU/g)	<10	<10
Salmonella spp (per 25 g)	Not Detected	Not Detected
Yeast and Mold (CFU/g)	<10	<10

Remark :* = Marked Test(s) is/are not Accredited

Table 9. Mean and standard deviation of consumer acceptance score of Chinese sausage. (n=35)

Appearance	Colour	Texture	Taste	Flavour	Overall
6.57±1.76	6.75±1.86	6.39±1.99	6.46±1.92	6.47±2.00	6.65±1.89

Percentage of consumers test

Definitely will buy	Probably	Might or Might not buy	Probably will not buy	Definitely will not buy
4.90	3.92	14.71	57.84	18.63

The results were expressed as mean values ±standard error.

Discussion

Chinese sausage is a traditional product with an unique flavour that has been around for a long time (Wang *et al.*, 1995). Although it has evolved into a more healthy food, the most important factor that consumers consider is the taste, flavor, and appearance to be as close to the original product as possible, because when Chinese sausage products lose their red color, consumers are less likely to accept or purchase them (Suksripisat, 2016). As a result, the development of ready-to-eat strip healthy Chinese sausage products is increasing the optimal cellulose gel 25 percent and glycerine 60 percent content, similar to Suksripisat (2016) study product and storage of ready-to-eat product fat Chinese sausage using technology replace fat with 25 percent cellulose gel, which has a texture similar to the control formula.

As a result, one of the most significant obstacles in the creation of ready-to-eat strip healthy Chinese sausage is the texture and taste of traditional products. It is a food that is good to the health of customers in order to lessen the health risk. Additionally, the target consumers of ordinary formula products transition to consume products that are helpful and have qualities that are acceptable to consumers throughout the shelf life, leading in greater health.

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