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Proximate amino acid, fatty acid and mineral composition of two Sudanese edible pentatomid insects

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Abstract. The amino acid, fatty acid and mineral composition of *Aspongubus viduatus* F. (melon bug) and *Agonoscelis pubescens* (Thunberg) (sorghum bug) were investigated. The approximate analyses of *A. viduatus* and *A. pubescens* adults showed 8.3 and 7.6% moisture, 27.0 and 28.2% crude protein, 54.2 and 57.3% fat and 3.5 and 2.5% ash on a dry-matter basis, respectively. The bug protein contained 16 amino acids, including all of the essential ones. Compared with the amino acid profile recommended by FAO/WHO, the protein was of medium quality. The most predominant fatty acids in melon bug oil were oleic, palmitic, linoleic and linolenic acids, viz. 45.5, 31.3, 4.9 and 0.48%, respectively, and in sorghum bug 41.15, 11.41, 35.28 and 1.28%, respectively. The mineral analysis indicated high P and K content. Scanning electron microscopy was used to study ground insect structure before and after oil extraction. Micrographs of full-fat ground insects were different from defatted ones.

Key words: *Aspongubus viduatus*, *Agonoscelis pubescens*, amino acids, fatty acids, minerals, scanning electron microscope

Introduction

More than a thousand insect species are used as human food; some of the more important groups include grasshoppers, caterpillars, beetles, winged termites, bees, wasps and a variety of aquatic insects. In Africa, beetles, termites, caterpillars, grasshoppers, crickets, bees, maggots and butterflies are significant sources of food, with varying levels of proteins, fat, minerals and vitamins (Womeni *et al.*, 2009). Larvae of the African palm weevil *Rhynchophorus phoenicis* (F.) (Coleoptera: Curculionidae) are fried and eaten in several parts of western Nigeria; they are also marketed. Caterpillars of *Gonimbrasia belina* (Westwood) (Lepidoptera: Saturniidae), known as the mopane worm, are a popular food in Botswana, northern South Africa, Zimbabwe and Namibia (Banjo *et al.*, 2006).

During the past few years, there has been a new upsurge of interest in insects as food. One factor that may be responsible is an increasing awareness in the western world that insects are traditionally and nutritionally important foods for many non-western cultures (Foliart, 1992). It has been postulated that insects could be an important source of proteins of good quality and high digestibility (Ramos-Elorduy *et al.*, 1997; Zhou and Han, 2006). Banjo *et al.* (2006) analysed 17 species of

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edible insects representing nine families for their nutrient composition. These insect species constitute a significant component of diet among the people of southwestern Nigeria. They found high crude protein contents (27–30%). In Thailand, over 50 species of insects are edible and can be consumed throughout the year; these include silkworm pupae, bamboo caterpillars, locusts, beetles and crickets (Yhoung-Aree *et al.*, 1997). Oil extracted from the melon bug *Aspongopus viduatus* F. and the sorghum bug *Agonoscelis pubescens* (Thunberg) (both Hemiptera: Pentatomidae) is used as famine food in the western parts of Sudan and has traditional medicinal uses (Mariod *et al.*, 2004). In a study to determine the antibacterial activities of melon bug crude oil, silicic acid column purified oil and phenolic compounds-free oil by agar diffusion assay against seven bacterial isolates, Mustafa *et al.* (2008) reported that the crude oil and the phenolic compounds-free oil showed high antibacterial activities against some test species, while the silicic acid column purified oil showed no antibacterial activity. Ramos-Elorduy *et al.* (1997), analysing the nutrient composition of 78 Mexican edible insect species, reported protein content ranging from 15 to 81%, fat content from 4.2 to 77.2%, with carbohydrates up to 77.7% on a dry-matter basis. Their protein chemical score ranged from 46 to 96%; in a few cases, there were deficiencies of tryptophan and lysine protein digestibility (the amount of protein absorbed into the body relative to the amount that was consumed), and varied between 76 and 98% for the species analysed. Eaten daily in some regions, the insects are roasted, fried or incorporated into a ragout dish, generally in the immature stage. In Sudan, many edible insects are consumed and the desert locust is considered most popular in many parts of the country beside sorghum and melon bugs (Mariod *et al.*, 2004, 2006*a*), and grasshopper (van Huis, 2003).

The melon bug is mainly distributed in the western states (Kordofan and Darfour) of Sudan where it is known as 'um-buga'. The oil is extracted from the bugs by hot water and used in cooking and some medicinal applications, e.g. skin lesion remedy (Mariod *et al.*, 2004). Melon bugs are considered to be edible in Namibia, where the last nymph stage is called 'nakapunda'. In this soft stage, the bug is cooked and eaten (http://www. science.mcmaster.ca (retrieved 25 April 2009)). Many Namibians collect the adults and use them as a relish or as a spice in a ground form for cooking meals (http://www. natmus.cul.na (retrieved 14 May 2009)). The bug has a 45% oil content containing 46.5, 3.4 and 44.2% oleic, linoleic and palmitic (if referring to the hexadecanoic acid) acids, respectively, with low amount of tocopherol 0.3 mg/100 g and high oxidative stability of 38 h under Rancimat test (Mariod *et al.*, 2004).

Agonoscelis pubescens is considered as the main pest of sorghum (durra) in both rainfed and irrigated areas in Sudan where it is known as 'dura andat'. In western Sudan, the adult bugs are collected and eaten after frying, while in some other areas of Sudan the collected oil is extracted from the bugs and used for cooking and as medicine. In the Botana area of central Sudan, nomads use tar obtained from highly heated bugs for their camels against dermatological infections. Sorghum bug oil content was 60% with 40.9, 34.5 and 12.1% of oleic, linoleic and palmitic acids, respectively; the oil also contains 34 mg/100 g tocopherols (Mariod *et al.*, 2004).

Published works on melon and sorghum bugs as edible insects include: Mariod *et al.* (2004) on the fatty acid, tocopherols, sterols and oxidative stability of edible oils from melon and sorghum bugs; Mariod *et al.* (2006*b*) on the effects of different processing steps on the quality and stability of edible oils from melon and sorghum bugs; and Mariod *et al.* (2006*a*) on the frying quality and oxidative stability of sorghum bug oil. In addition, Tauscher *et al.* (1981) reported that in remote areas of Sudan, oil from melon bug is used as sweet-oil, and no poisonous effect of this oil was found. The bug-oil corresponds in its fatty acid composition with most of the other animal-derived oils.

Melon and sorghum bugs are commonly eaten in some Sudanese communities as a source of lipid and protein. However, data on their approximate analyses and nutritive value are scarce. The present study was designed to evaluate their amino acid, fatty acid and mineral compositions.

Materials and methods

Sample solvents and reagents

All solvents used were of analytical grade. *n*-Hexane, methanol, chloroform and petroleum-ether were obtained from Prime Ltd (Khartoum, Sudan), whereas HCl, NaOH, and HNO_3 and H_2O_2 suprapure grade were from Merck Ltd (Darmstadt, Germany).

Agonoscelis viduatus and *A. pubescens* bugs were collected in the Ghibaish province and from the Rahad Agricultural scheme area in Sudan, respectively. The collected bugs were stored in tight polyethylene bags, killed by hot water treatment and then sun-dried. Before representative samples were taken for chemical analysis, they were ground to obtain homogeneous samples. For determination of the oven-dry weight, samples were dried at 105 °C for 24 h.

Proximate chemical analysis

Moisture, protein, lipid, ash and carbohydrate contents were determined following the standard

Table 1. Approximate chemical analysis (mean ± SD) of two Sudanese edible insects (g/100 g dry weight)*

Component	*Aspongubus viduatus*	*Agonoscelis pubescens*
Moisture	8.3 ± 0.51c	7.6 ± 0.43c
Protein	27.0 ± 0.64b	28.2 ± 0.76b
Fat	54.2 ± 0.82a	57.3 ± 0.80a
Ash	3.5 ± 0.32e	2.5 ± 0.31e
Carbohydrates	7.0 ± 0.51d	4.4 ± 0.42d

Values followed by different letters within a column indicate significant difference at $P > 0.05$.
*Values are means (±SD) of three ($n = 3$) measurements. Values are on a dry-matter basis.

methods of the Association of Official Analytical Chemists (AOAC, 1995). Insect samples' organic nitrogen content was quantified by the Kjeldahl method and an estimate of the crude protein content was calculated by multiplication of the organic nitrogen content by a factor of 6.25. The different insect samples were analysed in triplicate. Total carbohydrate content was calculated from the difference.

Minerals by atomic absorption spectrophotometer

Ashes were dissolved in nitric acid (analytical grade; Merck) and passed through an ash-free, acid-washed filter paper (Albet no. 242, 9 cm diameter). Major mineral elements (Na, K, P, Ca and Mg) were determined in a novAA® 300 flame atomic absorption spectrophotometer (Analytik Jena, Wembley, UK), equipped with an automatic 6-lamp hollow cathode lamp for each element and an air-acetylene burner. Standards of mineral elements for flame atomic absorption spectrophotometry were obtained from Analytik Jena (Wembley, UK).

Minerals by variable-pressure scanning electron microscope (VP-SEM) equipped with energy dispersive X-ray (EDX) microanalyser

EDX microanalysis has been applied before to determine which elements are present in samples. Following the method of Abbdewahab *et al.* (2009*a*), samples were cut into 1 × 1 mm and mounted on aluminium stub specimen holders and viewed under a VP-SEM model LEO 1455 with an Oxford INCA EDX 300 attachment. Samples were examined at an accelerating voltage of 20 kV. For such analysis, three spectra from each sample were acquired for 120 s with process number 5. This experiment was conducted at the Microscopy Unit, Institute of Bioscience (IBS), University Putra Malaysia (UPM), Malaysia.

Fatty acids composition by gas–liquid chromatography (GLC)

The fatty acid composition of the insects was determined by GLC. The insect oils were converted to their corresponding methyl esters according to the American Oil Chemists' Society Official Methods (AOCS, 1998). BF_3–methanol was used for methylation. Fatty acid methyl esters (FAME) analysis was performed using a Hewlett-Packard HP-5890 Series II gas chromatograph equipped with an Ultra 2 (25 m × 0.32 mm × 0.5 μm film thickness) of 5% biphenyl and 95% dimethyl polysiloxane (Hewlett-Packard, Waldron, Germany) capillary column, a split injector (split ratio 88:1) and a flame ionization detector (FID). The column temperature program was 5 min at 150 °C, 10 °C/min to 275 °C, and 10 min at 275 °C. The injector and detector temperatures were 250 and 280 °C, respectively. The carrier gas was nitrogen at a flow rate of 1.6 ml/min. Air and hydrogen flow rates were 460 and 33 ml/min, respectively. The peaks of fatty acids were identified by comparing the retention times with those of a mixture of standard FAME (Sigma Chemicals Co., Deisenhofen, Germany). Each fatty acid methyl ester sample was analysed in duplicate.

Amino acid composition by amino acid analyser

Preparation of hydrolysate sample

The content of dry matter and total nitrogen were determined according to procedures described by the AOAC (1995) method. The content of amino acids (except for tryptophan) in defatted insects was determined using an Amino Acid Analyzer model L-8900 (Hitachi High-Technologies Corporation, Tokyo, Japan) under the experimental conditions recommended for protein hydrolysates. Samples containing 5.0 mg of protein were acid hydrolysed with 1.0 ml of 6N HCl in vacuum-sealed hydrolysis vials at 110 °C for 22 h. Ninhydrine was added to the HCl as an internal standard. Tryptophan, cystine and cysteine are completely lost by acid hydrolysis, and methionine can be

Table 2. Mineral composition (mean ± SD)* of *Aspongubus viduatus* and *Agonoscelis pubescens* insects (mg/100 g)†

Mineral	*Aspongubus viduatus*	*Agonoscelis pubescens*
Magnesium	301.10 ± 0.61	309.22 ± 0.61
Calcium	1021.21 ± 0.52	759.51 ± 0.64
Potassium	200.08 ± 0.63	412.52 ± 0.72
Phosphorus	1234.33 ± 0.63	923.11 ± 0.63
Sodium	401.10 ± 0.60	340.41 ± 0.62

*Mean (±SD) of three determinations.
†Values are on a dry-matter basis.

Table 3. Mineral contents (weight %)* of the defatted and undefatted sorghum bug (SB) and melon bug (MB)

Element	SB undefatted	SB defatted	MB undefatted	MB defatted
C	27.04 ± 0.13	27.04 ± 0.16	27.08 ± 0.07	26.80 ± 0.16
O	72.17 ± 0.20	72.40 ± 0.17	72.44 ± 0.11	71.96 ± 0.25
Mg	0.06 ± 0.00	ND	0.05 ± 0.01	ND
Al	0.05 ± 0.03	ND	0.06 ± 0.03	ND
Na	0.22 ± 0.05	ND	ND	0.2 ± 0.10
Si	0.09 ± 0.05	0.08 ± 0.00	0.07 ± 0.03	0.26 ± 0.00
P	0.08 ± 0.03	0.12 ± 0.08	0.08 ± 0.04	0.21 ± 0.03
S	0.07 ± 0.05	0.14 ± 0.09	0.06 ± 0.01	0.18 ± 0.05
Cl	0.30 ± 0.12	0.08 ± 0.32	0.02 ± 0.01	0.50 ± 0.23
K	0.19 ± 0.16	0.23 ± 0.20	0.15 ± 0.03	0.32 ± 0.13
Ca	0.04 ± 0.02	0.15 ± 0.09	0.05 ± 0.02	ND
Fe	0.05 ± 0.00	ND	0.17 ± 0.26	ND

*Values are means (± SD) of three ($n = 3$) measurements.

destroyed to varying degrees by this procedure. Hydrolysates were suitable for analysis of all other amino acids. The tubes were cooled after hydrolysis, opened, and placed in a desiccator containing NaOH pellets under vacuum until dry (5–6 days). The residue was then dissolved in a suitable volume of a sample dilution Na–S buffer, pH 2.2 (Beckman Instruments, Inc., Fullerton, CA, USA), filtered through a millipore membrane (0.22 μm pore size) and analysed for amino acids by ion-exchange chromatography in a Beckman (model 7300) instrument, equipped with an automatic integrator. Nitrogen in amino acids was determined by multiplying the concentration of individual amino acids by corresponding factors calculated from the percentage nitrogen of each amino acid (Sosulski and Imafidon, 1990). The ammonia content was included in the calculation of protein nitrogen retrieval, as it comes from the degradation of some amino acids during acid hydrolysis (Mosse, 1990; Yeoh and Truong, 1996). The ammonia–nitrogen content was calculated by the multiplication of ammonia by 0.824 ($NH_3 = 82.4\%$ of N).

Expression of results

The composition of amino acids was expressed as milligrams per gram of nitrogen to estimate the quality of the protein in insect samples using amino acid score pattern where amino acid ratios = (mg of an essential amino acid (EAA) in 1.0 g of test protein/mg of the same amino acid in 1.0 g of reference protein × 100) for nine EAAs calculated by using the FAO/WHO (1991) method.

SEM analysis

The morphology of the fine ground insect samples (defatted and undefatted) was examined by VP-SEM/EDX microanalysis. Following the method of Abbdewahab *et al.* (2009*a*), samples were cut into 1 × 1 mm and mounted on aluminium stub specimen holders and viewed under a variable-pressure model LEO 1455 with an Oxford INCA EDX 300 attachment. Samples were examined at an accelerating voltage of 20 kV. For such analysis, three spectra from each sample were acquired for 120 s with process time number 5. This experiment was conducted at the microscopy unit of IBS, UPM, Malaysia.

Table 4. Fatty acid composition (%)* of *Aspongubus viduatus* and *Agonoscelis pubescens* oils

Fatty acid	*Aspongubus viduatus* (mean ± SD)	*Agonoscelis pubescens* (mean ± SD)
Lauric acid (12:0)	0.01 ± 0.01	0.12 ± 0.01
Myristic acid (14:0)	0.34 ± 0.02	0.21 ± 0.02
Palmitic acid (16:0)	31.33 ± 0.3	11.41 ± 0.11
Palmitoleic acid (16:1*n*-7)	10.62 ± 0.1	1.04 ± 0.02
Margaric acid (17:0)	2.43 ± 0.1	0.14 ± 0.01
Stearic acid (18:0)	3.47 ± 0.1	7.77 ± 0.20
Oleic acid (18:1*n*-9)	45.53 ± 0.3	41.15 ± 0.20
Vaccenic acid (18:1*n*-11)	0.46 ± 0.02	0.73 ± 0.04
Linoleic acid (18:2*n*-6)	4.90 ± 0.02	35.21 ± 0.22
Linolenic acid (18:3*n*-3)	0.45 ± 0.01	1.28 ± 0.08
Eicosanoic acid (20:0)	0.26 ± 0.02	0.70 ± 0.08
Gadoleic acid (20:1*n*-9)	0.17 ± 0.03	0.12 ± 0.05
Behenic acid (22:0)	0.03 ± 0.00	0.12 ± 0.02
SFA	37.87 ± 0.60	20.47 ± 0.51
MUFA	56.78 ± 0.41	43.04 ± 0.32
PUFA	5.35 ± 0.10	36.49 ± 0.31
PUFA/SFA	0.14	1.78
n-6/*n*-3	10.8	27.5

MUFA, monounsaturated fatty acids.
*All determinations were carried out in triplicate and mean values (± SD) reported.

Table 5. Amino acid composition of *Agonoscelis pubescens* and *Aspongubus viduatus* (mg/g crude protein)*

Amino acid	*Aspongubus viduatus*	*Agonoscelis pubescens*	Chicken egg
Threonine	18.1	16.6	44.7
Glycine	20.0	12.8	30.2
Alanine	38.9	13.9	50.3
Cysteine	21.2	4.5	19.0
Valine	25.9	17.4	54.2
Methionine	35.9	2.7	28.1
Isoleucine	20.8	14.2	48.8
Leucine	22.6	19.5	81.1
Tyrosine	17.4	8.6	38.1
Phenylalanine	10.5	18.0	48.2
Histidine	20.6	11.4	20.9
Lysine	15.5	6.4	65.9
Aspartic acid	18.0	16.6	89.2
Serine	12.9	7.7	67.2
Glutamic acid	16.6	30.8	121.3
Ammonia	32.8	30.8	N.I.
Arginine	12.8	36.9	57.0
Total	360.5	268.8	864.2

* All determinations were carried out in triplicate and mean values (± SD) reported. N.I., not identified.

Statistical analysis

The analyses were performed with three replicates. The mean values and standard deviation (mean ± SD) were calculated and tested using the Student's *t*-test ($P < 0.05$). Analysis of variance was performed on all values using Statgrafics® Statistical Graphics System version 4.0 (Statgraphics®, 1985–1989).

Results and discussion

The proximate composition

The values obtained for moisture, crude protein, fat, ash and carbohydrate content from the present study for *A. viduatus* were 8.3, 27.0, 54.2, 3.5 and 7.0%, while for *A. pubescens* they were 7.6, 28.2, 57.3, 2.5 and 4.4%, respectively (Table 1). *Agonoscelis pubescens* contained higher levels of protein and fat than *A. viduatus*. The two constituents (crude protein and fat) are high (85.5 and 80.2%) on a dry-matter basis, which makes the two insects a good source of protein and oil, which can be a supplement to fat and protein foods. The oil content was 54.2 and 57.3%, in *A. viduatus* and *A. pubescens*, respectively, which was different from the values reported by Mariod *et al.* (2008), i.e. 45% for *A. viduatus* and 60% for *A. pubescens*. Ramos-Elorduy *et al.* (1997) reported protein and fat content that ranged from 33 to 65% and 19 to 54%, respectively, for other hemipteran bugs.

Minerals

Mineral analysis by atomic absorption spectrophotometer

Concentrations of major elements such as Mg, Ca, K, P and Na in *A. viduatus* (301.10, 1021.21, 200.08, 1234.33 and 401.10 mg/100 g) were significantly ($P < 0.05$) higher (except for Mg and K) than in *A. pubescens* (309.22, 759.51, 412.52, 923.11 and 340.41 mg/100 g for Mg, Ca, K, P and Na, respectively) (Table 2). Calcium, a mineral that is essential to bone structure and function in *A. pubescens* was about 74% of that in *A. viduatus*. Potassium plays an important role in the human body and sufficient amounts from it in the diet protect against heart disease, hypoglycaemia, diabetes, obesity and kidney disease. The content of potassium in *A. pubescens* was twice the amount found in *A. viduatus*.

The calcium, sodium, phosphorus and potassium contents in the two insects are higher than that of four types of fish (Martínez-Valverde *et al.*, 2000), which were 351.0–476.0, 64.89–160.0, 421.0–1047.0 and 104.0–446.0 mg/100 g, respectively. In the

Table 6. EAA composition of two Sudanese edible insects compared with the FAO/WHO pattern (mg/g crude protein)*

			FAO/WHO (1991)		Amino acid score	
Amino acid	*A. viduatus*	*A. pubescens*	2–5 years old	Adult	*A. viduatus*	*A. pubescens*
Isoleucine	20.8	14.2	28	13	0.52	0.35
Leucine	22.6	19.5	66	19	0.32	0.28
Lysine	15.5	6.4	58	16	0.28	0.12
Methionine + cysteine	57.1	7.2	25	17	1.6	0.21
Phenylalanine + tyrosine	27.9	26.6	63	19	0.47	0.44
Valine	25.9	17.4	35	13	0.52	0.35
Histidine	20.6	11.4	19	16		
Total of EAAs	208.5	119.3	294	113		
Total of non-EAAs	152.0	149.5				
Percentage of EAAs in total AAs	57.8	44.4	40%			
Ratio of EAAs: non-EAAs	1.4	0.79	0.6			

* All determinations were carried out in triplicate and mean values (± SD) reported.

same manner, calcium, sodium, phosphorus and potassium contents were higher in the two insects than that of snails (Ozogul *et al.*, 2005), which were 726.3, 90.5, 104.5 and 82.2 mg/100 g, respectively.

Mineral analysis by EDX combined with VP-SEM microanalysis

Mineral analyses by SEM seem to be a very quick method, but it is a quantitative rather than a qualitative method, and many authors use this method to analyse different samples, e.g. medicinal plants (Abbdewahab *et al.*, 2009*a*,*b*). Apart from carbon and oxygen, both insects contain most of the elements. Defatted, dried and ground insects contained fewer minerals than the undefatted ones; and magnesium, aluminium, sodium and ferrous contents were not detected in the defatted insects (Table 3).

Fatty acid analysis

According to data in Table 1, *A. viduatus* and *A. pubescens* contain high concentrations of lipids (54.2 and 57.3%, respectively) and analyses were made to investigate the fatty acid profile. The fatty acid composition determined by gas chromatography in *A. viduatus* and *A. pubescens* oils is oleic (45.53 and 41.15%), linoleic (4.90 and 35.21%) and palmitic (31.33 and 11.41%) acid, respectively. Mariod *et al.* (2004) reported similar values, i.e. 46.6 and 40.9% for oleic, 3.9 and 34.5% for linoleic and 30.9 and 12.2% for palmitic acids in *A. viduatus* and *A. pubescens* oils, respectively. *Aspongubus viduatus* and *A. pubescens* have 37.9 and 20.5% of saturated

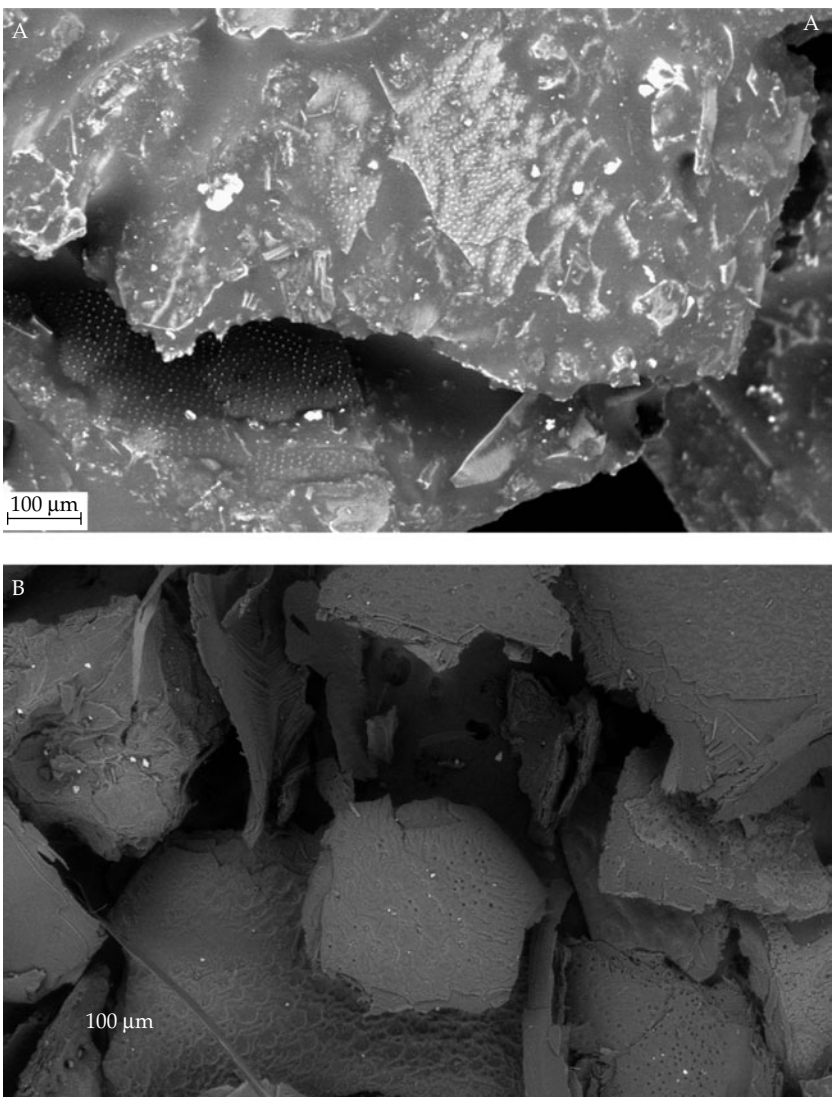

Fig. 1. Scanning electron micrographs of (A) full-fat melon bug and (B) defatted melon bug

fatty acids (SFA), 56.8 and 43.0% of monounsaturated fatty acids and 5.3 and 36.5% of polyunsaturated fatty acids (PUFA), respectively (Table 4).

The balanced ingestion of foods containing PUFAs reduces cardiovascular disorders. The PUFA:SFA ratio in the oil of *A. viduatus* is relatively lower (about 0.14), while it is relatively high (about 1.78) in the case of *A. pubescens* (Table 4). This ratio is recommended to be 0.45 for a healthy diet; so *A. viduatus* oil seems to be healthier than that of *A. pubescens*. In addition, the two insect oils have a *n*-6/*n*-3 fatty acids ratio (10.8 and 27.5 for *A. viduatus* and *A. pubescens*, respectively) that should be smaller than 4.0 as suggested by the UK Department of Health (1994).

Protein and amino acid analysis

Aspongubus viduatus and *A. pubescens* contain high concentrations of protein (27.0 and 28.2%, respectively, on a dry-matter basis) and analyses were made to investigate the amino acid profile (Table 5). The total amino acids were 360.5 and 268.8 mg/g crude protein in *A. viduatus* and *A. pubescens*, respectively, which was less than the 864.2 mg/g crude protein in chicken egg that is considered as a main protein source in the human diet (Table 5). The percentage of sulphur-containing amino acid (methionine and cysteine) in *A. viduatus* was 57.1 mg/g crude protein, while in *A. pubescens* it was 7.2% mg/g crude protein, which can be considered a reasonable amount for their important

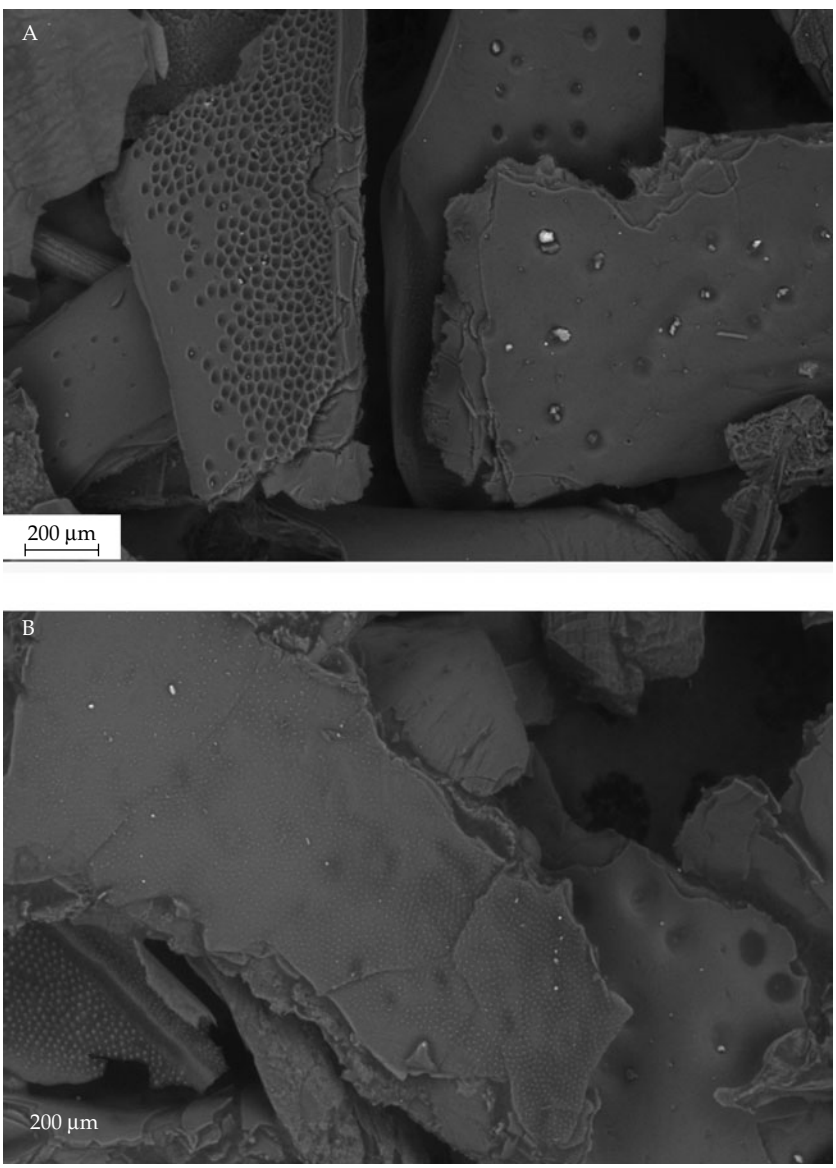

Fig. 2. Scanning electron micrographs of (A) full-fat sorghum bug and (B) defatted sorghum bug

function in the cell processes in the oxidation and reduction system (cysteine) and its role as a methyl donor (methionine) in metabolism (Heimann, 1980). The total amount of the EAAs found in *A. viduatus* and *A. pubescens* was 208.5 and 119.3 mg/g crude protein, respectively, which were higher than the values recommended by FAO/WHO (1991) (113 g protein for adults). The EAA profile of *A. viduatus* and *A. pubescens* protein (Table 6) revealed that the levels of EAAs were comparable with those of the FAO/WHO amino acid reference (FAO/WHO, 1991) established for human adults. According to the amino acid scores, the first limiting amino acid of the melon bug protein was lysine and the second was leucine followed by phenylalanine + tyrosine, while in the sorghum bug protein the first limiting amino acid was lysine and the second was methionine + cysteine followed by leucine.

SEM

SEM, widely applied in insect morphology (Korchi *et al.*, 1998; Tellam *et al.*, 1999; Hopkins *et al.*, 2000), was used to study the surface structures of the two bugs' particles (Figs 1 and 2). When the dried bugs were ground mechanically, oil and other cellular contents were exposed and oil drops were very clear in full-fat samples (Figs 1A and 2A). When the dried bugs were ground, cell walls were disrupted, exposing more lipid bodies; this exposure greatly improved the rate of extraction and oil yield. Clear changes were observed in the appearance of the defatted bugs (Figs 1B and 2B). When the oil was removed from the ground and dried bugs by solvent extraction, the insect structure under the SEM seemed to be clear of oil when compared with the full-fatted samples.

Conclusions

Insects are traditional foods in Sudanese cultures, mainly in the western (Kordofan and Darfur) and Blue Nile states where they play an important role in human nutrition, providing important nutrients. This study revealed that the melon bug *A. viduatus* and the sorghum bug *A. pubescens*, pests for watermelon and sorghum, also have high nutritional qualities and are indeed a good source of protein, fatty acids and other nutrients (minerals) that are often in short supply in parts of Sudan. The consumption of these insects, therefore, should be encouraged and it would be ideal if these species were not only collected but also cultivated.

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