

Development of Instrumental Methods for Textural Evaluation of Chili Paste

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ABSTRACT

Chili shrimp paste (CSP) is a traditional Southeast Asian condiment. It is a semi solid suspension that contains chunky chili pieces. The textural characteristics of the paste are important quality parameters for most CSP lovers because they prefer pastes with a certain degree of thickness and chunkiness. Unfortunately, there is no standard methodology available to evaluate the textural properties of these pastes. Various samples of CSP were prepared and evaluated using sensory, texture analyzer and rheometer measurements. The results from instrumental evaluation were consistent and comparable to sensory data. Texture analysis using the back extrusion method (spherical probe and cylinder) was found to be suitable for textural quantification of CSP. The $\tan \delta$ values measured using a vane-in-a-large-cup rheometer using an oscillation frequency sweep at 20 Hz correlated well with the sensory results, indicating that this method could effectively distinguish differences in CSP samples with different rheological properties. Both instrumental methods can be applied as quality control tools for CSP products.

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

INTRODUCTION

Chili shrimp paste (CSP), also known as *sambal belacan* in Malaysia, is well liked in many Southeast Asian countries (Passmore, 1991; Hutton, 1997) and was recognized as a national heritage food by the Malaysian Ministry of Cultural Arts and Heritage in February 2009 (Idris, 2009). This savory condiment is prepared by crushing fresh chilies combined with a small amount of fermented shrimp paste (*belacan*) using a stone mortar. Ingredients such as salt, sugar and calamansi juice are also added to the

CSP preparation (Morris and Mackley, 2007). The paste is usually consumed uncooked and only the shrimp paste is toasted before it is mixed with the chili to change its naturally acid flavor into a rich aromatic seasoning (Passmore, 1991; Leong *et al.*, 2009). The fermented shrimp paste is made of small shrimps through salt-controlled anaerobic fermentation (Steinkraus, 1996).

A stone pestle and mortar is a widely used tool in India, South Asia and Mexico for preparing spice pastes (Jill, 2004; Brissenden, 2007). Pounding CSP using a mortar helps to crush the ingredients and produce a heterogeneous paste

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with a unique texture. Commercialization of CSP and scaling up the process for greater production would require processing by machinery instead of a pestle and mortar. The use of machinery would probably lead to compromises between the unique textural quality of traditionally prepared CSP and productivity. With the increasing interest in ethnic foods including CSP, and the subsequent rise in the market share of heritage foods, textural integrity has become a significant factor for the quality assessment of CSP. Evaluation has been reported based on the physical, textural and rheological properties of many chili-based pastes and sauces (Ismail and Revathi, 2004; Martinez-Padilla and Rivera-Vargas, 2006; Gamonpilas *et al.*, 2011) as well as other similar semi solid foods (Patterson *et al.*, 2002; Sefa-Dedeh *et al.*, 2002; Akissoe *et al.*, 2006). Unfortunately, there is no standard methodology available to evaluate the textural properties of food containing semi solid mixtures such as that of the CSP. Thus, the objective of this study was to establish instrumental methods to determine the preferred textural properties of CSP.

MATERIALS AND METHODS

Sample source and formulation

Nine different CSP products were obtained for analysis. Of the nine samples, four samples were freshly prepared at popular local restaurants (coded with the letters A, B, C and D). Two samples were commercially processed CSP products that were obtained from a hypermarket (coded with the letters E and F) and three samples were freshly prepared in the laboratory (coded with the letters G, H and I). The local restaurants selected were establishments with a high volume of customers and the samples prepared in the laboratory were prepared by a professional chef. All CSP samples prepared in the laboratory had the same formulation, with the chili ground to varying levels of coarseness (G as fine, H as medium and I as coarse). The difference in coarseness was based

on the chef's experience using a granite mortar and pestle. Formulation of CSP made in the laboratory included 55% fresh red chili (*Capsicum annum*), 14% fresh bird's eye chili (*Capsicum frutescens*), 17% fermented shrimp paste (*belacan*), 7% sugar, 2% salt, 4% calamansi juice and 1% citric acid. The samples were brought into the laboratory under chilled conditions and kept under sealed conditions at 4 °C. All analysis was done within 3 d at room temperature (25 °C).

Sensory analysis

The acceptability of the nine CSP samples was evaluated using 31 untrained panelists. The panelists were Malaysians who were very familiar with CSP and consume it regularly. The panelists were asked to evaluate the samples based on two attributes (texture and viscosity) using a nine-point hedonic scale ranging from 1, 'dislike extremely' to 9, 'like extremely'. Samples were allowed to equilibrate to room temperature for 30 min before sensory evaluation and served according to the method described by Sobhi *et al.* (2010). Due to sensory fatigue, panelists could not evaluate more than six samples in a single sitting (Meilgaard *et al.*, 2007). Therefore, tasting of the CSP samples was divided into two sessions. In the first session (session I), the six purchased samples (A, B, C, D, E and F) were evaluated. The panelists identified the top three samples in terms of texture and viscosity scores. The top three samples were used in the second sensory session (session II) along with the remaining three samples (G, H and I) prepared by a chef in the laboratory. The samples in session II were evaluated by the same panelists. The outcomes from the second sensory session (texture and viscosity) were compared against instrumental data measured by a rheometer (HAAKE RheoStress 600, Karlsruhe, Germany) and a texture analyzer (TA.XT2i; Stable Micro Systems, Surrey, UK).

Oscillation frequency sweep

Oscillation frequency sweep tests were

performed using the rheometer in a frequency range from 1.00 to 40.00 Hz with a shear stress of 50.00 Pa. Before performing the experiments, the appropriate frequency range and shear stress were selected through preliminary study to produce consistent data. Rheological parameters of loss tangent and complex viscosity were determined in the frequency region using the RheoWin software package (version 3.30.0000; HAAKE; Karlsruhe, Germany).

For a semi solid system like CSP, a vane-in-a-large-cup, nonconventional geometry system was used, which was constructed according to the method published by Martinez-Padilla and Rivera-Vargas (2006). A four blade vane (HAAKE FL40, Karlsruhe, Germany) with the following dimensions was used: 40 mm diameter, 55 mm height, 0.9 mm blade thickness and a 12 mm hub radius. The vane was placed in a polymethacrylate baffled cylindrical cup (100 mm internal diameter, 100 mm length). Eight vertical symmetrical baffles ($10 \times 10 \times 100$ mm) were attached to the inside walls of the cup in order to provide an effective cup diameter of 80 mm. The clearance from the bottom of the vane to the bottom of the cup was 30 mm to avoid end effects. The rheological characteristics of the CSP samples were measured using this setup at 25 °C.

Textural profile

Textural measurements of CSP samples were performed through a back extrusion technique using the texture analyzer. A back extrusion cell is usually used for semi solid products. Unfortunately, this conventional back extrusion cell was found to be inapplicable for samples having a mixture of a liquid and a heterogeneous solid such as that in the CSP system. In order to have reproducible results, the method published by Nadia Sarina *et al.* (2010) where a spherical probe (SMS P/1S; Stable Micro Systems; Surrey, UK) was used instead of the conventional disc plunger to allow easy penetration of the mass of the paste. This type of probe was found to be effective for

producing consistent and reliable readings for the textural measurements. The two different probes (disc and spherical) are shown in Figure 1.

The tests were performed at a pre-test speed of 2.0 mm.s⁻¹, a test speed of 1.0 mm.s⁻¹ and a post-test speed of 5.0 mm.s⁻¹ with a target mode strain 70.0% at a high calibration of 100 mm. The samples were carefully scooped into cylindrical containers to minimize the presence of air pockets. The depth of the samples in the cylinder was 70 mm and the probe was calibrated to a starting distance 30 mm above the top of the sample surface. The spherical probe, which was positioned centrally over the sample container, gradually moved through the paste while readings were taken by the sensors. Firmness, consistency, cohesiveness and viscosity were measured using the Exponent Stable Micro Systems version 4.0.13.0 equipment software (Stable Micro Systems; Surrey, UK). Because the cohesiveness and viscosity were calculated from the negative portion of the force time curve, the higher negative values indicated more cohesiveness and viscosity. The textural profile of the CSP samples was measured at 25 °C.

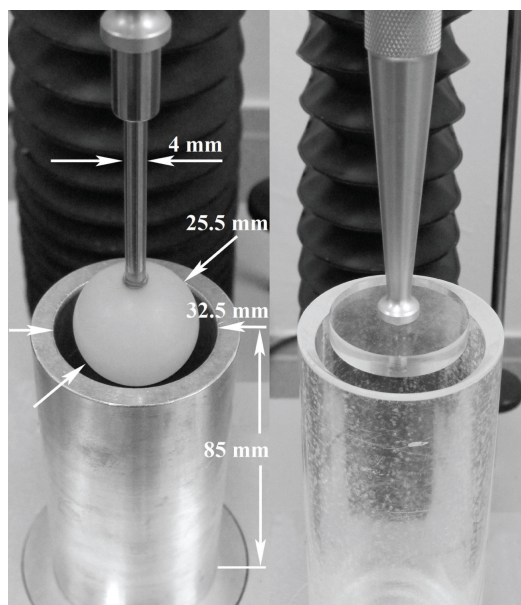


Figure 1 Conventional disc plunger (right) and round probe (left) of texture analyzer.

Statistical analysis

The data obtained were analyzed using Minitab V.14 software (Minitab Inc.; State College, PA, USA). The one way ANOVA and the Fisher's multiple range tests were used to generate confidence intervals for the differences between the means. Significant differences were tested at the ($P \leq 0.05$) level. The tests were replicated five times.

RESULTS AND DISCUSSION

The acceptability data of chili shrimp pastes based on texture and viscosity characteristics as evaluated by untrained panelists are shown in Table 1. Values closer to 1 indicate that the product was disliked, whereas values closer to 9 indicate that the product was liked by the sensory panelists.

Statistical analyses showed that samples C, D and E had higher mean texture and viscosity scores for the first sensory session. These three samples were not significantly different from each other. Samples C, D and E were chosen as the more preferred samples in this sensory session and were used together with samples G, H and I in the second sensory evaluation session. In Session II, sample G had the highest scores in terms of texture (6.79) and viscosity (6.72). The scores of sample G were significantly different from the scores of

other samples in Session II.

Typically, sauces are multiphase dispersed systems formed mainly by three types of particles: (i) solid rigid particles, (ii) solid deformable particles and (iii) liquid deformable particles such as oil droplets (Martinez-Padilla and Rivera-Vargas, 2006). Panelists described samples A and B as too watery and runny, while samples E and F were described as fine and homogeneous in terms of texture. The solid portion of chili in sample I was considered too chunky with relatively large chili bits and was not preferred by the panelists. Because CSP is often consumed with additional foods, such as cucumber or dry salted fish, its heterogeneous nature means that a liquid-like product is not preferred. Panelists preferred the slightly chunky chili bits in sample G as it was a heterogeneous product with chili pieces that were fine but large enough to provide a certain mouth feel during consumption. This observation related to preference for chunkiness in CSP was also reported by other researchers (Abdul Rashid *et al.*, 2008; Sobhi *et al.*, 2010).

Rheological characteristics of chili shrimp paste

In oscillatory instruments, samples are subjected to varying stress or strain so that the viscoelastic behavior of food can be quantified and interpreted. Such results are useful in the

Table 1 Mean score of acceptability of chili shrimp pastes based on texture and viscosity using a nine-point hedonic scale ranging from 1, 'dislike extremely' to 9, 'like extremely'.

Session I			Session II		
Sample	Texture score	Viscosity score	Sample	Texture score	Viscosity score
A	5.28 ^{ac}	5.34 ^{ad}	C	5.72 ^a	5.65 ^a
B	4.79 ^a	3.65 ^b	D	4.62 ^b	4.31 ^b
C	6.28 ^b	6.41 ^c	E	4.72 ^b	5.00 ^{ab}
D	5.45 ^{abc}	5.38 ^{ad}	G	6.79 ^c	6.72 ^c
E	5.90 ^{bc}	5.93 ^{ac}	H	5.24 ^{ab}	5.21 ^{ab}
F	4.86 ^a	4.76 ^d	I	4.86 ^{ab}	5.41 ^a

^{a-d} = Means having different superscripts within a column are significantly different ($P \leq 0.05$).

Samples A–F were purchased and samples G–I were prepared by a chef in the laboratory.

correlation of rheological properties to human sensory perception (Steffe, 1996). In the current study, the sensory test was considered to be the true measure of the textural quality of the CSP product. Yet, an attempt was made to use mechanical tools to analyze the viscoelastic properties of CSP and correlate the results with the sensory evaluation results. The term ‘chunky’ as described by the sensory panelists is a relative term. Similarly, laboratory samples G, H and I, which were prepared by a professional chef, were based on a coarseness profile of fine, medium and coarse. However, the definition of coarseness was very subjective and solely based on the chef’s professional experience. Due to the fact that texture is an important quality characteristic of CSP, it is important to establish a quantitative method to identify the profile of the most preferred sample from the sensory evaluation (in terms of texture) as a tool for quality control.

In general, semi solid products with greater solid contents are expected to have higher elastic modulus (G') values while products with greater liquid contents have higher values of loss modulus (G''). The loss tangent or $\tan \delta$ (G''/G')

is a more sensitive viscoelastic function, and it indicates whether elastic or viscous properties predominate in a material (Peon *et al.*, 2003). In the current study, however, the viscoelastic function of loss tangent in the frequency range was counterbalanced by the textural quality of CSP. Figure 2 illustrates the changes in $\tan \delta$ as a function of frequency in all of the samples.

Samples G, C, H and I were the more preferred samples in terms of texture as evaluated by sensory testing, and these samples had an increasing trend for $\tan \delta$ values in the given frequency range. In contrast, the less preferred samples (E, F, D, B and A) had decreasing values of $\tan \delta$. Differences in the loss tangent behavior of samples in the frequency range can be explained by the effect of frequency on the material. During the frequency scans, observations were made of trends and changes in each material’s behavior. Low frequencies allow the material to relax over time and respond so that flow dominates. In contrast, at higher frequencies materials do not have sufficient time to relax, leading to the domination of elastic behavior (Ahmed *et al.*, 2007; Menard, 2008).

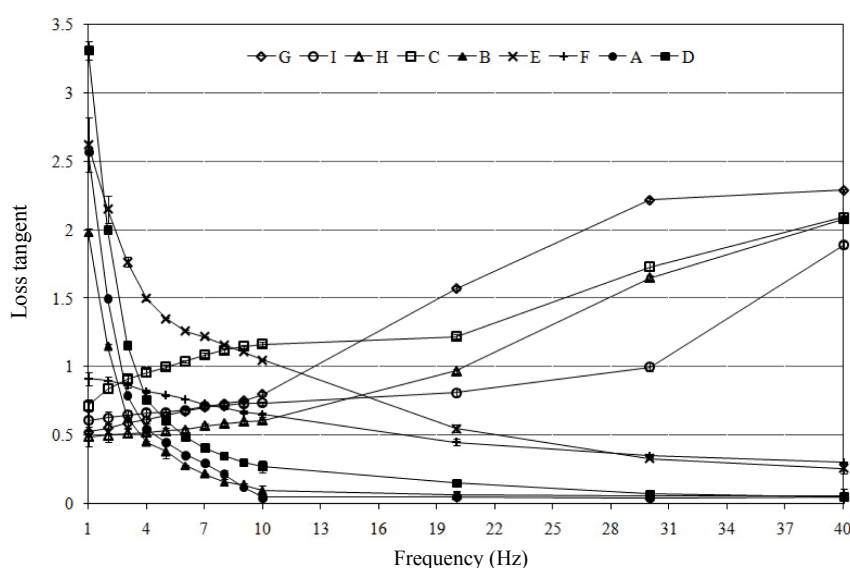


Figure 2 Effect of frequency on loss tangent values of chili shrimp paste using oscillation frequency sweep and vane-in-a-large-cup rheometer for samples A–I. Samples A–F were purchased and samples G–I were prepared by a chef in the laboratory.

Figure 3 shows the complex viscosity behavior of samples in the frequency range.

When the frequency increased, the complex viscosity (η^*) decreased. By decreasing the complex viscosity at a higher frequency, the CSP samples were evaluated as elastic material. At lower frequencies, when the CSP was evaluated as viscous material, soft and more watery CSPs represented the weaker structures with a higher loss tangent. Differences in the loss tangent behavior in the tested frequency range can be related to the presence of solid chili pieces in CSP. Solid pieces have natural air voids which create a weaker structure (higher $\tan \delta$) when the CSP was evaluated as an elastic material at higher frequencies. Such voids are created by air cells in the intact plant tissue (chili pieces) and were not observed in finely ground chili samples. The weight of the red chili was increased by 13% after infusion with water (Saurel, 2005). This approach could be used as a method to evaluate the textural quality of CSPs.

A linear regression model was used to correlate the mean texture score from the panelists

in sensory Session II with $\tan \delta$ in the chosen frequency range (14–40 Hz). Figure 4 shows the regression coefficient (R^2) values between loss tangents and the mean texture scores (given by panelists in sensory session II) for different frequencies, which indicate the correlation value between mechanical tools and the results of the sensory evaluation. The R^2 value adequately describes the correlation between the sensory scores and $\tan \delta$. The highest R^2 value (84.1%) occurred at 20 Hz and the linear correlation (texture score versus loss tangent for samples C, D, E, G, H, I) at this frequency is shown in the inset of Figure 4.

The correlation had the form *Loss tangent* = 1.512 *texture score* + 3.997, with a regression coefficient of 84.1%. Correlations in other frequencies were computed using the same method. A good fit of any model should have an R^2 value of at least 80% (Joglekar and May, 1987). At frequencies of 19–26 Hz, the order of samples preferred by panelists during sensory session II matched the order of $\tan \delta$ values. The sequence from the highest to the lowest was: sample G > C

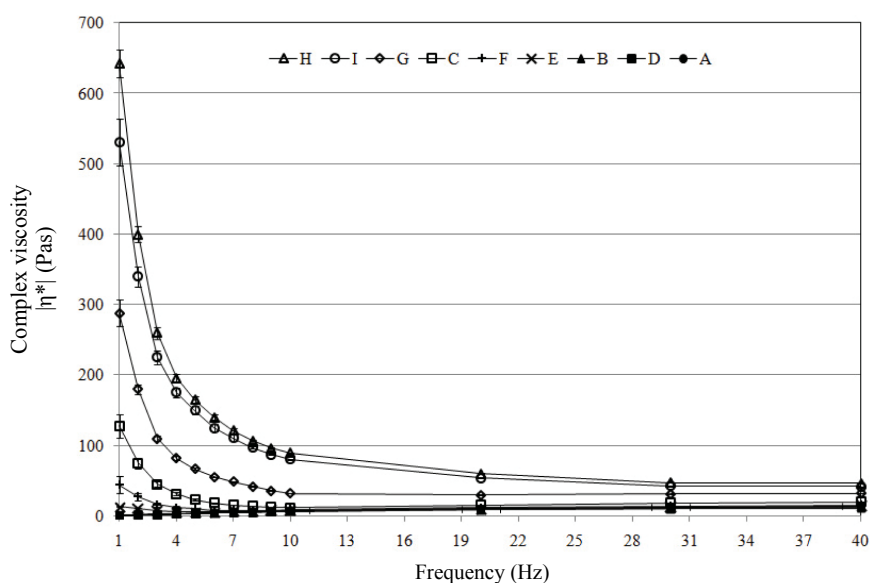


Figure 3 Complex viscosity of chili shrimp paste using oscillation frequency sweep and vane-in-a-large-cup rheometer for samples A–I. Samples A–F were purchased and samples G–I were prepared by a chef in the laboratory.

> H > I > E > D. The laboratory samples, G (fine), H (medium) and I (coarse), were in the expected order from fine to coarse, which indicates that the applied quantification method could identify the differences the degree of pounding of the CSP samples.

Textural characteristics of chili shrimp paste measured mechanically

All of the texture parameters determined in this study are shown in Table 2. Samples C (Restaurant 3) and G (Laboratory 1, fine) were the top two CSP samples that were preferred by panelists during sensory evaluation. With regard to textural parameters values in Table 2, the difference in textural profiles from samples C and G was not as great as the differences compared to the other CSP samples tested in this study. There was no significant difference between the two samples in terms of firmness, consistency and cohesiveness when these values were compared. The values of the preferred CSPs were 520 to 522 g (firmness), 13,255 to 13,288 g.s (consistency)

and -160 to -175 g (cohesiveness).

In another study, chili for CSP was milled using a two plate milling unit with an adjustable gap size between the plates (Nadia Sarina *et al.*, 2010) where it was reported that CSP samples prepared using chili pastes milled with a gap size of 120 μm were preferred by panelists. According to the authors, the textural profile of the milled chili paste (120 μm) when evaluated instrumentally was reported to be 356.74 ± 34.6 g (firmness), $10,284.79 \pm 762.12$ g.s (consistency), -218.10 ± 13.57 g (cohesiveness) and -508.79 ± 38.69 g.s (viscosity). The difference between the experimental data in the current study with the data from this previous study is probably due to the fact that the textural evaluation conducted in the current work was on CSP and not on the chili paste (an ingredient for CSP) that was used in the prior report. Nevertheless, it is also possible that the slight discrepancy occurred from differences in the size uniformity of the chili pieces. The milling unit produced uniform chili pieces, while pounding resulted in chili pieces with a wider

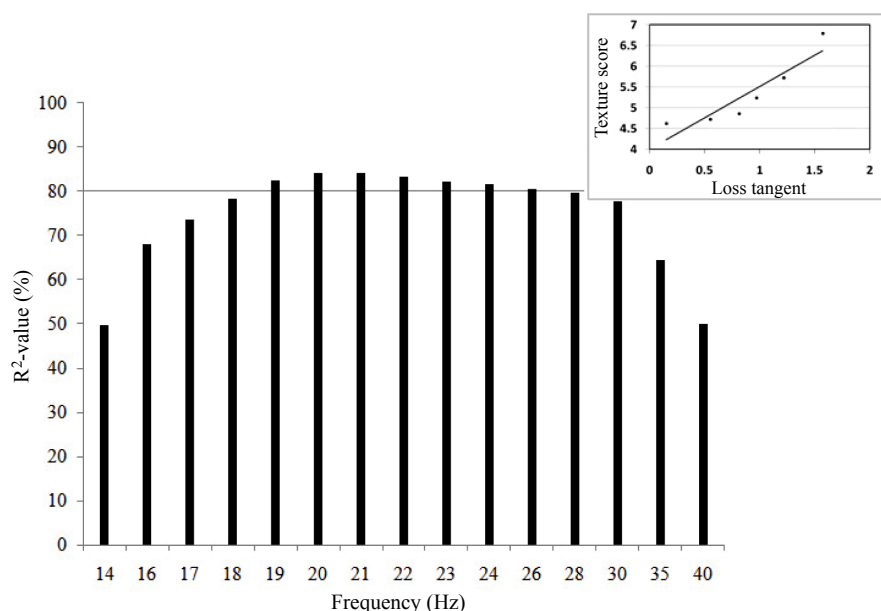


Figure 4 Regression correlation values (R^2) between loss tangents and texture score (given by panelists in sensory session II) measured at various frequencies. An example of the linear correlation at 20 Hz is shown in the inset.

size distribution range. Through the milling unit, the coarseness of chili pieces could be accurately controlled by setting the gap size between the two stone plates. However, for grinding, the coarseness of the pastes may not be uniform (Nadia Sarina *et al.*, 2010). Another point to note is that sample G was identified by the chef as ‘fine’ in terms of coarseness. It is probable that the term ‘fine’, as defined by the chef, refers to well ground chili that is still coarse enough for the panelists to feel in the texture assessment of the CSP.

For viscosity values, the difference between the two preferred samples, sample C (-404.89 ± 32.82 g.s) and G (-799.86 ± 36.99 g.s), were big. It is not clear if preference for the given samples was not affected by the viscosity characteristics of the liquid portion of the CSP system. Most of the flavor for CSP is in the liquid portion, especially that contributed by the ‘belacan’, chilli juice, salt, sugar and acidic ingredients. The chunky parts of CSP are mostly crushed chilli pieces. However, in this study the panelists evaluated only the textural properties of CSP and not the flavor.

With the back extrusion method, when the loss fitting round probe is forced down into the cylinder and the CSP flows up through the space between the probe and the cylinder, the crushing quality of CSP leads to friction between

the probe and the cylinder walls, which can affect the CSP flow quality and the texture analyzer force time curve. Large and hard fragments of chili can contribute to fluctuations in the curve. Figure 5 illustrates the back extrusion force time curves for all samples.

Laboratory sample I, which was identified as ‘coarse’ by the chef, had the largest fluctuation in the curve. Samples G, C and H were the top three preferred samples of the nine tested CSP samples, and there was medium fluctuation for these samples. Medium fluctuations observed in the samples defined by the chef as having ‘fine’ and ‘medium’ levels of coarseness with regard to the texture of CSP indicated the presence of large chili chunks or fragments in the CSP samples that were preferred by the panelists. Other samples with smoother curves indicated the presence of softer and smaller chili fragments in the CSP. These findings were supported by the results obtained with rheological measurements.

CONCLUSION

The textures of various CSP samples were evaluated using sensory and mechanical methods. The typical textural properties of CSP preferred by sensory panelists were verified by two instrumental methods (rheometer and texture

Table 2 Textural characteristics of chili shrimp paste using back extrusion method.

Sample	Firmness (g)	Consistency (g s)	Cohesiveness (g)	Viscosity (g.s)
A	140.26 ± 32.23^a	$3,061.27 \pm 142.28^a$	-22.68 ± 1.27^a	-6.36 ± 0.87^a
B	11.58 ± 1.75^b	546.38 ± 71.29^b	-1.37 ± 0.44^a	-0.94 ± 0.24^a
C	520.11 ± 70.5^c	$13,255.59 \pm 812.14^c$	-175.33 ± 15.91^b	-404.89 ± 38.82^b
D	96.63 ± 1.92^{ab}	$2,460.67 \pm 94.35^a$	-19.59 ± 0.81^a	-3.81 ± 0.72^a
E	45.71 ± 1.77^{bd}	$1,809.89 \pm 81.18^{ab}$	-30.42 ± 3.14^a	-210.36 ± 20.19^c
F	156.94 ± 45.69^a	$6,408.27 \pm 174.73^d$	-125.26 ± 11.07^b	-927.87 ± 57.20^d
G	521.99 ± 56.88^{ce}	$13,288.29 \pm 907.04^c$	-160.69 ± 14.27^b	-799.86 ± 36.99^e
H	645.07 ± 81.37^e	$18,484.48 \pm 1,307.06^e$	-327.24 ± 89.17^c	$-1,629.58 \pm 46.35^f$
I	$3,681.52 \pm 174.60^f$	$88,946.99 \pm 6,025.01^f$	-945.43 ± 161.51^d	$-4,376.19 \pm 131.51^g$

Data are shown as mean of five replicates \pm SE.

^{a-f} = Means having different superscripts within a column are significantly different ($P \leq 0.05$).

Samples A–F were purchased and samples G–I were prepared by a chef in the laboratory.

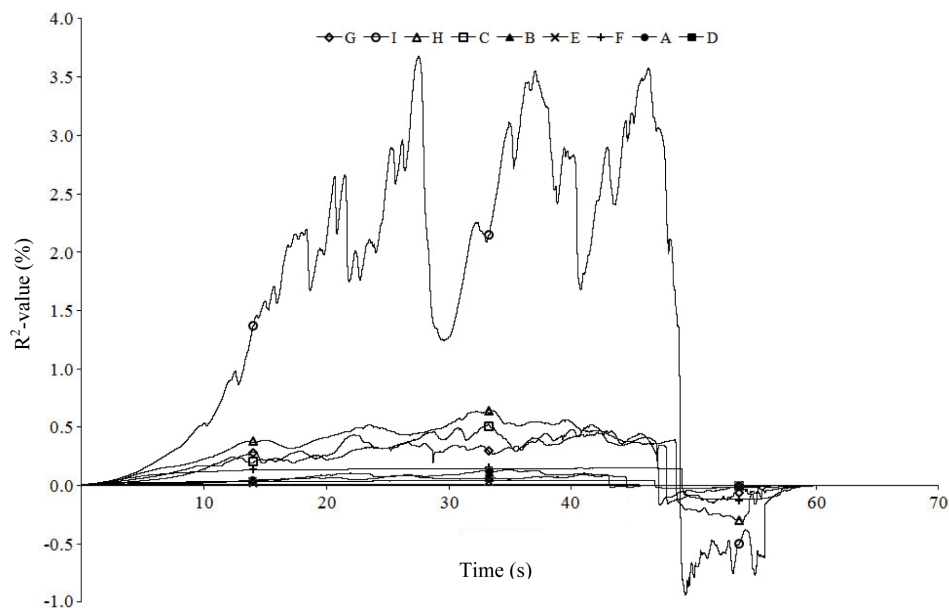


Figure 5 Instrumental texture analysis curve of chili shrimp paste applying back extrusion method for samples A–I. Samples A–F were purchased and samples G–I were prepared by a chef in the laboratory.

analyzer) that were developed for analyzing a solid liquid paste mixture such as CSP. Texture analysis using a back extrusion (spherical probe and cylinder) and a vane-in-a-large-cup rheometer using an oscillation frequency sweep was found to be suitable for textural quantification of CSP. The $\tan \delta$ values at 20 Hz correlated well with the sensory results, indicating that this method could distinguish effectively the differences in CSP samples with different rheological properties. This finding also suggests that the quantification method used could be a potential quality control tool when mass producing CSP or food systems similar to it.

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