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Formulation and process improvement for chili shrimp paste using sensory evaluation

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Abstract: This study was conducted to improve the formulation of chili shrimp paste (CSP) based on sensory evaluation in terms of acidity, source of acid and coarseness of chili paste and to improve the production process of CSP. The effectiveness of dimethyl dicarbonate (DMDC) as a microbial reduction agent was also evaluated. To produce CSP with different coarseness, a milling machine was used. Two types of preference test were conducted, i.e. ranking and hedonic. The preferred pH level was 4.0, the best acid source was kalamansi juice, and the most preferred coarseness for chili paste was when milling plates with a gap of 120 µm was used. DMDC has no effect on microbial reduction due to the presence of fat globules in CSP which hindered the inactivation action. Milling can substitute pounding as it is much faster and can produce a uniform CSP with higher volume.

Keywords: chili shrimp paste, sambal belacan, heritage food, sensory and texture

Introduction

Traditional foods reflect cultural inheritance and have influenced human dietary patterns (Trichopoulou *et al*., 2007). Some traditional foods are nutritionally important in the diet and can significantly contribute to the nutritional needs of a population (Musaiger *et al.*, 1990). Traditional foods are usually products made of specific raw materials created from recipes which have been known for a long time (Cayot, 2007), and the processing methods have been passed down from generation to generation by word of mouth (Trichopoulou *et al*., 2006).

Chili shrimp paste (CSP) is one of the heritage foods, which is regarded as a favourite spicy condiment in many Southeast Asian countries especially in Malaysia, Singapore, and Thailand. It is known by different names: *pazon ng api* (Burma), *sambal terasi* (Indonesia), *sambal belacan* (Malaysia), *blachan kapi* or *pherik kapi* (Thailand) and *mam tom* (Vietnam) (Passmore, 1991; Hutton, 1997). The preferably uncooked CSP is a must have condiment and consumed to enhance the palate and to improve the appetite during a meal (Abdul Rashid *et al*., 2008). It is typically made of raw chili which is pounded with toasted fermented shrimp paste (*belacan*). Ingredients such as salt, sugar and organic acids (juices of kalamansi, lemon, tamarind or vinegar) are also added in the preparation of CSP.

Traditionally, CSP is prepared by pounding the chili with a pestle in a stone mortar. It requires energy, allows limited production capacity and can be a really messy job (hassle some). Restauranteurs and housewives have complained that it is a strenuous job to pound the chilies with shrimp paste almost everyday. Each time the CSP is prepared, it is with varying degree of coarseness, juiciness and sour intensity. In hotels and bigger restaurants, pounding of chili has been substituted with grinding using a blender. However, this practice may produce watery or thin product consistency which alters the visual appearance, texture, color, and the taste of CSP (Abdul Rashid *et al.*, 2008). Many organic acids are present naturally in a number of foods, notably fruit and fruit juices. Acetic acid or vinegar is added into foods to increase the acidity or to impart sourness. It is known to have a preservative action at high concentration, hence the extended shelf-life of pickled vegetables. Organic acids from kalamansi, lemon, tamarind and vinegar are added to CSP mainly as a flavoring ingredient, but not for preservation purposes. When kept refrigerated, the CSP cannot last for more than 3 days (Passmore, 1991). For this reason, it is necessary to prepare fresh CSP in small batches so to deal with the limited shelf life.

Due to all the issues mentioned above, this study was conducted to develop a CSP formulation preferred by consumers and to improve the CSP preparation

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processes so that CSP can be produced commercially in a larger scale setting with consistent and uniform qualities. Thus, the objectives of this study were (i) to determine the preferred pH level and acid source to be used for chili shrimp paste; (ii) to determine the preferred coarseness of the chili shrimp paste; (iii) evaluate the effectiveness of dimethyl dicarbonate in reducing the microbial counts in chili shrimp paste; and (iv) to improve the processes involved in preparing chili shrimp paste so that it is suitable for a commercial production setup.

Materials and Methods

Preparation of chili shrimp paste (CSP)

A formulation for producing chili shrimp paste (CSP) was developed in the laboratory. The basic recipe was obtained from a trained chef (Table 1). The ingredients used in preparing the CSP were fresh red chili (*Capsicum frutescence*), fresh bird's eye chili (*Capsicum annum*), fermented shrimp paste (*belacan*), salt, sugar and an acid source (kalamansi, lemon, tamarind or vinegar). Both types of chilies were of commercial maturity stage. All ingredients were obtained from a local wholesale market. The stem of the chilies were removed before washing. The chilies were drained for 10 minutes to remove excess water. The wet shrimp paste was chopped into smaller pieces and heated in the oven (ST-2, SALVA, Spain) at 180°C for 25 minutes until dry. This drying step is crucial for flavor development of the shrimp paste, which will result in a flavorful CSP. All the ingredients were then mixed using a food processor (MX-898M, Panasonic, Malaysia) for 45 seconds at speed level 1.

Effect of acidity level on preference of CSP

Chili shrimp paste was prepared using the basic formulation as shown in Table 1. The kalamansi (*Citrfortunella microcarpa*) juice was used as an acid source and the volume of the juice was adjusted to reach the intended pH levels (3.0, 3.5, 4.0, 4.5 and 5.0). To evaluate the most preferred acidity of the samples, a hedonic scale was used and the samples were evaluated by 50 untrained panelists. The panelists were made up of Malaysian adults who are familiar with CSP and consume it regularly. The analysis was conducted in individual tasting booths at the Faculty of Food Science and Technology sensory evaluation laboratory in Universiti Putra Malaysia. Twenty grams of samples with varying pH levels (with cucumber slices as carrier) were served in small plates labeled with three digit random code number. The order of serving was also randomized and all samples were served at room temperature (26°C). A glass of plain water was provided for rinsing between samples during the evaluation to eliminate the residual taste between samples. Panelists were asked to evaluate the appearance, taste, flavor and overall acceptability of CSP using a nine-point hedonic scale ranging from ''dislike extremely'' (score 1) to ''like extremely'' (score 9).

Effect of acid source on preference of CSP

Chili shrimp paste was prepared using the basic formulation as shown in Table 1, with different acid sources used for different samples. These acid sources were the juices of kalamansi (*Citrfortunella microcarpa*), lemon (*Citrus limon*), tamarind (*Tamarindus indica L.*) and food grade vinegar (distilled vinegar). The amount of acid sources in the formulation was as mentioned in Table 1, but adjusted to reach the pH 4.0 in the final product. A ranking test was employed to establish the best acid source to be used in CSP. Fifty untrained panelists consisting of Malaysian adults who are familiar with CSP and consume it regularly evaluated the samples. Serving method for the samples were similar to the method mentioned in the previous section. The panelists assigned ranks to the four samples; with first being the most preferred and fourth being the least preferred.

Effect of degree of chili coarseness on sensorial and textural characteristics of CSP

Fresh (raw) chilies were subjected to milling using the Masuko Grinder Ultra Fine machine (Super mass colloider, Germany) with an adjustable gap size between two parallel stone plates to achieve varying degree of coarseness for chili pastes. The bottom plate rotates at 1,500 rpm while the upper plate stays static. Raw chilies were milled at different gap size (60, 80, 100, 120, 140 µm) and mixed with other ingredients as in Table 1 and processed according to the methods mentioned in preparation of CSP.

(i) Effect of degree of coarseness on preference of CSP

Sensory acceptance of the samples with varying degree of coarseness was evaluated using 60 untrained panelists. The panelists were Malaysian adults who are familiar with CSP and consume it regularly. Serving method for the samples are similar to the method mentioned in the previous section. Panelists were asked to evaluate each attributes using a nine-point hedonic scale ranging from ''dislike extremely'' (score 1) to ''like extremely'' (score 9). Three different sensory attributes (coarseness level,

Table 1. Basic formulation for preparing chili shrimp paste

Ingredients	Amount (%)
Red Chili	56.25
Bird-eye chili	6.25
Shrimp paste	15.63
Acid (kalamansi juice)	15.00
Sugar	6.25
Salt	0.62

Table 2. Mean score of overall acceptability for chili shrimp paste with different pH levels

pH	Mean score of overall acceptability*
3.0	5.72[a]
3.5	6.8[b]
4.0	7.0[b]
4.5	6.36[ab]
5.0	6.12[ab]

*Numbers within a column followed by different letters are significantly different ($P<0.05$)

hardness and overall acceptability) were used to evaluate the quality of CSP.

(ii) Effect of degree of coarseness on textural properties of CSP

The firmness, consistency, cohesiveness and the index of viscosity of raw chili paste was determined using a Texture Analyzer TA-XT2i (Stable Micro System Texture Analyzer, Surrey, UK), equipped with a standard ball type probe SMS P/1S and an aluminum cylinder (32.5 mm internal diameter and 85 mm length) using load cell capacity 5-kg and applying back extrusion technique. The test was replicated seven times at a pretest speed of 2.0 mm s^{-1}, test speed of 1.0 mm s^{-1}, post test speed 5.0 mm s^{-1}, target mode strain 70.0% at a high calibration 100 mm. Samples were placed in cylinder approximately 80% full and the ball probe which was positioned centrally over the sample container, gradually moved through the paste while readings were taken by the sensors. For comparison of cohesiveness and work of cohesion the probe must return to the same position above the samples after each test. The probe was calibrated to the distance that is the starting distance of 30 mm, above the top of the sample surface.

Preparation of chili pastes using various size reduction methods

Three methods for producing chili pastes were used: (i) milling, (ii) pounding and (iii) grinding. Raw chilies were subjected to milling using the Masuko Grinder Ultra Fine Friction machine (Super mass colloider, Germany) with a 120 µm gap size (most preferred coarseness by panelists). Pounding was done by using a set of mortar and pestle, while grinding was done by using a regular food processor. The chilies were pounded or ground until the consistency and textural characteristics (as determined by the Texture Analyser) were approximately similar to the values displayed by the milled sample preferred by panelists. The degree of pounding and grinding of fresh chili required to get the target level of paste characteristics (textural) was recorded for comparison purposes. Milled chili pastes with the degree of coarseness most preferred by panelists were used as the target product for comparison in this experiment.

Effect of dimethyl dicarbonate on microbial reduction in the most preferred CSP

The most preferred CSP was established from the results of the three sensory evaluation tests conducted. Dimethyl dicarbonate (DMDC) (Sigma-Aldrich, Co., D5520-25ML, Germany) stock solution was added to the most preferred CSP using micropipette into 100 g of CSP to obtain samples with various concentrations of DMDC (0, 50, 100, 150, 200, 250 ppm). The samples were prepared in triplicates. Each sample was homogenized using mixer (HR1456, Philips, China) at speed level 1 (830 rpm) for 5 minutes to ensure well distribution of DMDC in the CSP.

Twenty five grams of DMDC-treated CSP samples were homogenized in 225 ml of 0.1% sterile peptone water in a Stomacher lab-blender 400 (Seward Medical, West Yorkshire, England) for 1 min at 260 rpm. Triplicate homogenizations were made for each sample. From each triplicate sample, triplicate serial dilutions were made in peptone water. Total aerobic mesophilic bacteria were enumerated by pour plating using plate count agar Colonies were counted using a Galaxy Colony Counter (Galaxy 230, Taiwan) and reported as CFU/mL.

Total aerobic mesophilic bacteria were enumerated by pour-plating using plate count agar (Merck, Darmstadt, Germany), and the plates incubated at 35˚C for 18–24 h. Enumeration of yeasts and moulds was carried out in pour-plates of potato dextrose-maltose agar (Merck, Darmstadt, Germany) and The plates were incubated at 28˚C for 2–5 days. Colonies were counted using Galaxy Colony Counter (Galaxy 230, Taiwan) and reported as CFU/mL.

Statistical analysis

Data collected were analyzed by using SPSS (version 14.0) software (SPSS, Inc, Chicago, Illinois). One-way ANOVA and the Tukey's multiple range test were used to generate confidence intervals for the differences between means at $p < 0.05$.

Results and Discussion

Effect of acidity level on preference of CSP

Kalamansi juice is the most common acid source used by housewives and restauranteurs to prepare CSP. The taste of CSP is usually associated with a balance of spiciness (hotness), saltiness and sourness. Mean score of the overall sensory acceptability for CSP with different pH levels using kalamansi juice as an acid source is shown in Table 2. Results indicated that CSP with pH 4.0 has the highest mean score which was 7.0. However, CSP with pH 3.0 was significantly different ($p<0.05$) compared to samples with pH 3.5 and 4.0. Samples with pH 3.0, 4.5 and 5.0 were not significantly different ($p<0.05$) from each other and were less preferred compared to those with pH 3.5 and 4.0. The sourness for samples with pH 3.0 was probably too intense for panelists, while CSP with pH 4.5 and 5.0 probably did not provide sufficient acid taste and flavor as expected by the panelists.

Effect of acid source on preference of CSP

All acids provide acidic taste but the sensory character, intensity, and aftertaste are unique for the individual acid (Dziedak, 1990). The degree of tartness of each acid has marked effect on the flavor of a product and governs the level in which it is used in a given product. Each individual acidulant has a slightly different tartness. For example, the tartness of citric acid is described as clean, while vinegar as astringent and tartaric as sharp or bitter (Gardner, 1972; Sausville, 1974). Four different acid sources (kalamansi, lemon, tamarind and vinegar) were used in four CSP samples. The amount of acid sources in the formulations was adjusted to reach the pH 4.0 in the final product. The pH level was selected based on the most preferred pH level as mentioned in Table 2. The type of acid and the average score of ranking for each CSP sample is shown in Table 3. Results indicated that kalamansi juice had the highest score and were most preferred as an acid source for CSP. However, in terms of taste, statistical analysis indicated that samples with kalamansi and lemon juice were not significantly different ($p<0.05$) from each other but are significantly different ($p<0.05$) from CSP samples with tamarind and vinegar in terms of taste. Since kalamansi is available in the South East Asia at a cheaper price than lemon, the subsequent studies were conducted using CSP added with kalamansi juice. Citric acid is the dominant organic acid in kalamansi and it imparts as a tangy

Table 3. Ranking of preference for chili shrimp paste with various acid source

Acid source	Average rank score*
Kalamansi juice	0.033[a]
Lemon juice	0.015[a]
Tamarind juice	-0.009[b]
Vinegar	-0.039[b]

*Numbers within a column followed by different letters are significantly different ($P<0.05$)

Table 4. Overall acceptability scores (sensorial) of chili shrimp paste and textural (instrumental) attributes for chili paste with different degree of coarseness

Gap size of milling plates	Overall acceptability*	Firmness (g) (±S.D)	Consistency (g) (±S.D)	Cohesiveness (g) (±S.D)	Index of viscosity (g.s) (±S.D)
60µm	3.87[a]	200.53± 11.7	7124.88± 417.30	-168.98± 5.86	-506.44± 58.74
80µm	4.73[a]	201.01± 11.8	6614.59± 664.58	-171.12± 5.40	-482.56± 19.97
100µm	5.75[b]	136.90± 8.11	5116.64± 172.32	-131.07± 5.79	-435.80± 15.52
120µm	6.82[c]	356.74± 34.6	10284.79±762.12	-218.10± 13.57	-508.79± 38.69
140µm	5.77[b]	331.52± 14.98	10121.40±562.82	-196.99± 10.12	-455.89± 41.68

*Numbers within a column followed by different letters are significantly different ($P<0.05$)

citrus flavor (Gardner, 1966; Gardner, 1972).

Effect of degree of chili coarseness on sensorial and textural characteristics of CSP

The purpose of this experiment was to analyze the effect of various degrees of chili milling on consumer preference (based on textural properties) of CSP. The different levels of chili coarseness and their mean score for overall acceptability are shown in Table 4. Milling plates with a gap size of 120 µm had the highest mean score (6.82). There was significant difference ($p<0.05$) between this particular sample with other samples of different coarseness. Samples milled using gap size above and below 120 µm had lower acceptability scores. This is an indication that the panelists did not like CSP textures which are too fine and too chunky. Expert panels indicated that texture of CSP is crucial. Consumers prefer thick and coarse products and not watery CSP (Abdul Rashid *et al*., 2008; Sobhi *et al*., 2010). From visual observation made, CSP with 60 µm coarseness was more watery than the other coarseness.

Textural evaluation using the texture analyzer was conducted for milled chili pastes and not on CSP. The preferred coarseness level of chili paste by panelists was 120 µm with the average score 6.82 (Table 4). The values for textural attributes of chili pastes with different milling size (coarseness) are shown in Table 4. The value for firmness, consistency, cohesiveness and index of viscosity for each treatment level (coarseness) increased when the samples get coarser. When the milling plates were set wider apart, e.g. 140 µm, the samples were coarser. The least coarse (finest) pastes were those with plates set at a gap size of 60 µm. From visual observation, samples milled with gap size of 60 µm had very smooth texture, where the chili seeds were all broken and not visible. The pastes were also relatively watery and smoother compared to the coarser samples (Figure 1). For samples milled with a gap size of 120 µm and 140 µm, the textures were more gritty and chunky and the chili seeds can still be seen. The pastes were not as watery as the other finer samples (gap < 120 µm).

Comparison between three size reduction methods

Chili pastes with similar coarseness as the preferred paste (for degree of coarseness, with 120 µm gap of the milling plates) achieved through the milling machine were prepared by grinding (food processor) and pounding (mortar and pestle). Values from back extrusion method (texture analyzer) were used to verify that chili pastes prepared using all three size reduction methods (milling, grinding and pounding) were of the same coarseness level. These values are shown in Table 5. To produce similar coarseness as milled pastes with 120 µm coarseness, the chili must be pounded for around 1500 times with the mortar height of 14.5 cm of pestle and was dropped by using gravitational force. Meanwhile, for grinding, the food processor was operated for 40 seconds. The weight of every raw chili for all technique was 250 g. Table 6 illustrates the differences in efficiency of the different size reduction methods. Milling method was the fastest method for forming chili pastes, while pounding was the slowest. For milling, the coarseness can be accurately controlled by setting the gap size between the two stone plates but for grinding and pounding, the coarseness of the pastes may not be uniform.

Effect of dimethyl dicarbonate on microbial reduction in the most preferred CSP

Dimethyl dicarbonate (DMDC) is a processing aid usually used for extending the shelf life of fruit juices and carbonated drinks. CSP is normally prepared without any heat treatments (not cooked) as it is usually consumed raw by the consumers. According to Mah Hassan (2008), most of the consumers prefer fresh CSP samples which were not given heat treatments. Hence, the use of DMDC in CSP is to reduce microbial growth. The CSP samples prepared for this study were based on consumer preference, *i.e*. CSP with pH 4.0 and kalamansi juice as the acid source; the degree of coarseness was when the gap size of the milling plates was 120 µm. Table 7 shows the effect of various concentrations of DMDC (5, 10, 15, 20, 25 µg/ml) on microbial counts in the CSP. Two control samples were used, (i) CSP without DMDC (0 µg/ml) and was analyzed immediately (C1) and (ii) samples without DMDC (0µg/ml) and was stored for 8 hours at 4.0 ˚C before analysis (C2). All samples with DMDC were stored for 8 hours at 4.0 ˚C before analysis. The purpose for the holding time was to allow the DMDC to completely react and broken down by hydrolysis to form carbon dioxide.

The results clearly showed that microbial counts (total plate count and yeast and mould) were reduced as the concentration of the DMDC was increased but the effectiveness of DMDC is not sufficient as a preservative for CSP. There are several technical reasons to explain the unsatisfactory results of DMDC as a processing aid for microbial reduction in CSP. DMDC is only registered for the use in non-alcoholic beverages and wine under Codex and it is possible that the complex system of a CSP is not suitable for its application. Distribution of DMDC in the matrix must be ensured as it is a viscous compound which needs proper dispersion to be effective. Therefore, a

Table 5. Textural properties for different methods for size reduction of chili

Size Reduction Method	Firmness	Consistency	Cohesiveness	Index of viscosity
Milling	356.74±34.6	10284.79±762.12	-218.10±13.57	-508.79±38.69
Pounding	322.70±31.5	8566.33±700.10	-195.11±10.70	-489.90±34.99
Grinding	310.54±29.52	8162.99±669.12	-187.54±7.60	-445.01±30.15

Table 6. Efficiency and general description of various size reduction methods for chili pastes

Size Reduction Method	Time & Speed	Production volume and product description
Milling	5 seconds, 1500rpm, Fast	200 g – unlimited (continuous) Thick, uniform paste
Pounding	1500 pounds (gravitational force at 14.5 cm height), Slow	200 g – 500 g (batch) Thick, not uniform paste
Grinding	40 seconds, speed 1, Fast	200g – 1,000g (batch) Slightly watery, not uniform paste

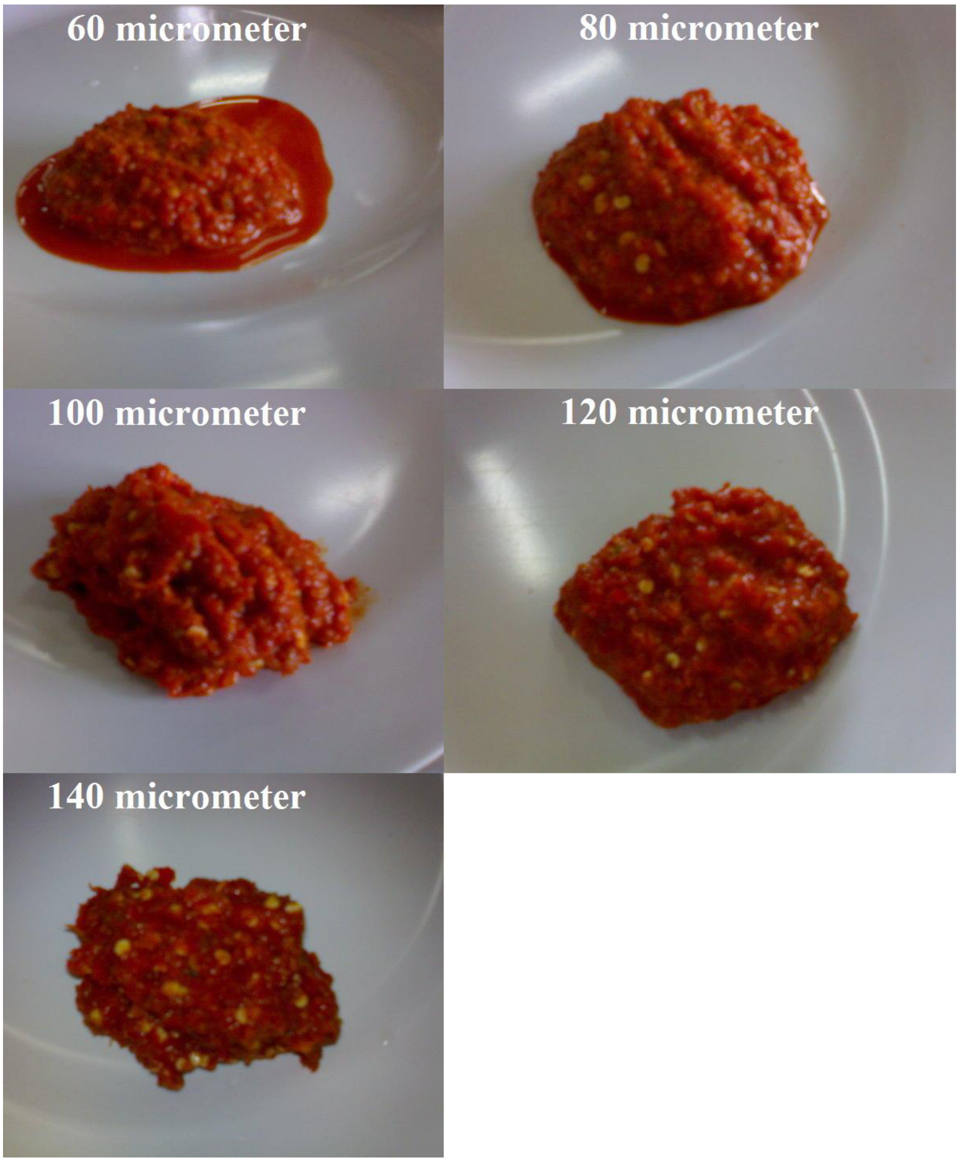

Figure 1. Appearance of milled chili pastes using various gap sizes of the parallel milling plates

Table 7. Effect of Dimethyl Dicarbonate concentration on microbial counts in chili shrimp paste

Concentration of DMDC	Total Plate Count (CFU/mL)	Yeast and Mould (CFU/mL)
Control (immediately)	6.0×10^4	1.1×10^4
0 µg/ml	7.9×10^3	5.6×10^3
50 µg/ml	6.0×10^3	3.9×10^3
100 µg/ml	7.3×10^3	4.2×10^3
150 µg/ml	5.1×10^3	4.0×10^3
200 µg/ml	4.9×10^3	4.0×10^3
250 µg/ml	4.7×10^3	3.7×10^3

special high pressure dosing pump for dosing DMDC is necessary. Due to limited availability of such equipments, the DMDC in CSP was homogenized using an automatic stirrer with a blunt paddle at speed 830 rpm for 5 minutes. However, such method was not sufficient to ensure well distribution of DMDC in the CSP. The DMDC was less effective in the CSP dispersion and probably did not dissolve quickly enough to act on the microorganisms (Lay, 2009). Another reason which might have reduced the efficiency of the DMDC in this case is the availability of fat in the CSP. According to the findings of Mah Hassan (2008), the percentage of fat in CSP is around 0.41% and the protein content is around 7.67%. The lethal mechanism of DMDC works by entering microbial cell wall as it is a lipophilic compound and inactivates various enzymes such as by reacting with imidazol groups, thereby deactivating the microorganism. If there are fat or oil droplets present, DMDC will enter the oil droplet and gradually hydrolyzes at the interface resulting in an efficacy drop for microbial inactivation (Lay, 2009).

Conclusion

Results from these studies were found to involve the development of a specified formulation and process improvement of chili shrimp paste (CSP). Most panelists preferred samples with pH 4.0 and kalamansi juice as the acid source to be used in CSP. The coarseness of chili paste was most preferred when the gap size of the milling plates was 120µm. The traditional time-consuming and tiresome pounding method can be replaced by a faster method *i.e.*, using a milling machine to produce larger volume of product and uniform CSP texture as it is preferred by consumers. Application of DMDC had no effect to the microbial growth in the CSP due to the presence of fat globules which reduces the efficiency of DMDC. Therefore, DMDC is not a suitable processing aid to be used for microbial reduction in a fat-containing food system such as CSP. An alternative for DMDC, possibly a non-thermal technique is recommended for preservation of CSP. For future research, focus on the stability of chili shrimp paste made using this preferred formulation and the improved processing method is necessary to prolong the shelf life of CSP.

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