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The effect of protein content in jasmine rice flour on textural and rheological properties of jasmine rice pudding

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Abstract

Rice pudding is an uncommon and unpopular dessert to Thais due to its rough texture and strong taste of egg. It generally composes of milk or skim milk, rice grain or flour, sugar, egg, and salt. Jasmine rice flour containing unique fragrance is a preferable choice to improve this product. A substitution of egg with jasmine rice flour in a developed rice pudding was carried out which the quality of the product should be similar to the non-substituted samples. The high protein (7.70% w/w: HPJF) and low protein (3.54% w/w: LPJF) jasmine rice flour were used in this study. Both flour samples were determined for viscosity by RVA and the phase diagram was investigated to assess the interaction between jasmine rice flour and skim milk protein (SMP). The rice pudding was prepared by mixing all ingredients together. The quantity of SMP, sugar, and salt were fixed, while the amount of rice flour and water content in the puddings were varied. After mixing, the samples were heated at 65^{o}C for 30 min and set to cool down and stored in a refrigerator for 16 days. During this period, these samples were randomly checked for textural and rheological properties at day 0, 2, 8 and 16. The results showed that HPJF presented higher pasting temperature, trough viscosity, final viscosity, and setback but lower peak viscosity and breakdown than LPJF. The phase diagrams of SMP with each of the flour exhibited the incompatible area. However, LPJF also showed gel zones in the diagram. Hardness, gumminess, and chewiness of LPJF-puddings were higher than those of HPJF-puddings, whereas adhesiveness, springiness, and cohesiveness values of HPJF-puddings were higher than those of LPJF-puddings. Solid-like (G'), liquid-like (G") behavior, and tan δ (G"/G') of HPJF-puddings were higher than those of LPJF-puddings at day 0 and 2. However, the more duration time of the storage increased, the higher G' and G" of LPJF-puddings presented. This was in contrast to HPJF-puddings. Thus, the LPJF gave the texture and rheological properties to the puddings better than HPJF.

Introduction

Rice pudding is a usually milk protein-based rice starch paste but uncommon to Thais. The compositions of rice pudding are milk or skim milk, rice grain or flour, sugar, egg, and salt. With a rough texture from rice grains and strong egg taste, rice pudding is not prevalently accepted by Thais. Jasmine rice flour containing unique fragrance and persisting soft texture is a preferable choice to improve this product. Thus, applying the jasmine rice flour as an eastern raw material in order to improve the acceptance of rice pudding is an alternative way for such product development.

In recent years, jasmine rice flour can be used as a raw material to substitute wheat flour in bakery products such as bread, cake, curry puff and Pa Thong Koo (Chinese fried-dough) (Haruthaithanasan *et al.*, 2002; Panya *et al.*, 2002; Lerswanichwatana *et al.*, 2003; Phongpa-ngan *et al.*, 2003; Tipkanon *et al.*, 2003; Suya *et al.* 2008). Panya *et al.* (2002) showed that jasmine rice flour could substitute wheat flour up to 30% (w/w) in sweet bread and the texture of the bread was still similar to that of bread from plain wheat flour. Also, Tipkanon *et al.* (2003) revealed that wheat flour could be substituted by jasmine rice flour up to 30% (w/w) in Pa Thong Koo which was accepted by consumers. Additionally, Lerswanichwatana *et al.* (2003) demonstrated that jasmine rice flour can substitute wheat flour of a curry puff shell up to 30% (w/w). However, there are a few studies of the substitution of any ingredient by jasmine rice flour in a pudding.

Up to date, in general, the substitution of milk by soy protein concentrate or soy isolate, rice drink, and pea isolate has been examined in pudding. Lim and Narsimhan (2006) studied on the pasting and rheological properties of soy protein-based

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pudding. Alamprese and Mariotti (2011) examined the effect of milk substitution by soy and rice drink on rheological and textural properties of puddings. They found that the quality in terms of textural and rheological properties of these substituted products deviated from the original properties. However, the substitution of pudding ingredient by jasmine rice flour has not been explored yet.

As the main ingredients in rice pudding, rice starches as polysaccharides and milk proteins such as casein and whey contribute to the structural and textural properties of the pudding. Normally, when mixing proteins with polysaccharides, the interactions of those polymers can be segregated or associative depending on types and concentrations of the biopolymers and conditions of the system (Corredig *et al*., 2011). In the case of skim milk protein (SMP) and polysaccharide mixture, the phase separation always occurred by depletion-flocculation mechanism (Thaiudom and Goff, 2003; McClement 2005; Chappellaz *et al*, 2009; Noisuwan *et al*., 2009; Goh *et al*., 2009). Thus, the developing of rice pudding in this study by substitution egg with jasmine rice flour varied protein content might affect the textural and rheological properties of such pudding. Also, the interaction between SMP and jasmine rice flour might be different from general phenomenon of the interaction between SMP and general polysaccharide. The phase diagram was used to explain the interaction phenomenon while the studies of textural and rheological properties were investigated using texture analyzer and rheometer, respectively.

Materials and Methods

Materials

Fresh eggs, sugar, salt, and margarine (83% w/w fat with salted, Bestfoods, Bangkok, Thailand) used in this study were purchased from a local supermarket in Nakhon Ratchasima province, Thailand. Skim milk powder (SMP) with 36% (w/w) total protein was purchased from Vicchi Enterprise Co., Ltd. (Bangkok, Thailand). Jasmine rice was received as a free sample from CP Intertrade Co., Ltd. (Bangkok, Thailand)

Preparation of jasmine rice flour

Jasmine rice was ground by centrifugal mill (ZM-100, Retsch, Haan, Germany) and passed through the 80 mesh sieve (Analysette 3, Fritsch, Idar-Obestein, Germany), resulting in the high protein jasmine rice flour (HPJF). To produce low protein jasmine rice flour (LPJF), the flour remaining on the sieve was extracted following Pongsawatmanit (2003) with a slightly modification. The flour was soaked in 0.35% NaOH at 20°C for 15 h. Then it was washed with distilled water and filtered by filter cloth. The washing and filtering processes were repeated until the final pH of the filtrate was 6.5-7. The flour on the filter cloth was collected and dried at 50°C in oven (UNE 550, Memmert, Schwabach, Germany) for 24 h. Then, the dried flour was ground and passed through 80 mesh sieve to obtain the LPJF. Both HPJF and LPJF were kept at 5°C in a refrigerator for further analysis

Chemical composition analysis of flour

Protein, fat, moisture, and ash content of HPJF and LPJF were determined following the Association of Official Analytical Chemists (AOAC, 2005). Amylose content of both flour was analyzed following Juliano (1971).

Viscosity and pasting properties

Viscosity and pasting properties of jasmine rice flour was determined using Rapid Visco Analyzer (RVA-4, Newport Scientific Inc., Warriewood, Australia) with the standard procedure (No. 1) provided by the RVA manufacturer. HPJF and LPJF (2.85 and 2.81 g, respectively) were weighed directly into the aluminum RVA sample cans, and distilled water was added to a total constant weight of 28 g in order to gain the same amount of total soluble solid in both samples. The starting and ending points of analytical temperature were 50°C. The rate of heating and cooling was 12°C.min^{-1}. The determination of flour swelling was hold at 95°C for 3.5 min with 160 rpm shearing force. Total analysis time from the starting to the ending was 13 min. Pasting temperature, trough viscosity, final viscosity, setback, peak viscosity, and breakdown were measured for all samples.

Phase diagram

The determination of phase diagram was determined following Bourriot *et al.* (1999) and Thaiudom and Goff (2003) with a slightly modification. HPJF and LPJF solution with various concentrations were separately dissolved and stirred in deionized water (DI) at 30°C for 15 min, then heated and stirred in a water bath at 90°C for 15 min. The solution was stored at 4°C for 24 h before further analysis. SMP with various concentrations was reconstituted with DI water and stirred at 30°C for 15 min to dissolve SMP completely. The reconstituted SMP in a container, placed in a water bath was then heated and stirred at 75°C for 15 min. The reconstituted SMP (in the range of 0 to 12% w/w) and rice flour solution (in the range of 0 to 5% w/w) were mixed at room temperature and homogenized by homogenizer (T25 basic, IKA, Staufen, Germany) at 8000 rpm, stored at 4°C for 24 h for aging. The mixes were then warmed to 25°C and centrifuged (CR 22G III, Hitachi Koki, Tokyo, Japan) at 1100×g for 30 min. The separation of the mixtes was visual observed and then generated for the phase diagrams.

Jasmine rice pudding preparation

Rice puddings in this study were a general formulation (GF), substituted formulation (SF) and control formulation (CF). The GF composed of 29.02% (w/w) jasmine rice flour paste (HPJF or LPJF), 56.29% (w/w) reconstituted SMP, 5.86% (w/w) egg, 7.27% (w/w) sugar, 0.09% (w/w) salt, and 1.47% (w/w) margarine. The egg in the GF was substituted by HPJF or LPJF for SF whereas the egg in the GF was substituted by distilled water for CF. The rest of all ingredients in SF and CF were fixed at a constant proportion as presenting in the GF formulation. The jasmine rice flour was mixed with water and heated at 95^{o}C for 30 min in order to make the 20% (w/w) flour paste and left at room temperature before further steps of the experiment. The skim milk powder also was reconstituted with water at room temperature to get 23.1% (w/w) milk solution. Then, all ingredients were gently mixed in a mixing blow and heated at 65°C for 30 min. The mixes were poured into polypropylene plastic cups (5.0 cm diameter x 3.0 cm depth) and cooled down at room temperature in order to let the puddings set themselves. The puddings were kept in a refrigerator at 5°C before further analysis. Total formulations in this study have 6 formulations: GF-HPJF (general formulation pudding made from high protein jasmine rice flour), GF-LPJF (general formulation pudding made from low protein jasmine rice flour), SF-HPJF (substituted formulation pudding made from high protein jasmine rice flour), SF-LPJF (substituted formulation pudding made from low protein jasmine rice flour), CF-HPJF (control formulation pudding made from high protein jasmine rice flour and CF-LPJF (control formulation pudding made from low protein jasmine rice flour).

Textural properties

The texture analysis was carried out following Nunes *et al.* (2003) and Suya *et al.* (2008) with a minor modification. Texture parameters (hardness, adhesiveness, gumminess, chewiness, springiness, and cohesiveness) of rice pudding were determined using the texture analyzer (TA. XT. Plus, Stable Micro System, Godalming, UK) in a texture profile analysis mode (TPA) with 25 mm diameter cylinder probe, 60% strain of penetration, 5 s of waiting time, and 2 mm.s^{-1} of test speed.

Rheological properties

The rheological properties of rice pudding were investigated following Alamprese and Mariotti (2011) using rheometer (AR-G2 Rheometer, TA Instruments, New Castle, USA). Dynamic test in oscillatory shear mode with a 40 mm diameter parallel plate geometry and 1 mm gap was used for a small destruction analysis. In order to determine the linear viscoelastic region (LVR), strain sweep was carried out at a constant frequency of 1 Hz in a range of strain from 0.01 to 100%. With a 0.1% constant strain from LVR analysis, the frequency sweep for all formulations of rice pudding was determined in the frequency range of 0.01 to 100 Hz. Storage modulus (G'), loss modulus (G") and loss tangent (tan δ) were measured.

Statistical analysis

The results obtained from all measurements were analyzed with statistical program using SPSS version 13.0(SPSS Inc., Ilinois, USA). Mean difference testing was conducted using Duncan's New Multiple Range Test (DMRT). All analyses were performed in triplicate

Results and Discussion

Chemical composition analysis

The chemical composition of HPJF and LPJF is shown in Table 1. The protein content in HPJF was significantly higher than that of LPJF ($p<0.05$). Normally, general rice flour approximately contained protein from 6 to 8% (w/w) (Sriroth and Piyajomkwan, 2003) but LPJF consisted of only 3.54% (w/w) protein which was lower than the protein content found in HPJF (7.70% w/w). This showed that the process of protein extraction for LPJF could efficiently reduce the protein content in such flour. In addition, the amylose content of HPJF was significantly less than that of LPJF but this was still in the range of amylose content which should be found in jasmine rice flour (15-19% w/w) (Pongsawatmanit, 2003). However, a large amount of protein content in HPJF might influence the amylose content by trapping the amylose in protein matrixes (Wansuksir *et al*., 2006), resulting in a difficulty of amylose leaching from starch granules. Additionally, Hamaker and Griffin (1993) and Wongdechsarekul and Kongkiattikajorn (2009) explained that the protein matrixes developed

Table 1. Chemical composition and pasting properties of HPJF and LPJF

		HPJF	LPJF
Chemical compositions	Protein	7.70±0.05^{a}	3.54±0.04^{b}
	Fat	0.69±0.04^{a}	0.13±0.08^{b}
	Ash	0.42±0.01^{a}	0.16±0.00^{b}
	Moisture	9.38±0.01^{a}	8.25±0.03^{b}
	Amylose	17.07±0.06^{a}	19.23±0.06^{b}
Pasting properties	Pasting Temperature (°C)	84.03^{a}	73.50^{a}
	Peak Viscosity (RVU)	99.17^{a}	129.63^{b}
	Trough Viscosity (RVU)	74.71^{a}	39.75^{b}
	Breakdown (RVU)	24.46^{a}	89.88^{b}
	Final Viscosity (RVU)	147.50^{a}	73.30^{b}
	Setback (RVU)	72.79^{a}	33.54^{b}
	Peak Time (min)	5.77^{a}	4.37^{b}

Different letters in the same row shows the significant mean difference at 95%. n =3.

more crosslinks and acted as a barrier to water penetration, hydration, and swelling of the starch granules during the gelation stage which affected the pasting properties and textural structure of rice flour. This rarely occurred in LPJF, resulting in the lower amylose content in HPJF than in LPJF.

Viscosity and pasting properties

The viscosity and pasting properties of HPJF and LPJF are also shown in Table 1. The pasting temperature of HPJF was higher than that of LPJF. This might be because the high protein content forming the protein matrixes might hinder the water absorption of starch granules by encircling the starch in the matrixes (Tamaki *et al.*, 1989a, b), resulting in the less swelling of starch granules. Consequently, the amylose in HPJF leached out from the protein matrixes less than did the amylose in LPJF (Martin and Fitzgerald, 2002; Naivikul, 2004; Xie *et al.*, 2008). This contributed to the higher peak viscosity of LPJF compared to that of HPJF.

The trough viscosity of HPJF was higher than that of LPJF during the shearing step in pasting measurement (Table 1) due to the effect of protein encircling as well. The protein matrixes might maintain the HPJF structure and obstruct the destruction by shearing force in this analysis which might be hardly ever found in LPJF. Moreover, when the temperature of this analytical system decreased, the denatured proteins, which were more proportionally found in HPJF than in LPJF during the trough viscosity measurement, could reform their structure by disulfide bonding in the cooling step. This might reinforce the strength of starch-protein interaction in HPJF rather than in LPJF. Thus, the structure of LPJF was easily destroyed by shearing force.

The breakdown value of starch refers to the shear resistance after gelatinization of starch granules. The breakdown of HPJF was lower than that of LPJF (Table 1). This meant that the shear resistance of HPJF was higher than that of LPJF. The higher shear resistance in HPJF after the gelation of starch granules might attribute to the high protein content found in HPJF which helped to maintain the structure of starch granules as well as to retain the overall structure of starch-protein interaction in HPJF better than did in LPJF.

The setback value defines the ability of starch retrogradation which mainly refers to the ability of amylose gelation rather than that of amylopectin (Vanderputte *et al.*, 2003; Ottrnhof and Farhat, 2004). Theoretically, the higher amylose content found in LPJF should exhibit the higher setback but, from our study, the setback of HPJF was higher than that of LPJF (Table 1). This implied that the protein content in HPJF had a greater dominant effect on this setback than amylose. Thus, the protein content plays an important role on setback in this study. Moreover, proteins in HPJF might hinder the water absorption of amylose, resulting in the less leaching of amylose from starch granules and protein matrixes (Martin and Fitzgerald, 2002; Naivikul, 2004; Xie *et al.*, 2008).

From the results (Table 1), we found that the final viscosity of HPJF was higher than that of LPJF even though the HPJF contained more proteins than LPJF. This implied that the amount of rice protein content

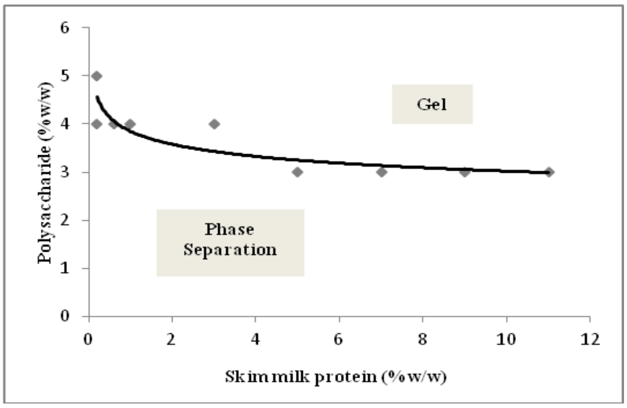

Figure 1. Phase diagram of low protein jasmine rice flour (LPJF) and skim milk powder (SMP)

greater influenced final viscosity than amylose content in this study (Pongsawatmanit, 2003; Wongdechsarekul and Kongkiattikajorn, 2010). Moreover, as mentioned previously, the encircling of rice proteins might affect the starch granules to be easily attached one and another, resulting in the rearranged granule networks with H-bonds which strengthened overall structure of such sample. Thus, this could enhance the final viscosity in this sample.

Phase diagram

Although the rice protein in previous part dominantly involved the attributes of rice flour, the effect of the interaction between rice flour and SMP as the main ingredients in rice pudding should not be abandoned. From the phase diagrams of the interaction between HPJF or LPJF and SMP (Figure 1), we found that there was no compatible area of both flour and SMP even though the low concentrations of flour and SMP were used. This was due to the depletion-flocculation which always occurred in the system containing polymeric molecules like polysaccharides and proteins (Thaiudom and Goff, 2003; Noisuwan *et al*., 2008, 2009; Chappellaz *et al*., 2009).

The mixtures between flour and SMP exhibited high viscous and looked like soft gel when the concentrations of HPJF and LPJF increased at a constant low SMP concentration. However, gel forming could be observed in the samples when the concentrations of LPJF and SMP increased more than 3 and 5% (w/w), respectively (Figure 1). This phenomenon could not be seen in HPJF samples. However, the phase diagram of the interaction between LPJF and SMP was quite different from the one of other polysaccharides and milk proteins studied in many researches (Schorsch *et al*., 1999; Hemar *et al.*, 2001; Thaiudom and Goff, 2003; Noisuwan *et al*., 2008, 2009; Chappellaz *et al.,* 2009; Gruijthuijsen *et al.*, 2012). The LPJF-SMP phase diagram did not showed the compatible or miscible area but it consisted of only incompatible and gel zones. This was in agreement with Thaiudom and Pongsawatmanit (2011) who studied for the phase diagram of modified starch and SMP.

From the results of viscosity and pasting analysis in previous part, setback value of HPJF showed the higher ability to form 3 dimension networks from the protein matrixes and amylose itself than LPJF. However, from the phase diagram results, the LPJF could form gel and more compatible than HPJF. This confirmed that the high amount of rice proteins found in HPJF could efficiently prevent amylose to bind or interact with SMP compared to the LPJF samples which contained less rice proteins. Moreover, the significantly high amount of amylose found in LPJF seemed to easily interact and form gel with SMP better than those in HPJF. The gelation of LPJF-SMP interaction might be attributed to casein-entrapped in starch granule three dimension networks when the LPJF samples were cooled down (Noisuwan *et al.*, 2009). This interaction contributed to the pudding attributes such as textural and rheological properties (Alamprese and Mariotti, 2011; Considine *et al*., 2011).

Textural properties of rice pudding

The textural properties of jasmine rice flour puddings during day 0 to day 16 of storage time are shown in Figure 2. In a consideration to type of jasmine rice flour for all pudding formulations, the hardness (Figure 2a), gumminess (Figure 2c), and chewiness (Figure 2d) of LPJF-puddings were higher than those of HPJF-puddings. These textural property values increased as the storage time increased. In contrast, the textural property values of HPJF-puddings increased from day 0 to day 2 and decreased after that. However, the adhesiveness (Figure 2b), springiness (Figure 2e), and cohesiveness (Figure 2f) of HPJF-puddings were obviously higher than those of LPJF-puddings, especially when the storage time increased. This might be due to the effect of high protein content in HPJF which could support the structure of such samples by disulfide bonding in the interaction of rice proteins and SMP or the interaction between rice proteins themselves. These specific protein interactions might increase the adhesiveness, springiness, and cohesiveness in such samples better than the interaction between rice starch and SMP. Interestingly, however, by visual observation, the HPJF-puddings looked like a concentrated solution while LPJF-puddings were more similar to soft gel throughout the storage study time. This was agreed with the hardness value of LPJF-puddings which was higher than that of HPJF-puddings. This implied

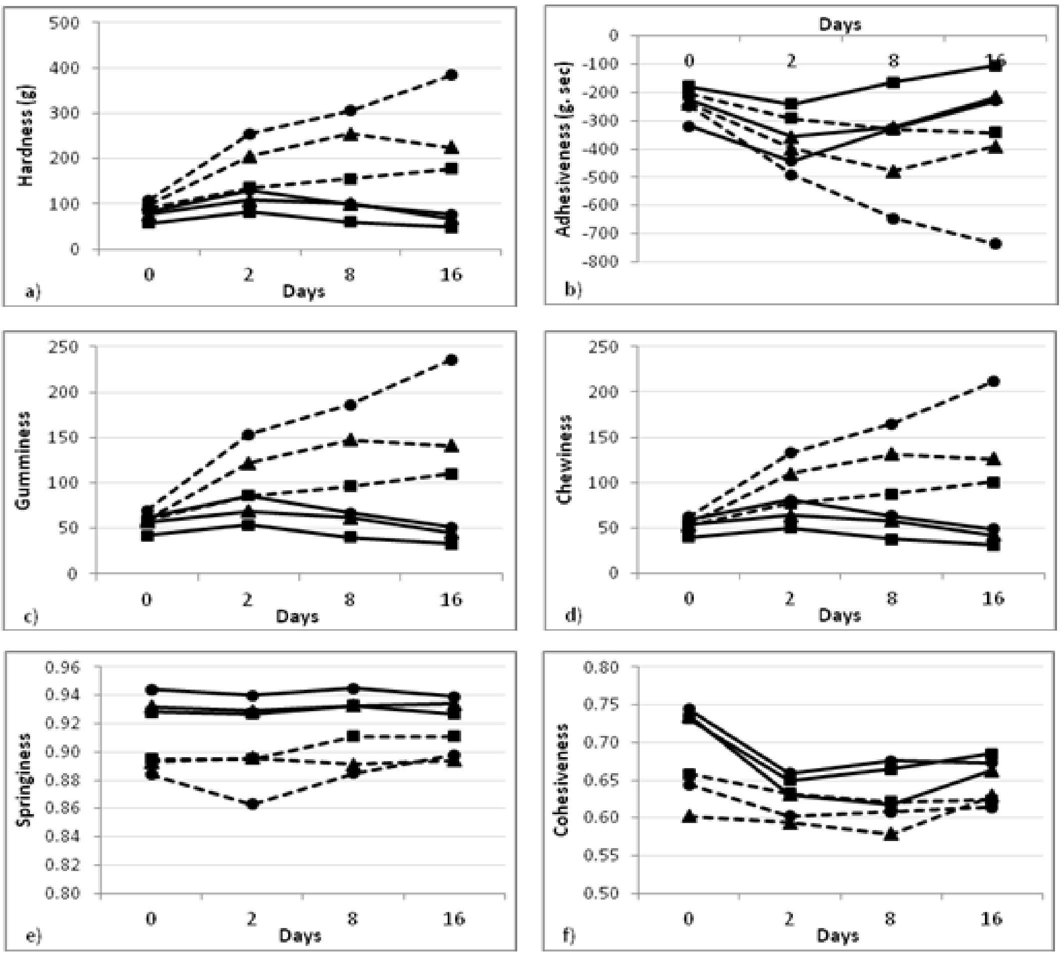

Figure 2. Textural parameters of pudding from different formulations: GF-HPJF (—▲—), GF-LPJF (- -▲- -), SF-HPJF (—●—), SF-LPJF (- -●- -), CF-HPJF (—■—) and CF-LPJF (- -■- -). n = 3.

that the interaction between SMP and rice starch, especially in LPJF dominantly greater affect the texture of such puddings than the interaction of rice protein and SMP or SMP and starch found in HPJF puddings. This confirmed that the protein matrixes in HPJF could hinder the interaction between rice starch and SMP in HPJF greater than that in LPJF. However, Noisuwan *et al.* (2009) suggested that the starch components (amylose and amylopectin), leached out from disrupted starch granules during pasting at high temperatures, could induce the phase separation in SMP-rice starch mixtures. Upon cooling process, the aggregated milk proteins might be entrapped in the gelled starch matrixes too.

Considering the effect of the different formulations, the hardness, gumminess, chewiness, springiness, and cohesiveness of each pudding formulation were not significantly different. However, throughout the period of storage time, the adhesiveness of CF-pudding was higher than that of GF- and SF-puddings, respectively. This might be because the water content in CF-pudding was higher than that in GF- and SF-samples. Consequently, the ingredients such as salt, sugar, and SMP could be absolutely dissolved and could react with each other or with starch better than they did in GF- and SF-puddings. In addition, the more water content in such formulation, the better swelling of amylose in starch granules resulting in more interaction between starch and SMP that provided the high adhesiveness value. However, GF- and CF-puddings containing LPJF showed the lower hardness, gumminess, chewiness, and adhesiveness than those of SF-LPJF-puddings. This might be due to the higher total solid found in SF-formulation than did in GF- and CF-puddings. Also, this might be implied that the possibility of the interaction among starches themselves and between starches and proteins in SMP in SF was higher than that in GF- and CF-puddings. However, the springiness and cohesiveness of all pudding formulations were not significantly different because the springiness was calculated from the distance of the detected height of the product on the second compression divided by the original compression distance while the cohesiveness was calculated as the area of work during the second compression divided by the area of

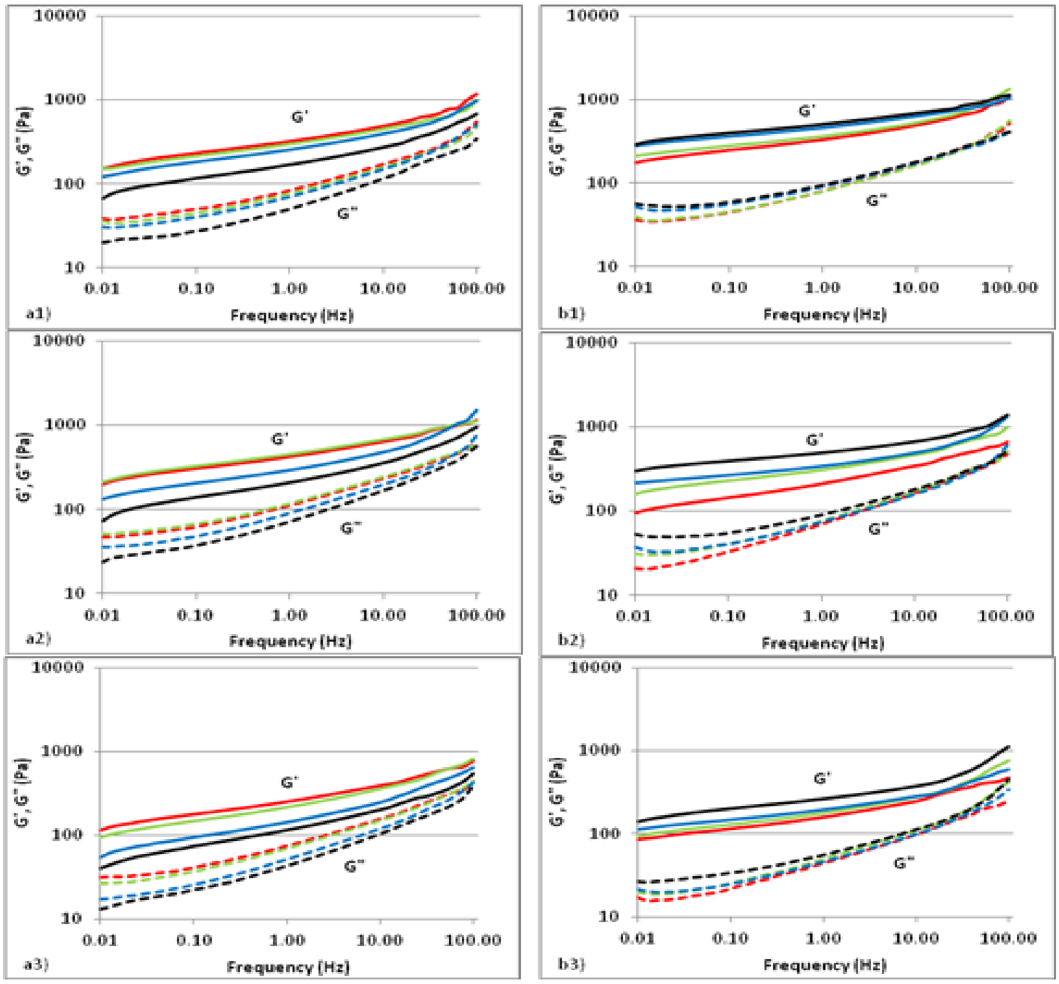

Figure 3. Storage modulus (G', solid line) and loss modulus (G", dashed line) of frequency sweep test of puddings from different formulations: GF-HPJF (a1); SF-HPJF (a2); CF-HPJF (a3); GF-LPJF (b1); SF-LPJF (b2); and CF-LPJF (b3) on day 0 (—), 2 (—), 8 (—) and 16 (—). n = 3.

work during the first compression. Thus, both values came up from the proportional calculation between two values as mentioned that this proportion might not be significantly changed when the formulations were changed.

Rheological properties of rice pudding

The rheological properties of rice puddings are shown in Figure 3 and 4. All puddings behaved as a weak gel since the storage modulus (G') was higher than the loss modulus (G'') throughout the storage period (Figure 3). This meant that there were ingredient interactions in all rice puddings, resulting in the structural formation of those puddings showing the greater elastic property (solid-like behavior) than the viscous property (liquid-like behavior). This was relevant to the loss tangent (tan δ) which decreased as the storage time increased (Figure 4), confirming that such puddings were a weak gel (Lim and Narsimhan, 2006; Alamprese and Mariotti, 2011).

Considering the effect of different type of rice flour, the HPJF-puddings (Figure 3 a1, a2, a3 and Figure 4 a1, a2, a3) gave the higher G', G'', and tan δ in a first two days than did LPJF (Figure 3 b1, b2, b3 and Figure 4 b1, b2, b3). However, when the storage time increased, G' and G'' decreased but tan δ increased. This revealed that, in HPJF samples, weak gel characteristic of such puddings decreased. In contrast, G' and G'' increased but tan δ decreased when the storage time increased. This meant that the structure of LPJF-puddings could stronger form than could HPJF-puddings. The greater forming structure of LPJF might be attributed to the hydrogen bonding between water and starch or the retrogradation of amylose in starch which was less hindered by protein matrixes less found in LPJF. On the other hand, the weaker forming structure of HPJF-puddings might be attributed to the higher protein content which could form the matrixes and could hinder the retrogradation of amylose and the interaction between water and starch, resulting in less strength of such puddings. This result was relevant to the finding of textural properties as the hardness value in textural property part mentioned previously.

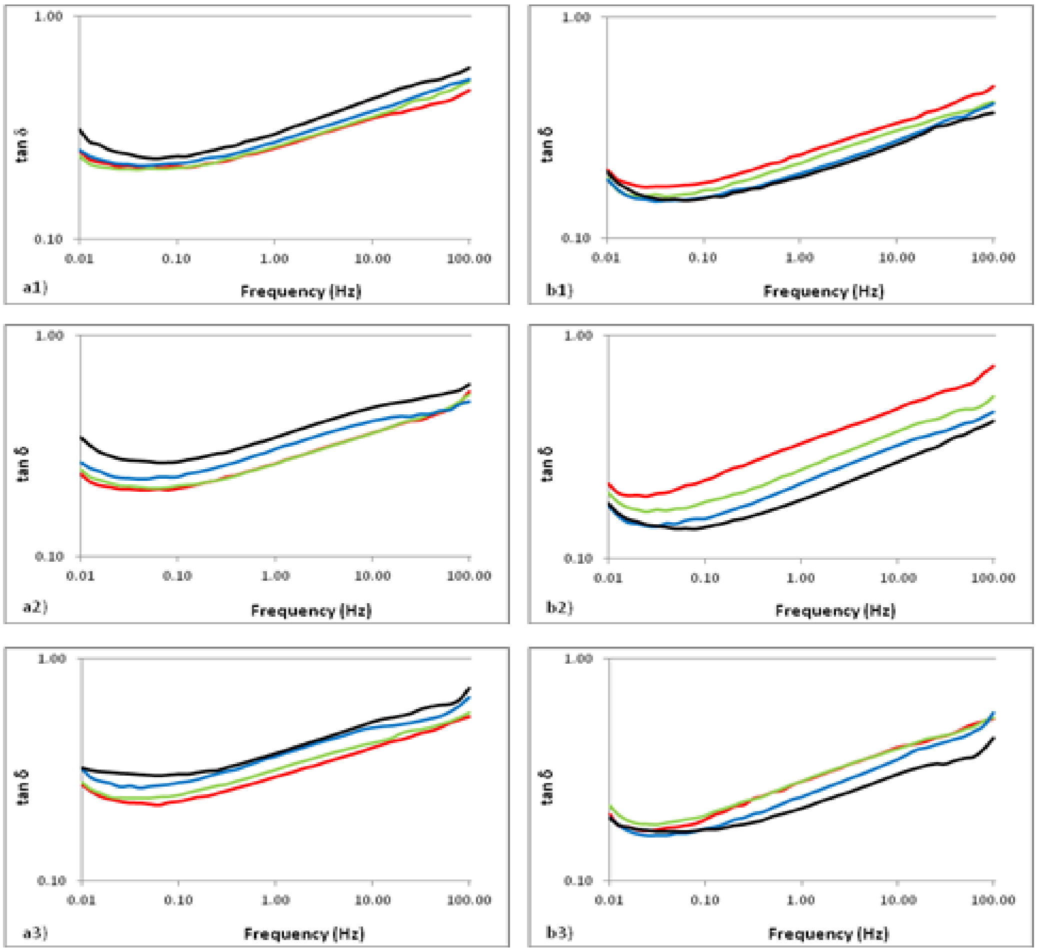

Figure 4. Loss tangent (tan δ) of frequency sweep test of puddings from different formulations: GF-HPJF (a1); SF-HPJF (a2); CF-HPJF (a3); GF-LPJF (b1); SF-LPJF (b2); and CF-LPJF (b3) on day 0 (—), 2 (—), 8 (—) and 16 (—). n = 3.

Regarding the different formulations, SF-puddings (Figure 3 a2, b2) showed the higher G' and G'' than the GF- (Figure 3 a1, b1) and CF-puddings (Figure 3 a3, b3), respectively. This meant that the texture of SF-puddings was more solid-like than that of GF- and CF-samples, respectively. In addition, considering to the tan δ of SF-puddings, the longer the storage time, the lower the tan δ. This confirmed that the total solid in the formulation evidently affected the pudding structure. However, in SF, the protein content in rice flour also manifestly influenced tan δ which could be seen as the tan δ of HPJF-puddings was always higher than that of LPJF-puddings. This might be the effect of protein matrixes as mentioned before.

Conclusion

The protein content in jasmine rice flour significantly influenced viscosity and pasting properties of the flour. Jasmine rice flour with lower protein content exhibited a weak gel area with skim milk protein in the phase diagram while the higher protein content flour was incompatible with skim milk protein. This compatibility was attributed to the depletion-flocculation mechanism. The results contributed to the different characteristics of puddings made from different protein content of jasmine rice flour, resulting in the different textural and rheological properties of jasmine rice puddings. The puddings made from low protein content flour seemed to give the better properties in texture and rheology than the flour with high protein content. In addition, puddings which egg was substituted by jasmine flour exhibited more solid-like characteristic than egg puddings, resulting in the higher values of hardness, gumminess, chewiness, G' and G'', compared to the egg or general puddings.

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