1 **Nutrient composition and bioaccumulation of an edible aquatic insect,**

2 ***Pantala* sp. (Odonata: Libellulidae) from the rice field**

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Abstract

Numerous edible aquatic insects have unanticipated nutraceutical potential and are consumed in a variety of Thai locations. The proximate composition, amino acid, fatty acid, mineral, and heavy metal content of *Pantala* sp. (Odonata: Libellulidae) aquatic edible nymphs were determined using standard analytical methods in this study. *Pantala* sp. had a proximate protein content of 445.14 ± 0.04 %, a fat content of 4.93 ± 0.05 %, an ash content of 5.24 ± 0.03 %, a moisture content of 35.11 ± 0.09 %, and a total carbohydrate content of 9.60 ± 0.11 %. Total energy was 263.25 ± 0.20 kcal/100 g, with fat energy accounting for 44.37 ± 0.43 kcal/100 g. Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) analysis revealed that this insect was high in phosphorus, iron, and copper for human consumption. In comparison to other edible insects studied, they were also excellent calcium sources. Agilent 7890B Gas Chromatograph (GC) analysis revealed that it contains 236.67 mg/100g of omega-3 and 523.32 mg/100g of omega-6. While the amino acids examined using High Performance liquid Chromatography contained all essential amino acids. ICP-OES was used to determine the levels of cadmium (Cd), lead (Pb), and arsenic (As). *Pantala* sp. had the highest concentration of As (average = 2.827 ± 0.289 mg kg⁻¹), followed by Cd (0.164 ± 0.007 mg kg⁻¹) and Pb (0.158 ± 0.015 mg kg⁻¹). Although the insects have nutraceutical potential, they also have toxic heavy metals in trace amounts, with the exception of As. This work could serve as a nutritional reference for local consumers interested in entomophagy.

Keywords: Edible aquatic insect, Odonata, nutritional value, bioaccumulation

Introduction

According to the FAO [1], the global population is predicted to reach 9.1 billion people in 2050, up 34% from now. When combined with rising economic affluence and purchasing power, the FAO forecasts that global food production will need to increase by 60% from current levels by 2050 to meet global food demands. Entomophagy is another option for dealing with these issues [2].

Entomophagy is practiced in almost every country, including Africa, Asia, and Australia [3]. According to studies, insects are a good source of protein, fat, carbohydrates, and other nutrients [4-5]. Aquatic insects are one of the most popular types of entomophagy among consumers, owing to their taste and widespread availability [6]. Insects with aquatic larvae have been documented as human food in 48 countries throughout the world. Macadam and Stockan [7] reported that Coleoptera (79 sp.) has the most edible food insect species, followed by Odonata (58 sp.) and Hemiptera (55 sp.). In Thailand, residents in the northeast consume around 150 insect species, whereas people in the north consume about 50 insect species. The richness of edible aquatic insects in Thailand is the subject of this study, which is a consequence of the country's wide ecological and climatic diversity. During the rainy season, these insects can be found in rice fields, forested areas, natural ponds, and streams [8-9]. True bugs, beetles, and dragonfly nymphs are among the most popular insects. According to a previous study, dragonfly larvae (Libellulidae, Aeshnidae, and Gomphidae) are consumed as food in China [3, 7, 10], India [11], Philippines [12], Laos [13-14] and Thailand [9]. Thailand is expected to have ten edible species, but only five have been identified, and only three have nutritional data accessible. Among the species of dragonfly, *Anax parthenope* (Selys) is the most common edible species. Several researchers have recorded the use of aquatic insects as food, but there are few investigations into their nutritional value and

bioaccumulations. Therefore, this study investigates the proximate composition, amino acids, fatty acids, minerals, and toxic heavy metal contents of commonly eaten edible aquatic insects, *Pantala* sp. (Odonata: Libellulidae), from the rice fields of central Thailand.

Materials and methods

Sample collection and preparation

Specimens of *Pantala* sp. (Odonata: Libellulidae) final instar nymphs (Fig 1) were captured from a rice field using an aquatic D-net before they left the water and emerged as adults. For nutritional analysis, they were identified using taxonomic keys, rinsed with clean water, and sun-dried.

Fig 1. *Pantala* sp. nymph (Odonata: Libellulidae)

Proximate analysis

The AOAC techniques 925.45, 991.20, 2003.05, and 923.03 were used to measure moisture, protein, fat, and ash content, respectively. The energy from fat in insects in Kcal/100 g was calculated by multiplying the percent fat by 9.0. [15]. The total energy of insects in kcal/100 g was calculated according to FAO [1].

Mineral analysis

The samples were digested for 1 hour at room temperature with nitric and perchloric acid (HNO₃: HClO₄ = 2:1), filtered with distilled water, the final volume made up of 50 ml, and the filtrate was utilized for mineral analysis. Inductively Coupled Plasma-Optical Emission

Spectroscopy (ICP-OES) was used to determine mineral and hazardous heavy metal concentrations.

Amino acid analysis

The samples were hydrolyzed for 24 hours at 110°C with 5 mL of 6 M HCl. The amino acid composition of the hydrolyzed samples was determined using High Performance liquid Chromatography (HPLC-Agilent 1260 Infinity series, Fluorescence Detector). The HPLC's operating conditions were as follows:

Instrument	High Performance liquid Chromatography (Agilent Technologies, Germany)
Column	Princeton SPHER C30, 250 mm, ID 4.6 mm
Detector	17 amino acid standard using FLD at Ex: 340, Em: 450; Proline using FLD at Ex: 270, Em: 316
Column temperature	30 °C
Flow rate	0.7 ml/min
Injection volume	16 and 10 µl
Moblie phase	Gradient NaH ₂ PO ₄ : (MeOH+ACH+H ₂ O: 45+40+15)
Run time	65 min
Post time	5 min

Fatty acid analysis

The fatty acid profile was determined using an Agilent 7890B Gas Chromatograph (GC) and modified Compendium of Methodology for Food Analysis methods [16].

Statistical analysis

The Statistical Package for Social Sciences (SPSS) version 19.0 was used to report the data as mean ± standard deviation.

Results and Discussion

Proximate compositions

The moisture, protein, total carbohydrate, lipid, ash, total energy, and energy from fat content of edible aquatic insects (*Pantala* sp.) were investigated. These results are presented in Table 1.

Table 1. Proximate compositions of *Pantala* sp.

Proximate compositions	Mean±SD	Recommended Adult Reference (g/day)*
Protein, % (factor 6.25)	45.14±0.04	50 g
Fat, %	4.93±0.05	70 g
Ash, %	5.24±0.03	-
Moisture, %	35.11±0.09	-
Total carbohydrate, %	9.60±0.11	260 g
Total energy, (Kcal/ 100 g)	263.25±0.20	2000 kcal/day
Energy from fat, (Kcal/ 100 g)	44.37±0.43	-

Results are in means of triplicate determinations ± SD. *Data derived from Williams and Williams [3].

In terms of moisture and ash content, *Pantala* sp. had a greater percentage of moisture (35.11%) and ash content (5.24%) than edible aquatic insects (Odonata: Libellulidae) reported by Shantibala *et al.* [17] and Narzari *et al.* [18]. This means that meals with a high moisture content are more susceptible to microbial growth and enzyme activity [19]. The mineral composition is determined by the ash content [6]. On a dry weight (DW) basis, the protein content of *Pantala* sp. was lower than that of *Sympetrum* sp., *Crocothemis servilia* (Drury), *Gomphus cuneatus* and *Lestes praemorsus* reported by Ying *et al.* [10], Shantibala *et al.* [17] and Narzari *et al.* [18]. Protein concentrations in aquatic insects such as Odonata can range between 40 and 65 percent [4,17]. However, the protein content of *Pantala* sp. was found to be higher than that of other edible aquatic insect species consumed in India (Coleoptera, Hemiptera, and Nepidae) [6].

Furthermore, when compared to all edible insects studied by Rahman *et al.* [20], the protein content of *Pantala* sp. was higher. Overall, the protein content of edible aquatic insects was comparable to that of chicken (42.58%), beef (35.31%), eggs (48.51%), pork (47.58%), and fish (49.63%) [21].

Lipids are essential because they provide 9 kilocalories per gram of energy [6]. The percentage of lipid content in *Pantala* sp. (4.93%) reflects its calorific value, which contributes 44.37 kcal/100 g of energy from fat. Lipids are one of the principal structural components of living cells [22]. *Pantala* sp. had a lower carbohydrate content (9.60%) than edible insects described by Narzari and Sarmah [18], but it was greater than edible insects reported by Rahman *et al.* [20] and Akullo *et al.* [23].

A total of about 263.25 kcal of energy was provided by 100 g, with approximately 1,149 nymphs. Insects are a good source of energy, with 400–500 kcal per 100 g of dry matter [24]. In comparison to the typical daily requirements of important dietary components [100 g of dried insect bodies is around 1/2 a cup], the protein yield of *Pantala* sp. is fairly high (90.28%) (Table 1). As a result, insects may be a good source of protein for those who are malnourished. Carbohydrate yield, on the other hand, is low. However, the carbohydrate amounts found in this study are higher than those found in the Shantibala *et al.* [17] report on five edible aquatic insects. The presence of carbohydrate content (9.60% [g/100g]) in *Pantala* sp. is evidence of a suitable dietary supply of carbohydrates, despite the fact that insects are not a good source of carbohydrates due to human demands of about 260 g/day [3, 25-26]. As a result, edible aquatic insects are high in macronutrients (protein, fat, and energy).

Mineral profile

The most abundant mineral profile in *Pantala* sp. was potassium (625.26 mg/100 g), followed by sodium, phosphorus, calcium, and magnesium, respectively (Table 2). Narzari *et al.* [18] found that aquatic insects such as *Sympetrum* sp. supplement a significant amount of macronutrients such as potassium (1,690.05 mg/100g), phosphorus (626.78 mg/100g), and sodium (240.80 mg/100g). Both potassium and sodium, as well as magnesium, are electrolytes that aid in the normal functioning of nerves and muscles. These substances are located in the extracellular and intracellular fluids. Magnesium is involved in nearly all of the cell's major metabolic and biochemical systems, including muscular contraction and relaxation, neurological function, and neurotransmitter release [27].

Table 2. Minerals of *Pantala* sp. mg/100 g dry weight.

Elements	<i>Pantala</i> sp. (mg/100 g DW) ^a	Thai Dietary Reference Intakes ^b (mg per day)	% Thai RDI
Macro minerals			
Potassium (K)	625.26±16.65	3500	17.86
Sodium (Na)	557.24±13.08	2400	23.22
Phosphorus (P)	500.30±8.30	800	62.54
Calcium (Ca)	206.03±5.84	800	25.75
Magnesium (Mg)	73.13±2.35	350	20.89
Micro minerals			
Iron (Fe)	78.88±6.43	15	525.87
Zinc (Zn)	5.01±0.14	15	33.4
Copper (Cu)	1.34±0.05	2	67

^a The results are based on triplicate determinations ± SD. ^b The 2,000 kcal diet is used to calculate the percent of Thai Recommended Dietary Intakes (Recommended Dietary Allowances and Adequate Intakes of Energy and Selected Nutrients) for people over the age of six [28].

Pantala sp. had a calcium content of 206.03 mg/100g, which was higher than the calcium content of all edible insects reported by Das and Hazarika [6], Shantibala *et al.* [17], Narzari *et al.* [18], Akullo *et al.* [23], Idowu *et al.* [26], Adeduntan [29], Rumpold and Schlüter [30], Adámková *et al.* [31] and Das and Hazarika [32]. Calcium is the most abundant primary mineral in the human body, accounting for 1.5-2% of total body weight as bones and teeth. A calcium deficit in adults can cause osteoporosis, which is marked by bone loss and skeletal discomfort [33]. In the case of calcium insufficiency, edible aquatic insects (*Pantala* sp.) could be a potential source of calcium to supplement the diet. It is also used as a replacement for people who have a milk allergy or sensitivities to other calcium-rich foods. The recommended daily intake (RDI) amount for adults is 800-1000 mg of calcium per day [28, 34]. The source of calcium would be *Pantala* sp., which would provide between 20.60 and 25.75 percent of the daily requirements. Moreover, edible aquatic insects can be utilized as a calcium supplement for your child's growing body, as their bones and teeth are still developing.

Phosphorus is the second most abundant major mineral in the body. It is found in every cell and part of DNA and RNA. The main role of phosphorus, together with calcium, is to aid in the calcification of bones (the skeleton contains 85% of the body's phosphorus) and to assist the body in energy production [35].

Pantala sp. is high in iron, zinc, and copper, all of which are important minerals for human health. The iron content of *Pantala* sp. was 78.88 mg/100g, which was higher than those of all aquatic insects reported by Das and Hazarika [6] and Narzari *et al.* [18]. Mineral deficiencies (particularly Fe and Zn) are frequent health problems around the world, resulting in major health issues like anemia, poor pregnancy outcomes, and stunted growth, among other things [36]. Consuming 100 g of *Pantala* sp. would provide consumers with a supplement of

macronutrients (potassium, sodium, phosphorus, calcium) as well as micronutrients (iron, zinc, copper) for optimal health and nutrition.

Amino acid composition

Table 3 shows the amino acid content of *Pantala* sp. (g/100 g dry weight). Our samples contained all of the essential amino acids when compared to an aquatic edible insect, *Sympetrum* sp. (Odonata: Libellulidae) from Assam, northeast India [18]. Methionine, lysine, leucine, isoleucine, tryptophan, valine, threonine, phenylalanine, and histidine are the essential amino acids (required for the young, but not for adults). Among the essential amino acids detected, histidine is quantitatively the most abundant, with histidine being essential for the growth of infants and young children [37]. According to Igwe *et al.* [38], insect larvae are high in essential amino acids such as lysine and threonine, which are deficient in some cereals and vegetables [14]. This finding indicates that *Pantala* sp. has a high lysine content. The levels of lysine and histidine were higher than in commonly consumed meat animals such as beef, pork, and chicken. *Pantala* sp., for example, contains 2.25 g/100g lysine and 0.82g/100g histidine in beef meat, 1.80 g/100g lysine and 0.82 g/100g histidine in pork meat, and 1.79 g/100g lysine and 0.69g/100g histidine in chicken meat [39].

Table 3. *Pantala* sp. amino acid (AA) content (g/100 g dry weight).

Essential AA	Total EAA	Non-Essential AA	Total NEAA
Threonine	1.53 ± 0.13	Aspartic acid	2.63 ± 0.25
Valine	1.65 ± 0.12	Glutamic acid	4.05 ± 0.39
Methionine	0.41 ± 0.04	Serine	1.57 ± 0.11
Isoleucine	1.42 ± 0.10	Glycine	2.14 ± 0.14
Phenylalanine	0.86 ± 0.03	Alanine	2.07 ± 0.18
Tryptophan	1.94 ± 0.15	Proline	4.32 ± 0.35
Leucine	1.83 ± 0.17	Arginine	2.69 ± 0.25
Lysine	2.25 ± 0.22	Tyrosine	0.95 ± 0.09
Histidine	5.35 ± 0.47	Cystine	1.10 ± 0.06
Total Essential AA	17.24	Total Non-Essential AA	21.52

The results are based on triplicate determinations $\pm$ SD.

Fatty acid compositions

Table 4 summarizes 22 fatty acids from three different categories, namely saturated (SFA), monounsaturated (MUFA), and polyunsaturated (PUFA). Palmitic acid (C16:0) is the most abundant fatty acid in *Pantala* sp., which is consistent with data from the black soldier fly [40]. The second most abundant fatty acid is stearic acid (C18:0), followed by cis-9-oleic acid (C18:1n-9) and linolenic acid (C18:2n-6). These findings are similar to those reported previously in lesser mealworms (*Alphitobius diaperinus* Panzer; Coleoptera: Tenebrionidae) by Oonincx *et al.* [41]. In this insect, total SFA concentration was highest, followed by monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA). SFA concentrations ranged between 10.00 mg/100g and 1,300.00 mg/100g. Palmitic acid (C16:0) was the most abundant SFA in this insect, followed by stearic acid (C18:0) and heptadecanoic acid (C17:0). The MUFA concentration ranged between 10.00 mg/100g and 610.00 mg/100g. Cis-9-oleic acid (C18:1n-9c) was the most abundant MUFA in this insect, followed by palmitoleic acid (C16:1) and cis-10-Heptadecenoic acid (C17:1n-10). The PUFA content ranged from 13.33 mg/100g to 363.33 mg/100g. Linoleic acid (LA, C18:2n-6c) was the most abundant PUFA in this insect, followed by alpha-linolenic acid (ALA, C18:3n-3) and arachidonic acid (AA, C20:4n-6).

Table 4. Fatty acid concentration (mg/100g DW) of *Pantala* sp.

Name	Formula	Concentration (mg/100g of DM)
Lauric acid	C12:0	16.67 $\pm$ 5.77
Tridecanoic acid	C13:0	10.00 $\pm$ 0.00
Myristic acid	C14:0	93.33 $\pm$ 5.77
Pentadecanoic acid	C15:0	156.67 $\pm$ 5.77
Palmitic acid	C16:0	1,300.00 $\pm$ 45.83
Heptadecanoic acid	C17:0	266.67 $\pm$ 5.77
Stearic acid	C18:0	796.67 $\pm$ 32.15
Arachidic acid	C20:0	93.33 $\pm$ 5.77

Heneicosanoic acid	C21:0	26.67 ± 11.55
Behenic acid	C22:0	73.33 ± 5.77
Total SFA		2,833.33
Palmitoleic acid	C16:1	260.00±0.00
cis-10-Heptadecenoic acid	C17:1n-10	144.33±5.77
trans-9-Elaidic acid	C18:1n-9t	13.33±5.77
cis-9-Oleic acid	C18:1n-9c	610.00±10.00
cis-11-Eicosenoic acid	C20:1n-11	10.00±0.00
Total MUFAs		1,036.67
Linoleic acid (LA)	C18:2n-6c (ω-6)	363.33±32.15
gamma-Linolenic acid (GLA)	C18:3n-6 (ω-6)	23.33±5.77
alpha-Linolenic acid (ALA)	C18:3n-3 (ω-3)	176.67±20.82
cis-11,14-Eicosadienoic acid	C20:2	20.00±0.00
cis-8,11,14-Eicosatrienoic acid	C20:3n-6 (ω-6)	13.33±5.77
Arachidonic acid (AA)	C20:4n-6 (ω-6)	123.33±15.28
Eicosapentaenoic acid (EPA)	C20:5n-3 (ω-3)	60.00±10.00
Omega 3 (n – 3)		236.67
Omega 6 (n – 6)		523.32
Total PUFAs		780.00
Total UFA		1,816.67
PUFA/SFA ratio		0.28

Results are in means of triplicate analysis ± SD ($n=3$). SFA (saturated fatty acid); MUFA (monounsaturated fatty acids); PUFA (polyunsaturated fatty acids); UFA (unsaturated fatty acid = MUFA + PUFA). The total omega-3 fatty acid composition was calculated as the Σ (alpha-linolenic acid [C18:3n3]+EPA [C20:5n3]). The total omega-6 fatty-acid composition was calculated as the Σ (linoleic acid [C18:2n6c]+ gamma-linolenic acid [C18:3n6]+cis-8,11,14-eicosatrienoic acid [C20:3n6]+arachidonic acid [C20:4n6]).

The current study demonstrates that edible aquatic insects have diverse fatty acid composition profiles. Omega-6 and omega-3 fatty acids are essential because humans, like all mammals, cannot produce them and must obtain them through diet. Linoleic acid (LA; 18:2n-6) represents omega-6 fatty acids, while alpha-linolenic acid (ALA; 18:3n-3) represents omega-3 fatty acids [42]. Among the detected n-6 PUFAs, LA (C18:2n-6c) was the most abundant. GLA (18:3n-6), AA (C20:4n-6), and eicosatrienoic acid are some other n-6 fatty acids (C20:3n-6).

Linoleic acid was discovered in this species at a concentration of 363.33 mg/100g, which is much higher than that found in a commonly edible insect such as crickets (*Acheta domesticus* Linnaeus) [40]. These LA fatty acids are extremely important to humans because LA is the precursor of AA (C20:4n-6), which is the precursor of prostaglandin E2 (PGE2), which is also known as eicosanoids and is involved in the regulation of gene expression. Linoleic acid is also a structural component of cell membranes and plays an important role in cell signaling. Furthermore, high PUFA n-6 family intake has been shown to lower plasma cholesterol concentrations (lower risk of coronary heart disease) [43].

Consuming n-3 PUFAs has been shown to reduce the risk of diabetes by decreasing glucose intolerance, preventing insulin resistance, decreasing thrombotic tendency, and lowering blood pressure [44]. Surprisingly, we discovered a significant amount of ALA (C18:3n-3) in our current study. In contrast, Bophimai and Siri [45], Raksakantong *et al.* [46], and Ghosh *et al.* [47] discovered trace amounts of ALA in six edible dung beetle species (20.3-96.2 mg/100g DM), eight Thai edible terri-colous insect species (2.46-39.82 mg/100g), and four commercial edible insects (10-110 mg/100g DM). Long-chain PUFA were typically found in aquatic insects, particularly omega-3 fatty acids such as ALA and EPA, whereas ALA was found in terrestrial species [48]. Aquatic insects obtain long-chain PUFA from their larvae and algae diets or synthesize them using the D5 and D6 desaturase enzymes [49]. Alpha-Linolenic acid is primarily used as a precursor in the synthesis of EPA. EPA has been shown to be a precursor of prostaglandin E3 (PGE3) and to be beneficial to the cardiovascular system. However, the recommended polyunsaturated to saturated fatty acid ratio (P/S ratio) for humans should be greater than 0.4 in order to reduce the risks of cardiovascular disease, cancer, and asthma, among

other diseases [50]. Although *Pantala* sp. had a lower P/S ratio of 0.4, the normal P/S ration of meat was also around 0.1.

The total PUFA concentration of this species is comparable to raw lean meats such as mutton (673 mg/100g), lamb (603 mg/100g), and beef (448 mg/100g), and much higher than that found in some edible terricolous insects such as the june beetle (516.73 mg/100g), termite (465.06 mg/100g), cicada (213.15 mg/100g), longan stink bug (420.84 mg/100g) and short tailed cricket (771.63 mg/100g) that consumed in Thailand [46, 51]. As a result, direct consumption of edible aquatic insects could significantly contribute to human healthy fat requirements.

Bioaccumulation

Heavy metals such as Pb, Cd, and As were found in *Pantala* sp. during the study (Table 5). Narzari and Sarmah [18] previously estimated the nutritional aspects of *Sympetrum* sp. (Odonata: Libellulidae), but toxic heavy metals were missing. In our study, arsenic concentrations in *Pantala* sp. were relatively high, followed by Cd, and Pb had a limit of detection of 0.05 mg kg⁻¹. This result was comparable to that of Aydoğan *et al.* [53]. They discovered that some aquatic insects (Coleoptera: Hydrophilidae) from Turkey's Karasu River had high arsenic levels (0.2 - 14.4 mg kg⁻¹). Similarly, Addo-Bediako and Malakane [54] reported As levels (range: 7.3 - 32.326 mg kg⁻¹) in Gomphidae (Odonata) larvae from the Blyde River that were higher than our results.

Table 5. Mean ± SD (n = 3) of heavy metal concentrations detected in *Pantala* sp. (mg kg⁻¹, dry weight) in the rice field.

Heavy metal	As	Cd	Pb
Limit of detection	0.02	0.01	0.05
mean	2.827	0.164	0.158
SD	0.289	0.007	0.015

Lead concentrations ranged from 0.142 to 0.172 mg kg⁻¹, with an average of 0.158 ± 0.015 mg kg⁻¹. Nasirian and Irvine [18] reported Pb and Cd levels in *Pantala flavescens* larvae (Odonata: Libellulidae) from the Shadegan and Hawr Al Azim wetlands that were similar to those in Table 5, though our Cd levels were higher. Furthermore, Choudhury *et al.* [5] discovered trace amounts of toxic heavy metals in the edible aquatic insect *Dytiscus marginalis* (Coleoptera: Dytiscidae). Local bioavailability, such as heavy metals from streams and sediments, could be one explanation. In particular, larger volumes of runoff due to rainfall and domestic waste enter the rice fields between May and October. Furthermore, these metals are commonly found in fertilizers and pesticides that are approved for use in Thailand. They could be present in the environment as natural or industrial contaminants [55]. Metal concentrations (i.e., Cd, Ni, Cr, As, Pb, Cu, Ti, Zn, and Mn) in aquatic insects may vary due to body size, life cycle stages, and different bioaccumulation patterns [56]. Thailand has no maximum levels for heavy metals in insect products. In contrast, the accumulation of Pb, Cd, and As in the edible aquatic insect *Pantala* sp. was compared to that of seafood. An edible aquatic insect from this study had a lower As content when compared to 13 different types of seafood (0.401 – 7.032 mg kg⁻¹) and a lower Cd content than the bivalve group (blood cockle = 0.731 mg kg⁻¹) from Rayong province, Thailand [57]. According to Thailand's Ministry of Public Health [58], the Cd content in this sample did not exceed the 1.0 mg kg⁻¹ maximum level for Cd in fish or the 2.0 mg kg⁻¹ maximum level for cephalopods, marine bivalve mollusks, and gastropods. The highest level of Pb found in this insect was less than 0.3 mg kg⁻¹, which is the maximum level for Pb in fish. Analyzing samples for arsenic content revealed that levels of 2.827 ± 0.289 mg kg⁻¹ exceeded the permissible limits (2.0 mg kg⁻¹) for food in Thailand. Arsenic is a common metalloid that can be found in low concentrations in rocks, soil, and natural water. Currently, no maximum levels of

arsenic in food have been established in the EU [59]. The source of arsenic contamination was unknown, but it was thought to be a combination of fertilizers, pesticides, and industrial effluent [60]. These findings provided information about contaminated heavy metals in edible aquatic insects that could be used to improve food safety in this region. However, this paper does not indicate that the levels of toxic metals detected in edible aquatic insects pose a risk to human health, but they can cause bioaccumulation in consumers. Long-term accumulation of Cd in the human body can cause carcinogenesis in the skeletal and respiratory systems, as well as damage to the lungs and kidneys, whereas Pb can harm the gastrointestinal, neurologic, hematologic, cardiovascular, and renal systems. As can cause cancer in the skin, lungs, liver, and bladder, and it is toxic to the nervous and pulmonary systems [61].

Conclusion

Eating insects has both benefits and disadvantages. According to this study, the edible aquatic insect found in rice fields contained high levels of protein, phosphorus, calcium, and iron. Furthermore, the tested insects act as reservoirs for essential amino acids (particularly lysine and histidine) and essential fatty acids (especially omega-3 and omega-6). Although insects have high nutritional value, edible insects must also be considered in terms of toxic metal bioaccumulation. This is about the possibility of food products entering the food chain. The concentration of heavy metals (particularly arsenic) in aquatic insects is determined by the metal concentration in the substrate in which they live and the stage of development of the insect. As a result, edible aquatic insects must assess their toxic elements as well, ensuring that the consumption of selected insects is safe.

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