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Effects of baking time and temperature on product quality of ready to eat crispy stretched shrimp

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Abstract - Baking conditions play an important role in producing crunchy foods of good quality. Recent studies focus on proper baking conditions for commercial production of ready to eat crispy stretched shrimp, acceptable to consumers. The aim of this study is to evaluate how different baking times and temperatures affect product quality of ready to eat crispy stretched shrimp. Cooked, stretched shrimps were baked at three different temperatures (75°C, 80°C, and 85°C), and three different times (8h, 10h and 12h). Sensory quality assessment, determining the appropriate baking time and temperature for crispy stretched shrimp, was performed with 30 participants, using the hedonic nine-point scale. Results found that baking temperature and time had a significant ($p \leq 0.05$) effect on physical and chemical quality of the product. Higher value of color, hardness, a_w, and moisture was found in conditions of baking stretched shrimp at 80-85°C, with an 8-hour baking time. However, products baked at 80°C, with a 10-hour baking time, were most acceptable, in terms of color, flavor, taste, texture and overall preference. Mean hedonic acceptance ratings (n=100), for overall acceptance of the products baked under this baking condition, were 8.0, indicating a high point. In 100-gram samples, carbohydrate, protein, fat, fiber, cholesterol, and sodium were 34.40g, 47.04g, 3.47g, 2.61g, 0.42g, and 1.06g, respectively. Energy content was 356.99 Kcal per 100 grams. The finding of this study recommends optimal baking conditions for crispy stretched shrimp to be baked at 80 °C for 10 hours. This will, prepare nutritionally rich and organoleptically acceptable product, using stretched shrimp.

Keywords: Baking time, baking temperature, product quality, crispy stretched shrimp

1. Introduction

Thailand is one of the world's major shrimp producers and exporters (Sriboonchitta *et al*., 2001). After export and domestic consumption of fresh/frozen shrimp, the remaining shrimp production is transformed into value added processed foods, which further preserves shrimp as a food and increases alternative menus for consumers. Stretching shrimps, for example, is a new product, created by local knowledge, during routine cooking culture. It is generally known that when shrimp are cooked, their bodies bend. However, in order to increase straightness, as desired in some shrimp dishes, shrimp bodies need to be straightened. This is done, by using heavy weighted objects that forces the body to straighten, then seasoned with salt and sugar, and steamed. Stretched shrimp products recently are becoming a very popular One Tambon, One Product (OTOP), as a locally marketed Thailand creation, able to generate a large amounts of household income (Khumnon & Sriwongkaeo, 2022). Shelf life of stretched shrimp product is about 5 days at ambient temperature, and about 30 days in the refrigerator. However, when cooked shrimp are kept at low temperatures, its meat can become tough and unappetizing (Department of Trade and Industry Torry Research Station, n.d.) This issue can deteriorate marketing and product development.

Baking, a cooking method that uses dry heat in an enclosed space, is typically done in an oven, and usually regarded as the method for preparing ready to eat crispy products. The baking process and techniques are not difficult for making shrimp crispy. Using this method, moisture content of food is evaporated out, so that the amount of water in food is less than 0.6 free water activity (a_w), allowing it to be safe from pathogenic microorganisms, and inhibiting formation of fungal toxins (Erkmen & Bozoglu, 2016). Drying also makes food lighter and reduces volume, a convenience for transportation, consumption or use as a raw material for processing other food products. In order to develop stretched shrimp products that are crispy, it is necessary to know temperature levels inside the oven and appropriate baking times. This study, therefor aims to clarify the influence of baking time and temperature on product quality of ready to eat crispy stretched shrimp. Nutritional composition analysis and sensory acceptability tests were conducted to support the objectives of this study.

2. Materials and methods

2.1 Preparation of seasoned stretched shrimp product

One kilogram of Pacific white shrimp (*Litopenaeus vannamei*), with an approximate size of 10-12 gram each, were prepared, bought from local market in Chanthaburi province. They were cleaned and their rostrum were cut off. Their bodies were stretched and laid out in layers on a stainless-steel sieve, placed in a 60 cm. diameter pot. Condiments, composed of sugar, chili and salt in a ratio of 90:5:5 were sprinkled evenly over each shrimp layer. A weighted object, Mortar, was then placed over the top shrimp layer, to keep shrimp bodies straight. Afterward, the pot was heated, using medium heat, for 45-60 minutes. The shrimp were then cooked, until they turned an attractive orange color.

2.2 Study effects of baking temperature and time on product quality of ready to eat crispy stretched shrimp

2.2.1 Experimental Design

The study focused on determining appropriate baking condition for ready to eat crispy stretched shrimp, using the 3^2 factorials, in a completely randomized design. Cooked stretched shrimp from 2.1 were baked at three different baking temperatures (75°C, 80°C and 85°C) with three different baking times (8, 10 and 12 hours). Selected baking times and temperatures were chosen, based on the results of preliminary experiments. A drying oven with forced convection (Binder, FD240, Germany) was used for baking all shrimp products.

2.2.2 Physical and chemical quality analysis and sensory evaluation

Physicochemical characterization of the products

Hardness of all sample products was measured using a texture analyzer (Lloyd instruments, TAplus, UK). Color was determined by CIE color scales L*, a* and b*, using a lab digital colorimeter (Nippon, ZE-2000, Japan). Water activity (a_w) was determined by the chilled mirror technique, using a water activity meter (AQUA LAB, series 3, USA). Moisture content was determined according to A.O.A.C standard methods (Association of Official Agricultural Chemists, 2010). Total soluble solids content (TSS) was measured using a portable brix refractometer (ATAGO, ATC-1E, Japan). Sodium chloride (NaCl) was measured using a portable salinity refractometer (ATAGO, FG-211, Japan). The analysis included performing triplicate for each sample.

Sensory evaluation

Quantitative descriptive analysis was applied to evaluate sensory quality of the sample products, in terms of color, flavor, taste, texture and overall preference. Thirty untrained panelists were selected to participate in the development of sensory profiles. The samples, labeled with three-digit numerals, were presented monadically to panelists following a complete randomized block design. Hedonic scale (from 1-9) was used, to ensure consistency between panelists, across repeated evaluation.

Nutritional composition and microbial contamination analysis

After creation, the crispy stretched shrimp products were stored at room temperature, for 12 weeks, then examined for nutritional composition and microbial contamination. Carbohydrate, protein, fat, fiber, cholesterol, and sodium content were determined, according to A.O.A.C standard methods (Bacteriological Analytical Manual Online, 2001). The total viable plate count method, knowing and counting the number of viable microorganism present in the sample, was adopted, as described by Bacteriological Analytical Manual (Palka & Duan, 1999). All colonies on Plate Count Agar (PCA) were counted as Total Viable Count (TVA), while yeast and mold counts were obtained from Potato Dextrose Agar (PDA). Analysis required performing four replicates for each sample.

2.3 Consumer acceptance testing

Sensory scores of crispy stretched shrimp products were tested, via consumer acceptance. Consumers (n = 100) were recruited for their willingness to participate in this study. The consumer test was designed using a CLT (central location test) method. The test method incorporated a nine-point hedonic scale (9 = like extremely, 5 = neither like nor dislike, and 1=dislike extremely), for evaluating sensory characteristics of color, flavor, tastes, texture and overall acceptance.

2.4 Statistical analysis

Physicochemical data, were analyzed using a two-way analysis of variance. Sensory data was analyzed using the analysis of variance (ANOVA). Significant difference among treatments was compared using the average values with Duncan's new multiple range test at a confidence level of 95%. All Data was analyzed, using SPSS Statistics for Windows, Version 20 (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp; 2011)

3. Results

3.1 Physicochemical properties of the products from nine baking conditions

A summary of basic physical and chemical quality of different varieties of crispy stretched shrimp is shown in Table-1 and Table-2, having statistically significant differences ($p \leq 0.05$) in all condition.

Table 1. Physical properties of crispy stretched shrimp product, from nine baking conditions

Temperature (°C)	Baking time (hours)	Color			Hardness (N)
		(L*)	(a*)	(b*)	
75	8	53.36±0.41^{b}	13.37±0.63^{a}	27.51±1.54^{d}	17.91±0.52^{c}
	10	51.50±0.16^{c}	12.04±0.15^{b}	32.93±0.45^{a}	17.52±0.65^{c}
	12	53.43±0.51^{a}	11.3±0.22^{c}	28.69±1.40^{c}	18.59±0.35^{c}
80	8	48.16±0.54^{d}	10.55±1.58^{d}	26.76±0.56^{d}	19.85±0.24^{b}
	10	51.04±0.60^{c}	12.75±0.74^{b}	28.16±0.43^{c}	18.77±0.73^{c}
	12	51.26±0.84^{c}	10.79±0.25^{d}	26.28±0.23^{d}	18.38±0.21^{c}
85	8	49.16±0.16^{c}	12.40±1.47^{b}	30.49±0.34^{b}	21.59±0.41^{a}
	10	48.03±1.85^{d}	8.86±0.36^{e}	22.58±0.16^{f}	20.23±0.57^{b}
	12	44.23±0.36^{e}	8.06±0.72^{e}	23.46±0.56^{e}	21.08±0.63^{b}

Note: Different alphabet letters in each column indicate the significant statistical difference ($p \leq 0.05$)
Hunter color values: L = lightness (100 = light, 0 = dark)
a = + show redness, - show greenness
b = + show yellow, - show blueness

From Table 1, it was found that crispy stretched shrimp product color (a* and b*) and texture properties were significantly affected by the main factors of, baking temperature and time, and also their interaction. Redness (a*) and yellowness (b*) value tended to decrease, when baking temperature and time increased. The highest red scale was found in products baked at 75°C and 8 hours; while, the highest yellow scale was found in products baked at 75°C and 10 hours. Lightness was affected by baking time and interaction between baking temperature and time. Crispy stretched shrimp, baked at lowest temperature and longest time, had the highest lightness values. Hardness was more predominant when increasing the baking temperature, with highest values found in products baked at 85 °C and 8 hours.

As shown in Table 2, water activity (a_w) was affected by baking time. Water activity tended to decrease when baking time was increased. Moisture was significantly affected by baking temperature and time, and also by interaction between baking temperature and time. Percentage moisture decreased, when baking temperature and time were increased. TSS (% Brix) was significantly affected by baking temperature and time, and by interaction between baking temperature and time. Crispy stretched shrimp, baked at highest temperature and longest time had the highest TSS. Saltiness was not affected by either baking temperature or time.

Table 2. Chemical properties of the crispy stretched shrimp product from different baking conditions.

Temperature (°C)	Baking time (hours)	a_w	Moisture (% wb)	TSS (% Brix)	NaCl ns (%)
75	8	0.40±0.09^{ab}	10.2±0.86^{a}	20.5±0.42^{d}	18.8±0.53
	10	0.41±0.02^{ab}	8.77±1.20^{b}	22.4±0.20^{c}	18.6±0.40
	12	0.36±0.01^{bc}	6.73±0.67^{d}	24.6±0.20^{b}	18.2±0.2
80	8	0.42±0.02^{a}	8.40±0.58^{c}	22.6±0.20^{c}	18.2±0.2
	10	0.35±0.01^{bc}	6.87±0.89^{d}	24.4±0.40^{b}	18.0±0.00
	12	0.33±0.02^{c}	6.20±0.42^{ef}	26.0±0.15^{a}	18.3±0.42
85	8	0.37±0.01^{abc}	6.90±0.57^{d}	24.4±0.20^{b}	18.5±0.38
	10	0.35±0.01^{bc}	6.23±0.39^{e}	25.9±0.15^{a}	18.7±0.46
	12	0.33±0.01^{c}	6.00±0.54^{f}	26.4±0.26^{a}	18.2±0.50

Note: Mean followed by different letters in the same column differs significantly ($p \leq 0.05$)
ns = not significant different

3.2 Sensory evaluation

Panelist sensory scores, in their evaluation for each product, are shown in Table 3; having statistically significant differences ($p \leq 0.05$) in all condition. Highest scores for color, flavor, taste texture and overall preference, were observed in products baked at 80 °C and 10 hours.

Table 3. Sensory score (n = 30) of crispy stretched shrimp products, baked, using three varying levels of baking temperature and time (mean±SD)

Temperature (°C)	Baking time (hours)	Sensory scores				
		Color	Flavor	Taste	Texture	Overall preference
75	8	6.03±0.56^{de}	6.53±0.73^{c}	6.27±0.74^{b}	6.37±0.62^{c}	4.93±1.01^{e}
	10	6.43±0.68^{cd}	6.33±0.61^{c}	6.33±0.96^{b}	6.67±0.67^{bc}	4.77±1.28^{e}
	12	6.23±0.43^{cde}	6.67±0.76^{bc}	5.53±1.07^{c}	6.80±0.67^{b}	6.17±0.79^{cd}
80	8	6.57±0.99^{c}	6.97±1.10^{b}	6.50±1.21^{b}	6.80±0.10^{b}	5.87±0.99^{d}
	10	7.53±0.63^{a}	7.87±0.73^{a}	8.13±0.78^{a}	7.83±0.53^{a}	8.07±0.74^{a}
	12	6.57±0.73^{c}	6.53±0.73^{c}	6.27±0.74^{b}	6.40±0.62^{c}	6.03±0.56^{cd}
85	8	7.03±0.72^{b}	6.33±0.61^{c}	6.33±0.96^{b}	6.67±0.66^{bc}	6.03±0.56^{cd}
	10	5.96±1.35^{ef}	6.67±0.76^{bc}	5.53±1.07^{c}	6.80±0.67^{b}	6.40±0.62^{c}
	12	5.60±0.86^{f}	7.03±0.72^{b}	6.50±0.73^{b}	6.80±0.61^{b}	7.03±0.72^{b}

Note: Mean followed by different letters in the same column differs significantly ($p \leq 0.05$)

3.3 Nutritional composition and microbial contamination of crispy stretched shrimp product

The final product, accepted by most consumers (using 80 °C with 10-hours baking condition), was then determined for chemical composition and microbial contamination. Results showed that carbohydrate, protein, fat, fiber, cholesterol, and sodium were 34.40g, 47.04g, 3.47g, 2.61g, 0.42g, and 1.06g, respectively. Energy content was 356.99 Kcal per 100 grams. Results found that total bacteria count to be lower than 100 CFU/g, while yeast and mold counts were not found.

3.4 Consumer acceptance of final product

Hedonic ratings (n=100) were obtained for crispy stretched shrimp product samples, using 80°C of baking temperature and 10 hours of baking time. Mean overall hedonic acceptance ratings for the product averaged 8.0 or high point. If this crispy stretched shrimp product was on the market, eighty two percent of consumers expressed their opinion that they would buy it to eat, being of good taste, new and unique. Prices for this product would be acceptable, if around 100 baht per a 100-gram package.

4. Discussion and conclusion

Texture is multi-faceted and tied to consumers' sensory expectations, and may be affected during the baking process. Among the texture characteristics, hardness is often used to determine the freshness of food (Kadam *et al*., 2015). However, it was used to determine the effect of baking process on changes in physical properties of crispy stretched shrimp product. When hardness of shrimp product is different, it requires changed chewing force, and probably has an effect on the texture preference score. This study found that hard-

ness value of shrimp tended to increase as the temperature and duration time of baking increases. However, the texture preference score did not relate with increasing hardness. Highest preference scores for texture were observed in products baked at 80 °C and 10 hours, significantly higher than other baked condition. The increase in hardness of baked shrimps was probably attributed to the thermal shrinkage of shrimp muscle proteins (Martínez-Alvarez *et al.*, 2009; Niamnuy *et al.*, 2007). Shrinkage of shrimp muscle occurred due to shrinkage of myofibrillar proteins and collagen, which denatured and coagulated during cooking (Niamnuy *et al.*, 2007). This might be associated with decreased water activity and moisture of shrimp muscles (after heating) tending to increase the density of shrimp muscle fiber (Johnston *et al.*, 2000).

Moisture loss was generally associated with heat-induced protein denaturation and coagulation during cooking, causing less water to be trapped within the protein structures held by capillary forces (Aaslyng *et al*., 2003; Domínguez *et al*., 2014). Thermal denaturation of proteins and shrinkage of fibre could lead to loss of moisture (Niamnuy *et al*., 2007). When the temperature of muscle was higher than 60°C, the connective tissue network and muscle fibres began to cooperatively shrink longitudinally. The extent of shrinkage increased with increasing temperature, thus causing cumulative water loss during cooking (Tornberg, 2005). Baking shrimp at higher temperatures causes a decrease in moisture content. Similar results were observed in boiled Pacific white shrimps, whereby cooking loss increased when the core temperature of shrimps increased from 65°C to 90°C (Manheem *et al*., 2012).

Shrimp meat color is an indicator of cooked meat doneness, and is an important factor influencing consumer preference (Dai *et al*., 2013). As shown in Table 1, increasing baking temperature and time resulted in significantly decrease in L*, a* and b* values, suggesting that the product showed quite dark and brown. Cooking shrimp by heat, caused the L*, a* and b* values in shrimp to increased (Xu *et al*., 2016). Due to higher temperature causing protein degradation, red astaxantin was released from ovoverdin, resulting in to increase redness of the carapace (Niamnuy *et al*., 2007; Martínez-Alvarez *et al*., 2009). However, in this study it was found that as temperatures increased, L*, a* and b* values decreased. This is because crispy shrimp products are seasoned with sugar. Reactions between sugars and proteins or amino acids, known as the Maillard reaction, lead to the formation of brown products (Knerr *et al.*, 2001). These brown compound causes crispy shrimp products to become darker. The L*, a* and b* value therefore, decrease.

Baking temperature and time has been shown to affect a_w moisture and total soluble solids content. This study found that crispy stretched shrimp, baked at higher temperature and longer time, had a decrease in a_w and moisture content, but TSS increase. Heat causes water to evaporate from food. When the heat is increased, water evaporates more rapidly from the food. This makes impurities in the water remain after evaporation, becoming more detectable. The salty evaluation results are similar to the observations of Panghorn *et al.* (1970) and Lipscomb *et al*. (2016), where temperature had no effect on salt intensity.

In sensory evaluation, analysis of variance indicated significant difference in the preference between the nine treatments. Highest hedonic score of all parameter was found in the product baked at 80°C with 10-hour, with score was around 7, indicating that during sensory testing the product was "liked moderately".

Physical and chemical properties of crispy stretched shrimp using the baking condition at 80 °C and 10 hours showed that the product is decently colored, did not fad compared to the lower temperature baking condition (75 degrees) and did not darken further, in response to higher temperature baking condition (85 degrees). Moreover, at the same temperature level (80 °C), he lightness of product baked for 10 and 12 hours was not different, but the baking time at 10 hours showed redness and yellowness values, higher than 12 hours. This indicates that crispy shrimp baked at condition at 80 °C for 10 hours showed a darker and more vibrant color compared to baked at condition at 80 °C for 12 hours.

In addition, stretched shrimp baked at temperature of 80 °C, have good hardness and toughness. It therefor requires less masticating force than stretched shrimp baked at higher temperatures. Although stretched shrimp baked at 80 °C had a hardness value almost similar to that of 75 °C, the stretched shrimp baked at 75 °C had higher moisture content, indicating that stretched shrimp baked at 75 °C has more viscosity. Based on physical and chemical properties, as mentioned above, stretched shrimp baked at 80 °C for 10 hours has the highest sensory scores, significantly higher than other baking conditions.

After the crispy stretched shrimp product was stored at room temperature for 12 weeks, microbial results indicated that the product met standards of microbiology for Ready-to- eat Food product, as determined by Thai community product standard (Ministry of Industry, 2003).

Results conclude that baking conditions, having a level of 80°C for 10-hours was most acceptable. The final product was highly accepted by consumers, with hedonic acceptance ratings at high point. Minimum microbiology standards for canned food were exceeded.

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