Impact of Mulberry Silkworm (*Bombyx mori* L.) Pupae Powder on Physicochemical Properties and Consumer Preference of Ready-to-Eat Smoked Fish Paste

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ABSTRACT

There is a worldwide interest towards new natural alternative food sources that possess nutritional and physiological benefits for human health, and because the mulberry silkworm (*Bombyx mori*) pupae contains nutritional compounds, so it is a promising novel nutritional supplement in preparing functional food products. Mulberry silkworm pupae (SWP) powder was used as smoked tilapia fish meat replaces in processed ready-to-eat fish paste. Physicochemical properties and sensory evaluation were performed to investigate the effect of substitution on the quality and consumer preference of the produced fish paste. Ready-to-eat fish paste was prepared by replacing smoked tilapia fish meat with SWP at different levels (5, 10, 15, 20, and 25%). The results of SWP powder showed that SWP contained high levels of protein (58.38%), total carbohydrate (17.96%), and crude ether extract (18.26%) and also could be considered a rich source for phosphorous, magnesium, calcium, zinc, potassium, and iron. Ethanolic extract of SWP had a phenolic content of 37.64 mg GAE/100 g with DPPH inhibition activity (27.45%) and total flavonoid content (22.39 mg RE/100 g). The prepared fish paste products with SWP showed significantly increased crude ether extract content, caloric value, and pH, whereas the crude protein content was decreased when increasing SWP concentration. The SWP addition changed the colour and enhanced the cohesiveness and chewiness of all products. Statistically, there were significant differences noted in all the sensory attributes between the control and those containing 10, up to 25% replacement. On the other hand, the panelist accepted the all SWP smoked fish paste products.

Keywords: Mulberry silkworm pupae, alternative food, novel nutritional supplement, fish paste.

INTRODUCTION

By 2050, there will be 9 billion people on the planet, which will increase demand for food. As a result, nutritionists are interested in finding natural and sustainable alternative food sources (Glausiusz, 2022). In recent years, the use of insects as a sustainable food source has increasingly interested widespread attention from industry, and the general public globally, where it can satisfy all dietary needs (FAO, 2018). The consumption of edible insects started nearly 7000 years ago (Ramos-Elorduy, 2009). There are over 2300 species that have been reported as edible insects (Jon-gema, 2017). Although some species are extensively farmed, the majority of them are harvested from nature, where these insects inhabit both terrestrial and aquatic environments (Tang *et al*., 2019). The researches have focused on the utilization of edible insects, which have long formed part of human diets in Asia, Latin America, and Africa (Simeone and Scarpato, 2022). Nowak *et al*. (2016) and Wu *et al*. (2021) showed that edible insects are a food source with a high nutritional value. They are rich in protein, Fats, vitamins, minerals, and contain a low amount of carbohydrates (Lange and Nakamura, 2021).

The typical unfavourable emotional reaction of consumers to the acceptability of eating insects is decreasing over time. Recent research revealed a considerable increase in people's willingness to accept and consume insect-based snacks (House, 2016). Edible insects are increasingly being used to enhance a variety of food products, such as bread (Roncolini *et al*., 2019). pasta (Duda *et al*., 2019), biscuits (Akande *et al*., 2020a), sausages (Kim *et al*., 2016), and ice cream (David-Birman *et al*., 2022).

The main by-product of the silk industry is silkworm pupae, which are highly degradable, sometimes used as fertilizer or as waste after the silk is removed from the cocoon (FAO, 2013), which are a good source of protein, lipids, minerals, and vitamins, and are considered a good source of nutrients for humans (Tomotake *et al*., 2010). They may be utilized as food or as animal feed, which supports circular production chains and preventing the release of potentially

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hazardous waste into the environment (Tassoni *et al*., 2022).

The characteristics of the used of silkworm pupae in the biological field, and their biomedical applications were recently discussed. According to studies, silkworm pupae have beneficial effects on immune enhancement, antitumour, liver protection, antibacterial, regulation of blood glucose and blood lipids, and blood pressure reducing, and they can be used as medicine to treat wounds, sore throats, fever, brain haemorrhage, haemorrhoids, and other conditions (Meyer-Rochow, 2017 and Wu *et al*., 2021). Silkworm pupae also have antioxidant activity and contain phenolic compounds (Butkhup *et al*., 2012), B_1, B_2, and E vitamins (Singh and Jayasomu, 2002). According to FAO/WHO recommendations, silkworm pupae contain all of the amino acids required by the human body in the appropriate proportions (Köhler *et al*., 2019). Silkworm pupae oil is high in linolenic acid, an essential fatty acid in the human diet. Moreover, silkworm pupae contain a glucosidase inhibitor, 1-deoxynojirimycin, that may reduce postprandial hyperglycemia and carbohydrate absorption. As a result, silkworm pupae are valuable sources of food (Kotake-Nara *et al*., 2002). Due to their high nutritional value and variety of biological activities, silkworm pupae are now used as raw materials in the food industry (FAO, 2013).

Consumer acceptance of insect-based foods is one of the main hurdles and issues in societies unusual to consume insects as food. This is probably a result of both disgust, which is an immediate emotional response of revulsion, and food neophobia, which rejects, avoids, and is biassed negatively toward unfamiliar foods. There are few studies on consumer preferences for eating insects. There are still challenges and gaps in scientific knowledge to be addressed. Unfavorable consumer perceptions are one of the challenges to promoting edible insects as a human food in Middle Eastern nations, where such foods are not typically regarded as conventional. The present study aims to assess the potential of mulberry silkworm (*Bombyx mori* L) pupae powder as an alternative functional food ingredient, evaluate its proximate composition, and mineral content, utilize it as a fish substitute with different levels in ready-to-eat smoked fish paste manufacturing and evaluate the effect of these substitution levels on the final product's quality attributes and consumer acceptability. These attempts could increase consumer acceptance, increase nutritional value, and broaden the use of such products to combat anti-insect prejudice and feelings of repulsiveness.

MATERIALS AND METHODS

Materials

Fresh Nile tilapia (*Oreochromis niloticus*) was obtained in 2022 from EL-Nozha Airport Farm, Alexandria, Egypt. Sugar, refined fine iodized salt, refined sunflower oil, garlic, mustard, cumin powder, turmeric powder, ginger, red chilli powder, lemon, cornstarch, polyethylene bags, and glass jars were purchased from the local market in Alexandria, Egypt. Natural smoke concentrate was obtained from Meat and Fish Research Department, Agriculture Research Center, Giza, Egypt. The mulberry silkworm (*Bombyx mori* L.) pupae powder, used for this work, was obtained from the U.S. Walmart hypermarket in California, USA (Brand: JR Unique Foods Ltd., Part, manufacturer of edible insects). All reagents and chemicals used in this study were of analytical grade.

Methods

Technological methods

Smoked tilapia fish fillets preparation:

Fresh Nile tilapia were kept in insulated boxes with crushed ice in the 1:2 (w/w) ratio before being immediately transferred to the fish processing unit at the Faculty of Agriculture, Alexandria University, to produce fish paste. Tilapia fish fillets were prepared in accordance with Alimentarius (2013) as the fish were washed and hand filleted, then salted for 5 min in brine containing 10% NaCl at a 2:1 (v/w) brine/fresh fillets ratio, then the brined fillets were left on racks for 10 min to drain excess water, and finally the fish fillets were smoked using liquid smoke solution (natural smoke concentrate : water as 1:1, v/v) since the tilapia fish fillets were sprayed with liquid smoke solution every 5 min. The smoking process was carried out in a smoking kiln (AFOS, MK2, Torry mini & maxi smoker, England) for 1 h at 60°C. Then the samples were cooled at ambient temperature (24± 2°C) for 15 min before being packaged under vacuum in polyethylene bags and stored at 4°C to produce a high-quality smoked tilapia fish paste.

Smoked tilapia fish paste preparation:

The fish paste was prepared using the method described by Dhanapal *et al*. (2016) and Samarakoon *et al*. (2021) with some modifications. The smoked tilapia fish was completely minced using the Braun Cutter Machine (Combi Max 700, USA). Table (1) shows the ingredients used for the preparation of smoked tilapia fish paste. After mixing all the ingredients, the mixture was homogenized with a blender (Braun type: 4262, USA).

Table 1. Different ingredients used in the formulations of fish paste

Ingredients (%)	Formulas of fish paste					
	0% SWP	5% SWP	10% SWP	15% SWP	20% SWP	25% SWP
Smoked tilapia mince	50	47.5	45	42.5	40	37.5
Silkworm pupae powder	-	2.5	5	7.5	10	12.5
Sugar	2	2	2	2	2	2
Salt	1.5	1.5	1.5	1.5	1.5	1.5
Sunflower oil	15	15	15	15	15	15
Garlic mince	4	4	4	4	4	4
Mustard	0.5	0.5	0.5	0.5	0.5	0.5
Cumin	0.5	0.5	0.5	0.5	0.5	0.5
Turmeric	0.5	0.5	0.5	0.5	0.5	0.5
Ginger	0.5	0.5	0.5	0.5	0.5	0.5
Red chili powder	0.5	0.5	0.5	0.5	0.5	0.5
Cornstarch	4	4	4	4	4	4
Lemon peel mince	1	1	1	1	1	1
Lemon juice	5	5	5	5	5	5
Water	15	15	15	15	15	15

0% SWP (control) formula: fish paste without SWP

5% SWP, 10% SWP, 15% SWP, 20% SWP, and 25% SWP formulas: smoked fish mince replaced with SWP at 5, 10, 15, 20, and 25%.

The paste was then filled into glass jars and sterilized in an autoclave (YX-280B, China) at 121ºC for 15 min. At the end of thermal treatment, the fish paste samples were cooled to room temperature by pumping potable water into them and stored at room temperature until analyzed. Different fish paste formulations were manufactured by replacing smoked tilapia fish mince with 5, 10, 15, 20, and 25% of silkworm pupae (SWP) powder (Table 1).

Analytical methods

(1) Chemical analysis

(a) **Chemical composition:** Official methods of the AOAC (2019) were used to determine moisture, crude protein, crude ether extract, and ash content. By using the difference, total carbohydrates were calculated. Total calories were calculated according to Mohammed *et al*. (2019) using the following equation:

Total calories (kcal/100 g) = (g of protein ×4) + (g of lipids×9) + (g of carbohydrates×4).

(b) **Mineral composition**: Minerals including Ca, K, Mg, P, Zn, Fe, Mn, Cu, and Se were measured in ash solution using ICP-O ES Agilent 5100 VDV according to the method of AOAC (2019).

(c) Bioactive compounds and antioxidant activity

Total phenolic content: Using gallic acid as a standard, the total phenolic content were determined using the Folin-Ciocalteu method (Singleton and Rossi, 1965). Total phenolic compounds were calculated as mg of gallic acid equivalent (GAE)/g.

Total flavonoid: The total flavonoid content in the ethanolic extracts was determined using the aluminium chloride colorimetric assay as described by Barros *et al*. (2011).

DPPH scavenging activity (%): Radical scavenging activity was determined using the DPPH (1, 1-diphenyl-2-picrylhydrazyl) method as described by Brand-Williams *et al*. (1995). The percentage of DPPH scavenging activity (%) for samples was calculated using the equation as follows:

DPPH scavenging activity % = [(A control- A sample) / (A control)] x 100.

(2) Physicochemical properties

pH value: pH value was measured in sample homogenates using a digital pH meter (pH MVx100 Beckman, USA) according to Goulas and Kontominas (2007).

Thiobarbituric acid (TBA) assay: According to Park *et al*. (2007), the thiobarbituric acid (TBA) value was calorimetrically estimated as mg malondialdehyde/kg using a UV-Vis Spectrophotometer (Model 91102, Laxco, Inc., USA).

Colour measurement: According to the method described by Santipanichwing and Suphantharika (2007), the colour values, which include L* (lightness), a* (redness), and b* (yellowness), were estimated using a Hunter Lab Ultra Scan, VIS model colorimeter (USA).

Texture profile analysis (TPA): Texture profile analysis was carried out with the TA-XT 2 Texture meter (Texture Pro CT3 V1.2, Brookfield, USA) according to the method of Yuan and Chang (2007). The texture parameters such as hardness, cohesiveness, gumminess, chewiness, and springiness were determined.

Sensory evaluation.

Sensory attributes, i.e., appearance, odour, colour, taste, spreadability, and overall acceptability of fish paste samples were assessed by 10 panelists from the Food Science and Technology Department, Faculty of Agriculture, Alexandria University. The panelists were asked to score the above attributes according to a 9-point hedonic scale (9 = like extremely to 1 = dislike extremely), according to Meilgaard (1999).

Statistical analysis.

According to Gomez and Gomez (1984), the data were subjected to proper statistical analysis of variance using SAS (Statistical Analysis System) ver.9.01, 2004. Means were compared by the least significant difference (L.S.D.) at the 5% level of probability.

RESULTS AND DISCUSSION

Nutritional properties of silkworm pupae powder

Table (2) shows the chemical composition, total calories, bioactive compounds, antioxidant activity, and mineral composition of silkworm pupae (SWP) powder, which was used to prepare fish paste samples. The moisture content of the SWP powder sample was 9.04%, which is higher than the 7.90-8.26% reported by Kim *et al*. (2017) and Omotoso (2015). The majority of SWP was made up of crude protein (58.38%). Previous studies found that the protein content of SWP range from 48% to 60% on a dry weight basis (Rumpold and Schlüter *et al*., 2013; David-Birman *et al*., 2019 and Zhou *et al*., 2022), which is higher than that of other typical animal products (Singh and Jayasomu, 2002). Mulberry leaves, which are the only food source for silkworms and have high protein content, have an impact on the silkworms' high protein content (Yu *et al*., 2018). The protein of SWP has been investigated qualitatively and found to be safe for human consumption (Zhou and Han, 2006b). Studies have further established that SWP proteins are considered complete proteins because they contain high levels of essential amino acids such as phenylalanine, methionine, and valine (Wang *et al*., 2009 and Zhou *et al*., 2022).

According to the data in Table (2), the SWP powder has a considerable amount of crude ether extract (18.26%). These results agree with those found by Rodriguez-Ortega *et al.* (2016), and Kim *et al*. (2017). Furthermore, pupae contain ether extractives in the range of 25-35% by dry weight (Oonincx *et al*., 2015; Akande *et al*., 2020b; Ghosh *et al*., 2020 and Hirunyophat *et al*., 2021). The high content of fat reflects the importance of using SWP to produce oil. The edible oil extracted from SWP is an important nutrient due to the presence of essential fatty acids (EFA), particularly polyunsaturated fatty acids (PUFA), which have a higher n-3 to n-6 fatty acid ratio (Chieco *et al*., 2019 and Longvah *et al*., 2012). Aiyesanmi and Oguntokun (1996) mentioned that fat is very important for digestion, protecting vital organs, storing energy, and also very important in preserving the flavour of food.

As stated in Table (2), the ash content of SWP was 6.34%. This value was higher than that reported by Kuntadi *et al*. (2018), Lamberti *et al*. (2019), and Hirunyophat *et al*. (2021). On the other hand, it was lower than that reported by Kim *et al*. (2016). The total carbohydrate content of SWP was 17.96%. This value is lower than those mentioned by Omotoso (2015) and Kim *et al*. (2017), but higher than those reported by Trivedy *et al*. (2010), Wu *et al*. (2021), and Hirunyophat *et al*. (2021). SWP is a good source of energy at 469.70 kcal/100 g, which is agreed with those stated by Altomare *et al*. (2020), and Akande *et al*. (2020b). The nutritional value of SWP powder may be influenced by genetic makeup, sex, the type of feed used, the type of mulberry used as a food source, rearing methods, and environmental conditions (Ying *et al*., 2022).

The data in Table (2) illustrate the total phenolic, total flavonoid content, and antioxidant activity in SWP were recorded low values of 37.64 mg GAE/100 g, 22.39 mg RE/100 g, and 27.54%, respectively. The antioxidant activity percentage in SWP powder ranged from 54 to 68 (Wannee and Butkhup, 2020). Additionally, the carotenoids in the SWP contain the effective antioxidants lutein and hexoxanthin (Priyadharshini and Swathiga, 2021).

Table (2) shows the mineral composition of SWP. It can be noted that SWP had the highest content of minerals such as K, P, Mg, and Ca (1461.34, 1073.22, 258.13, and 112.56 mg/100 g, respectively).

Table 2. Nutritional properties of silkworm pupae powder

Components	Value*
Chemical composition:	
Moisture (%)	9.04±0.48
Crude protein (%)	58.38±0.72
Crude ether extract (%)	18.26±0.93
Total ash (%)	6.34±0.18
Total carbohydrate** (%)	17.96±0.54
Total calories (kcal/100 g)	469.70±3.67
% of protein calories to total cal.	49.72±1.35
Bioactive compounds:	
Total phenolic content (mg GAE/100 g)	37.64 ±0.69
Total flavonoid content (mg RE/100 g)	22.39±0.44
DPPH scavenging activity (%)	27.45±0.38
Mineral composition (mg/100 g):	
Ca	112.56±1.73
K	1461.34±3.99
Mg	258.13±2.49
P	1073.22±2.56
Zn	19.64±0.29
Fe	10.82 ±0.17
Mn	1.66±0.09
Cu	2.17±0.14
Se	0.06±0.03

*Data as mean ± SD (on dry weight basis).

**Calculated by difference.

Cu and Mn were present in small amounts (2.17 and 1.66 mg/100 g, respectively). On the other hand, very low concentration of Se (0.06 mg/100 g) was also detected. These results are in agreement with Kim *et al*. (2017) and Zhou *et al*. (2022), who found that SWP had the highest content of some minerals, such as P, Ca, and Mg. Moreover, the SWP contained higher levels of some important minerals such as Zn (19.64 mg/100 g) and Fe (10.82 mg/100 g). The results obtained in the present study also noted that the concentrations of Fe and Zn in SWP were higher than the findings by Kim *et al*. (2017), David-Birman *et al*. (2019), and Köhler *et al*. (2019), which are essential for the strengthening of the immune system (Talwar *et al*., 1989). According to Tassoni *et al*. (2022), the concentrations of Fe, Ca, Mn, Zn, and Mg varied from 2.83 to 4.95, 92 to 181, 1.08 to 2.3, 1.39 to 24.4, and 89 to 280 mg/100 g, respectively. The mineral composition of SWP varies depending on their environment of growth (Zhou and Han, 2006a).

The chemical composition of fish paste

Data in Table (3) illustrated the changes that occurred in the chemical composition of processed fish paste formulas by substituting smoked tilapia fish meat with SWP. The moisture content in the different samples with SWP powder was significantly lower than the control sample. This could be attributed to the lower moisture content of SWP powder. Also, the data in Table (3) show that the protein content for all treatments with SWP powder was significantly decreased, whereas crude ether extract and ash contents were significantly increased with increased SWP powder substitution. No significant differences were found in carbohydrate content between the control sample and the fish paste samples containing SWP powder. According to previous studies reported, increasing levels of SWP powder decreased the protein content of chicken bread spread and meat batter, while fat content increased (Park *et al*., 2017 and Karnjanapratum *et al*., 2022). It can be concluded that the energy value of processed fish paste formulas with SWP was increased (Table 3). The highest value was for the fish paste at 25% SWP (569.59 kcal/100 g), followed by 20% SWP (569.40 kcal/100 g), 15% SWP (567.68 kcal/100 g), 10% SWP (564.00 kcal/100 g), 5% SWP (563.45 kcal/100 g), and finally the control sample (561.79 kcal/100 g). The change in chemical composition of the fish paste samples is affected by the difference in chemical composition of SWP and tilapia fish, especially the protein and fat contents.

Table 3. Effect of fish replacement by SWP powder on the chemical composition of fish paste

Components*	0% SWP	5% SWP	10% SWP	15% SWP	20% SWP	25% SWP	L. S. D.
Moisture (%)	64.11^{a}±0.30	62.37^{b}±0.51	61.81^{bc}±0.90	60.98^{cd}±0.57	59.96^{de}±0.64	58.97^{e}±0.61	1.162
Crude protein (%)	42.31^{a}±0.57	40.97^{b}±0.49	40.48^{b}±0.56	40.02^{bc}±0.81	39.17^{cd}±0.82	38.24^{d}±0.31	1.232
Crude ether extract (%)	37.31^{c}±0.37	37.77^{c}±0.68	38.12^{bc}±0.45	38.72^{ab}±0.73	39.28^{a}±0.54	39.51^{a}±0.45	0.909
Total ash (%)	6.19^{b}±0.50	6.35^{b}±0.41	6.65^{ab}±0.26	6.48^{ab}±0.34	6.75^{ab}±0.46	6.99^{a}±0.32	0.614
Total carbohydrate** (%)	14.19^{a}±0.54	14.71^{a}±0.61	14.75^{a}±0.81	14.78^{a}±0.28	14.80^{a}±0.62	15.26^{a}±0.83	1.207
Total calories value (kcal/100 g)	561.79^{d}±3.55	563.45^{cd}±2.62	564.00^{bcd}±3.17	567.68^{abc}±4.69	569.40^{ab}±4.40	569.59^{a}±2.32	5.495

*Data as mean ± SD (on dry weight basis)

**Calculated by difference.

Means in the same row sharing the same letters are not significantly different at $P< 0.05$ level.

Tilapia fish had a higher protein content (81.86%) and a lower fat content (8.38%) (Hashem *et al.*, 2017) compared to SWP.

Physicochemical properties

The physicochemical properties of fish paste formulas are described in Table (4). The results showed that the pH values of the fish paste samples were within the range of 5.27 to 5.70. The pH of fish paste samples containing SWP was significantly higher than that of the control sample. The same trend was reported by Kim *et al*. (2016), who found that the addition of SWP flour slightly increased the pH of emulsion sausage. On the other hand, Karnjanapratum *et al*. (2022) reported that SWP levels had no significant effect on the pH of the final product of chicken bread spread because there were no significant differences in pH between chicken breast and SWP. The TBA values of the different fish paste formulas ranged from 0.061 to 0.067 mg malondialdehyde /kg sample (Table 4). These values were below the level of incipient rancidity (≥ 1) (Okerman, 1976). The SWP levels had no significant difference in effect on the TBA of the final product. No significant differences were observed in TBA among all fish paste samples, including the control sample.

As stated in Table (4), the colour parameters (lightness L^*, redness a^*, and yellowness b^*) of fish paste samples were greatly affected by the replacement level of SWP powder. It could be observed that there was a significant decrease in lightness (L^*) with a steady increase in the percentage of SWP in fish samples. The fish paste containing 25% SWP had the lowest lightness value. These findings were consistent with those reported by Kim *et al*. (2016) and Park *et al*. (2017), who found that increasing the ratio of SWP powder in meat products resulted in a significant decrease in lightness. Furthermore, Karnjanapratum *et al*. (2022) reported that the lightness value of the chicken bread spread decreased significantly with increasing levels of SWP. Regarding redness (a^*), the data showed that using SWP in fish paste resulted in a significant increase in redness value when compared to the control. On the other hand, there was no significant increase in redness value for fish paste products containing 5%, 10%, 15%, and 20% SWP. The yellowness (b^*) value of the SWP samples was lower than the control sample. but there was no significant difference between the 10% SWP, 15% SWP, and 20% SWP samples. Increasing SWP levels resulted in dark-coloured final products, as indicated by a significant increase in redness and yellowness (Kim *et al.*, 2016 and Karnjanapratum *et al.*, 2022). In general, increasing levels of SWP significantly changed the colour value of food products.

The texture properties were impacted by the replacement of fish with SWP, as shown in Table (4). The hardness of fish paste samples was significantly increased by increasing the level of SWP replacement, compared with the control sample. Due to the decreased moisture content and increased solid compounds, the increased hardness of SWP formulations was an unavoidable result. Pereira *et al*. (2011) suggest that the potential for a large number of protein-protein interactions, which can be identified as the primary factors influencing an increase in hardness of products. SWP formulations increased the gumminess, chewiness, and cohesiveness of fish paste compared to the control, while a replacement had no effect, even when 15% SWP was replaced. The springiness of fish paste samples decreased significantly as the level of SWP powder replacement increased, while there were no significant differences between all SWP-containing samples. Kim *et al*. (2016) obtained similar results, observing an increase in hardness, gumminess, cohesiveness, and springiness values of sausage by increasing the level of SWP powder. Polysaccharides-proteins interactions are play a significant role in the structure, stability, and functional properties of fish processed products (Luo *et al*., 2008).

Sensory evaluation

Sensory properties of fish paste samples are depicted in Figure (1). Panelists accepted all the fish paste prepared by SWP powder substitution. The acceptance of all the attributes ranged from like very much accepted to like slightly accepted. The panelists showed that the products that contain 5% SWP had nearly the same score for the sensory properties of the control fish paste. Statistically, there were significant differences between the control sample and all of the fish paste containing SWP, ranging from 10% to 25% substitution levels in all the attributes. Also, the findings of the appearance and colour evaluation for the control fish paste were 8.7 and 8.6 (like very much), respectively, while for the SWP smoked fish paste, the variations were between 6.0 (like slightly) and 8.4 (like very much). Similar trend was seen in the scores for the odour which ranged between 6.2 (like slightly) and 8.6 (like very much). Also, the data showed that the taste attributes of 10 and 15% substitution levels were like moderately accepted, being over the numerical value of (7). The spreadability score decreases with increasing substitution levels, it decreased from 8.5 in control to 8.2, 7.4, 6.6, 6.1, and 6.0, with the replacement of 5, 10, 15, 20, and 25% SWP. The overall acceptability score gradually decreased from 8.7 for the control sample to 8.4, 7.5, 7.1, 6.7, and 6.1 for fish paste, with SWP of 5, 10, 15, 20, and 25%, respectively.

Table 4. Effect of fish replacement by SWP powder on physicochemical properties of fish paste

Properties*	0% SWP	5% SWP	10% SWP	15% SWP	20% SWP	25% SWP	L. S. D.
pH Value	5.27^{d}±0.05	5.52^{c}±0.06	5.58^{bc}±0.02	5.60^{b}±0.03	5.69^{a}±0.03	5.70^{a}±0.01	0.07
TBA value	0.063^{a}±0.005	0.067^{a}±0.001	0.066^{a}±0.003	0.061^{a}±0.007	0.065^{a}±0.005	0.062^{a} ±0.008	0.009
Colour values:							
Lightness (L*)	49.04^{a}±0.48	44.58^{b}±0.42	42.87^{c}±0.15	42.62^{c}±0.64	38.88^{d}±1.02	37.04^{e}±0.12	1.066
Redness (a*)	2.76^{c}±0.32	3.98^{b}±0.44	3.88^{b}±0.50	4.28^{ab}±0.56	3.87^{b}±0.35	5.08^{a}±0.68	0.965
Yellowness (b*)	22.08^{a}±0.69	18.59^{b}±0.57	15.88^{c}±0.43	15.20^{c}±0.52	16.03^{c}±0.46	13.14^{d}±0.41	0.827
Texture profile analysis:							
Hardness (g)	121.46^{d}±1.73	129.75^{c}±1.00	136.81^{b}±3.00	135.49^{b}±1.15	138.62^{b}±1.24	149.77^{a}±1.32	3.249
Gumminess (g)	23.22^{c}±1.02	24.12^{bc}±1.71	25.08^{abc}±1.84	24.25^{bc}±1.09	26.19^{ab}±1.62	27.33^{a}±1.56	2.418
Cohesiveness	0.31^{b}±0.21	0.32^{ab}±0.03	0.32^{ab}±0.03	0.31^{b}±0.02	0.34^{ab}±0.02	0.36^{a}±0.01	0.043
Springiness (mm)	3.77^{a}±0.44	3.13^{b}±0.46	2.96^{b}±0.47	2.90^{b}±0.42	2.74^{b}±0.44	2.72^{b}±0.37	0.553
Chewiness (mg)	0.53^{c}±0.07	0.59^{bc}±0.03	0.65^{bc}±0.04	0.62^{bc}±0.036	0.72^{b}±0.14	0.89^{a}±0.08	0.146

*Data as mean ± SD.

Means in the same row sharing the same letters are not significantly different at $P< 0.05$ level.

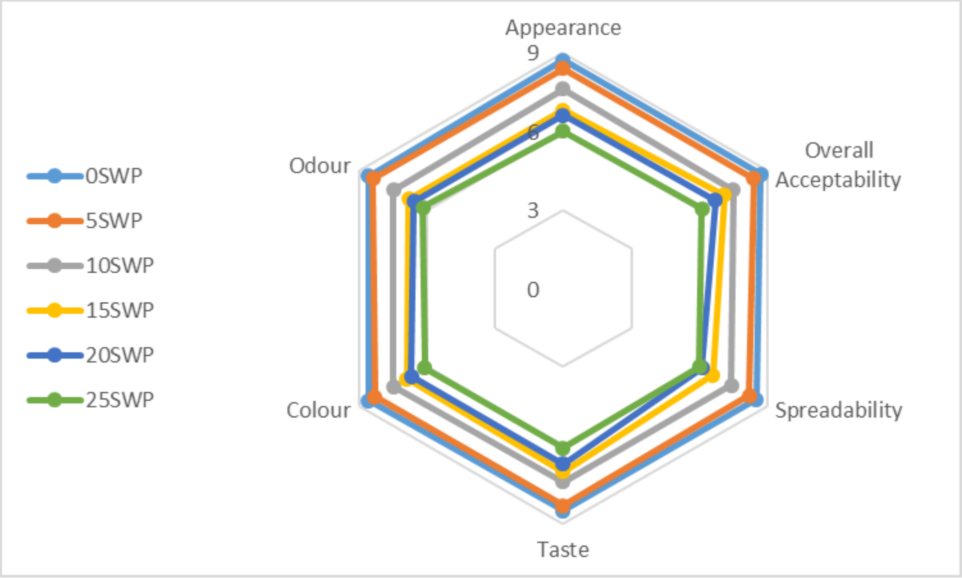

Figure 1. Effect of fish replacement by SWP powder on sensory properties of fish paste

Generally, the findings indicated that all fish paste samples containing different replacement levels (5-25% SWP) were judged as acceptable by the panelists. This means that replacing fish with SWP in the fish paste formulation can produce an acceptable product. This is probably because the edible SWP have been combined with other ingredients and are rarely visible to the eye, and the panelists' repulsive feelings are unexpressed. The results of the present study agreed well with those obtained by Hirunyophat *et al.* (2020) and Karnjanapratum *et al.* (2022), who found that an increased level of SWP powder affected the reduction of sensory properties scores in the breakfast cereal product and chicken bread spread. In addition, the breakfast cereal product and chicken bread spread with SWP were accepted by the consumers. In contrast, no significant differences were observed between products containing SWP (samosa snacks, pies, and high-energy biscuits) and control in sensory properties (Akande *et al.*, 2020a and Akande *et al.*, 2020b). Studies have shown that average values for liking scores of insect-containing foods usually favour the control ones (Osimani *et al.*, 2018).

CONCLUSION

This study demonstrated that edible mulberry silkworm pupae, as a source of protein, fat, and mineral content, are promising as functional ingredients in preparing food products and could be a very beneficial low-cost alternative food source in the majority of developing and developed nations. Future research should therefore focus on the role of silkworm pupae in the food industry, pharmaceutical applications, and consumer acceptability.

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الملخص العربي

تأثير إستخدام مسحوق شرانق دودة قز التوت (*Bombyx mori* L.) على الخواص الكيموطبيعية وقبول المستهلك لمعجون السمك المدخن الجاهز للأكل

سعدية محمد هاشم

هناك إهتمام في جميع أنحاء العالم نحو إيجاد مصادر غذائية جديدة طبيعية ذات فوائد غذائية وفسيولوجية على صحة الانسان ولما تمتاز به شرانق دودة قز التوت (*Bombyx mori*)، من حيث إحتوائها على مركبات تغذوية لذا فهى تعتبر مكمل غذائي جديد واعد في إنتاج منتجات تغذوية وظيفية. تم إستخدام مسحوق شرانق دودة قز التوت (SWP) كبديل للحم سمك البلطي المدخن في إنتاج معجون السمك الجاهز للأكل. تم تقييم الخواص الكيموطبيعية والإختبارات الحسية لدراسة تأثير الإستبدال على جودة ودرجة تقبل المستهلك لمعجون السمك الناتج. صنع معجون السمك بإستبدال لحم سمك البلطى المدخن بنسب مختلفة من SWP (٥، ١٠، ١٥، ٢٠، ٢٥٪). أوضحت النتائج أن مسحوق SWPيحتوى على تركيزات عالية من البروتين (٥٨,٣٨٪) والكربوهيدرات الكلية (١٧,٩٦٪) ومستخلص الإثير الخام (١٨,٢٦٪)، كما يمكن إعتباره مصدرًا غنيًا لمعادن الفوسفور والماغنسيوم والكالسيوم والزنك والبوتاسيوم والحديد، كما أوضحت النتائج أن مستخلص الإيثانول SWP يحتوى على المركبات الفينولية الكليه (٣٧,٦٤مجم/١٠٠ جم) والتى أظهرت نشاط للشقوق الحره (٢٧,٤٥٪) المقدر بطريقة DPPH ومحتوى من الفلافونيدات الكلية (٢٢,٣٩مجم/١٠٠ جم)، أظهرت نتائج منتجات معجون السمك المصنعة بمسحوق SWP زيادة معنوية فى محتوى كل من مستخلص الإثير الخام، والسعرات الحرارية الكلية، ودرجة الحموضة (pH)، بينما إنخفض محتوى البروتين الخام عند زيادة نسبة تركيز مسحوق SWP فى المنتج، إضافة مسحوق SWP أدى إلى تغيرات فى خاصية اللون وتحسين فى خاصية التماسك والمضغ فى جميع المنتجات، إحصائيا أظهرت النتائج وجود إختلافات معنوية في جميع الخواص الحسية بين العينة المرجعية والمنتجات الاخرى المصنعة من ١٠ إلى ٢٥٪ SWP ، علاوة على ذلك حازت جميع المنتجات المصنعة من SWP على قبول المحكمين.

الكلمات المفتاحية: شرانق دودة قز التوت، غذاء بديل، مكمل غذائي جديد، معجون سمك.