



การรายงานฉบับสมบูรณ์

**ชื่อโครงการ Preparation of insect powder from Bombay locust and its application as
protein supplement in brown rice cake**

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ชื่อโครงการ Preparation of insect powder from Bombay locust and its application as protein supplement in brown rice cake

รายงานฉบับสมบูรณ์

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Abstract

Protein-enriched brown rice flours were developed by fortification of defatted Bombay locust powder (BL) at different levels (10, 20, 30%). The physicochemical characteristics of the mixed flours were then investigated. The application of resulting mixed flour on preparing protein-enriched cake was also studied. The chemical composition, water activity, color as well as rheological property of the resulting mixed flours were varied at different levels of BL added. The protein content of resulting mixed flours was effectively improved, especially at 30% replacement provided almost 4-fold increased (11 to 42%), compared with control (BRF without BL fortification) ($p \leq 0.05$). Protein-enriched cakes prepared using the mixed flours, showed the differences in their physicochemical properties, texture profiles, chemical composition and sensory characteristics, which were influenced by BL fortification level. The 20% replacement of brown rice flour by BL (20-MF) provided a protein-enriched cake (20.8% of protein) with liking score ranged from 7.0-7.4 for all attributes tested, indicating the good acceptability. Scanning electron microscopy (SEM) of the 20-MF cake revealed that it had a denser structure with the less porosity than the

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control. Therefore, BL might be a promising alternative protein source for developing protein-enriched flour and baked product, particularly cakes.

Keywords: *Patanga succincta* L.; edible insect; Bombay locust powder; brown rice flour; protein-enriched cake

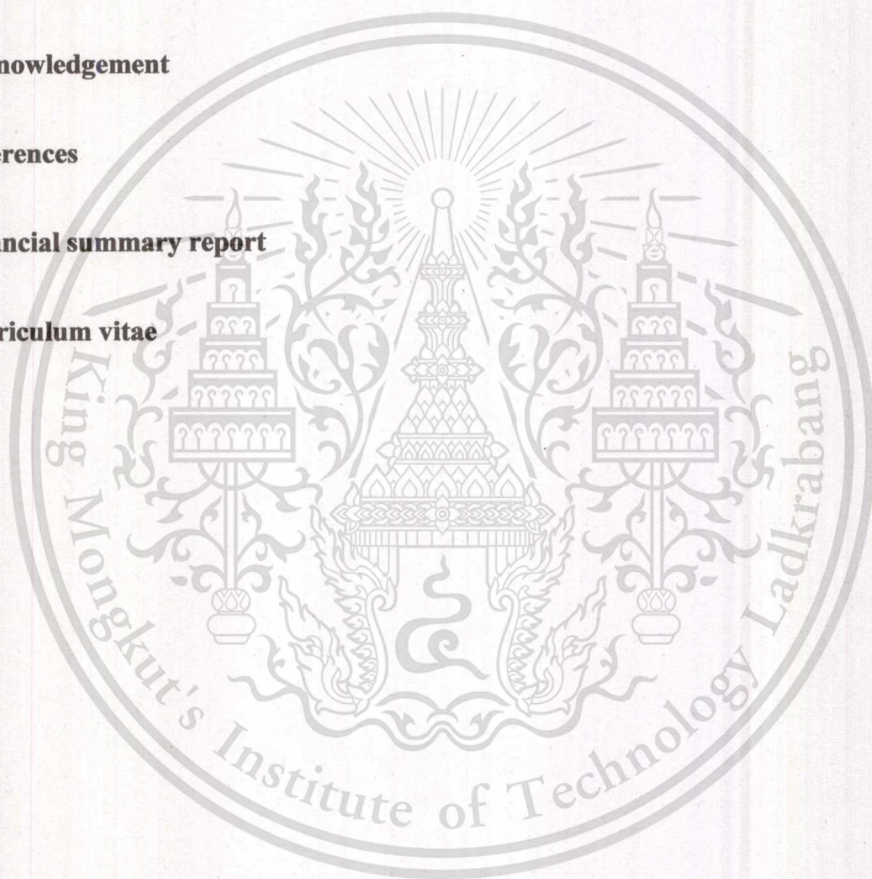


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1. Introduction

Recently, protein content is a leading concern of food product development, where the promote of non-animal-based protein sources has brought about enthusiasm for plant- and insect-based protein (Zielińska, Karaś, & Baraniak, 2018). Insects are becoming one of the most important alternative protein sources and they emerge as a solution limited for protein production. More than 1,900 insect species have been used as food and ~2 billion people eat insects regularly (Van Huis et al., 2013). Moreover, they contain high nutrients contents, especially protein (15-82% dry basis) and fat (4-77% dry basis) (Kim, Weaver, & Choi, 2017; Köhler, Kariuki, Lambert, & Biesalski, 2019; Kouřimská & Adámková, 2016; Paul et al., 2017).

Bombay locust (*Patanga succincta* L.) is commonly marketed insects in the southwest and southeast Asia (Yen, 2015). Köhler et al. (2019) reported that Bombay locust contains the highest protein content (36% wet basis) with both essential and non-essential amino acids compared to scarab beetle, house cricket and mulberry silkworm. However, insect-based food products acceptance is a great challenge due to the unique sensory characteristics including taste, flavour, texture and appearance of insect. Insect powder is an interesting and effective way to tackle those psychological and palatability factors, such as disgusting and food fear of the unusual for eating insects (Attila, Ryan, Dalma, & Howard, 2017; Dobermann, Swift, & Field, 2017). Fat removal, by using various type of solvents, is one optional in insect powder processing that has been applied for concentrating protein content and improving lipid oxidation stability (Ahmed et al., 2016; Bußler, Rumpold, Jander, Rawel, & Schlüter, 2016). Moreover, some pigments and off-odour compounds could be eliminated, during solvent defatting (Ribeiro et al., 2019). It was reported that fat removal by hexane led to a less brownish insect powder (Bußler et al., 2016; Mishyna, Martinez, Chen, & Benjamin, 2019). In addition, some pheromones, which was responsible for the taste and odor of insects,

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could also be removed (Vogt, 2005). The protein enrichment level could be then maximized by adding larger proportions of insect powder, with less offensive properties, to the final products. Several edible insect powders have been developed as alternative protein source, marketed as insect flour or insect protein-enriched wheat flour (Azzollini, Derossi, Fogliano, Lakemond, & Severini, 2018; Campbell, Euston, & Ahmed, 2016; Terry, Lupul, & Coate, 2017).

Rice (*Oryza sativa* L.) flour is a commonly consumed gluten-free cereals. Brown rice or unpolished rice is rich in phytochemicals (Mohan et al., 2014). Brown rice flour (BRF) contains a higher fiber (1.2% (w/w) dry basis) but lower protein content (8.5-9.5% (w/w) dry basis), compared with wheat flour (12.6% protein, 0.85% fiber, (w/w) in dry basis) (Khoshgozaran-Abras, Azizi, Bagheripoor-Fallah, & Khodamoradi, 2012; Mohan et al., 2014). Fortification improved protein content and quality of BRF food products, especially baked products (de la Hera, Martinez, Oliete, & Gómez, 2013; de Oliveira, da Silva Lucas, Cadaval, & Mellado, 2017; Gadallah, 2017; Islam, Taneya, Shams-Ud-Din, Syduzzaman, & Hoque, 2012). Protein enrichment, from both vegetable and animal sources, noticeably impacted on characteristics and quality of the final product, such as color, texture, batter rheology and sensory properties (Gadallah, 2017; González, Garzón, & Rosell, 2019). The level of protein enrichment, especially in the form of mixed flour, should be optimized to obtain good nutritional value and satisfactory product quality. Therefore, it is congenial to utilize Bombay locust powder for protein enrichment of BRF, in which the nutritional value, especially protein content, was improved in a practical application in baked products. The aim of the present work is to develop and characterize a protein-enriched brown rice flour and cake, fortified of Bombay locust powder (BL), where the enrichment level was optimized. The characteristics and pasting properties of resulting mixed flour were then measured. The application of mixed flour in cake model was studied in terms of cake batters and cake products were also analyzed.

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2. Materials and Methods

2.1 Ingredient

Brown Rice Flour (BRF) was procured from Bangyai Supply Limited, Nonthaburi, Thailand. Corn flour (Kitch, King Milling Co. Ltd, Samut Prakan, Thailand), canola oil (Naturel, Lam Soon Public Co., Ltd, Samut Prakan, Thailand), baking powder (Imperial, KCG Corporation Co., Ltd, Bangkok, Thailand) and other ingredients were purchased from a local market in Latkrabang, Bangkok, Thailand.

2.2 Preparation of Bombay locusts powder

Frozen Bombay locusts (*Patanga succincta* L.) were obtained from a commercial supplier (Mr. BUC FOOD, Phra Nakhon Si Ayutthaya, Thailand). The samples were thawed by submerging under cold tap water until the core temperature of sample reached to 4-5°C. The insects were then washed with running tap water and drained using a plastic sieve. Then, it was packed in polyethylene (PE) bag (1 kg/pack) and kept in a deep freezer (DW-40L262, Haier, Qingdao, China, -40°C, 24 h) before freeze-drying (CoolSafe 55 Freeze dryer, ScanLaf A/S, Lynge, Denmark) under vacuum (2.1 mPa, -50°C, 48 h). The dried sample was ground into powder using a laboratory grinder (MF-800, Tefal®, France) and sieved using a 10-mesh (2 mm) screen. The obtained powder (29.8% fat) was then subjected to fat removal following Bußler et al. (2016) with slight modification. Briefly, sample powder was mixed with hexane with a ratio of 1:5 (w/v) and continuously stirred for 3 h. The solvent was changed every hour, three times in total. After draining, the sample was dried on an aluminium foil tray under a fume hood. The resulting Bombay locust powder was referred to as 'BL'. Composition of BL was included 78.7% protein, 5.0% carbohydrate, 11.8% moisture, 3.3% ash, and 1.2% fat, in wet basis.

2.3 Preparation of protein-enriched brown rice flour by Bombay locust powder fortification

Different levels of BL were mixed with BRF to obtain final concentrations at 10%, 20% and 30% of mixed flour (w/w). After mixing, the mixed flours were ground using a pin mill (ZM-200, Retsch®, Germany, 6,000 min⁻¹, 0.25 mm sieve), resultant particles were < 40 µm in diameter. The resulting mixed flours with 10%, 20% and 30% BL replacement were referred to as '10-MF', '20-MF', and '30-MF', respectively. The BRF with 0% BL was used as the control, 'Control'.

2.4 Impact of Bombay locust powder fortification on characteristics of brown rice flour

2.4.1 Chemical compositions and fiber content

Protein, fat, moisture, ash and fiber content (% wet basis) were determined according to AOAC methods (AOAC, 2000). Total carbohydrate (% wet basis) content was calculated by subtracting the sum of protein, fat, moisture and ash from the total sample weight.

2.4.2 Water activity (a_w) and color

Water activity (a_w) of sample was measured using a water activity meter (Aqua Lab 4TE, SN S40002336, Decagon Devices, USA). The color of sample was measured as L^* (lightness), a^* (redness) and b^* (yellowness), in triplicates, using a colourimeter (CR-400 Chroma Meter, Konica Minolta Sensing Americas, Inc., USA). Total differences of color (ΔE^*) and chroma (ΔC^*) was then calculated following Benjakul and Karnjanapratum (2018).

2.4.3 Pasting properties

The samples were subjected to microvisco-amylograph tests (UNI 10872:2000), according to international standard methods, using the Brabender microvisco-amylograph (Viscograph-E 803301,

Brabender Measurement & Control Systems, Germany) analyzed their pasting properties (Taccari et al., 2016).

2.5 Application of protein-enriched brown rice flour by Bombay locust powder fortification for preparing cake product

2.5.1 Preparation of brown rice cake batter

Table 1 Brown rice cake recipe.

Ingredients	Baker's percentage (%) [*]	Amount (g) ^{**}
Pre-mix batter		
Rice flour	100	108
Corn flour		36
Salt		0.4
Baking powder	0.1	0.2
Egg yolks	62.5	90
Milk	68.8	99
Canola oil	43.8	63
Vanilla extract	3.5	5
Cinnamon powder	3.5	5
Egg white foam		
Egg white	125	180
Sugar	78.5	113
Cream of tartar	0.3	0.4

^{*}based on total weight of flours.

^{**}based on total weight of batter weight.

Mixed flours with different replacement levels of BL (10-MF, 20-MF and 30-MF) were used for preparing the cake. The formulation used for cake preparation followed the traditional rice flour cake recipe and the procedure of Qasem et al. (2017b) with slight modification (Table 1). Cake formulation had of two

main parts, including pre-mix batter and egg white foam. The protein-enriched cakes were prepared in the same manner but the mixed flour was used instead of BRF. The batter was subjected to analyze on the rheological properties.

2.5.1.1 Rheological property

The viscoelastic properties of cake batters were investigated by measure elastic modulus (G') using a rheometer (HAAKE RheoStress 1, Thermo Fisher Scientific, Karlsruhe, Germany), following Hesso et al. (2015).

2.5.2 Preparation of brown rice cake

The cake batter (70 g) was poured into rectangular baking pan ($166 \times 35 \times 29 \text{ mm}^3$) and baked (180°C , 40 min) in a preheated oven (Model YXD-10A, South Star®, Canada). After baking, the cakes were removed from the baking pan and allowed to cool at room temperature ($25\text{-}28^\circ\text{C}$) for 3 h. Then, they were packed in a zip lock bags and kept at 25°C until used for characterization and sensory property analysis within 24 h.

2.5.3 Characterization of Bombay locust protein-enriched brown rice cakes

2.5.3.1 Water activity (a_w) and color

Determination of water activity and color measurement of crust and crumb was determined as described in section 2.4.2.

2.5.3.2 Cake quality

Cake qualities including baking loss, dimensions (specific volume, cake volume and density) and physical properties (volume index, uniformity and symmetry), were determined according to the AACCI method 10-91 (AACC, 2010).

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2.5.4 Texture profile analysis

Texture profiles of cake crumbs were determined, using a texture analyzer (TA.XT.plus®, Texture Technologist Corp., USA), following AACCI method 74-09 (AACC, 2010).

2.6 Chemical compositions and energy value

Protein, fat, moisture, ash and total carbohydrate contents (% wet basis) were determined according to AOAC methods - see section 2.4.1. Energy value was calculated according to the Atwater system (Merrill & Watt, 1973).

2.7 Sensory evaluation

Sensory properties were evaluated on a hedonic 9-point scale with 50 untrained panelists for all protein-enriched and control cakes. Cakes properties were appearance, color (crust and crumb), aroma, taste, texture, flavour, after-taste and overall acceptability. All of the cakes were evaluated in random orders to the panelists. During the evaluation, panelists rinsed their mouths with water before-and-after sample testing.

2.8 Scanning Electron Microscopy (SEM)

Based on sensory evaluation of cakes, a brown rice cake made from 20-MF was selected for analysis of its microstructure, in comparison with control (without BL). The cake microstructure was captured using a scanning electron microscopy (SEM) with low-vacuum mode and SED detector. The specimens were visualized with a scanning electron microscope (Quanta 250, FEI, Eindhoven, Netherlands) at an acceleration voltage of 10 kV.

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2.9 Statistical analysis

Experiments were run in triplicate. Resulting data were subjected to analysis of variance. Comparison of means was analyzed using Duncan's multiple range tests at confidence level of 0.05 (Steel & Torrie, 1986). Statistical analysis was performed using Statistical Package for Social Science (IBM SPSS Statistics 25, IBM, New York, USA).

3. Results and discussion

3.1 Impact of BL fortification on characteristics of protein-enriched brown rice flour

3.1.1 Chemical composition and fiber content

Chemical composition and fiber content of brown rice flour, fortified with Bombay Locust powder (BL) at different replacement levels (10, 20 and 30%), are shown in Table 2 in comparison with BRF without fortification (control). Carbohydrate (72.4%) was the major component of BRF, followed by moisture (12.8%) and protein (11.5%) with minor amounts of fat and ash content. Fortification of BL markedly increased the protein content of BRF in a dose-dependent manner ($p \leq 0.05$) and the highest protein content was obtained from 30-MF (42.1%) by a 4-fold increase the control. Apart from protein content (78.7%) of BL, the significant amounts of fat (1.2%) and ash (3.3%) contents were also observed. Thus, fat and ash contents notably increased in the mixed flours. The lower carbohydrate and moisture contents were found in BL fortified flour, which indicated the dilution effect of BRF content with increasing of dry matter from insect powder. As an alternative gluten-free mixed flour provision, flour quality should be considered, as well as a food safety concerns and consumer acceptance. Moisture content is one of the quality parameters

Table 2

Characteristics of protein-enriched brown rice flours fortified with Bombay locust powder at different levels.

Characteristics	Control	10-MF	20-MF	30-MF
Chemical composition				
Protein (%) [*]	11.47 ± 0.10 ^d	21.00 ± 0.30 ^c	31.11 ± 0.31 ^b	42.11 ± 0.46 ^a
Fat (%)	1.81 ± 0.16 ^c	2.78 ± 0.21 ^b	3.06 ± 0.02 ^{ab}	3.29 ± 0.08 ^a
Ash (%)	1.47 ± 0.01 ^d	1.67 ± 0.01 ^c	1.85 ± 0.01 ^b	2.04 ± 0.01 ^a
Moisture (%)	12.85 ± 0.06 ^a	12.44 ± 0.02 ^b	12.38 ± 0.02 ^b	11.84 ± 0.10 ^c
Carbohydrate (%)	72.39 ± 0.25 ^a	62.10 ± 0.44 ^b	51.60 ± 0.63 ^c	40.72 ± 0.66 ^d
Fiber content (%)	1.59 ± 0.07 ^d	2.62 ± 0.20 ^c	3.57 ± 0.15 ^b	5.04 ± 0.09 ^a
Water activity	0.525 ± 0.008 ^a	0.502 ± 0.009 ^b	0.509 ± 0.010 ^{ab}	0.491 ± 0.014 ^b
Color				
L [*]	88.29 ± 0.14 ^a	74.04 ± 0.03 ^b	68.28 ± 0.08 ^c	65.32 ± 0.08 ^d
a [*]	0.87 ± 0.02 ^d	5.02 ± 0.07 ^c	6.39 ± 0.03 ^b	7.20 ± 0.11 ^a
b [*]	12.44 ± 0.14 ^d	14.72 ± 0.09 ^c	16.06 ± 0.16 ^b	17.30 ± 0.18 ^a
ΔE [*]	-	15.01 ± 0.16 ^c	21.06 ± 0.12 ^b	24.32 ± 0.20 ^a
ΔC [*]	-	4.74 ± 0.07 ^c	6.60 ± 0.04 ^b	7.98 ± 0.19 ^a
Pasting properties				
Pasting temperature (°C)	72.9 ± 0.1 ^b	87.2 ± 0.5 ^a	50.2 ± 0.0 ^c	50.3 ± 0.0 ^c
Peak viscosity (BU)	927.5 ± 15.5 ^a	22.0 ± 0.0 ^b	12.0 ± 0.0 ^b	12.0 ± 0.0 ^b
Breakdown viscosity (BU)	478.0 ± 9.0 ^a	7.0 ± 0.0 ^b	2.0 ± 0.0 ^b	2.0 ± 0.0 ^b
Setback viscosity (BU)	507.0 ± 6.0 ^a	15.0 ± 0.0 ^b	5.0 ± 0.0 ^{bc}	2.0 ± 0.0 ^c
Final viscosity (BU)	958.0 ± 0.0 ^a	30.5 ± 1.5 ^b	15.0 ± 0.0 ^c	12.0 ± 0.0 ^d

Data are expressed as mean ± standard deviation (n=3).

^{*}The conversion factor used is 6.25.

Control: Brown rice flour (BRF) without Bombay locust powder fortification.

10-, 20-, 30-MF: Mixed brown rice flour fortified with Bombay locust powder at 10, 20, 30%, respectively.

Different lowercase superscripts in the same row indicate significant difference ($p \leq 0.05$).

that has important roles in some reactions, especially for microbial growth. A high moisture of rice grain and flour leads to food spoilage, generally due to fungal growth, with shortened shelf life (Abdullah,

Nawawi, & Othman, 2000). According to CAC (1985), the resulting mixed flours met the standard of flours for moisture content, which did not exceed 15.5% (w/w). The current international Recommended Dietary Allowance (RDA) for protein is 0.8 g/kg of body weight, regardless of age (WHO, 2007). The Daily Reference Values (DRVs) of protein for adult is 50 g based on the reference of caloric intake of 2,000 calories, while the reference nutrients intake is set at 0.75 g protein per kg body weight per day for adult (FDA, 2016b). The consumption of BL fortified brown rice flour at the reference amount customarily consumed (30 g) is sufficient to meet 10% of DRV of protein (FDA, 2016a, 2016b). Therefore, the resulting mixed flours meet the FDA requirement for protein-enriched flour (FDA, 2016b). Gluten-free composite flour blends have been developed by using rice flour, potato starch, cassava starch, millet flour and corn flour (Quiñones, Macachor, & Quiñones, 2015). Nevertheless, those composite flours had low protein content, compared with commercial wheat flour (12.58%). The protein has been enriched in flours by adding different protein sources, e.g. egg white, soy and beans as well as insect powder (Campbell et al., 2016; da Rosa Machado & Thys, 2019; de Oliveira et al., 2017; Majzoobi, Ghiasi, Habibi, Hedayati, & Farahnaky, 2014; Osimani et al., 2018; Singh, Benjakul, & Karnjanapratum, 2019). da Rosa Machado and Thys (2019) developed protein-enriched gluten-free breads, using cricket powder, buckwheat and lentil flours, added to rice flour. Cricket powder fortification provided the bread with higher protein content (12.5%), compared to others (6.2-7.1%). In addition, the fiber content of mixed flours was gradually increased with BL level ($p \leq 0.05$) (Table 2). This result was consistent with the composition of BL, a good source of insoluble fiber from chitin exoskeletons (9.6%) (Rumpold & Schluter, 2015). Osimani et al. (2018) found that enriched breads, incorporated with cricket powder, were considerably richer in fiber (2.6%), especially at 30% of wheat flour substitution, compared to control breads. Therefore, BL was an effective protein source for improving the nutritional value of brown rice flour, particularly protein content.

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3.1.2 Water activity (a_w) and color

Table 2 shows water activity and color of protein-enriched brown rice flours fortified with different levels of BL. Water activity of all mixed flours, ranging from 0.491 to 0.525, was comparable ($p > 0.05$). Generally, microbes, especially fungi, could not grow at a_w less than 0.62–0.70 and the safe storage level is considered at 0.65 of a_w could maintain the moisture content for long-term storage (Abdullah et al., 2000). BL notably contributed to change in color of mixed flours ($p \leq 0.05$). BL fortification decreased L^* (lightness), but increased a^* (redness) and b^* (yellowness) of mixed flour, with increase in BL replacement. This indicated the effect of the natural BL brown color ($L^* : 54.38$, $a^* : 7.68$, $b^* : 18.37$). Color differences between the mixed flours and the control (BRF) were evaluated through a total difference of color (ΔE^*) and chroma difference (ΔC^*). Both ΔE^* and ΔC^* increased with BL concentration in a dose-dependent manner ($p \leq 0.05$). In general, the color of baked products was directly related to the color of the raw materials used. The presence of mealworm and black soldier fly larvae and cricket in the wheat flour led to brownish bread crumbs, consistent with decreased L^* and increased b^* observed in mixed flour by González et al. (2019). Therefore, adding BL contributed into the color changes of the protein-enriched brown rice flour, which could influence the color of the final product prepared by using these mixed flours.

3.1.3 Pasting properties

Pasting properties of flours describe the behaviour changes of flour paste viscosity along with a change in temperature, which varies mainly with their composition and characteristics of starches and proteins (Shevkani, Kaur, Kumar, & Singh, 2015; Singh et al., 2014). The effect of BL on pasting properties of protein-enriched brown rice flour is shown in Table 2. Pasting temperature indicates the minimum temperature required for flour cooking and starch gelatinization temperature (Iwe, Onyeukwu, & Agiriga, 2016). The highest PT was found for 10% of BL replacement (10-MF) ($p \leq 0.05$). The control (BRF) had

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72.9°C of PT, which was lower than that of 10-MF (87.2°C). PT could be increased as the moisture content decreased (Sun, Xing, Qiu, & Xiong, 2014), where water-soluble proteins from BL, especially at 10% replacement, could displace water proportion during gelatinization. On the other hand, significant decrease of PT was observed from 20-30% of BL addition, which might be caused by decreased starch content in mixed flour. The similar result was reported by Shevkani et al. (2015) who studied the impact of cowpea (*Vigna unguiculata*) protein enrichment in rice flour. PT was also governed by binding efficiency of starch pastes, related to released amylose/amylopectin from starch grains, and its chain length as well as other molecular components (Kumar & Khatkar, 2017). BL increment markedly changed behaviour of flour paste viscosity with decreased peak viscosity (PV), breakdown viscosity (BV), setback viscosity (SV) and final viscosity (FV). PV defines the swelling level or water-binding capacity of starch during the heating process. Thus, BV will be reached when the viscosity is dropped afterward, which indicates starch stability degree during cooking (Wani et al., 2012). SV measures the tendency of starch retrogradation upon cooling of cooked starch pastes (Gadallah, 2017). FV indicates the viscous paste formation ability of flours upon cooling (Shevkani et al., 2015). Remarkable decrease of PV and SV of mixed flours was observed, compared with the control ($p>0.05$). In addition, FV and SV were drastically reduced with BL addition as dose dependent manner. Jane et al. (1999) found that a high value of PV and BV was caused by the presence of high amylose content and high proportions of very long amylopectin branch chains. Complete gelatinized starch granules in rice flour paste, had not only increased viscosity due to the leached-out linear molecules but also the lost crystallinity (Kim & Shin, 2014). Lower SV and FV, indicated lower retrogradation and staling tendency of rice flour-based products during storage, *vice versa* (Gani, Wani, Masoodi, & Salim, 2013; Thiranusornkij, Thamnarathip, Chandrachai, Kuakpetoon, & Adisakwattana, 2018). The control flour (100% BRF) obtained the highest SV and FV which was 958 BU and 507 BU, respectively. The increment

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of protein addition level caused the reduction of PV, BV, SV and FV of rice flour (Shevkani et al., 2015). Protein, lipid and insoluble chitin from exoskeleton contents, inhibit water permeation into starch granules, so that results in lowering swelling capability of starch granules (Li & Zhu, 2017). Decreasing of BV, might reveal more proteins from BL fortification, provided the starch granules with higher resistance to disintegrate at high temperature (Shevkani et al., 2015). BL addition might inhibit starch retrogradation of BRF. The paste viscosities of flours are mainly influenced by their starch properties. Apart of starch dilution effect from BL replacement, not only protein content but also fat, ash and fiber contents (Table 2), could govern the amount of water absorbed by rice flour granules, consequently, demonstrated their pasting properties (Martin & Fitzgerald, 2002). Thus, pasting properties of BRF was greatly affected with extensively declined by BL addition, which could contribute to the feasibility of resulting mix flours for preparing the baked products.

3.2 Application of protein-enriched brown rice flours by BL fortification on the preparation of cake products

3.2.1 Rheological property of protein-enriched brown rice cake batter

Elastic modulus (G') refers to elastic behaviour and reflects deformation energy stored in the sample while it is sheared. This viscoelastic property predominantly contributes to structure changes, especially during baking, which could define the structure formation and final texture of baked products (Hesso et al., 2015; Shevkani et al., 2015). Viscoelastic properties of brown rice cake batter without and with BL fortification at various substitution levels (10-30%) during heating from 25-95°C, are illustrated in Fig. 1.

The batters with different viscosity were obtained by adding different levels of BL. Increasing of G' was observed with increased BL replacement level, especially at 20% (20-MF) and 30% (30-MF) replacement.

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The greater viscoelasticity of the batters might be attributed to the higher water-binding/absorption capacity that reduced the availability of free water to facilitate the particles movement in the batter (Hesso et al., 2015; Shevkani et al., 2015). The constant G' was observed for all batters tested at the first region of heating (25-40°C). The G' was then increased continuously as increased temperature. The control (BRF) and mixed flours had a similar trend of G' changed during heating. Nevertheless, the sharp increase of G' was found from the control at 45-75°C, which was mainly affected by the presence of a higher amount of carbohydrate or starch content. This was consistent with its pasting properties, which showed the highest peak viscosity (Table 2) at 72.9°C, compared with others. The lower changing rate of G' could be observed from mixed flours, especially 20-MF and 30-MF, which related with their lower pasting viscosity. Although 30-MF batter showed the highest G' from the first region, the highest G' was reached for all sample tested at the end of the heating process (80-88°C) with similar viscoelasticity. These characteristics revealed the protein

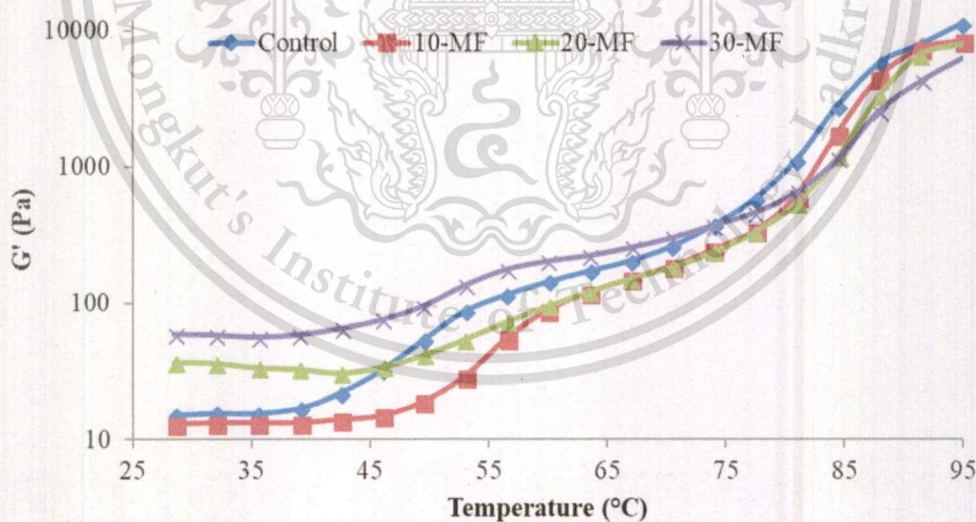


Fig. 1. Elastic modulus (G') of protein-enriched brown rice cake batter fortified with Bombay locust powder at different levels during heating from 25 to 95°C. Control; brown rice cake prepared using brown rice flour without Bombay locust powder fortification, 10-, 20-, 30-MF; brown rice cake prepared using brown rice flour fortified with Bombay locust powder at 10, 20, 30%, respectively.

denaturation, starch gelatinization as well as structure fixation (Lee, Inglett, & Carriere, 2004). This viscoelasticity difference was determined by an interaction between ingredient used in cake batter. Singh et al. (2019) studied different level egg white powder (EWP) replacement using ultrasonicated squid ovary powder (USOP) in cake batter. They found that USOP inclusion improved the viscoelastic properties of cake batter as well as strengthened its structure during baking. Therefore, the BL fortification to brown rice flour markedly affected the viscoelasticity of resulting cake batter, which mediated the structure formation of cake during baking as well as the final cake properties.

3.2.2 Characteristics of protein-enriched cake prepared using BL mixed brown rice flour

3.2.2.1 Water activity (a_w) and color

The baking process involves several chemical reactions, i.e. Maillard reactions, protein denaturation, moisture content reduction and physical transformations, such as a change in color, volume, and texture (Sun, Zhou, Yan, Huang, & Lin, 2018). Table 3 shows water activity and color of crust and crumb of protein-enriched cakes prepared using BL fortified brown rice flour at various levels. The slight decrease of water activity was observed for all resulting cakes (0.843-0.860) from BL mixed flour ($p \leq 0.05$), compared with that of control (0.873). This result might be caused by the lower moisture content and water activity of the mixed flour used for preparing the cake (Table 2). Moreover, the lower water activity implied rapid loss of moisture, occurred within crumb during baking (Cauvain & Young, 2011). The BL fortification to BRF could distinctively determine the color of the resulting cake (Fig. 2). Reducing of lightness with decreased L^* was obtained, in which increasing of greenness and blueness with lowered a^* and b^* were found from both crust and crumb as increased BL addition level. Consequently, increasing of the total differences of color (ΔE^*) and chroma (ΔC^*) of BL enriched brown rice cakes, was observed when BL content

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increased. Overall, cake became darker in color, when BL was mixed with BRF (Fig. 2). These results were in line with the color of mixed flours from BL fortification (Table 2). The major content of BL was protein, which might enhance the color changes via Maillard reaction, especially color of crust (Premi & Sharma, 2018). Similar trend of crumb color was found in the fortified gluten-free cake with germinated chickpea flour

Table 3

Water activity and color of protein-enriched cakes prepared using brown rice flours fortified with Bombay locust powder at different levels.

Parameters	Control	10-MF	20-MF	30-MF
Water activity	0.873 ± 0.006 ^a	0.860 ± 0.007 ^b	0.843 ± 0.005 ^c	0.844 ± 0.005 ^c
Color of crust				
L*	56.29 ± 0.12 ^a	48.90 ± 0.58 ^b	46.39 ± 0.44 ^c	42.31 ± 0.49 ^d
a*	15.46 ± 0.26 ^a	15.04 ± 0.13 ^a	13.96 ± 0.10 ^b	13.16 ± 0.36 ^c
b*	28.97 ± 0.49 ^a	23.20 ± 0.68 ^b	20.01 ± 0.12 ^c	16.26 ± 0.69 ^d
ΔE*	-	10.04 ± 0.29 ^b	13.45 ± 0.08 ^b	19.05 ± 0.62 ^a
ΔC*	-	6.34 ± 0.33 ^c	9.24 ± 0.30 ^b	12.93 ± 0.52 ^a
Color of crumb				
L*	61.56 ± 1.03 ^a	51.46 ± 0.88 ^b	46.67 ± 0.51 ^c	44.14 ± 0.56 ^d
a*	4.91 ± 0.39 ^d	6.46 ± 0.29 ^c	6.99 ± 0.14 ^b	7.77 ± 0.14 ^a
b*	18.87 ± 0.53 ^a	19.29 ± 0.28 ^a	17.91 ± 0.66 ^b	17.18 ± 0.33 ^b
ΔE*	-	10.24 ± 0.39 ^c	15.04 ± 0.59 ^b	17.70 ± 0.99 ^a
ΔC*	-	1.64 ± 0.06 ^c	2.09 ± 0.07 ^b	3.12 ± 0.13 ^a

Data are expressed as mean ± standard deviation (n=3).

Control: Brown rice flour (BRF) without Bombay locust powder fortification.

10-, 20-, 30-MF: Mixed brown rice flour fortified with Bombay locust powder at 10, 20, 30%, respectively.

Different lowercase superscripts in the same row indicate significant difference ($p \leq 0.05$).

(Gadallah, 2017). Varies protein sources color was defined by the presence of different coloring constituents

in flours, e.g. polyphenols which could react with proteins (Xu & Diosady, 2000). Also, the crumb color

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was determined by ingredients used in cake formulation as temperature inside of cakes could not facilitate Maillard reactions (Premi & Sharma, 2018). Thus, the color and protein content of BL influenced the color of resulting protein-enriched brown rice cake.



Fig. 2. Appearance of top surface (A) and cross-sectional (B) views of protein-enriched brown rice cakes fortified with Bombay locust powder at different levels. Control; brown rice cake prepared using brown rice flour without Bombay locust powder fortification, 10-, 20-, 30-MF; brown rice cake prepared using brown rice flour fortified with Bombay locust powder at 10, 20, 30%, respectively.

3.2.2.2 Cake quality

Quality of protein-enriched cakes, prepared using BL fortified brown rice flours, at different levels, were evaluated as baking loss and dimensions of cake (Table 4). Increasing of baking loss (%) was observed with increased BL level, and the lowest baking loss was obtained from 20-MF (22.0%) and 30-MF (21.8%) ($p \leq 0.05$). Baking loss difference was directly attributed in cake dimensions difference. The lower baking loss, resulted in the higher weight and density, with lower cake volume and specific volume. This result was consistent with the greater batter viscosity (Fig. 1) and the higher water activity of cakes (Table 3). The batter with a higher G' would obstruct the incorporation and expansion of air bubbles during the first stage of baking (Sahagún, Bravo-Núñez, Báscones, & Gómez, 2018). Replacement a part of the flour with BL, caused the starch content reduction, as well as the present of non-soluble exoskeleton chitin from BL, in the phase surrounding the bubbles, which could decrease the film layer consistency (Sahagún et al., 2018). Thus, the greater collapse and escape out of bubbles during baking would be occurred. Besides, the higher water-holding capacity of proteins due to chemical structure and their interaction with the food ingredients, could reduce water loss, increase final moisture content and water activity of cake, compared with starch (Nammakuna, Barringer, & Ratanatriwong, 2015; Shevkani & Singh, 2014). Then, protein-enriched brown rice cake with moist and dense crumb was obtained by BL addition.

Physical properties of final cakes were also evaluated as volume, uniformity and symmetry index as shown in Table 4. There was no difference in volume index of all samples tested. Replacement brown rice flour with BL affected symmetry and uniformity index of final cakes. Generally, the symmetry index is an indicator of surface contours, while uniformity index is a measure of cake symmetry. Significant decrease of symmetry index was obtained when BL was added ($p \leq 0.05$), which indicated the flat surface

Table 4

Quality characteristics and texture properties of protein-enriched cakes prepared using brown rice flours fortified with Bombay locust powder at different levels.

Parameters	Control	10-MF	20-MF	30-MF
Baking loss (% w/w)	29.46 ± 1.70 ^a	26.18 ± 1.78 ^b	21.99 ± 0.88 ^c	21.70 ± 0.79 ^c
Dimensions				
Cake volume (cm ³)	332.64 ± 19.80 ^a	237.60 ± 7.48 ^b	198.72 ± 7.48 ^c	149.04 ± 11.22 ^d
Specific volume (cm ³ /g)	6.82 ± 0.31 ^a	4.66 ± 0.04 ^b	3.69 ± 0.10 ^c	2.76 ± 0.18 ^c
Density (g/cm ³)	0.14 ± 0.00 ^d	0.21 ± 0.00 ^c	0.27 ± 0.01 ^b	0.36 ± 0.02 ^a
Physical properties				
Volume index (cm)	8.10 ± 0.17 ^a	8.00 ± 0.00 ^a	8.00 ± 0.20 ^a	7.87 ± 0.06 ^a
Uniformity index (cm)	0.00 ± 0.00 ^b	0.00 ± 0.00 ^b	0.10 ± 0.00 ^a	0.07 ± 0.06 ^a
Symmetry index (cm)	-0.20 ± 0.00 ^a	-0.50 ± 0.00 ^b	-0.60 ± 0.20 ^b	-0.67 ± 0.06 ^b
Texture properties				
Hardness (N)	1.40 ± 0.28 ^a	1.00 ± 0.01 ^b	0.79 ± 0.03 ^b	0.66 ± 0.01 ^b
Springiness (mm)	0.94 ± 0.03 ^a	0.86 ± 0.06 ^{ab}	0.80 ± 0.08 ^{ab}	0.80 ± 0.01 ^b
Cohesiveness	0.80 ± 0.01 ^a	0.69 ± 0.03 ^b	0.69 ± 0.01 ^b	0.80 ± 0.01 ^a
Gumminess (N)	1.12 ± 0.21 ^a	0.69 ± 0.04 ^b	0.54 ± 0.01 ^b	0.44 ± 0.00 ^b
Chewiness (N)	1.05 ± 0.17 ^a	0.59 ± 0.01 ^b	0.44 ± 0.05 ^b	0.36 ± 0.01 ^b
Resilience	0.40 ± 0.01 ^a	0.28 ± 0.02 ^b	0.28 ± 0.01 ^b	0.28 ± 0.01 ^b

Data are expressed as mean ± standard deviation (n=3). Control: Brown rice flour (BRF) without Bombay locust powder fortification. 10-, 20-, 30-MF: Mixed brown rice flour fortified with Bombay locust powder at 10, 20, 30%, respectively. Different lowercase superscripts in the same row indicate significant difference ($p \leq 0.05$).

of cake. Increasing uniformity index was observed from the protein-enriched cake, especially at replacement level higher than 10% ($p \leq 0.05$), compared with the control. This was in line with the rheological property of cake batter (Fig. 1). Qasem et al. (2017a) reported that viscosity of cake batter demonstrated the cake quality parameters, particularly cake symmetry.

3.2.2.3 Texture profile

Texture profile of protein-enriched brown rice cakes is shown in Table 4 in comparison with the control (without BL fortification). The control cake required the highest compression force to deform the cake, which indicated the highest hardness ($p \leq 0.05$), compared to other cake samples. The lower hardness of fortified cake was observed, while no significant difference between fortification levels tested was observed ($p > 0.05$). This decrease in hardness of enriched cake might due to the decrease of starch content, which played a crucial role on cake structure formation baked from rice flour (Sozer, 2009). It was reported that grasshoppers contain chitin ranging from 9.6-14.9% dry matter basis (Fombong, Van Der Borgh, & Broeck, 2017). Insect protein and insoluble fiber of chitin particle from exoskeleton, interfered the development of gelatinized starch network (de Oliveira et al., 2017), while interaction between insect protein and other components in batter was not strong as those generated in the control cake, rendering cake structure with weak backbone (Finke, 2007; Premi & Sharma, 2018; Rumpold & Schluter, 2015). Moreover, a crumbling matrix could be obtained with a low internal cohesion within crumb that might lead to the less compression resistance of cake. This result was in line with decreasing of springiness and cohesiveness of BL fortified cakes, which indicated the less elasticity with the weak adhesion between components, particularly BL protein and gelatinized starch, in cake matrix (Premi & Sharma, 2018). However, BL-fortified cake with 30% replacement (30-MF) showed similar cohesiveness with

the control cake ($p>0.05$). It might relate to the lowest specific volume with the highest density of 30-MF cake (Table 4), which provided the moist and dense cake structure. A similar result was found for gumminess, chewiness and resilience of protein-enriched cake prepared using BL mixed brown rice flour, which was lower than control ($p\leq 0.05$), regardless of BL proportion added. The decrease in gumminess and chewiness indicated lower energy needed to disintegrate and masticate a solid food for swallowing, respectively. Additionally, decreased resilience reflected the lack of ability to recover their original shape after deformation, which caused by non-uniformity with a dense and crumbly matrix of cake (Cornejo & Rosell, 2015; Phattanakulkaewmorie, Paseephol, & Moongngarm, 2011). Nevertheless, no significant difference in those parameters was detected when different BL proportions were added ($p>0.05$). There were many factors, including component, moisture content, cake volume, batter viscosity, which directly contributed the texture properties of final baked products (Arora & Saini, 2016; Miranda-Villa, Mufari, Bergesse, & Calandri, 2018; Moore, Schober, Dockery, & Arendt, 2004).

3.3 Chemical compositions and energy value

Chemical compositions and energy value of BL fortified brown rice cake are shown in Table 5, in comparison with control. Significant increase of protein content was obtained as increased BL level added ($p\leq 0.05$), compared with that of the control. According to CAC (1997), the cakes could be claimed as 'source of protein', when their protein content was ranging from 14.9-24.9%. Therefore, BL-fortified cakes could be claimed as 'high protein source', especially at more than 10% BL added level. It was noted that BL addition increased protein content, while fat and ash contents were not affected. It was reported that insect powder

inclusion increased protein content as well as fat and ash content of bread product (de Oliveira et al., 2017; Osimani et al., 2018). This might indicate the impact of fat removal process, implemented in BL production

Table 5

Chemical compositions and energy value of protein-enriched brown rice cakes prepared using brown rice flours fortified with Bombay locust powder at different levels.

Parameters	Control	10-MF	20-MF	30-MF
Protein (%) [*]	14.94 ± 0.58 ^d	18.40 ± 0.59 ^c	20.83 ± 0.15 ^b	24.94 ± 0.30 ^a
Fat (%)	21.55 ± 0.57 ^a	22.17 ± 0.36 ^a	21.49 ± 0.41 ^a	21.90 ± 0.64 ^a
Ash (%)	1.26 ± 0.08 ^a	1.29 ± 0.06 ^a	1.33 ± 0.04 ^a	1.35 ± 0.02 ^a
Moisture (%)	41.18 ± 0.92 ^a	38.72 ± 1.15 ^b	37.26 ± 1.03 ^b	37.44 ± 0.68 ^b
Carbohydrate (%)	21.08 ± 1.84 ^a	19.42 ± 1.36 ^a	19.10 ± 0.89 ^a	14.26 ± 0.48 ^b
Energy value (kcal/100 g)	337.94 ± 3.62 ^a	350.83 ± 6.32 ^a	353.13 ± 6.06 ^a	354.33 ± 5.86 ^a

Data are expressed as mean ± standard deviation (n=3).

^{*}The conversion factor used is 6.25.

Control: Brown rice flour (BRF) without Bombay locust powder fortification.

10-, 20-, 30-MF: Mixed brown rice flour fortified with Bombay locust powder at 10, 20, 30%, respectively.

Different lowercase superscripts in the same row indicate significant difference ($p \leq 0.05$).

process, which could concentrate protein content and reduce fat content in the resulting BL. Decreasing moisture content was found from BL fortified cakes, compared with that of the control ($p \leq 0.05$). This result was under the higher water activity (0.873) (Table 3) of the control cake compared with BL fortified cakes ($p \leq 0.05$), where water activity and moisture content had a positive correlation on cake making (Noorlaila, Nor Hasanah, Yusoff, Sarijo, & Asmeda, 2017). On the other hand, decreased carbohydrate content was found for BL fortified cakes, especially at the highest BL level added ($p \leq 0.05$). This result reconfirmed dilution effect of carbohydrate and starch contents of mixed flour (Table 2), and the corresponding cake due to BL replacement. However, there were no significant differences in energy value of the resulting cakes. This result was in line with energy value of protein-enriched bread using mealworm powder (Roncolini et al., 2019).

3.4 Sensory properties

Sensory properties of protein-enriched brown rice cake, prepared using mixed brown rice flour, with different levels of BL, were evaluated and presented as likeness score, in comparison with the control cake (without BL fortification) (Table 6). The control showed good acceptability with the highest likeness score ($p \leq 0.05$) for all attributes tested. It was found that BL addition affected sensory properties of the resulting cakes, especially at the highest level used (30-MF), where the significant lower score was obtained for all attributes tested, compared with those of the control ($p > 0.05$). This was related to the dark color (Table 3), dense and crumbly texture (Table 3) with a distinct change of appearance (Figure 1) for the cake incorporated with 30% BL. Appearance, color of crumb and aroma of cake were changed by BL addition at the lowest level used (10-MF), which directly demonstrated panelist's acceptance with lowered overall likeness score, compared with the control ($p \leq 0.05$). The results indicated the adverse effect of BL addition

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Table 6

Sensory properties of protein-enriched brown rice cakes prepared using brown rice flours fortified with Bombay locust powder at different levels.

Sensory properties	Likeness score			
	Control	10-MF	20-MF	30-MF
Appearance	8.3 ± 0.6 ^a	7.8 ± 0.6 ^b	7.4 ± 0.8 ^b	6.9 ± 0.9 ^c
Color of crust	8.2 ± 0.8 ^a	8.0 ± 0.7 ^a	7.2 ± 0.7 ^b	6.7 ± 0.9 ^c
Color of crumb	8.4 ± 0.5 ^a	7.7 ± 0.7 ^b	7.3 ± 0.8 ^b	6.7 ± 1.0 ^c
Aroma	7.6 ± 1.0 ^a	7.0 ± 0.8 ^b	7.0 ± 0.8 ^b	6.4 ± 1.0 ^c
Taste	7.7 ± 0.8 ^a	7.6 ± 1.0 ^a	7.0 ± 1.0 ^b	6.2 ± 0.9 ^c
Texture	7.5 ± 0.6 ^a	7.3 ± 0.8 ^a	7.2 ± 1.0 ^a	6.2 ± 1.0 ^b
Flavor	7.4 ± 0.5 ^a	7.0 ± 0.9 ^a	7.0 ± 0.8 ^a	6.3 ± 1.0 ^b
Aftertaste*	7.4 ± 0.9 ^a	7.2 ± 1.0 ^a	7.0 ± 0.6 ^a	5.9 ± 0.8 ^b
Overall	8.0 ± 0.7 ^a	7.6 ± 0.7 ^b	7.1 ± 0.8 ^b	6.2 ± 0.9 ^c

*the any left-over flavor or sensations that occur after the sample has been swallowed.

Control: Brown rice flour (BRF) without Bombay locust powder fortification.

10-, 20-, 30-MF: Mixed brown rice flour fortified with Bombay locust powder at 10, 20, 30%, respectively.

Different lowercase superscripts in the same row indicate significant difference ($p \leq 0.05$).

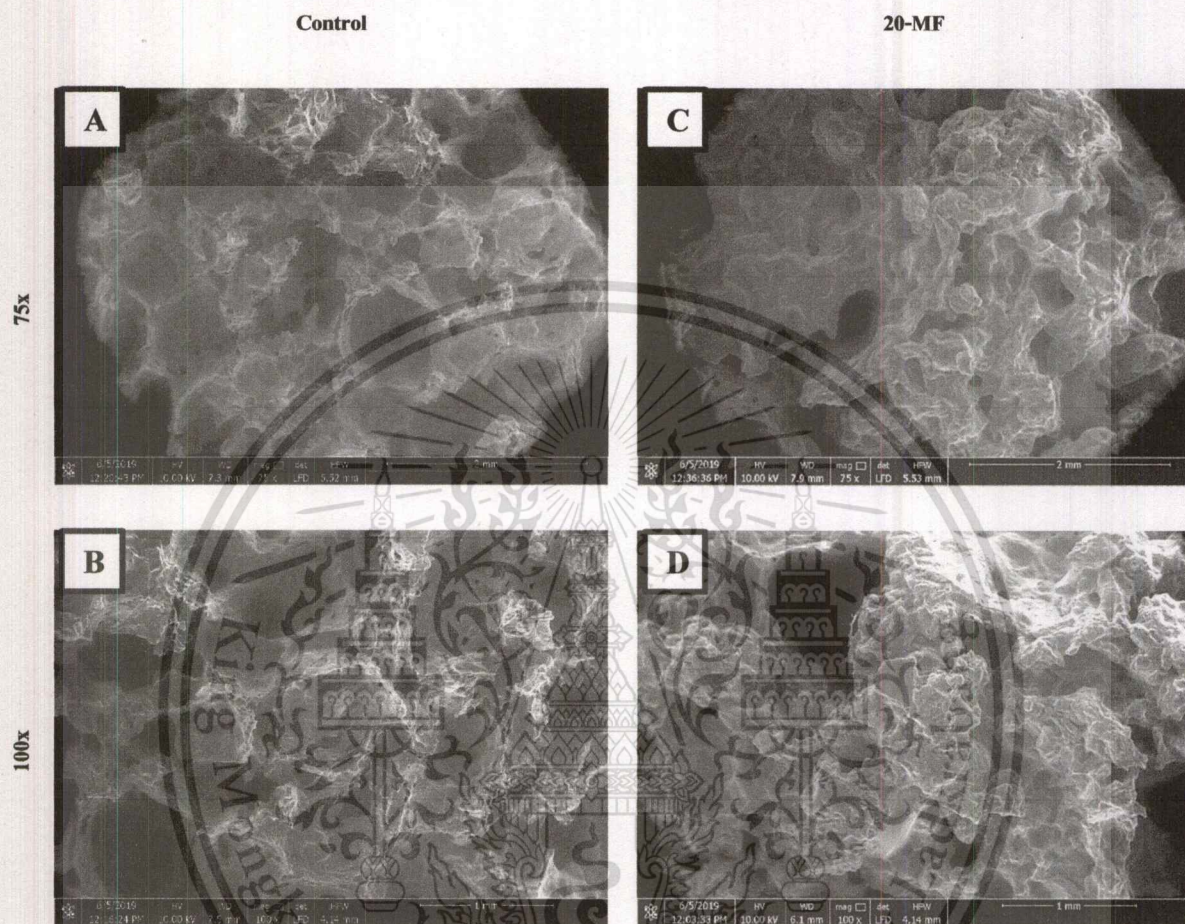
on organoleptic properties due to dark color with a unique odor of BL. However, the fortified brown rice cake with BL up to 20%, had similar likeness score on texture, flavor and aftertaste, to the control cake ($p > 0.05$), while the acceptability for other attributes was in the desirable range (7-9 likeness score) (Bhaduri, 2013). Majzoobi et al. (2014) reported that the appropriate level of the soy protein isolate had crucial roles on texture, sensory properties as well as consumer acceptability of cakes, where the SPI addition of less than 20%, provided a protein-enriched cake with acceptable quality. Osimani et al. (2018) found that the maximum level of cricket powder addition on bread was 10% (w/w) with acceptable liking score. The result suggested that protein-enriched cake, with good consumer acceptance, could be successfully prepared using

BL mixed brown rice flour at 20% (20-MF), without a baneful effect on sensory properties. The 20-MF cake was then selected and subjected to study for microstructure in comparison with the control.

3.5 Microstructure

The inner surface of cakes was captured and observed using a scanning electron microscope (SEM). Microstructures of the selected protein-enriched cake prepared using 20% BRF replacement by BL (20-MF) are presented in Fig. 3 in comparison with the control. Both samples showed a sponge-like structure, where the control cake (Fig. 3 (A)) had a rough crumb and open structure with more porosity from the gap and air cells, compared with 20-MF cake (Fig. 3 (B)). Besides, the denser structure with less porosity was obtained from protein-enriched (20-MF) cake. Similar structure was also observed from gluten-free cake prepared using gums mixed rice flour. Different types of gums affected the pore area fraction and number of pores in a cake crumb (Turabi, Sumnu, & Sahin, 2010). More uniform structures were obtained from the control cake, in which distribution of air bubbles was more homogenous, compared to a 20-MF cake. Shevkani and Singh (2014) reported that cake batter viscosity influenced the ability of batter to entrap and retain air bubble during mixing and baking. The too high or too low viscosity of batter rendered the final cake with low volume. This result was consistent with the different viscoelasticity (Fig. 1), cake batter and volume of cake (Table 4), obtained from 20-MF and the control. Protein from BL might enhance the formation of interconnected structure between the strands and fill the void, thus yielding a denser structure. Moreover, exoskeleton insoluble chitin in BL distributed throughout cake matrix, might interrupt the aeration property of cake batter during baking (Melgar-Lalanne, Hernández-Álvarez, & Salinas-Castro, 2019). Similar result was also found for baked product enriched with squid ovary powder (Singh et al., 2019), cricket (*Acheta*

domesticus) (Osimani et al., 2018), cinereous cockroach (*Nauphoeta cinerea*) powders (de Oliveira et al., 2017).



4. Conclusion

Quality characteristics of protein-enriched brown rice flour and cake were influenced by different levels of BL addition. Characteristics and pasting properties of mixed brown rice flour varied with different BL levels added. Application of mixed flour for preparing cake confirmed the impact of BL addition on the change of rheological properties of cake batter. Mixed flours with different levels of BL added affected

physicochemical and sensory properties of final cakes differently. The 20% replacement levels of BL could be an optimum level, rendering brown rice cake with high nutrient composition, especially protein content, and good acceptability. Therefore, BL could be an alternative protein source for developing high protein flour and baked product, particularly brown rice flour-based product.

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Financial summary report

สัญญาเลขที่ KREF206220

**ชื่อโครงการ Preparation of insect powder from Bombay locust and its application as protein
supplement in brown rice cake**

ชื่อหัวหน้าโครงการวิจัย ผู้รับทุนนางสาวสุพัตรา กาญจนประทุม สังกัดคณะอุตสาหกรรมเกษตร

สรุปงบประมาณค่าใช้จ่ายที่ใช้นับตั้งแต่เริ่มทำการวิจัยถึงปัจจุบัน

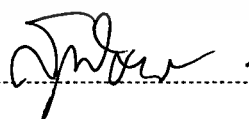
หมวดค่าใช้จ่าย	งบประมาณรวม ทั้งโครงการ	ค่าใช้จ่าย จากรายงานครั้งก่อน	ค่าใช้จ่าย งวดปัจจุบัน	รวมค่าใช้จ่าย สะสมถึงปัจจุบัน	คงเหลือ (หรือเกิน)
งบบุคลากร :ค่าจ้าง ชั่วคราว	-	-	-	-	-
งบดำเนินงาน					
ค่าตอบแทน	-	-	-	-	-
ค่าใช้สอย	57000	0	39,510	39,510	14,640
ค่าวัสดุ	93000	0	102,990	102,990	-12,840
ค่า สาธารณูปโภค	-	-	-	-	-
งบลงทุน: ค่าครุภัณฑ์	-	-	-	-	-
รวม	150000	0	142,500	142,500	7,500

จำนวนเงินที่ได้รับและจำนวนเงินที่ใช้จ่าย

งวดเงินที่ได้รับ	จำนวนเงินที่ได้รับ(บาท)	เมื่อ (ระบุนวัน เดือน ปี)
งวดที่ 1	142,500	9 ส.ค. 2562
งวดที่ 2		
ดอกเบี้ย ครึ่งที่ 1		
ฯลฯ		
รวม	142,500	①

งวดที่	จำนวนเงินที่ใช้จ่าย (บาท)	
งวดที่ 1	142,500	
งวดที่ 2		
ฯลฯ		
รวม	142,500	②

จำนวนเงินคงเหลือ ① - ② 0 บาท



ลงนามหัวหน้าโครงการวิจัยผู้รับทุน



ลงนามเจ้าหน้าที่การเงินโครงการ

Curriculum vitae

Asst. Prof. Dr. Supatra Karnjanapratum

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EDUCATION

Doctor of Philosophy (Ph.D.)

February, 2016

Food Science and Technology

Prince of Songkla University, Songkhla

GPA: 4.00

Thesis:

Title: Development of gelatin hydrolysate from skin of unicorn leatherjacket with enhanced bioactivities

Master of Science (M.Sc.)

August, 2011

Marine Food Science and Technology

Gangneung-Wonju National University, Rep. of Korea

GPA: 4.31/4.5

Title: Structural characteristics and Bioactivities of Sulfated Polysaccharides from Green Seaweeds, *Monostroma nitidum* and *Capsosiphon fulvescens*

Bachelor of Science (B.Sc.)

February, 2008

Food Science and Technology (HONS.)

Chiang Mai University, Chiang Mai

GPA: 3.67/4.0

Title: Characterization of physicochemical properties and standardization of Longan honey

SCHOLARSHIPS/GRANTS

- **Research Grant for New Scholar (MRG) 2019-2021, Thailand Research Fund, Thailand.**

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- *Academic Melting Pot (KREF206220) 2019-2020, KMITL Research and Innovation Service, KMITL, Thailand.*
- *Postgraduate Scholarship (KREF126201) 2019-2021, KMITL Research and Innovation Service, KMITL, Thailand.*
- *Research Grant for New Academic Staff (KREF186014) 2017-2018, KMITL Research and Innovation Service, KMITL, Thailand.*
- *Royal Golden Jubilee Scholarships 2012-2014, Thailand Research Fund (TRF)*
- *Korea Research Foundation Grant 2009-2011, Korean Government (MEST) (The Regional Core Research Program/Medical & Bio-Materials Research Center)*
- *The Research Academic Development Grant 2009-2011, Gangneung-Wonju National University*

RESEARCH EXPERIENCES

Biochemical techniques

- Characterisation of protein pattern using Polyacrylamide Gel Electrophoresis (PAGE)
- Purification of enzyme using Aqueous Two Phase System (ATPS)
- Fractionation of protein and polysaccharide by ion exchange and size exclusion chromatography
- Antioxidative analysis using *in vitro* chemical assay
- Purification and identification of peptide
- Preparation and characterization of surimi and fish based products
- Characterization of chemical and structural properties of polysaccharides extracted from seaweeds
- Chemical modification of polysaccharide (sulfate content and molecular weight)
- Characterization of chemical and physical properties of honey
- Development of dessert formula (cookie, bread, dried fruit)

Molecular and Immunological technique

- Cell culture, Anticancer and immunomodulatory activities
- ELISA (Enzyme-Linked Immunosorbent Assay)
- RT-PCR (Reverse Transcription-Polymerase Chain Reaction)

TECHNICAL EXPERIENCES

- PAGE (Polyacrylamide Gel Electrophoresis)
- HPLC (High Performance Liquid Chromatography)
- Ion exchange and Size exclusion chromatography columns

- Aqueous Two Phase System (ATPS) for protein purification
- ELISA
- RT-PCR
- Agarose gel electrophoresis
- HPSEC-MALLS-RI (High Performance Size Exclusion Chromatography Column linked to a UV, Multi-Angle Laser Light Scattering and Refractive Index Detection System)
- Color Quest II Colorimeter
- Brookfield Viscometer
- Texture analyzer
- SPME GC-MS (Solid-Phase Microextraction Gas Chromatography Mass Spectrometry)
- Micro-Kjeldahl
- Spray-dryer, Freeze-dryer, Rotary evaporator
- Vacuum packaging

SCIENTIFIC PRESENTATIONS

- 1) Poster Presentation title “Molecular characteristics of sulfated polysaccharides from *Monostroma nitidum* and their *in vitro* anticancer and immunomodulatory activities”, 2010 Annual Meeting of Korean Society of Food Science and Technology, Incheon, Korea 16th - 18th May, 2010.
- 2) Poster Presentation title “Immunomodulatory activities of sulfated polysaccharides from green seaweed *Capsosiphon fulvescens*”, Green and Personalized Foods International symposium and annual Meeting, Daegu, Korea 27th-29th October, 2010.
- 3) Poster Presentation title “Immunomodulatory activities of sulfated polysaccharides from green seaweed *Capsosiphon fulvescens*”, Medical & Bio Material Research Consortium at Kangwon National University, Gangwon, Korea 28th January, 2011.
- 4) Poster Presentation title “The effects of chemical modifications on water extractable polysaccharides from *Capsosiphon fulvescens* on biological activities”, 2011 Annual Meeting of Korean Society of Food Science and Technology, Deagu, Korea 8th-10th June, 2011.
- 5) Poster Presentation title “The effects of chemical modifications on water extractable polysaccharides from *Capsosiphon fulvescens* on biological activities”, 12th Asean Food conference 2011, Bangkok, Thailand 16th - 18th June, 2011.

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- 6) Poster Presentation title “Nutritive value and chemical compositions of Asian hard calm (*Meretrix lusoria*) from the coast of Andaman Sea”, 13th ASEAN Food Conference (AFC2013). The MAX Atria, Singapore Expo, 9th-11th September, 2013.
- 7) Poster Presentation title “Characteristics and antioxidative activity of gelatin hydrolysates from unicorn leatherjacket skin as affected by autolysis-assisted process”, RGJ-Ph.D. Congress XV. Jomtien Palm Beach Hotel and Resort, Pattaya, 28th-30th May 2014.
- 8) Poster presentation title “Antioxidative Maillard reaction products derived from gelatin hydrolysate of unicorn leatherjacket skin”, ICFSN 2015: 17th International Conference on Food Science and Nutrition. Holiday Inn London, Wembly, London, 28th-29th June 2015.
- 9) Oral presentation title “Antioxidative activity enhancement of gelatin hydrolysate from unicorn leatherjacket skin using Maillard reaction”, 113th TRF Seminar Series in Basic Research: From Basic Research to Applications. Seminar Room, Faculty of Science, Prince of Songkla University, Thailand, 25th September 2015.
- 10) Oral presentation title “Fortification of antioxidative galactose-fish skin gelatin hydrolysate Maillard reaction product in instant coffee”, International Conference on Food and Applied Bioscience. The Empress Hotel, Chiang Mai, Thailand, 4th-5th February 2016.
- 11) Poster presentation title “Oil from Asian bullfrog (*Rana tigerina*) skin: Antimicrobial activity and its application in emulsion gelatin-based film.”, International Conference on Food and Applied Bioscience (FAB 2018), Empress Hotel, Chiangmai, Thailand, 1st-2nd February 2018.
- 12) Poster presentation title “Antimicrobial Activity of Oil Extracted from *Rana Tigerina* Skin and Its Impact on Gelatin-based Film ”, The 3rd International Conference on Agriculture and Agro-Industry 2018 (ICAAI2018), Mae Fah Luang University, Chiang Rai, Thailand, 15th-17th November 2018.

PUBLICATIONS

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