Effects of Soy Protein and Rice Protein on Stability and Pasting Properties of Brown Rice Beverage

Panorjit Nitisuk[1,*], Juntanee Uriyapongson[1] and Inteaz Alli[2]

Abstract

The objective of this research was to investigate the effects of protein addition on the viscosity, pasting properties, suspension stability and storage stability of brown rice beverage. In this study, six protein ingredients, including soy flour, soy protein isolate (SPI) and rice protein extracts (albumin, globulin, glutelin and prolamin) were used at two concentrations (0.5 and 1.0%, w/w). The non-pasteurized beverages subject to the addition of 1.0% SPI and 0.5% prolamin and measured by RVA showed the highest peak of viscosity, final viscosity and setback. Meanwhile, the pasteurized samples at temperature 4 °C showed higher viscosity than those at 25 °C. The addition of SPI 1.0% at temperature 4 °C demonstrated the highest viscosity, followed by 0.5% addition. The samples added with 1.0% of soy flour and SPI, and 0.5% of prolamin gave the highest suspension and storage stability, compared to those of the control and other protein extracts. This study has demonstrated that prolamin from rice extract should be considered as suitable protein addition for brown rice beverage to improving its small particles, suspension stability and storage stability.

Keywords: Brown rice beverage, Rice protein, Storage stability, Pasting property

[1] Department of Food Technology, Khon Kaen University, Khon Kaen, 40002, Thailand,

[2] Department of Food Science and Agricultural Chemistry, McGill University, Montreal, Quebec, 21111, Canada

* Corresponding author(s), e-mail: spanorjit@gmail.com

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1. Introduction

Recently, the consumer demand for healthy food has significantly increased; thus, a number of attempts have been made to search for supplementary materials. Alternatively, such cereal grains wheat, corn, barley, rice, oat, etc. have been reported as functional food and nutraceuticals due to their high levels of fiber and micronutrients, which contribute to potential health benefit for instance the reduction of oxidative stress, inflammation, hyperglycemia and carcinogenesis (Das *et al*., 2012).The consumption of cereal-based beverages has considerably increased because of the absence of cholesterol and lactose, considerably suitable particularly for group of individuals from lactose intolerance and heart disease (Sethi *et al*., 2016). Rice beverage, which has been consumed for almost three decades (Mitchell *et al*., 1988), is a good source of phytosterols, especially β-sitosterol and γ-oryzanol, which provide protective benefits against several diseases, such as anti-diabetic, anti-inflammatory and antioxidative effects (Biswas *et al*., 2011; Faccin *et al*., 2009). However, rice milk contains high starch content likely to undermine emulsion stability. Consequently, a number of studies have attempted to address this drawback. Mitchell *et al*. (1988) improved the emulsion stability in rice beverage by enzymatic hydrolysis by alpha and beta amylase or glucosidase. Utthapon *et al*. (2017) improve the stability in rice bran milk by hydrocolloids, they suggests that the mixing hydrocolloids (guar gum and xanthan gum) can improve stability of emulsion. Like bovine milk, the cereal and grain beverages are colloidal emulsions and suspensions of the particles or droplets at least one linear dimension in the size ranging from 1 nm to about 1 μm (Dickinson, 1992). These emulsions are the oil droplets stabilized with surface-active agents such as proteins and lipids while the suspensions are insoluble solid particles, such as undissolved protein, starch, fiber and other cellular material suspended in the aqueous solution. In emulsions, the total number of droplets, their size and arrangement in space can completely change over time (Dickinson and Stainsby, 1988). Indeed, physicochemical properties of beverages are primarily influenced by several factors, including functionality of ingredients, processing conditions, and interactions between colloidal ingredients (Cano-Ruiz and Richter, 1998) and, during storage of emulsions and suspensions product, stability is also related to rheology, critical for product development (Durand and Hosken, 1999).

Despite low the proteins content regarded slightly low (7–9 g/100 g), rice's amino acid composition is more complete compared to other cereals; rice proteins are relatively rich in lysine content compared to wheat, corn and sorghum and possess a more balanced amino-acid profile (Hegsted, 1979; Wang *et al*., 2000). In addition to being colourless and possessing bland taste, hypoallergenic and hypocholesterolemic (Ju *et al*., 2001), rice proteins contain no the toxic epitope responsible for celiac disease, thus making these protein valuable. Milled rice or rice endosperm contains 3.8–8.8% albumin, 9.6–10.8% globulin, 2.6–3.3% prolamin and 66–78% glutelin. (Gloria *et al*., 1976). Rice prolamin is reported to affect pasting properties of rice starch by increasing rate of water absorption of starch granules, thereby reducing both hardness and adhesiveness of rice gels (Graeme *et al*., 2004). However, very little is known about mixed proteins-starch systems when observing oil droplet covered by proteins (Dickinson, 2001) since individual proteins at the interface exhibit distinct behaviors due to molecular properties (Dalgleish, 1996). The charge of protein at a certain pH, its molecular flexibility, and the thickness of the film formed will affect the stability of oil droplets (Dalgleish, 1996; Graeme *et al*., 2004). Soy flour is a versatile soy food ingredient due to its functionality, nutritional quality and low cost (Devi and Haripriya, 2014). Soy protein isolates (SPI) with protein content of about 92%, provide better fat, moisture retention and gelling ability than other forms of soy proteins (Kinsella, 1979). However, soy protein supplies all 9 essential amino acid and provides many functional benefits to food processors and for a healthy diet (Singh *et al*., 2008). The aim of this study is to investigate the effect of different protein types and concentrations on pasting property, viscosity, suspension stability and storage stability of brown rice beverage.

2. Materials and Methods

2.1 Raw materials

The raw materials were purchased and treated as follows. Brown rice, purchased from Roi-Et province, Thailand, was prepared by dehusking Jasmine rice cultivar (Kao Dok Mali 105) (*Oryza sativa* L.). Dried soy beans were ground into a fine powder by dry-milling using a hammer mill (Perten lab mill 3100, Sweden), then sifted through a 100 mesh sieve to obtain soy flour. The commercial soy protein isolate (SPI) was purchased from Union Chemical 1986 Co., Ltd., (Thailand).

2.2 Protein isolation

The extraction procedure was based primarily on the method adopted by Ju *et al*. (2001) with some modifications. Prior to protein extraction, the brown rice was ground into a fine powder. Eventually, 100 g brown rice flour was defatted with 400 ml hexane by solid-liquid extraction. The defatted rice flour was then dried under a hood at ambient temperature for 24 h. Subsequently, albumin fraction was extracted using water extraction by shaking the flour with 400 mL distilled water at room temperature for 4 h and centrifuged at 3000 × g for 30 min. Similarly, the flour residue was extracted with 400 mL 5% NaCl to obtain globulin fraction. The residue from this step was further extracted with 300 ml 0.1 M NaOH at room temperature for 30 min to obtain glutelin fraction, followed by prolamin extraction with 300 mL of 70%

ethanol at room temperature for 4 h. Albumin, globulin, glutelin and prolamin were precipitated from their supernatants by adjusting pH to their isoelectric points (Ips). To increase the reliability each extraction was subjected to repeat twice. Finally, to obtain protein powder, the precipitated proteins (albumin, globulin, glutelin, and prolamin) were washed twice with distilled water and adjusted to pH 7.0, with subsequent lyophilization.

2.3 Brown rice beverage preparation

The dehusked brown rice was soaked in water at 25 °C for 3 h. The soaked brown rice was then mixed with water at the ratio 1:8 (w/w) and blended using a Waring blender at low speed for 1 min and another 1 min at high speed, respectively. Each protein (i.e., soy flour, SPI and rice proteins, including albumin, globulin, glutelin and prolamin) were added at two concentrations, including 0.5 and 1.0% (w/w), whereas, the beverage without protein addition was assigned as a control. The beverages with and without protein addition was homogenized using a homogenizer (D-79282 from Ystal GmbH, Ballrechten-Dottingen, Germany) at 22,000 rpm for 2 min, then pasteurized at 85 °C for 15 min.

2.4 Pasting properties

A Rapid Visco Analyzer (RVA, Model-4D, Newport Scientific Inc, Australia). was used to record and analyze the pasting properties of non-pasteurized beverage sample was prepared by adding 25.00 mL of the sample directly into a metal RVA canister. Paddle was jog up and down to remove any lump that formed. The pasting profile was recorded in triplicate under a constant shear rate (160 rpm) with heating and cooling cycles of 50 °C to 95 °C for 15 min (AACC, 2000). Peak viscosity, trough/hold, breakdown, final viscosity, setback, peak time and pasting temperature were recorded from the RVA curve. Stability ratio was the ratio of hold viscosity to peak viscosity and setback ratio was the ratio of final viscosity to hold viscosity.

2.5 Viscosity

The viscosity of brown rice beverages was measured at 4 and 25 °C using Brookfield viscometer (Model DV-II version 2.0, UK) with a modified method of Lee and Rhee (2003). The measurement was operated at speed 100 rpm with spindle No.1.

2.6 Suspension stability

All treatments of brown rice beverage were tested for suspension stability according to the modified method of Lee and Rhee (2003), by undergoing measurement from the top to bottom ratio of total solids in the samples stored undisturbed in a 100 mL cylinder for 5 days at 4 °C. The portions (3 mL) were withdrawn using a 5 mL syringe from the center of the upper 1/3 of the bottle and from the lower 1/3 of the bottle. The samples from all 3 mL portions were analyzed for total solid content by drying at 105 °C for 12 h. The ratio of solid weight from 3 mL upper and 3 mL lower was calculated.

2.7 Storage stability

Storage stability was determined according to a procedure modified from the method described by Huang *et al*. (2001). The visual stability was made by a line of demarcation between upper and lower portions of the beverage stored in 100 ml cylinder up to 14 days of quiescent storage at 4 °C. Once the line of demarcation was observed, its height of the upper portion was measured at 7 and 14 days of storage time, calculated and expressed as a percentage of a ratio to a total height of the beverage. The storage stability value of 100% indicated no separation nor observed line of demarcation.

2.8 Particle size distribution

The particle size distribution was measured by the light scattering technique with a Malvern Mastersizer 2000 according to a method described by Durand *et al*. (2003). The samples were diluted with distilled water to obtain a constant obscuration for the instrument. Measurements for as-received, floating and sinking phases were duplicated after centrifugation for 30 min at 1000 rpm in order to separate the oil droplets (floating phase) and the non-fat solids (sinking phase).

2.9 Statistical analysis

Analysis of variance (ANOVA) was performed, and differences among samples were determined by Duncan Multiple Range Test (DMRT) using the Statistical Analysis System Version 9.1 (SAS Institute, Cary, NC) program. The level of significance was defined at $p \leq 0.05$. At least three replicates of each measurement were carried out. Uncertainly for each result was expressed as the standard deviation.

3. Results and Discussion

3.1 Pasting properties and viscosity

The RVA pasting properties of non-pasteurized beverages were shown in Table 1. Pasting temperature refers to the temperature at which starch granules begin to swell and gelatinize due to water uptake, thereby resulting in increased viscosity and peak viscosity reflects the extent of granule swelling. While peak time refers to amount of time spent on reaching the peak viscosity. A drop in viscosity from a maximum value or peak viscosity to a minimum viscosity is regarded as a breakdown value, which reflects the stability of the paste during cooking, whereas the final viscosity at 50 °C indicates the stability of the cooked paste. In term of setback value, this value shows the viscosity increase on cooling to 50 °C, indicating the extent of retrogradation of the starch product. According to the study, all of pasting parameters were significantly affected by the interaction of protein types and concentrations. The addition of protein led to the increase of water binding capacity and concentration of dispersion in the mixture, in addition, the rise of viscosity during gelatinization was found due to disulfide bonds. Degree of gelatinization and gel strength increased when protein disulfide bonds were cleaved. Protein with intact disulfide bonds makes the swollen granules less susceptible to breakdown, either by conferring strength to the swollen granules or by reducing the degree of swelling. (Hamaker and Griffin, 1993). Other evidence for the involvement of protein in starch gelatinization was obtained by Chandrashekar and Desikachar (1981), who showed that the addition of papain to sorghum four prior to heating resulted in an increased water uptake. Among the beverages, the addition of 1% SPI and 0.5% rice prolamin resulted in the highest peak of viscosity (3.13 and 3.5 RVU, respectively); however, the present of other proteins led to the decreasing of viscosity, likely due to the dilution effect on the starch concentration (Marcoa and Rosell, 2008). In term of the setback value, the samples added with 1% SPI and 0.5% prolamin exhibited the highest setback (2.63 and 2.75 RVU, respectively), suggesting that the reorganization of the denatured proteins could result in a significant change of the setback (Marcoa and Rosell, 2008). Moreover, 1% SPI and 0.5% prolamin addition improved the final viscosity (5.75 and 6.25 cP, respectively) compared to the control (4.33 cP), whereas, the addition of prolamin at a higher concentration failed to increase this value, which could suggest that the presence of prolamin at a high concentration influenced on the weakness of the three-dimensional network in the matrix (Baxter *et al*., 2004). Furthermore, there were no significant differences in breakdown value, except for 0.5% of rice glutelin due to an increased rate of starch granule rupturing during the RVA measuring (Baxter *et al*., 2004). Nevertheless, the peak time of all samples showed no a significant change ($p > 0.05$). The pasting temperature value was observed merely for 0.5% addition of SPI, prolamin and glutelin at 95.37, 95.08 and 95.38 °C, respectively, while other samples could not be detected. Similarly, the peak viscosity of all proteins had no significant difference ($p > 0.05$). On the other hand, soy protein isolate 0.5% exhibited the lowest peak of viscosity, soy flour 0.5 and 1.0% showed faster swelling properties, and brown rice beverage showed lower pasting temperature than other proteins. However, due to the concentrations of starch and proteins in the beverage system were too low for RVA measurement, the RVA results may not be believable enough to draw conclusions about interactions between starch and proteins in the beverage.

Viscosity is one of the essential properties of foods attributed to mouth feel and the texture of the beverage (Yu *et al*., 2007). In this study, the viscosity of pasteurized brown rice beverages was measured by Brookfield viscometer at the storage temperature for both refrigerated temperature (4 °C) and room temperature (25 °C). Table 2 shows the viscosity of beverages at 4 °C were higher than those at 25 °C. A possible explanation for this result is maybe due to the starch retrogradation as well as gel forming property of protein at a lower temperature (Ryann and Brewer, 2004). Moreover, the increase in protein concentration results in the higher viscosity. This could be explained that the high protein concentration improves the ability of protein-protein interaction (McClements, 1999), resulting in the increased viscosity. The addition of SPI accounts for the highest viscosity (20.05–21.05 cP) at cold temperature, which can be associated with the higher protein content contents of SPI providing a better formed solid-like gel at low temperature when compared to the other proteins. (Malhotra and Coupland, 2004). According to Roesch *et al*. (2003), due to protein-protein interactions that heat-treated emulsions prepared with soy protein concentrate and oil showed a gel-like behavior upon storage at 4 °C for 20 days. This finding corroborates the results by Renkema *et al*. (2000), who found that heat denaturation of SPI was the crucial factor in gel formation as SPI can absorb the large amount of water upon hydration resulting in the higher viscosity either before or after heating (Yu *et al*., 2007).

Table 1 The pasting property of non-pasteurized brown rice beverage added with different protein concentrations.

Protein addition	Concentration (%)	Peak Viscosity (RVU)	Trough (RVU)	Breakdown (RVU)	Final Viscosity (cP)	Setback (RVU)	Peak Time (min) ^{ns}	Pasting Temp (°C)
Control	0.0	2.54 ± 0.06^{c}	2.54 ± 0.06^{bc}	0.00 ± 0.00^{b}	4.33 ± 0.12^{b}	1.79 ± 0.05^{b}	6.66 ± 0.37	na
Soy flour	0.5	1.54 ± 0.06^{de}	1.43 ± 0.14^{d}	0.09 ± 0.12^{b}	2.50 ± 0.24^{ac}	0.96 ± 0.18^{cd}	5.86 ± 0.09	na
	1.0	1.46 ± 0.06^{de}	1.29 ± 0.06^{d}	0.90 ± 0.00^{b}	1.62 ± 0.06^{ef}	0.17 ± 0.12^{b}	6.10 ± 0.52	na
SPI	0.5	0.96 ± 0.06^{de}	0.79 ± 0.06^{e}	0.17 ± 0.00^{b}	0.96 ± 0.06^{g}	0.00 ± 0.00^{g}	6.16 ± 0.33	95.37 ± 0.45
	1.0	3.13 ± 0.06^{de}	3.13 ± 0.06^{b}	0.00 ± 0.00^{b}	5.75 ± 0.00^{a}	2.63 ± 0.06^{a}	6.76 ± 0.05	na
Albumin	0.5	1.33 ± 0.12^{de}	1.21 ± 0.06^{d}	0.13 ± 0.06^{b}	2.16 ± 0.08^{ef}	0.83 ± 0.00^{cde}	6.24 ± 0.79	na
	1.0	1.25 ± 0.00^{de}	1.25 ± 0.00^{d}	0.00 ± 0.00^{b}	2.16 ± 0.86^{ef}	0.92 ± 0.12^{cd}	5.86 ± 0.09	na
Globulin	0.5	1.83 ± 0.12^{d}	1.83 ± 0.12^{c}	0.00 ± 0.00^{b}	2.96 ± 0.04^{cd}	1.12 ± 0.04^{c}	6.17 ± 0.14	na
	1.0	1.29 ± 0.06^{de}	1.25 ± 0.00^{d}	0.04 ± 0.06^{b}	2.25 ± 2.25^{ef}	0.96 ± 0.04^{cd}	6.16 ± 0.23	na
Glutelin	0.5	2.84 ± 0.83^{bc}	2.00 ± 0.35^{c}	0.84 ± 0.47^{a}	3.20 ± 0.53^{c}	0.37 ± 0.00^{efg}	6.23 ± 0.71	95.08 ± 0.04
	1.0	1.42 ± 0.12^{de}	1.25 ± 0.11^{d}	0.17 ± 0.00^{b}	3.21 ± 0.11^{ef}	0.83 ± 0.29^{cde}	6.36 ± 0.01	na
Prolamin	0.5	3.5 ± 0.00^{a}	3.50 ± 0.00^{a}	0.00 ± 0.00^{b}	6.25 ± 0.00^{a}	2.75 ± 0.02^{a}	6.80 ± 0.10	95.38 ±0.39
	1.0	1.33 ± 0.23^{cd}	1.25 ± 0.24^{d}	0.08 ± 0.00^{b}	1.87 ± 0.88^{ef}	0.54 ± 0.65^{def}	6.06 ± 0.65	na

Note: values are means $\pm$ SD. $^{a\text{-}g}$: Different letters within columns indicate a significant difference (p<0.05) determined by Duncan's multiple range test (DMRT).

na : Not detected

Table 2 The viscosity of brown rice beverage added with different protein concentrations under temperature at 4 and 25 °C.

Protein addition	Concentration (%)	Viscosity (cP)	
		4 °C	25 °C
Control	0.0	18.15 ± 0.05^{d}	14.95 ± 0.05^{cd}
Soy flour	0.5	16.25 ± 0.35^{h}	15.10 ± 0.14^{bc}
	1.0	17.05 ± 0.07^{fg}	13.05 ± 0.07^{g}
SPI	0.5	20.05 ± 0.07^{b}	16.20 ± 1.97^{a}
	1.0	21.05 ± 0.21^{a}	14.30 ± 0.42^{de}
Albumin	0.5	19.20 ± 0.28^{c}	15.95 ± 0.07^{ab}
	1.0	18.20 ± 0.30^{d}	15.80 ± 0.28^{abc}
Globulin	0.5	19.15 ± 0.21^{c}	15.75 ± 0.07^{abc}
	1.0	17.35 ± 0.21^{ef}	14.30 ± 0.14^{de}
Glutelin	0.5	17.55 ± 0.35^{e}	14.70 ± 0.28^{bcde}
	1.0	19.20 ± 0.14^{c}	15.25 ± 0.07^{abc}
Prolamin	0.5	17.05 ± 0.21^{fg}	13.60 ± 0.28^{ef}
	1.0	16.65 ± 0.21^{gh}	14.55 ± 0.21d^{cde}

Note: values are means ± SD.

$^{a–h}$: Different letters within columns indicate a significant difference (p < 0.05) determined by Duncan's multiple range test (DMRT).

3.2 Suspension and storage stability

Stability of particles in the brown rice beverage at cold storage was assessed for its suspension stability by measuring the ratio of total solids from the top to bottom (Figure 1) and for its storage stability by measuring a line of demarcation calculated and expressed as percentage of a ratio to total height of the beverage (Figure 2). Addition of the different proteins to rice beverage resulted in significantly different suspension and storage stability ($p \leq 0.05$). Soy flour, SPI, rice albumin and rice prolamin increased suspension stability at both 0.5 and 1.0%. The higher levels (1.0%) of soy flour and SPI showed, the higher suspension stability compared to that of low level (0.5%). Nevertheless, the different levels of albumin and prolamin (0.5 and 1.0%) showed no significant difference in its suspension stability ($p > 0.05$). Similarly, rice globulin and glutelin at both levels were not significantly different in its suspension stability compared to the control beverage (p > 0.05). Soy flour and SPI at 1.0% contributed to the highest suspension stability (0.34) compared to the control (0.18) and the other proteins (0.18–0.32).

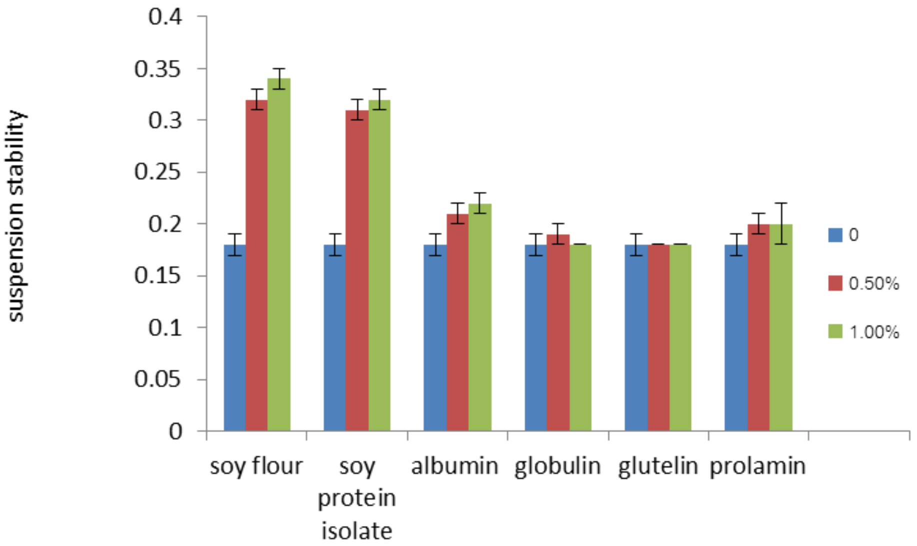

Figure 1 Suspension stability of brown rice beverage added with different protein concentrations stored for 5 days at 4 °C

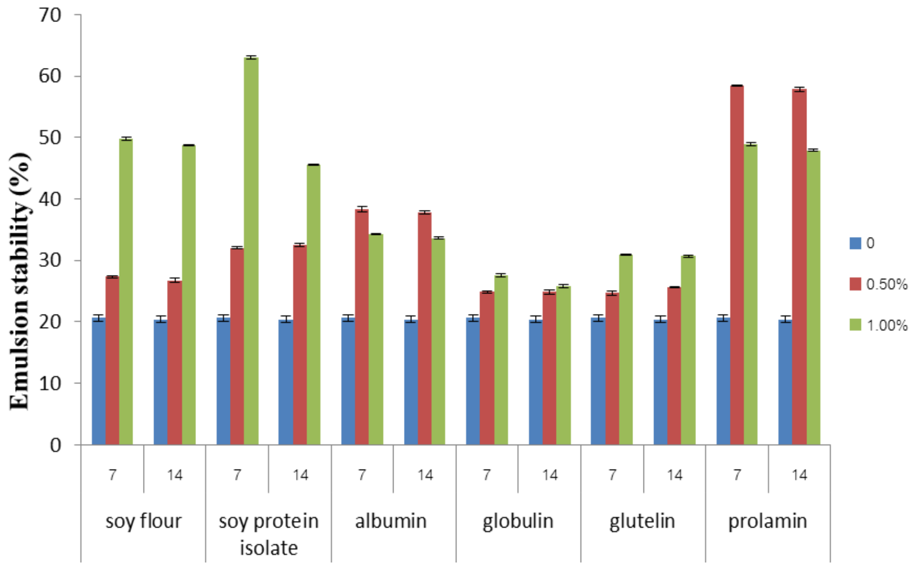

Figure 2 Storage stability of brown rice beverage added with different protein concentrations stored for 7 and 14 days at 4 °C

The effects on storage stability of the brown rice beverage showed a similar trend as those on suspension stability, to illustrate all proteins increased the stability; particularly, soy flour, SPI, and rice albumin and prolamin at 0.5 and 1.0% exhibited higher stability for both suspension and storage (Figure 2). Soy protein and SPI at 1.0% demonstrated higher storage stability than those at 0.5% ($p \leq 0.05$). Rice prolamin and albumin at 0.5% showed higher storage stability than at 1.0%. Protein materials with intact disulfide bonds make the swollen granules less susceptible to breakdown (Hamaker and Griffin, 1993). SPI at 1.0% showed the highest storage stability at 7 days of cold storage (63.05%) compared to the control (20.65%) and other brown rice added with other proteins at 0.5 and 1.0% (24.70-58.405). In addition, rice prolamin at 0.5% showed highest storage stability at 14 days of cold storage (57.87%) compared to the control (20.40%) and other proteins at 0.5 and 1.0% (24.90–48.75%). However, at 7 day of storage, rice prolamin at 0.5% showed similar storage stability to SPI at 1.0% and at 0.5% and it also provided the highest storage stability at both 7 and 14 days of storage.

Indeed, physicochemical properties of beverages are influenced by certain crucial factors, including functionality of ingredients, processing conditions, and interactions between colloidal ingredients (Cano-Ruiz and Richter, 1998). Bovine milk and beverages from cereal and grains are thus considered colloidal emulsions and suspensions, with disperse particles or droplets with the size ranging from of 1 nm to about 1 μm; in other words, the emulsions in these beverages are likely to-be the small fat or oil droplets, stabilized with surface-active agents such as proteins and lipids. Our study found that the soy flour and SPI provided better storage stability for the brown rice beverage suspension stability; this finding is supported by the finding described by Deak and Johnson (2007). Additionally, Bodenstab *et al*. (2003) reported that soy flour exhibited emulsifying activity corresponding to the 40% of commercial lecithin (Comas *et al*., 2006); therefore, the effect of soybean proteins may be attributed to the formation of hydrophilic protein–lipid complexes during processing. Durand *et al*. (2003) also reported that small oil droplets and small protein solids produce stable milks; nevertheless, larger oil droplets and protein solids can produce quick-separating milk. In other words, proteins play two major roles: (1) lowering surface tension between the interfaces formed during the emulsification process; meanwhile, forming a macromolecular layer surrounding the dispersed particles, (2) making it possible to unfold and re-orient their amino acid chain so that the hydrophobic groups align with the oil and the hydrophilic groups align with the aqueous phase can reduce the rate of coalescence which structurally stabilizes the emulsions (Dickinson and Pawlowsky, 1996). However, further research is needed on the functional properties of rice beverage by combined protein.

3.3 Particle size distribution

We found that the addition of all proteins significantly affected particle size distribution in respect of increasing the amount of small particles and reducing amount of large particles in the beverages ($p \leq 0.05$), as shown in Figure 3a, 3b and 3c. In the illustration, the addition of all proteins to brown rice beverage increased suspension stability except for the glutelin and storage stability, which could be explained by the account that the reduction of large particle size (>100 μm) and increased small particle size (5–40 μm) of all samples rests on types of protein added. It is clear that the beverage with smaller sized particles remain stable for a longer period of time. The least stable beverage would benefit from milling or grinding the nonfat solids to produce a finer particle size before the beverage is formulated or better homogenization (Durand and Hosken, 1999) of the product. The addition of soy protein, SPI, and rice prolamin led to relatively small particle size (<5μm); however, the addition of prolamin could increase the small particle size (5–40 μm) up to 99% allowing the rice beverage to contain prolamin the highest stability at 7 and 14 days of cold storage. According to Hinds *et al* (1997), beverages with relative densities of particles in diameters of 34 to 52 μm could impart a mouthfeel similar to that of commercial cow's milk. In addition, the highest stability due to the use of prolamin could result in enhanced gelling properties with high viscosity and binding capacity, which could provide a colloidal system with better dispersion (Baxter *et al*., 2004). Huang et al. (2001) reported that stability of beverage through the addition of soy proteins was higher than stability properties shown by the proteins extracted from rice. Our results are relevant to these reports merely on the case of the short storage (7 days) but not the longer storage (14 days). Give suspension, the beverage suspensions refer to the insoluble solid particles, such as undissolved protein, starch, fiber and other cellular materials. In suspensions, the dense particles can aggregate and subject to sediment out; thus, the stability of the storage depends upon droplet size and aggregation. However, particles in cereal and grain beverages including brown rice milk are not as uniform in size as in bovine milk (Durand *et al*., 2003). The stability of storage to gravitational separation can therefore be enhanced by reducing the size of the droplets (Lee and Rhee, 2003). In general, physicochemical properties of beverages are influenced by certain essential factors, including functionality of ingredients, processing conditions, and interactions between colloidal ingredients (Cano-Ruiz and Richter, 1998). In this study, homogenization widely used in the food industry such as in the production of dairy and food emulsions to improve texture, taste, flavor and shelf-life (Paquin, 1999) was used to reduce size droplets.

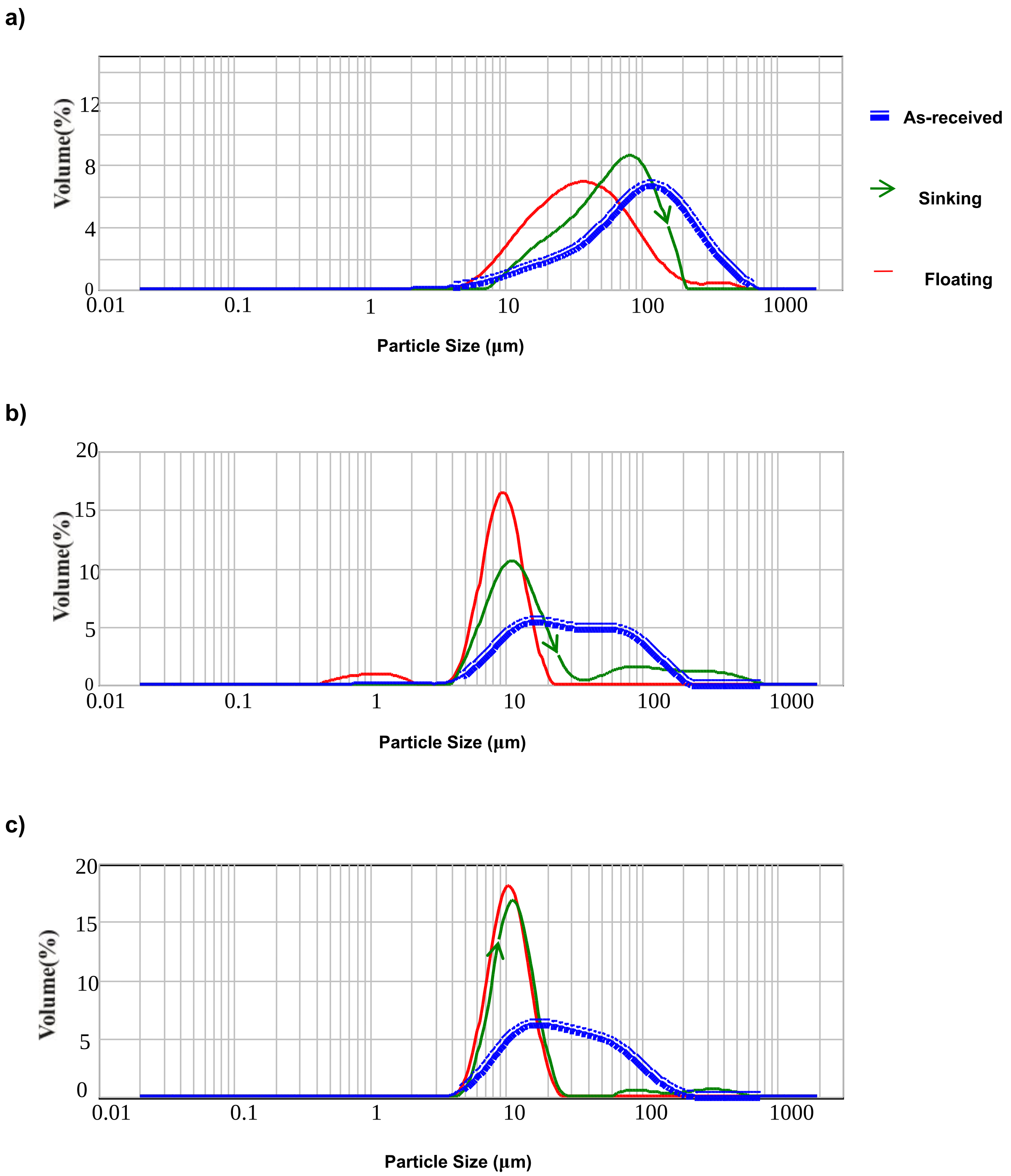

Figure 3 Particle size distribution of brown rice beverage of as-received, floating and sinking portions: a) control, b) containing 0.5% soy flour and c) containing 0.5% rice prolamin

4. Conclusions

This study has shown that the addition of different protein types and concentrations in brown rice beverage has significant effect on pasting properties given RVA and viscosity. In addition, storage under cold temperature contributes to the increased viscosity in beverages. Suspension and storage stability are essential characteristics of beverages especially those derived from cereals in which aggregates are formed because of high starch and cellulose contents. Even though protein addition is likely to improve the stability, the level of improvement depends primarily on types and protein levels. This study suggests that soy flour, soy protein isolate and prolamin extracted from rice could provide improved stability; however, prolamin offers the highest storage stability at the long storage time up to 14 days.

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