Current Applied Science and Technology Vol. 22 No. 6 (November-December 2022)

Research article

Development and Characterization of Thai Fish Cake (Tod Mun Pla) Fortified with Sago Palm Weevil Larvae (*Rhynchophorus ferrugineus*)

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Received: 21 January 2022, Revised: 22 February 2022, Accepted: 10 March 2022

DOI: 10.55003/cast.2022.06.22.011

Abstract

Keywords

Thai fish cake;

Tod mun pla;

edible insects;

sago palm weevil larvae

Edible insects are promoted as new alternative sustainable sources of food. However, consumption is still limited to specific groups of consumers because of food neophobia and unwillingness to eat insects. One of the techniques that can alleviate the neophobia is to process edible insects into familiar foods. Thus, the aim of this study was to develop and characterize Thai fish cake (Tod mun pla, TFC) fortified with sago palm weevil larvae (*Rhynchophorus ferrugineus*) (SPWL). Different ratios of fish mince: sago palm weevil at 100:0, 80:20, 60:40, 40:60, 20: 80, (w/w), were investigated. The breaking force, deformation and gel strength of TFC increased (P<0.05) while the expressible moisture content (P<0.05) decreased when the ratio of SPWL was increased. Texture profile analysis (TPA) of TFC was improved when low levels of SPWL were added, particularly at the treatment of 80:20 (P<0.05). The color of TFC intensified when fortified with SPWL (P<0.05). Oily characteristics of TFC were observed with SPWL incorporation at a higher level as indicated by stereomicroscope, a result which was concomitant with the greater fat content (P<0.05). Fortifying the TFC with SPWL at the ratio of 80:20 (w/w) provided the highest sensory acceptance for all attributes amongst all treatments. However, higher ratios of SPWL had a negative effect on sensory acceptance. Therefore, TFC fortified with SPWL at an appropriate level could reduce food neophobia and increase sensory acceptance.

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1. Introduction

Nowadays, the world population is rapidly growing, and urbanization is exponentially rising in developing countries resulting in the highly demanding of food around the world [1]. On this aspect, the consumption of insects and insect products are considered as one of the solutions for the global challenges regarding the increase of food demanding [2]. Food and Agriculture Organization (FAO) has launched a campaign entitled "Edible insects - Future prospects for Food and Feed Security" to encourage edible insect consumption [3]. Edible insects are known and recognized as good sources of macro- and micronutrients such as proteins, fats, minerals, vitamin, and fibers [4, 5]. More than 2000 insect species are currently consumed globally, and those insects can be consumed at different stages of their development; they can be eaten as eggs, larvae, pupae and adults, but it is in the form of larvae or pupa that most of the registered species are consumed [6-8].

Even though approximately 1.9 billion people around the world are familiar with insect consumption as food, some people have a negative attitude towards insect consumption which is a type of food neophobia [4, 5]. A food neophobia is generally regarded as the reluctance to try novel or unfamiliar food [3]. Deconstruction of the whole insect into an invisible form and supplementation into familiar food or food products is considered to be the best solution for alleviating food neophobia [5, 9]. Thus, the development of new food products fortified with insects (invisible forms) is interesting and challenging for researchers and insect food industry.

Recently, incorporation insect has been incorporated into foods such as cookies [10], pasta [11], burger [12], sausage [1] and bread [13]. Currently, there is no information regarding the fortification of insects into Thai cuisine. Thailand is remarkable in food cuisine. The unique flavor of Thai food is recognized by many international people [14]. Thus, it is interesting to study and develop Thai foods that can provide alternative source of future food and can be used to promote Thai cuisine to the world.

Thai fish cake, or the common name as known in Thailand as Tod mun pla, is made from fish mince mixed with Thai ingredients including Thai curry paste, kaffir lime leaf and other ingredients depending on recipes and region of Thailand. The gelling properties of Thai fish cakes are important characteristics that are strongly related to the sensory acceptance of consumers.

Sago palm weevil larvae (*Rhynchophorus ferrugineus*), is a commonly marketed insect larvae in Southern Thailand [7] because of its unique taste and rich nutritional value. The chemical composition of sago palm weevil larvae was revealed by Chinarak *et al*. [7] who reported that the composition of sago palm weevil larvae consisted of 52.4-60.1% fat, 18.0-28.5% protein and 3.8-4.5% chitin. According to these compositions, sago palm weevil larvae show possibly potential candidates for development as a future food product. Even though the sago palm weevil larvae have been promoted to be a future food, little has been published on their application as a food. For example, Ayensu *et al*. [15] documented the development of biscuits fortified with palm weevil larvae.

Therefore, this study aimed to develop and characterize Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae (*Rhynchophorus ferrugineus*).

2. Materials and Methods

2.1 Materials

Frozen sago palm weevil larvae (*Rhynchophorus ferrugineus*) (SPWL) (Brand: Mae U Rai, 190-200 larvae/kg) and Thai curry paste (Brand: Nam-Jai) were purchased from a supermarket located in Chiang Mai, Thailand. Minced Featherback fish and ingredients (Table 1) were purchased from a local market in Chiang Mai, Thailand. SPWL, frozen larvae, which had been frozen during transportation, Thai curry paste and minced feather back jack were kept in a polystyrene box containing crushed ice to keep cold condition and transported to Faculty of Agro Industry, Chiang Mai University, Chiang Mai, Thailand within 1 h.

Table 1. Thai fish cake formulations modified from the internal document of Dusit Thani College

Ingredients	Thai fish cake formulations (g) (fish minces: larvae)				
	100:0	**80:20**	**60:40**	**40:60**	**20:80**
Minced Featherback fish	100.0	80.0	60.0	40.0	20.0
Sago palm weevil larvae	-	20.0	40.0	60.0	80.0
Thai curry paste	15.0	15.0	15.0	15.0	15.0
Egg	10.0	10.0	10.0	10.0	10.0
Sugar	2.5	2.5	2.5	2.5	2.5
Fish sauce	1.5	1.5	1.5	1.5	1.5
The mixing of sliced lemon grass: Kaffir lime peel (ratio 9:1, w/w)	2.5	2.5	2.5	2.5	2.5
Kaffir leaves	1.0	1.0	1.0	1.0	1.0

2.2 Preparation of sago palm weevil larvae (*Rhynchophorus ferrugineus*)

The frozen sago palm weevil larvae (*Rhynchophorus ferrugineus*) samples were washed with rinsing water. The head and bottom parts of the cleaned samples were cut off. Then, the samples were squeezed manually using a sheet cloth. The samples were minced for 30 s with a 5 s rest interval for a total of 4 min using a blender (PHILIPS model HR2118/02).

2.2.1 Preparation of Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae *(Rhynchophorus ferrugineus)*

The flesh of the Featherback fish was minced in a blender (KENWOOD model type FDM30) for 2 min. Then, the Thai curry paste, and all ingredients (Table 1) were added to the minced fish samples. The mixtures were mixed for 30 s with a 5 s rest interval for a total of 4 min to obtain a homogenized paste. Each paste was transferred to a mixing bowl and kneaded manually for 4 min until it presented a gel-like character. The 15 g paste sample was cast in a cylinder mold (4 cm diameter, 1 cm height). The cast paste was cooked by steaming for 5 min. The cooked paste sample was further cooked using a deep fry technique (140ºC) for 3 min. Thereafter, the samples were cooled by leaving on the rack at 28ºC and then kept in a refrigerator at 4ºC until use.

2.3 Analyses

2.3.1 Expressible moisture content (EMC)

EMC was measured as per the method of Wijayanti *et al*. [16] with some modifications. Each sample (3.5 diameter and 1 mm thickness) was weighed (A). The samples were then put between Whatman paper No. 4 with 3 pieces on the top and 3 pieces at the bottom of the samples. A standard weight (5 kg) was located on the top and left for 2 min. The pressed gel samples were weighed (B) after being taken off the papers. EMC was measured by gravimetry using this following calculation,

$$\text{Expressible moisture content} = \frac{(A-B)}{A}\, x\, 100 \quad (1)$$

2.3.2 Color

The color of samples (6 samples per treatment) was measured using a Hunterlab model Miniscan EZ (color global co., LTD) with CIELAB color mode. The $L*$ coordinate indicates brightness of color with values ranging from 0 = black to 100 = white. Coordinates $a*$ and b* indicate color directions: $+a*$ is the red direction, $-a*$ is the green direction, $+b*$ is the yellow direction, and -b* is the blue direction [17]. The color was randomly measured at the center of both sides (front and back). Three samples were analyzed. The average colors which were $L*$, $a*$ and $b*$ were reported. Moreover, the whiteness index was calculated as follows:

$$\text{Whiteness index} = 100 - [(100 - L*)^2 + (a*)^2 + (b*)^2]^{(1/2)} \quad (2)$$

2.3.3 Gel strength

Breaking force and deformation of Thai fish cake samples were conducted using a Stable Micro System, UK model TA-XT.plus. The breaking force indicated that the highest force could break the sample while the deformation force explained the distance of the probe moving from the surface of the sample until it breaks [18]. The samples were cut into 1 cm high cylinders with 3.5 cm diameter, and their mechanical properties were measured using a spherical plunger probe (5 mm in diameter) at room temperature. The operation was set as follows: compression mode, testing speed was 1.1 mm/s, pressing distance was 15.0 mm, and the trigger type was set to auto (force). Ten samples were analyzed for each treatment. The gel strength of the samples was calculated as follows:

$$\text{Gel strength} = \text{breaking force x deformation}$$

2.3.4 Texture profile analysis (TPA)

Thai fish cake samples were subjected to texture testing using texture profile analyses (TPA) method following the procedure of Wijayanti *et al*. [16] with a slight modification. Thai fish cake samples with 3.5 cm diameter and 1 mm thickness was measured using a texture analyzer (Stable Micro System, UK model TA-XT.plus) equipped with a P/50 cylinder probe. Operation was done by the TPA Macro Mode (Pre-test speed = 1 ms/s, Test speed = 5.0 mm/s, Post-test speed = 5.0 mm/s, 50% Strain, Time 5 sec and Trigger types = 5 g. The results were reported as hardness, springiness, cohesiveness, gumminess, resilience and chewiness. Ten samples were analyzed for each treatment.

2.3.5 Proximate compositions

The determination of proximate compositions including moisture, protein, fat, and ash using analytical Nos. 976.05, 948.15, and 938.08, respectively, and was done as described by AOAC [19]. The content was reported on a dry weight basis. The carbohydrate content was calculated by considering the rest of constituents.

$$\text{Carbohydrate} = 100\% - [\%\text{ of protein} + \%\text{ of fat} + \%\text{ of ash}]$$

2.3.6 Morphological analysis

A stereo microscope (Leica S8APO, Germany) was used for the morphological analysis of Thai fish cake. For sample preparation, the Thai fish cake samples were cut to a cross section. The prepared samples were placed on the sample holders of the machine and visualized using the stereo microscope. Magnification of 20X was used for the analysis.

2.3.7 Sensory evaluation

The sensory quality of sample was made using descriptive analysis. The protocol conducted followed the method of Kingwascharapong *et al*. [17] with slight modifications. Thirty untrained panelists (aged more than 18) who lacked of health conditions were recruited for the sensory evaluation. The panelists were required to complete a questionnaire that consisted of three parts 1: General information 2. Food attitudes and behavior among the novel food (Data of part 1 and Part 2 not shown) and 3. Sensory acceptance of Thai fish cake fortified with sago palm weevil larvae. The sensory acceptance of samples was assessed using 9-point hedonic scales; where 9 = like extremely; 7= like moderately; 5 = neither like or not dislike; 3 = dislike moderately; 1 = dislike extremely. Samples were kept at 25°C before testing. All panelists were asked to evaluate the appearance, odor, color, taste, flavor, texture, and overall acceptance based on personal likeness. Samples were presented on plates coded with three-digit random numbers and served under the fluorescent day-light-type illumination at room temperature. The acceptance level was a score higher than 7.

This study was ethically approved by Research Ethics Office of Rangsit University together with approval number/ID RSU-ERB2021- 135.

2.4 Statistical analysis

A completely randomized design was used in this study. Data were subjected to analysis of variance (ANOVA). A randomized complete block design was performed for sensory analysis. Comparison of means was carried out by Duncan's multiple-range test to identify significant differences ($P < 0.05$) among treatments [20]. Data are given as mean ± standard deviation. Statistical analysis was done using the SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA).

3. Results and Discussion

3.1 Expressible moisture content

In general, expressible moisture content can be used to indicate the water holding capacity (WHC) of protein gel products such as surimi, sausage [16, 21]. A lower expressible moisture content indicates an increasing water-holding capacity of prepared gels, resulting in higher gel strength and strong protein network [22]. The expressible water content of the Thai fish cake (Tod mun pla) (TFC) fortified with insect larvae at different levels is shown in Table 2. It was observed that the expressible water content of TFC was significantly increased (P<0.05) when the insect larvae were added into the TFC, except at the lowest levels of insect fortification. The highest expressible moisture content was found in the sample fortified with SPWL at the highest level (20:80) (P<0.05). The result was in accordance with Shi *et al*. [23] who reported that the increasing the vegetable oil concentration increased the expressible water content of surimi gel. The exudates such as oil and water that could not be trapped in the gel matrix might be involved in the measurement of expressible water content. A significantly higher expressible water content was observed in all fortified samples. This might be explained by the lipids which are the main components in the SPWL, interrupting protein gel formation and thus preventing protein-water interaction [24]. It is interesting that at the lowest level of fortification SPWL into TFC (80:20), the expressible water content was significantly decreased. This phenomenon might be explained by the oil component of SPWL (which was the dominant fraction of the SPWL) interacting with the protein gel resulting in an oil-water-protein complex system [25]. Jiao *et al*. [25] reported that oils present in surimi gel prevent water migration within the gel network by producing an oil–water–protein complex. Therefore, the addition of SPWL, especially at low levels, was able to decrease water holding capacity of TFC.

Table 2 The expressible moisture content, breaking force, deformation and gel strength of Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae at different ratios

The ratio of fish mince: larvae	Expressible moisture content (%)	Breaking force (g)	Deformation (cm)	Gel strength (g.cm)
100:0	4.51±0.57^{e}	940.87±64.65^{a}	0.97±0.05^{a}	910.80±78.70^{a}
80:20	2.53±0.87^{d}	593.54±45.95^{b}	0.72±0.12^{b}	432.00±99.37^{b}
60:40	8.01±0.23^{c}	429.98±49.43^{c}	0.65±0.07^{bc}	280.72±50.96^{c}
40:60	21.34±0.95^{b}	254.20±25.54^{d}	0.73±0.32^{b}	182.53±71.99^{d}
20:80	26.86±1.13^{a}	184.29±17.41^{e}	0.52±0.06^{c}	95.59±19.49^{e}

†Mean±SD (n=10)
Note: Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae (*Rhynchophorus ferrugineus*) at the ratios of 100:0, 80:20, 40:60, 60:40 and 20:80 (fish mince: sago palm weevil larvae; W/W). Different lowercase superscripts in the same column indicate significant differences (P<0.05).

3.2 Color

Color is an important parameter indicating the customer acceptance [26]. The color properties of the TFC are presented in Table 3, where the basic properties are explained as chroma L^*, a^*, b^* and whiteness index. Among them, L^* and a^* are indicative of the water content, and b^* relates to the oil content present in the product [27]. TFC fortified with SPWL at various concentrations had varying degrees of impacts on L^*, a^*, b^*, and the whiteness index of the resulting gel. As the levels

Table 3. The color (*L**, *a** and *b**) and whiteness index of Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae at different ratios

The ratio of Fish mince: Larvae	*L**	*a**	*b**	Whiteness Index
100:0	38.67±1.53^{a}	15.58±0.50^{a}	30.66±2.13^{a}	29.65±1.30^{b}
80:20	40.73±2.25^{a}	15.15±0.96^{a}	29.84±2.04^{a}	31.89±1.60^{a}
60:40	39.04±1.67^{a}	14.15±0.68^{b}	27.55±1.71^{b}	31.59±1.06^{a}
40:60	38.51±1.87^{a}	12.20±0.86^{c}	26.00±1.45^{b}	32.10±1.15^{a}
20:80	35.50±1.69^{b}	9.38±0.30^{d}	23.47±2.05^{c}	30.68±0.90^{ab}

†Mean±SD (n=6)
Note: Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae (*Rhynchophorus ferrugineus*) at the ratios of 100:0, 80:20, 40:60, 60:40 and 20:80 (fish mince: sago palm weevil larvae; W/W). Different lowercase superscripts in the same column indicate significant differences (P<0.05).

of SPWL increased in TFC, the *L**, *a** and *b** values significantly decreased (P< 0.05). The color of protein gel products varies depending on the types and concentration of added additives or the raw material used [28]. The visual color of TFC fortified with SPWL showed a darkening in color (Figure 1) reflected in decreased *a** and *b** values which represented the greenish and bluish color of product observed. The lowest *L**, *a** and *b** values were found in TFC fortified with SPWL at the ratio of 20:80 sample. The brown color of SPWL containing melanin pigment could possibly have resulted in brownish, black colors, or darker colors of the TFC paste [29]. These results were consistent with the investigation by Sánchez *et al*. [24], who revealed that the lower *b** value was observed in the micro-powders when fly larvae were added at the higher levels. Based on the parameters *L**, *a** and *b** values, it can be concluded that color of the TFC depends on the level of SPWL used.

Whiteness is an important sensory index and higher whiteness is more acceptable to consumers [30]. The lowest whiteness was found in control sample; however, the whiteness of TFC gradually increased with the addition of SPWL (P<0.05). This might be due to the increase of oil content in the TFC sample when the SPWL was added resulting in a reduction of protein-protein interaction. As a consequence, greater light scattering was observed. The improvement in color parameters may be attributed to the light scattering of gels, which is caused by the formation of emulsion in the protein-oil-water system [25]. The result was in agreement with Jiao *et al*. [25] who reported that the whiteness of silver carp surimi gel was more dominant when the fish oil concentration was increased. However, the whiteness of TFC supplemented with highest levels of SPWL slightly decreased (P<0.05). This might be caused by the brownish color of SPWL. Moreover, the Maillard reaction might be generated during the preparation of TFC through the oxidation process of the lipid and protein that exist in the TFC sample. This could have resulted in a darkening color of the TFC sample [16]. Therefore, SPWL addition with sufficient level directly improved the whiteness of TFC sample.

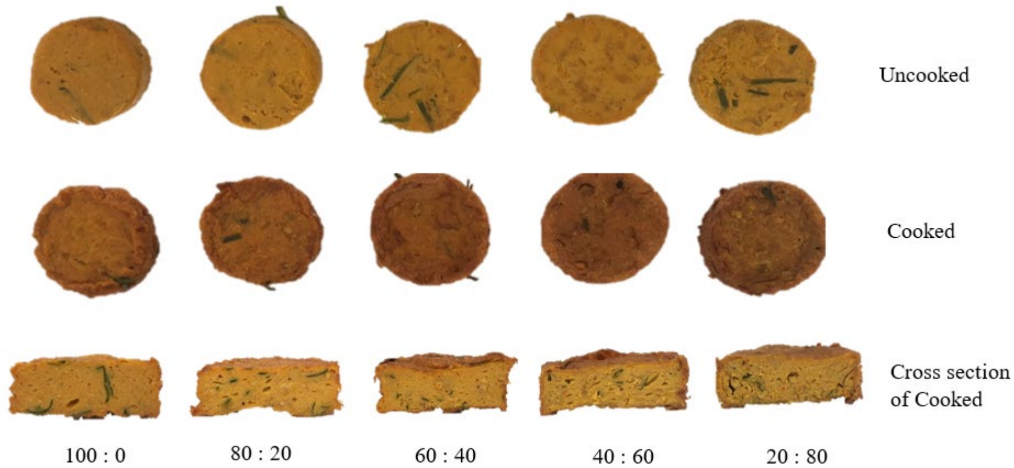


Figure 1. The character of cooked and uncooked of Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae (*Rhynchophorus ferrugineus*) at the ratios of 100:0, 80:20, 40:60, 60:40 and 20:80 (fish mince: sago palm weevil larvae; W/W)

3.3 Gel strength

Gel strength is an indispensable indicator of the quality of surimi-based products, and products with poor gel strength are generally not accepted by consumers [25]. The changes in gel strength of TFC containing SPWL samples with different levels are shown in Table 2. The highest gel strength was found in the control sample (P<0.05). During gelation, a three-dimensional gel network formed by myofibrillar protein imbibes water more efficiently [31]. With the SPWL fortification, significant decrease in the breaking force, deformation and gel strength were observed ($P < 0.05$), which was in accordance with the work of Scholliers *et al*. [1] who reported that higher insect levels in cooked sausage resulted in lower G' values and, thus, reduced gel strength. SPWL more likely showed the interfering effect on protein-protein interaction in the gel matrix, thus lowering the strength as shown by decreased breaking force. Lin *et al*. [32] stated that appropriate amounts of oil can enhance the emulsification stability and gel strength of surimi, whereas excessive amounts of oil reduce gel strength. Breaking force is positively correlated with gel strength, while deformation represents the elasticity of the gels [33]. It was noted that TFC became of low elasticity with higher levels of SPWL added, as shown by the decreased deformation. Shi *et al*. [23] revealed that slight decrease in deformation was found when the oil concentration was increased. These results indicated that supplementation of SPWL (with excessive amounts) in TFC reduces the gel strength and destroys the protein gel matrix.

3.4 Texture profile analysis (TPA)

Generally, TPA parameters have been widely used for the investigation of the rheological properties and sensory parameters of several foods [16]. The TPA of TFC fortified with SPWL at different levels is depicted in Table 4. Hardness is used for assessing the change of food structure during the first bite of the product [16]. The addition of SPWL at higher levels showed a slightly increasing

Table 4. Texture profiles of Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae at different ratios

The ratio of fish mince: larvae	**Hardness (g) ns**	**Adhesiveness (g.sec) ns**	**Cohesiveness**	**Springiness**	**Gumminess**	**Chewiness**	**Resilience**
100:0	2.73±0.07^{a}	0.82±0.54^{a}	0.753±0.014^{ab}	0.899±0.017^{a}	2.049±0.514^{a}	1.839±0.454^{a}	0.343±0.013^{a}
80:20	2.75±0.51^{a}	0.56±0.30^{a}	0.789±0.117^{a}	0.929±0.144^{a}	2.158±0.419^{a}	2.005±0.503^{a}	0.330±0.027^{ab}
60:40	2.78±0.66^{a}	0.61±0.33^{a}	0.717±0.017^{b}	0.840±0.060^{ab}	1.997±0.490^{a}	1.669±0.378^{ab}	0.304±0.047^{b}
40:60	2.85±0.47^{a}	0.53±0.34^{a}	0.707±0.073^{b}	0.719±0.141^{c}	1.999±0.305^{a}	1.420±0.254^{bc}	0.270±0.053^{c}
20:80	2.91±0.40^{a}	0.79±0.39^{a}	0.516±0.054^{c}	0.789±0.040^{bc}	1.497±0.254^{b}	1.185±0.236^{c}	0.125±0.013^{d}

†Mean±SD (n=10).

Note: Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae (*Rhynchophorus ferrugineus*) at the ratios of 100:0, 80:20, 40:60, 60:40 and 20:80 (fish mince: sago palm weevil larvae; W/W). Different lowercase superscripts in the same column indicate significant differences (P<0.05).

trend of hardness compared to control (P>0.05). The addition of SPWL, especially at the higher level, might interrupt the formation of the gel network. The high lipid content of SPWL can obstruct protein gelation and negatively impact the gel structure. Similar results were confirmed by Kim *et al*. [34] and Park *et al*. [35] who reported that emulsion sausages added with silkworm pupae and mealworm had higher hardness values than control sausages due to reduced moisture contents after the addition of edible insects. Moreover, this result coincided with the decreased moisture content of TFC samples containing SPWL at higher concentrations. Meng *et al*. [36] reported that the low moisture content in surimi directly affects the hardness of surimi gel by increasing the hardness of the product. Nevertheless, some opposite tendency could be observed in other investigations with different vegetable/marine lipids incorporated into surimi paste [18, 25]. Adhesiveness and springiness were originally described as elasticity [16]. Adhesiveness is measured as the negative area under the curve of TPA profile [25], but no significant change was found among samples when SPWL was added at different ratios (P > 0.05). The highest springiness was observed for TFC fortified with SPWL at 80:20 (w/w) when compared to all tested samples (P<0.05).

Cohesiveness is the extent which is an applied force that can overcome the internal bonding until deformation [37]. The cohesiveness of TFC fortified with SPWL also decreased continuously when the concentrations of SPWL were augmented (P<0.05), especially at the highest level of SPWL.

Chewiness is the energy required for chewing a solid food until it is ready for swallowing [18]. The chewiness is described as the force to chew the solid sample to a stable state for swallowing (springiness × gumminess) [16]. TFC fortified with SPWL at 20% (w/w) possessed higher chewiness than other samples. Similarly, the gumminess of TFC fortified with SPWL at 20% (w/w) was greater than those fortified SPWL at other levels (P< 0.05). Gumminess is the force needed to collapse semi-solid samples to a suitable state for swallowing.

Higher resilience was observed in the control, compared to those TFC fortified with SPWL at all levels (P < 0.05).These results are consistent with the report of Chang *et al*. [38], who found that at higher level of soybean oil added to surimi, lower resilience values were dominant compared to control.

Therefore, the addition of SPWL at an appropriate level (20%) to the TFC was likely to contribute to the improved gel structure of TFC as indicated by increased springiness and chewiness.

3.5 Proximate analysis

The proximate composition of TFC containing SPWL is shown in Table 5. The moisture content of TFC containing SPWL decreased, particularly at higher levels of SPWL addition. It is postulated that the adding SPWL into TFC could interfere with the protein-water interaction resulting in the loss of water in the gel matrix. This result could be associated with the fact that the SPWL contained higher fat contents that might affect the moisture of TFC product. SPWL was rich in crude fat, protein and chitin which were 52.4-60.1%, 18.0-28.5% and 3.8-4.5% (dry weight), respectively [7]. The result was in accordance with Zhou *et al*. [39] who reported that the moisture content of surimi gel decreased when the amount of camellia tea oil increased.

For protein content, a decreasing trend was observed in TFC samples at higher level of SPWL supplementation (P<0.05). The protein content of the TFC supplemented with SPWL samples ranged from 39.33-21.39%. The results were in accordance with Akande *et al*. [40] who reported that the protein content of pie produced with African palm weevil was lower than that produced by beef. This might be due to the ratio of fat content in SPWL being higher than protein content. As a consequence, the protein content of TFC was reduced.

Table 5. The proximate compositions of Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae at different ratios

The ratio of fish mince: larvae	Moisture content (%)	Protein (%)	Fat (%)	Ash (%)	Carbohydrate (%)
100:0	64.71±0.35^{a}	44.45±0.21^{a}	17.20±0.63^{e}	8.03±0.02^{a}	30.32±0.63^{a}
80:20	60.53±1.62^{b}	39.33±0.95^{b}	35.01±0.32^{d}	6.59±0.04^{b}	19.07±0.24^{b}
60:40	55.95±0.76^{c}	30.75±0.13^{c}	46.33±0.70^{c}	5.65±0.08^{c}	17.27±0.73^{c}
40:60	50.02±1.90^{d}	24.52±0.39^{d}	55.35±1.46^{b}	4.53±0.02^{d}	15.60±0.88^{d}
20:80	45.05±1.77^{e}	21.39±0.12^{e}	56.87±0.90^{a}	4.47±0.01^{e}	17.27±0.82^{c}

†Mean±SD (n=3)

Note: Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae (*Rhynchophorus ferrugineus*) at the ratios of 100:0, 80:20, 40:60, 60:40 and 20:80 (fish mince: sago palm weevil larvae; W/W). Different lowercase superscripts in the same column indicate significant differences (P<0.05).

Fat is very important for the digestion; it stores energy and protect vital organs. Fat is also very important in retaining the flavor of food [40]. The fat content of the TFC ranged from 35.01% to 56.87%, and it increased with increasing percentage of SPWL substitution. The results were in line with Ayensu *et al*. [15] who reported that the fat content of biscuits enriched with palm weevil larvae was increased up to 44.33% when those biscuits were substituted with palm weevil larvae at the level of 70%. Palm weevil larvae are known to contain 65% fat, predominantly composed of saturated fats [15]. The increasing of fat content in TFC samples affects the firming properties of TFC product as observed by decreasing the breaking force.

The ash content of the TFC containing SPWL ranged from 6.59-4.47%. The ash content of TFC decreased when the supplemented ratios of SPWL were increased (P<0.05). This was possibly due to the major components of SPWL being lipid, which may interfere with the amount of inorganic matter in the TFC sample. The result was in contrast to the finding of Niaba-Koffi *et al*. [41], who revealed that the ash content of wheat biscuits fortified with defatted *Macrotermes subhyalinus* significantly increased following increase in the amount added.

3.6 Sensory acceptance

Consumer acceptability is a key parameter for launching a new food product into the market [42]. The results of the sensory evaluation of TFC fortified with different levels of SPWL compared to the controls are shown in Table 6. Overall likeness of TFC fortified with SPWL at higher levels tends to decrease, except at the ratio of fish mince: larvae at 80:20 (w/w). The TFC fortified with SPWL at the level of 80:20 showed the highest overall likeness (P<0.05). This highest consumer acceptance could be attributed to the texture being similar to the control sample. Moreover, the unique light aroma of SPWL was still present in that product. The similar result was in agreement with Yazici and Ozer [43] who found that biscuits enriched with 5% termite had better results for all attributes than the control sample which was made with 100% wheat flour. At the higher levels of SPWL added, the strong aroma and smell of SPWL were dominant in the TFC samples as

Table 6. Sensory acceptance of Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae

The ratio of fish mince: larvae	Appearance	Color	Odor	Flavor	Taste	Texture	Overall likeness
100:0	7.43±1.01^{a}	7.46±1.04^{a}	7.23±1.17^{a}	7.14±7.23^{a}	7.23±1.29^{a}	7.06±1.53^{ab}	7.29±1.32^{a}
80:20	7.46±0.89^{a}	7.46±0.82^{a}	7.00±1.06^{a}	7.14±1.06^{a}	7.06±0.98^{a}	7.51±0.98^{a}	7.40±1.03^{a}
60:40	6.86±0.94^{b}	6.89±1.05^{b}	6.37±1.21^{b}	6.37±1.24^{b}	6.57±1.22^{a}	6.57±1.17^{b}	6.49±1.27^{b}
40:60	6.26±1.17^{c}	6.26±1.31^{c}	5.77±1.54^{b}	5.29±1.81^{c}	5.14±1.80^{b}	5.40±1.67^{c}	5.46±1.63^{c}
20:80	5.51±1.20^{d}	5.26±1.27^{d}	5.11±1.35^{c}	4.34±1.47^{d}	4.20±1.47^{c}	3.94±1.35^{d}	4.23±1.26^{d}

†Mean±SD (n=30)

Note: Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae (*Rhynchophorus ferrugineus*) at the ratios of 100:0, 80:20, 40:60, 60:40 and 20:80 (fish mince: sago palm weevil larvae; W/W). Different lowercase superscripts in the same column indicate significant differences (P<0.05).

confirmed by the lowering of odor likeness score. Furthermore, the existence of the strong aroma in the product probably had a direct negative effect on the overall acceptance.

As expected, the cooked products of TFC containing SPWL showed a darker color (Figure 1). High proportion of SPWL in the cooked TFC product showed intense color. The darkened color of the cooked TFC fortified with SPWL may depend not only on the levels of SPWL used, but also on the conditions of the technological process in which reactions resulting in a color change may occur, i.e. caramelization and Maillard reactions. Both reactions depend on the temperature, the content of reducing sugars, and amino groups, and can occur simultaneously during the heating process [44]. Similar results for color darkening in insect supplemented products were observed by many researchers for biscuits enriched with *Tenebrio molitor* [45] and cricket powder [46], and pasta enriched with cricket powder [11].

In terms of odor, flavor and taste, significantly lower values were observed (P<0.05) in the TFC samples fortified with SPWL at higher levels, and especially at 40%, 60% and 80% of SPWL supplementation. Considering at the higher levels of SPWL added, the strong flavor and other unique characters of SPWL were more dominant in the TFC product, resulting in the original taste of TFC being altered. As a consequence, less acceptance was observed. In general, the insects at their larval stage have unique characteristics which are a sweet taste that is almost nutty in character; a cocoa-like smell; and a light to medium brown color [42]. Those features might have been present in the TFC product, and contributed to a reduction in overall acceptance.

In the case of appearance and texture of TFC fortified with SPWL, it was noted that higher amount of SPWL had a negative impact on the TFC product as observed by the decreasing appearance and texture likeness scores (P<0.05), and especially at the amount of SPWL higher than 20%. The lower appearance and texture liking scores might be associated with the interference from the fat and lipid content of SPWL, thus deviating the unique odor, and gelling properties of in TFC product. These results were in agreement with the quality changes of samples, including gel strength, deformation, breaking force, as well as texture profile of the product.

Considering all sensory attributes, scores were above than the acceptable limit (>7.00). Therefore, SPWL at 20% was the optimum ratio for fortifying the TFC product as determined by the likeness score, which was above the acceptable limit.

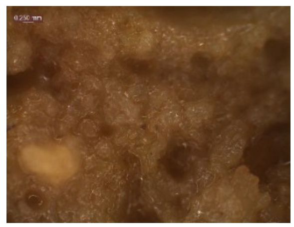
3.7 Microstructure

The microstructures of TFC fortified with SPWL at different levels are illustrated in Figure 2. A fine and well-organized three-dimensional network without oily surface was observed in TFC gel without SPWL fortification. This was in agreement with the higher springiness and chewiness of the gel. With the addition of SPWL, the surfaces of samples became rougher and oily, and this effect was more pronounced at higher SPWL content. This indicated that the gel had a looser network. In general, gels from TFC fortified with SPWL had a coarser network with the large voids compared to control samples. This might be related to the oil present in the protein matrix that could interrupt protein-protein interaction by increasing the intermolecular distances between protein chains [18]. The addition of fat/oil into the protein matrix can change the textural properties of the protein products [47]. Therefore, the addition of SPWL influenced the oily characters of the TFC product, which determined the textural characteristics of the resulting TFC.

100:0
(Fish mince: Larvae)

80:20
(Fish mince: Larvae)

60:40
(Fish mince: Larvae)



40:60
(Fish mince: Larvae)

20:80
(Fish mince: Larvae)

Figure 2. The structure of Thai fish cake (Tod mun pla) fortified with sago palm weevil larvae (*Rhynchophorus ferrugineus*) at the ratios of 100:0, 80:20, 40:60, 60:40 and 20:80 (fish mince: sago palm weevil larvae; W/W) using stereo microscope

4. Conclusions

In this study, it was investigated how the partial replacement of TFC by SPWL (at different fish meat: insect ratios) influenced the physicochemical properties of the fish cakes. The addition of SPWL decreased the breaking force (g), deformation (cm), gel strength (g.cm) of TFC as the levels of SPWL increased. Supplementation with SPWL at the lowest level (20%) could enhance the texture profile of TFC paste indicated by the higher cohesiveness, springiness, gumminess, chewiness. A slightly higher whiteness index was noticed in TFC supplemented with SPWL. Based on sensory properties, TFC supplemented with SPWL at the ratio of 80:20 (w/w) showed the highest overall likeness score. The oily structure of TFC was obviously observed when the SPWL was added. Thus, the TFC containing SPWL at the levels of 80:20 (w/w) could be used as an alternative nutritional additive for food sustainability.

5. Acknowledgements

This research was supported by Dusit Thani College Grant.

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