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Formulation of sweetened condensed rice-milk fortified with cereals in retortable pouch

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Abstract The addition of single cereal such as Job's tear (J), almond (A) and white sesame (S) in sweetened condensed rice-milk caused lower viscosity than the other cereal formulations (p<0.05). Almond mixed with white sesame (AS) sweetened condensed rice-milk formulaton had the highest viscosity of 2,381.67 cP which was comparable with commercial sweetened condensed milk (control) with 1,890 cP. The total soluble solid of the developed products ranged from 23.90 to 26.63°Brix, water activity (a_w) of 0.966-0.970 and pH values of 6.07-6.26. Sweetened condensed rice-milk fortified with Job's tear mixed with almond (JA), Job's tear mixed with white sesame (JS) and almond mixed with white sesame (AS) had high viscosity and were selected for sensory evaluation. There was no significant difference in appearance and color in all samples compared with a commercial product. However, sweetness, oiliness and viscosity scores of the three formulations ranged from 5.49-5.90, 5.35-5.75 and 4.95-5.22, respectively.

Keywords: Cereals, Coffee test, Retortable pouch, Sweetened condensed rice-milk

Introduction

Rice is a staple food and one of the most important cereal crops, especially for people in Asia (Rohman *et al*., 2014). Thailand has been a globally important producer and exporter of rice. There are so various types of rice and each of them has its unique properties. Generally, the major component of rice is carbohydrate that provides energy for the body. In addition, rice is a good source of thiamine (vitamin B_1), riboflavin (vitamin B_2) and niacin (vitamin B_3) (Rohman, 2014). Besides, rice is naturally gluten-free, which makes it a great carbohydrate option for people with celiac disease or non-celiac gluten sensitivity (Raman, 2018). However, the carbohydrate in rice may cause diabetis and obesity because polished white rice has a high glycemic index (GI), meaning that its carbohydrate can be converte quickly into blood

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sugar than unpolished rice or low glycemic index rice. Some studies revealedd that the higher intake of white rice is associated with the higher risk of type 2 diabetes (Sun *et al.*, 2010). The glycemic index of unpolished rice is categorized as medium (Osman *et al*., 2017). RD 43 rice is a low glycemic index rice, which has low amylose content and good cooking quality. Therefore, RD 43 rice should be alternative rice variety for type 2 diabetes patients (Wasusun *et al*., 2017).

Currently, the development of innovative rice products is required in Thailand in order to raise the value of Thai rice and expand the market. Examples of rice products available in the market are rice bran oil, rice cereal, rice flour, rice noodles, and rice milk. The rice products that offer distinctive functional properties have potential in the export market. Rice milk is a plant-based or non-dairy milk alternative product. Rice milk is becoming a popular healthy drink among health-conscious consumers in terms of nutritional facts. Rice milk contains essential amino acids that promote growth, strengthen the immune system, has low cholesterol, low fat and no allergen. Milk alternatives, such as rice, oat, soy and almond are fluids which imitates cow's milk in terms of appearance and consistency (Sethi *et al.*, 2016). These milks are lactose-free and are perfect alternative products for people who suffer from lactose intolerance or for vegetarian persons.

The consumption of cereals provides many health benefits and improves the nutrition balance of food in the body. Almond has naturally high in fiber and protein contents at 12.20% and 21.22% respectively. The total fat content in almond is mainly monounsaturated fatty acids of about 62%, thus reducing risk of chronic diseases such as coronary heart disease and type 2 diabetes. Almond also contains vitamin E, vitamin B_2 and some minerals such as calcium, magnesium and phosphorus (Richardson *et al.*, 2009). Job's tear or Coix seed is rich in starch, dietary fiber and protein, which is high in leucine and proline. It is composed of unique compounds including coixol, coixenolide, coixin and lactams. Job's tear seed can be categorised as a low glycemic index food at 55, in which signals low risk of obesity and diabetes (Zhu, 2017). Sesame consists of macronutritions and micronutritions, for example, protein, carbohydrate and antioxidants. The important antioxidants in sesame include sesaminol, sesamolinol, sesamolin, and sesamin that maintain fats and promote the integrity of body tissues (Prasad *et al*., 2012). Rice, almond, and Job's tear are gluten free cereals, which can be used to develop food products for people with celiac diseases.

Sweetened condensed milk is made by adding sugar and removing water content by one-half of the whole milk. The product is sealed in containers without sterilization, as the sugar act as a preservative (Hess, 2003). Typically, sweetened condensed milk contains around 8% fat, 45% sugar and 20% non-fat-solids (Siddique, 2017). The excessive sugar level gives enough osmotic pressure to prevent the growth of microorganisms which stops the spoilage. Sugar also reduces the water activity of the product to 0.78-0.82. In the case of low-acid foods, the product that has an acidity greater than pH 4.6 and water activity (a_w) greater than 0.85 must be thermally processed to obtain commercial sterility (Dantas and Dantas, 2016). Practical sterilization requires processing the food at temperatures above 100 ℃ (Berk, 2013). Retorting is heating process of low acid foods inclined to microbial spoilage in hermetically sealed containers in order to prolong their shelf life. Foods can be sterilized in rigid containers like glass, metal can and plastic or flexible retort pouches (Lalpuria *et al.*, 2012).

The innovative rice product was developed in this study. The objective of this research was to study the formulation of sweetened condensed rice-milk fortified with cereals in retortable pouch and to determine the physical and sensory qualities of sweetened condensed rice-milk compared to commercial sweetened condensed milk product.

Materials and Methods

The experiment was conducted from January to April, 2019 in the laboratory at Thammasat University, Pathum Thani, Thailand. White rice RD 43 (Pkakan Co., Ltd., Phra Nakhon Si Ayutthaya, Thailand), Job's tear (Thanya Farm Co.,Ltd., Nonthaburi, Thailand), almond (Heritage Snacks & Food Co., Ltd., Bangkok, Thailand), white sesame (Thanya Farm Co.,Ltd., Nonthaburi, Thailand), coconut milk (Thai Agri Foods Public Co., Ltd., Samut Prakan, Thailand), soy milk (Tofusan co., Ltd., Samut Prakan, Thailand), sugar (Mitrphol Co.,Ltd., Bangkok, Thailand), prebiotic syrup (Rajburi Sugar Co., Ltd., Rajburi, Thailand) and rice bran oil (King Rice Oil Group Co., Ltd., Bangkok, Thailand) were purchased from supermarkets in Pathum Thani. Xanthan gum and inulin powder were supplied by Chemipan Corporation Co., Ltd., Bangkok, Thailand and DPO (Thailand) Ltd., Bangkok, Thailand. Flexible retort pouches were supported by Meiwa Pax Co., Ltd., Samut Sakhon, Thailand.

Sweetened condensed rice-milk was prepared by the following procedures of Khuenpet *et al.* (2016). Rice, Job's tear (J), almond (A) and white sesame (S) were separately soaked in the water in ratio of rice or cereal: water at 1:4.5 (w/w) and kept in a cool room at 10 ± 2 ^{o}C for 16 hours. Then, rice and each cereal were blended independently with water and sediment was separated by filtering through a filter cloth in order to get rice milk and cereal milk samples. Rice milk was warmed up to 60 ^{o}C and added a single cereal milk of J, A, S or a combination two cereals milk of JA, JS and AS. Totally, six formulations of rice-cereal milk were prepared. All rice-cereal milk recipes were mixed with the same amounts of coconut milk, soybean milk and sugar. Sweetened rice-cereal samples were stirred and heated up to 70 ^{o}C. Xanthan gum and inulin were added into sweetened rice-cereal milk to increase the viscosity and dietarty fiber content of rice-cereal milk. Samples were continuously heated at 70^{o}C for 10 min and homogenized by a hand homogenizer (Elextrolux, Model ESTM5417S, Thailand) at high speed level for 15 min. After that, rice bran oil was added and mixed, then sweetened rice-cereal milk samples were concentrated from 24 ^{o}Brix to 30 ^{o}Brix by evaporation on the hot plate with stirring. Sweetened condensed rice-cereal milk samples were filled in flexible retort pouches, sealed and sterilized at 121°C for 18 min by a water spray retort (Owner Food Machinery Model PP500 Thailand).

Quality determination

The viscosity measurement method of sweetened condensed rice-cereal milk was adapted from Suwonsichon (2010). Sweetened condensed rice-cereal milk samples (12 mL) was poured into a SC4 sample chamber and measured by a Brookfield viscometer equipped with small sample adapter. A SC4-28 type rotor with 100 rpm rotation speed was chosen. All measurements were conducted at 25±0.1°C. The viscosity was expressed as centipoise (cP).

The color of sweetened condensed rice-cereal milk was analyzed by a colorimeter (Model ColorFlex CX2687, Hunter Lab, USA) and expressed as L* (lightness), a* (redness) and b* (yellowness) values in CIE system. Whiteness and total different color (ΔE) were calculated by equations 1 and 2.

$$\text{Whitness} = 100 - \sqrt{(100\text{-}L)^2 + a^2 + b^2} \qquad (1)$$

$$\text{Total different color } (\Delta E) = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \qquad (2)$$

Total soluble solid, a_w and pH of sweetened condensed rice-cereal milk samples were measured by a hand refractometer (MASTER-2M, ATAGO, Japan), a water activity meter (CX2, Aqualab, USA) and a pH meter (Sartorius, PB-20, Germany), respectively.

The coffee test method of sweetened condensed rice-cereal milk was adapted from Teehan *et al*. (1997a). The coffee test was performed at 80 ^{o}C and the infusions were made by pouring 200 mL of hot water over 1.6 g, 3.0 g and 5.0 g of coffee. The 4 g of commercial sweetened condensed milk (control) and six samples of sweetened condensed rice-milk fortified with cereals were added to different coffee infusions. Each mixture was stirred for 6 sec by using a spoon (6 times in a clockwise direction and 6 times in an counter-clockwise direction) and set aside for 10 min. The mixture was poured into 50 mL centrifuge tube and allowed to stand for 5 min. Then, tubes were placed in a rotor and centrifuged for 5 min at 170 g. The amount of residues (mL) was recorded from the scale.

Three formulations of sweetened condensed rice-milk with appropriate viscosity, color and easy to infuse in coffee were selected for sensorial evaluation in terms of appearance, color, rice flavor, sweetness, oiliness, viscosity and overall acceptability. The sensory analysis was evaluated using a 9-point hedonic scale test (9 = extremely like, 5 = either like or dislike, 1 = extremely dislike) by 60 panelists. Each panelist evaluated three sweetened condensed rice-cereal milk samples and one commercial product (control).

All quality determinations were conducted in triplicate and the results were expressed as means with standard deviations. A completely randomized design (CRD) was applied on physical and chemical parameters. Sensory evaluation was carried out by Randomized Complete Block Design (RCBD). The data were analyzed using SPSS software version 20.0. One-way analysis of variance (ANOVA) was used to determine significant differences between formulations (p < 0.05). Multiple comparisons of means were performed by using Duncan's multiple range test.

Results

The viscosity of commercial sweetened condensed milk (control) was found to be 1,890 ± 54.08 cP. This value was compared with the viscosity of the different formulations before and after sterilization. It appeared that before sterilization, viscosity of samples ranged between 1,747.50 and 2,498.33 cP. The sweetened condensed rice milk blended with one type of cereal milk, J sample had lower viscosity than A and S formulations. The mixture of JA had the significantly lowest viscosity while AS had the significantly highest viscosity. The viscosities of all sweetened condensed rice-cereal milk formulations decreased after sterilization and the values ranged from 929.17 to 2,381.67 cP. It was noticed that the addition of single cereal resulted in lower viscosity than that of two cereal combination after heating. Sterilized J, A and S samples had lowered viscosity by 2-2.5 times when compared with their samples prior to sterilization. While, the viscosity of sterilized JA, JS and AS treatments was ecreased by 1-1.5 times when compared to samples before sterilization.

Table 1. Viscosity of commercial sweetened condensed milk and sweetened condensed rice-milk with different cereal milks

Sweetened condensed rice-cereal milk formula	Viscosity (cP)	
	Before sterilization	**After sterilization**
J	$2,191.50^{c} \pm 118.90$	$929.17^{d} \pm 61.76$
A	$2,373.00^{ab} \pm 116.39$	$840.83^{d} \pm 156.44$
S	$2,314.17^{bc} \pm 114.25$	$1,200.00^{c} \pm 163.37$
JA	$1,747.50^{d} \pm 172.42$	$1,563.33^{b} \pm 80.79$
JS	$2,295.00^{bc} \pm 125.78$	$1,493.33^{b} \pm 178.79$
AS	$2,498.33^{a} \pm 130.33$	$2,381.67^{a} \pm 118.01$
Control	$1,890.00 \pm 54.08$	

1/: Means with the different superscript within same column are significant different ($p < 0.05$). Control = commercial sweetened condensed milk, J = Job's tears, A = Almond, S = White sesame, JA = Job's tears mixed with almond, JS = Job's tears mixed with white sesame, AS = Almond mixed with white sesame.

The color values of sweetened condensed rice-milk fortified with cereals before and after sterilization are shown in Figure 1. The value of lightness (L*) of all formulations decreased after sterilization. The lightness of the sterilized products ranged between 74.09 and 75.98 compared with commercial sweetened condensed milk (control) which was 76.2. The redness (a*) and yellowness (b*) of sweetened condensed rice-cereal milk increased after sterilization as shown in Figure 1(B) and 1(C), thus presenting yellow and slightly red tone of the products (Figure 2). The commercial sweetened condensed milk (control) had the highest yellowness (b*). Total color differences (ΔE) were calculated from sweetened condensed rice-milk samples before and after sterilization. The graph (Figure 1(D)) revealed that sterilized S and AS sweetened condensed rice milk samples had larger color difference. However, there was no significant difference ($p \geq 0.05$) in whiteness values of all sterilized sweetened condensed rice-cereal milk samples and commercial product (Figure 1(E)). The whiteness of all sterilized treatments were in the range of 70.18-72.45.

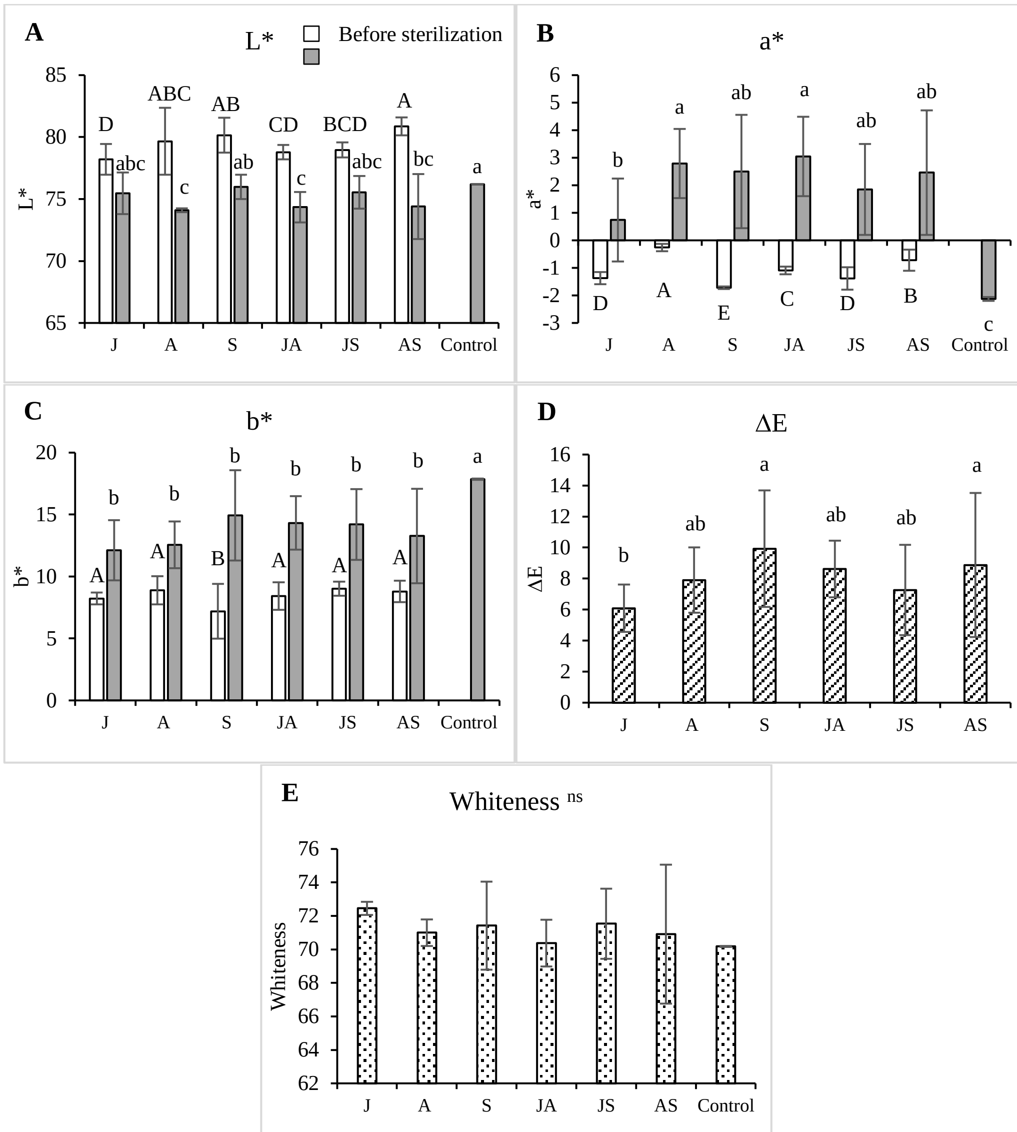

Figure 1. L*; Lightness (A), a*; redness (B), b*; yellowness (C), ΔE; total color difference (D) and whiteness (E) of sweetened condensed rice-milk fortified with cereal before (☐) and after (■) sterilization

^{A,B} Different letters on white bar graph are significant different (p < 0.05);

^{a,b} Different letters on grey bar graph are significant different (p < 0.05);

ns = not significant different;

J = Job's tears, A = Almond, S = White sesame, JA = Job's tears mixed with almond, JS = Job's tears mixed with white sesame, AS = Almond mixed with white sesame.

Condition	J	A	S	JA	JS	AS	Control
Before Sterilization							
After Sterilization							

Figure 2. Photographs of sweetened condensed rice-milk mixed with different cereal milks before and after sterilization including commercial sweetened condensed milk (control)

The residue volumes for sweetened condensed rice-milk were measured following the coffee test method (Table 2). It was found that there was no significant difference in residues volume between sweetened condensed rice-milk and control samples. The weight of residues was in the ranges of 0.03-0.07 g, 0.01-0.07 g and 0.03-0.07 g for 1.6 g, 3 g and 5 g of coffee solution. However, the volume of the residue (ml) of sweetened condensed rice-cereal milk in coffee solution after centrifugation was below 0.1 ml according to the general guideline. Thus, all samples had a higher reconstitution in hot coffee solution.

Table 2. Effect of coffee strength on the amount of residues in the coffee test of sweetened condensed rice-milk fortified with different cereal milks

Sweetened condensed rice-cereal milk formula	Residues (ml.)	Weight of residues in coffee solution (g)		
		1.6 g/200 ml.^{ns}	3 g/200 ml.^{ns}	5 g/200 ml.^{ns}
Control	< 0.1	0.03 ± 0.01	0.01 ± 0.02	0.03 ± 0.02
J	< 0.1	0.07 ± 0.02	0.04 ± 0.02	0.07 ± 0.01
A	< 0.1	0.05 ± 0.03	0.07 ± 0.02	0.05 ± 0.01
S	< 0.1	0.04 ± 0.01	0.04 ± 0.03	0.04 ± 0.02
JA	< 0.1	0.05 ± 0.01	0.06 ± 0.03	0.07 ± 0.01
JS	< 0.1	0.06 ± 0.02	0.05 ± 0.01	0.04 ± 0.03
AS	< 0.1	0.05 ± 0.02	0.05 ± 0.01	0.06 ± 0.02

1/: Means with the different superscript within same column are significant different ($p < 0.05$).
ns = not significant different;
Control = commercial sweetened condensed milk, J = Job's tears, A = Almond, S = White sesame, JA = Job's tears mixed with almond, JS = Job's tears mixed with white sesame, AS = Almond mixed with white sesame.

The total soluble solid, water activity (a_w) and pH value of sweetened condensed rice-cereal milk products and commercial sweetened condensed milk (control) are illustrated in Table 3. All sterilized samples had total soluble solid, water activity and pH values which ranged from 23.90-26.63 ^{o}Brix, 0.966-0.970 and 6.07-6.26, respectively. It appeared that AS sweetened condensed rice-milk formula exhibited a significantly ($p < 0.05$) low total soluble solid, 23.90 ^{o}Brix while water activity and pH were almost insignificant different among samples excepting the control for the water activity value and the JS sweetened condensed rice-milk sample for the pH value. Sweetened condensed milk (control) had the highest total soluble solid content at 70.00 ^{o}Brix and the lowest water activity content at 0.837 comparing with other sweetened condensed rice-cereal milk formulas.

Table 3. Total soluble solid, water activity and pH of sweetened condensed rice-milk fortified with different cereal varieties

Sweetened condensed rice-cereal milk formula	**Total soluble solid (^{o}Brix)**	**Water activity**	**pH**
Control	$70.00^{a} \pm 0.00$	$0.837^{b} \pm 0.00$	$6.26^{a} \pm 0.01$
J	$24.97^{bcd} \pm 0.15$	$0.970^{a} \pm 0.00$	$6.18^{a} \pm 0.01$
A	$24.30^{cd} \pm 0.90$	$0.969^{a} \pm 0.00$	$6.26^{a} \pm 0.04$
S	$26.63^{b} \pm 2.57$	$0.968^{a} \pm 0.00$	$6.20^{a} \pm 0.10$
JA	$25.78^{bc} \pm 0.75$	$0.969^{a} \pm 0.00$	$6.18^{a} \pm 0.06$
JS	$25.13^{bcd} \pm 1.41$	$0.966^{a} \pm 0.01$	$6.07^{b} \pm 0.14$
AS	$23.90^{d} \pm 1.06$	$0.966^{a} \pm 0.00$	$6.18^{a} \pm 0.10$

1/: Means with the different superscript within same column are significant different ($p < 0.05$). Control = commercial sweetened condensed milk, J = Job's tears, A = Almond, S = White sesame, JA = Job's tears mixed with almond, JS = Job's tears mixed with white sesame, AS = Almond mixed with white sesame

The overall scores from the 9-point hedonic scale test of four samples are summarized in Table 4. The results illustrated that there was insignificant difference in appearance and color of the samples between sweetened condensed rice-cereal milk samples and commercial product (control). The sensory scores were in the range of slightly like in rice flavour and sweetness of sweetened condensed rice-cereal milk samples. The sweetened condensed milk (control) had preferencial sensorial score higher than sweetened condensed rice-milk formulations in terms of sweetness, oiliness, viscosity and overall acceptability, whereas it had a low score preference in rice flavour due to the fact that rice is not an ingredient in commercial formulation.

Table 4. Sensorial scores of sweetened condensed rice-milk fortified with different cereal varieties

Formula	Apperance^{ns}	Color^{ns}	Rice flavor	Sweetness	Oiliness	Viscosity	Overall acceptability
C	6.72±1.54	6.68±1.57	4.60±2.01^{b}	6.53±1.69^{a}	7.05±1.44^{a}	7.25±1.53^{a}	6.90±1.45^{a}
JA	6.57±1.61	6.30±1.59	6.45±1.54^{a}	5.90±1.71^{b}	5.42±1.86^{b}	5.00±1.77^{b}	5.88±1.58^{b}
JS	6.63±1.38	6.32±1.66	6.10±1.64^{a}	5.65±1.84^{b}	5.35±1.84^{b}	4.95±1.77^{b}	5.77±1.53^{b}
AS	6.54±1.52	6.34±1.64	6.24±1.56^{a}	5.49±1.90^{b}	5.75±1.71^{b}	5.22±1.86^{b}	5.78±1.51^{b}

1⁄: Means with the different superscript within same column are significant different ($p < 0.05$); Control = commercial sweetened condensed milk, J = Job's tears, A = Almond, S = White sesame, JA = Job's tears mixed with almond, Js = Job's tears mixed with white sesame, AS = Almond mixed with white sesame.

Discussion

It was found that all sweetened condensed rice-cereal milk before sterilization had higher viscosity than after sterilization. The explanation is that all sweetened condensed rice-milk were homogenized at 13,200 rpm for 15 min by a hand homogenizer in order to produce homogeneous texture. Sweetened condensed rice-milk is emulsion system, thus the homogenization step may cause high amount of fat droplet in the system and resist the flow. Similar results were reported by Chiewchan *et al*. (2006) who demonstrated that the homogenized coconut milk sample with heat treatment provides fat globules disperse in the sample and also resist the flow. Maria and Victoria (2018) reported that the starch in cereals including rice, Job's tear, almond and white sesame caused gelation when sample was heated over 72℃. Kouchaksaraei *et al.* (2015) also demonstrated that white sesame contained a high amount of lipid that may occur the formation of lipid-protein complex, thus giving the viscosity increased. Therefore, the viscosity values of all sweetened condensed rice-cereal milk before sterilization were high. Next, the viscosity of samples was decreased after sterilization at 121°C for 18 minutes. This should be due to the starch granule in rice milk and cereals milk was broken down by high temperature during the process (Gutierrez *et al*., 2016). The different viscosity between single cereal in sweetened condensed rice-milk and two cereals combination have been related to gelatinization temperature of cereals starch. Moreover, the gelatinization temperature of rice starch is 55-79°C and depended on the types of rice (Bhattacharya, 1979). Job's tear (J) and white sesame (S) were gelatinized at 67-81°C (Chaisiricharoenkul *et al.*, 2011) and 75.6°C (Zouari *et al.*, 2016), respectively. During the sterilization process, the temperature of the water spray retort increased from room temperature to 121°C which is higher than the gelatinization temperature of cereal starches. For the initial step, starch granules swell and leak which resulted to a higher viscosity of sweetened condensed rice-milk. Next, in the starch granules, the intermolecular bond got disrupted allowing the hydrogen bonds to engage more water which led to lower viscosity. Besides, the composition of ingredients also influenced the viscosity of samples. The fat content of white sesame, almond and Job's tear is 52.61% (Kanu, 2011), 49.42% (Richardson *et al*., 2009) and 7.12% (Liu *et al*., 2015). White sesame and almond had higher fat content than Job's tear. During the sterilization process, high heating temperature affects the structure of fat globule. The fat globule in cereals and coconut milk of sweetened condensed rice-milk were aggregated when the heat treatment was applied. Thus, the aggregates of fat globule in emulsion system increase the prevention to flow (Chiewchan *et al*., 2006; Peamprasart and Chiewchan, 2006). The combination of almond and white sesame sweetened condensed rice-milk formulation had higher in fat content, thus it had the highest viscosity.

The value of lightness was reduced after sterilization. The explanation is that Maillard reaction occurred during the process. In this study, almond mainly contains 23.3-20.6% protein (Ahrens *et al*., 2005). This is higher than Job's tear and white sesame at 14.48% (Liu *et al*., 2015) and 22.20% (Kanu, 2011), respectively. Moreover, the amino acid in almond was glycine, lysine, tryptophan and tyrosin, which constituted 5.74%, 2.18%, 0.99% and 1.35%, respectively (Ahrens, 2005). Protein and amino acids are classified as substance in Maillard reaction when amino acid reacts with reducing sugar under heat treatment more than 100°C, this causes yellow-brown coloration in sweetened condensed rice-milk. Therefore, A and JA sweetened condensed rice-milk resulted in a lower in lightness (L*) and higher in redness (a*) and yellowness (b*). Furthermore, the loss of pigment in raw material of sweetened condensed rice-milk may happen during the longer sterilization time leading to brown color development. According to Parnsakhorn and Langkapin (2012) the effect of heat treatment and homogenizing condition on cereal cream milk resulted in a lower in lightness and slightly higher in redness and yellowness when compared with unheated treatment. The highest yellowness (b*) in commercial sweetened condensed milk also resulted from Maillard reaction. Lactose as reducing sugar in sweetened condensed milk which can react with protein in the Maillard reaction. Some studies revealed that casein and lactose were reactants in color change of product (Patton, 1952). Also, caramelization reaction occurred at high temperature above 100°C (Viteri, 2015). These phenomena provide the yellow color for the product. AS and S had the highest in total color difference (ΔE) because of the Maillard reaction and relied on the initial color of raw material.

To explore insoluble particles of dried milk and milk products after reconstituting in hot coffee, the procedure for coffee test reported by Teehan *et al.* (1997b) was adapted for analysis. It was found that the residues volume of samples after centrifugation at 170 g for 5 min was lower than 0.1 ml. The number of residues depended on several parameters such as the temperature of the coffee solution, pH, and the strength of coffee infusion. In this study, the residues of samples might be effected by the pH of coffee infusion. The typical pH value of aqueous coffee solution containing 1.6, 3 and 5g of coffee in 200 ml of hot water is 5.82, 5.42 and 5.26, respectively which is a result of denaturation of protein. However, the residues volume did not exceed the standard. In addition, high-temperature treatment in the sterilization process may affect the structure and properties of food components. In the case of starch, the water solubility depends on the crystalline melting temperature. The melting of crystalline regions occurred at a low temperature around 60-100°C in the presence of excess water due to water acts as plasticizing agents in these regions. When some crystalline structure was melted, it promotes the melting of adjacent regions such as amylopectin molecules that obstruct the crystalline region to be able to move (Jackson, 2003). For the coffee test, the sweetened condensed rice-cereal milk was dissolved in hot water at 80°C which was higher than crystalline melting temperature (68.8°C for 28% amylose rice). Thus, starch-containing food products are soluble in solution. Zbikowska and Zbikowski (2006) reported that evaporated UHT milk showed satisfactory stability in hot coffee. Besides, commercial sweetened condensed milk contains sugar, skim milk powder, palm oil and whey protein. The residues of the commercial product resulted from the membrane surface layer protein-induced aggregation of the homogenized fat globules (Hoffman *et al*., 1996).

The total soluble solid of sweetened condensed rice-cereal milk was lower than the control because commercial sweetened condensed milk (control) contains high sugar (47%) and composed of skim milk powder and whey protein, which cause the increase in total soluble solids. Moreover, sugar is an excellent humectant and used to lower water activity for microbial control. In accordance with the report of Fontana (2005), the addition of monosaccharide to sucrose solution would maximize the total soluble solid and lower the water activity. In this study, sweetened condensed rice-milk contains sugar around 7%, which is much lower than control, resulting in the higher water activity. Sweetened condensed rice-cereal milk products can be classified as low-acidic foods due to their low pH and high water activity (a_w) which were greater than 4.5 and 0.85, respectively. Therefore, sweetened condensed rice-cereal milk products must be thermally processed to obtain commercial sterility for safe consumption and being long shelf-life (Dantas and Dantas, 2016).

Sweetened condensed rice-cereal milk was nots ignificantly different in terms of appearance and color compared to the control. Remarkably, the sweetened condensed rice-milk were produced from cereals such as Job's tear, almond and white sesame, which gave it the white shade. Sweetened condensed milk had higher scores in sweetness, oiliness, viscosity and overall acceptance than samples due to the different ingredients in the products. Sweetened condensed milk (control) contains 47% sugar, 10% skim milk powder, 8% palm oil, 4.8% whey powder and some thickening agent and stabilizing agent. The sugar and oil additions in control are higher than sweetened condensed rice-milk, thus providing sweetness and oiliness of the product. The viscosity of the product is one of the attributes that affect to consumer acceptance. The overall acceptability scores of sweetened condensed rice-milk ranged between 5.77-5.88 (either like or dislike); thus, the taste and texture of the sample should be further developed in order to improve the sensorial quality of the product.

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References

Ahrens, S., Venkatachalam, M., Mistry, A. M., Lapsley, K. and Sathe, S. K. (2005). Almond (*Prunus dulcis* L.) protein quality. Plant Foods for Human Nutrition, 60:123-128.

Berk, Z. (2013). Thermal processes, methods and equipment. Chapter 18, Food Process Engineering and Technology (Second Edition), 421-438.

Bhattacharya, K. R. (1979). Gelatinization temperature of rice starch and its determination. Proceedings of the workshop on chemical aspects of rice grain quality, International Rice Research Institute, 24:116-118.

Chaisiricharoenkul, J., Tongta, S. and Intarapichet, K. O. (2011). Structure and chemical and physicochemical properties of job’s tear (*Coix Lacryma-jobi* L.) kernels and flour. Suranaree Journal of Science and Technology, 18:109-122.

Chiewchan, N., Phungamngoen, C. and Siriwattanayothin, S. (2006). Effect of homogenizing pressure and sterilizing condition on quality of canned high fat coconut milk. Journal of Food Engineering, 73:38-44.

Dantas, F. B. H. and Dantas, S. T. (2016). Canned food and packaging parameters. Chapter, Reference Module in Food Science, pp.1-5.

Fontana, A. J. (2005). Water activity for confectionery quality and shelf-life. Retrieved from https://courses.ecolechocolat.com/lobjects/pdf/water_activity_confectionery.pdf.

Gutierrez, J. L. V., Johanson, D. and Langton, M. (2016). Effects of added inulin and wheat gluten on structure of rye porridge. Food Science and Technology, 66:211-216.

Hess, H. J. (2003). Condensed milk. Chapter, Encyclopedia of Food Sciences and Nutrition (Second Edition), 1574-1581.

Hoffman, W., Moltzen, B. and Bucheim, W. (1996). Photometric measurement of coffee-cream stability in hot coffee solutions. Milchwissenschaft, 51:191-4.

Jackson, D. S. (2003). Starch functional properties. Chapter, Encyclopedia of Food Sciences and Nutrition (Second Edition), 5572-5575.

Kanu, P. J. (2011). Biochemical analysis of black and white sesame seed from China. American Journal of Biochemistry and Molecular, 1:145-157.

Khuenpet, K., Vatthanakul, S., Sirisansaneeyakul, S., Songpim, M. and Jittanit, W. (2016). Formulation and production of sweetened condensed rice milk. Thailand Patent No. 1603002232.

Kouchaksaraei, Z. A., Varidi, M., Varidi, M. J. and Pourazarang, H. (2015). Study of stability characteristics of sesame milk: effect of pasteurization temperature, additives, and homogenisation pressure. Quality Assurance and Safety of Crops & Foods, 7:677-686.

Lalpuria, M., Anantheswaran, R. and Floros, J. (2012). Packaging technologies and their role in food safety. Microbial Decontamination in the Food Industry, 701-745.

Liu, X., Zhang, X., Rong, Y. Z., Wu, J. H., Yang, Y. J. and Wang, Z. W. (2015). Rapid determination of fat, protein and amino acid content in coix seed using near-infrared spectroscopy technique. Food Analytical Methods, 8:334-342.

Maria, M. F. and Victoria, A. T. (2018). Influence of processing treatments on quality of vegetable milk from almond (*Terminalia catappa*) kernels. Acta Scientific Nutritional Health, 2:37-42.

Osman, N. M. H., Yusof, B-N M. and Ismai, A. (2017). Estimating glycemic index of rice-based mixed meals by using predicted and adjusted formulae. Rice Science, 24:274-282.

Parnsakhorn, S. and Langkapin, J. (2012). Study on Production of Pasteurized Cereal Cream Milk Substitute Coconut Milk Product. Rajamangala University of Thanyaburi, Thailand.

Patton, S. (1952). Studies of heated Milk. IV. Observations on browning. Journal of Dairy Science, 35:1053-066.

Peamprasart, T. and Chiewchan, N. (2006). Effect of fat content and preheat treatment on the apparent viscosity of coconut milk after homogenization. Journal of Food Engineering, 77:653-658.

Prasad, N., KR, S., Prasad, D. S., Vijay, N., Kothari, R. and Swamy, N. (2012). A review on nutritional and nutraceutical properties of sesame. Journal of Nutrition and Food Sciences, 2:1-6.

Raman, R. (2018). Is White Rice Healthy or Bad for You? Healthline. Retrieved from https://www.healthline.com/nutrition/is-white-rice-bad-for-you#nutrition.

Richardson, D. P., Astrup, A., Cocaul, A. and Ellis, P. (2009). The nutritional and health benefits of almonds: a healthy food choice. Food Science and Technology Bulletin Functional Foods, 6:41-50.

Rohman, A., Helmiyati, S., Hapsari, M. and Setyaningrum, D. L. (2014). Rice in health and nutrition. International Food Research Journal, 21:13-24.

Sethi, S., Tyagi, S. K. and Anurag, R. K. (2016). Plant-based milk alternatives an emerging segment of functional beverages: a review. Journal of Food Science and Technology, 53:3408-3423.

Siddique, N. A., Islam, N., Habib, R., Rashid, H. U., Islam, A. and Afrin, S. (2017). Evaluation of the quality of sweetened condensed milk of different brands available in local markets of Bangladesh. International Journal of Natural and Social Sciences, 4:64-70.

Sun, Q., Spiegelman, D., Dam, R. M., Holmes, M. D., Malik, V. S., Willett, W. C. and Hu, F. B. (2010). White rice, brown rice, and risk of type 2 diabetes in US men and women. Archives of Internal Medicine, 170:961-969.

Suwonsichon, S. (2010). Development of table syrup from super refined molasses. Thai Science and Technology Journal, 18:42-55.

Teehan, C., Kelly, P.M., Devery, R. and O'Toole, A. (1997a). Evaluation of test conditions during the measurement of coffee stability of instant whole milk powder. International Journal of Dairy Technology, 50:113-121.

Teehan, C. M., Kelly, P. M., Devery, R. D and O'Toole, A. (1997b). Factors Affecting the Coffee-Stability of Instant Whole Milk Powder. (Master's Thesis). Dublin City University, Ireland.

Viteri, P. C. L. (2015). Study of the Cooking Effect Induced by Sterilization Heat Treatment Processes for Chilled Dairy Desserts. (Master's Thesis). Wageningen University, Netherlands.

Wasusun, A., Wongpiyachon, S., Songchitsomboon, S., Sukviwat, W., Maneenin, P. and Pakkethati, S. (2017). Rice Variety RD43: medium glycemic index rice for niche market. 34th Proceeding of rice and temperate cereal crops conference, pp.300.

Zbikowska, A. and Zbikowski, Z. (2006). Stability of milk concentrates in hot coffee. Polish Journal of Food and Nutrition Sciences, 15:253-258.

Zhu, F. (2017). Coix: Chemical composition and health effects. Trends in Food Science and Technology, 61:160-175.

Zouari, R., Besbes, S., Ellouze-Chaabouni, S. and Ghribi-Aydi, D. (2016). Cookies from composite wheat-sesame peels flours: Dough quality and effect of *Bacillus subtilis* SPB1 biosurfactant addition. Food chemistry, 194:758-768.

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