Original Research Article

Protein Fractions, Physicochemical and Functional Properties of Flour and Oil from the Shea Caterpillar *Cirina butyrospermi* Vuillet Consumed in Northern Côte d'Ivoire

ABSTRACT (ARIAL, BOLD, 11 FONT, LEFT ALIGNED, CAPS)

The Shea Caterpillar *Cirina butyrospermi* Vuillet is one of the most widely eaten insects in the Northern Côte d'Ivoire as alternative protein source. The present study was aimed at evaluating the physicochemical and functional properties of flours and oil from dried *C. butyrospermi* larvae for further food products formulation. Fresh *C. butyrospermi* larvae were collected from *Vitellaria paradoxa* trees in the different regions producing shearbutter in northern Côte d'Ivoire. The larvae were oven dried and ground to obtain crude flour. Flours and Oil extracted from this insect was analysed for physicochemical properties and fatty acid constituents using standard methods. The chemical composition revealed that it contains crude protein about 60.09%, crude fat 22.23%, ash 3.71% and total carbohydrate 6.69%. These results suggest that *C. butyrospermi* larvae can be used in human diet to prevent undernourishment due to protein. Albumin and glutelin constitute the main part of protein fractions. The defatted flour showed good functional properties such as water and oil absorption capacity (77.96 and 150.00 % respectively), dispersibility (70.90 %), wettability (5 min) and foam stability (50.05 %) making it suitable for many food product formulations. As regards oil, it exhibited good physicochemical properties as saponification and stability. Fatty acids profile reveals that the unsaturated fatty acids accounted for 49.33 % of the total fatty acids, whereas the saturated fatty acids constituted 49.83 % of the fatty acids. when compared with oils which have been reported of high quality, *C. butyrospermi* oil has potentials that could be exploited for nutritional and pharmaceutical purposes.

Keywords: Cirina butyrospermi larvae, Protein, Fat, Physicochemical and Functional Properties, Northern Côte d'Ivoire

1. INTRODUCTION

In the context of sustainable diet, eating of insect (entomophagy) has a significant role to play in assuring food security and improving the livelihood of many peoples in world [1, 2]. Indeed, entomophagy has a long history as part of human diets [3] and more than 2 000 insect species have been documented in the literature as edible, most of them in tropical and developing countries[4].In Africa, Asia and Latin America, approximately 2.5 billion people eat insects as a part of their common diets in a similar way as eating meat or fish. Assiélou et al. [5] argue that insect's consumption has become especially important as the need for alternative protein sources increases due to rapid urbanisation in developing countries and the shifts in the composition of global food demand.

Concerning the nutritional content, edible insects have been noted as comparable to conventional livestock meat[6].They are considered food with satisfactorily energy, macronutrient and micronutrient (such as minerals copper, iron, magnesium, manganese, phosphorous, selenium, and zinc and the vitamins riboflavin, pantothenic acid, biotin, and in some cases folic acid) contents [7]. Many studies have pointed out the high protein content and the good quality of fats from caterpillar and larvae as *Imbrasia oyemensis* [8 – 10], *Imbrasia belinae* [11], *Oryctes boas* and *Oryctes rhinoceros* [12], *Oryctes awariensis* [5, 13], *Rhynchophorus phoenicis* [14], *Cirina forda* [15].These caterpillars were found to be highly nutritious and then, contributed to the significant reduction of protein and other nutrient deficiencies [16]. Moreover, they also provide economic advantages insofar as they create profitable activities based on their collection, processing and sale on national and international markets [17].

In Africa, most edible caterpillars belong to Saturniidae, Notodontidae and Sphingidae families of the order Lepidoptera. Among them, the *Cirina butyrospermi* Vuillet caterpillar, commonly known as *shitumu*, an insect pest of *Vitellaria paradoxa*, the shearbutter tree [16]. This edible insect is mainly found in the western and south-western regions of Burkina Faso and neighbouring countries as Côte d'Ivoire where they are found mainly in the north region. Basically, the lifecycle of *C. butyrospermi* comprises a larval, a nymphal and an adult stage[18]. The larvae are collected in the rainy season and then, processed into the dried form and consumed as a delicacy served in snacks or as an essential ingredient in vegetable soup along with carbohydrate food[19, 20].These larvae are widely accepted and prized as protein and fat sources the north of Côte d'Ivoire. The present paper focuses on the physicochemical and functional properties of flours (full fat and deffated) and oil from dried *C. butyrospermi* larvae for further food products formulation. Indeed, as regards functional properties of foods, they are intrinsic physicochemical characteristics affecting the behaviour of protein in food systems [21]. Also, physicochemical properties and fatty acid composition of *C. butyrospermi* larvae oil would reveal any possibility of its use as conventional oils for human and animal nutrition and industrial purposes.

2. MATERIAL AND METHODS

2.1. Larvae collection and sample preparation

Alive *C. butyrospermi* larvae were collected from *Vitellaria paradoxa* trees in the different regions producing shearbutter in northern Côte d'Ivoire. These are mainly the regions of Katiola (8°08'15" N and 5°06'07" W), Bondoukou (8°02'23" N and 2°47'54" W), Bouna (9°16′09″ N and 2°59′42″ W), Korogho (9°27′41″ N and 5°38′19″ O), Ferké (9°35′37″ N and 5 11′50″ O), Boundiali (9°31′18″ N and 6°29′12″ O), Odienné (9°30′05″ N and 7°33′45″ O). At least 10 kg of Caterpillar were collected per region. The collected caterpillars were conditioned in a cooler containing ice to maintain their freshness and then transported to the laboratory for treatment and sample preparation. At the laboratory, the different samples are put together to form a single batch for flour preparation. Then, 10 kg of larvae were cleaned with distilled water, drained and oven dried at 65°C for 72 h. the raw flour is obtained by grinding dry caterpillars using a Moulinex brand.

2.2. Protein fractionation

The modified method of Hu and Essen [22] was used to fractionate proteins of *C. butyrospermi* larvae. The extraction solvents were deionized distilled water, 0.5 M NaCl (30 mL: 1 g), 70% ethanol (w/v) and 0.1 M NaOH (25 mL: 1 g). Albumin, globulins, prolamins and glutelins constitute respectively, the water-soluble fraction, fraction soluble in salt solution, the ethanol soluble fraction and NaOH soluble fraction. Proteins were extracted by simply stirring, using a flour to solvent ratio of 1:10 (w/v), for 14-16h at 4°C. Insoluble residue

was removed by centrifugation at 6000 rpm for 30 min. The obtained fractions were dialysate against their own solvent, then against deionized water. The final dialysates were kept in the freezer at about -20 °C. The protein amounts of soluble fraction were measured according the folin ciocalteu's method of Lowry et al. [23]. Bovine serum albumin (BSA) was used as the protein standard. The nitrogen content of insoluble fraction (residue) was determined by Kjeldahl method [24].

2.3. Oil extraction

Oil was extracted from 3 g of caterpillar flour (full-fat flour) with 70 mL of n-hexane in a Soxhlet extractor [24]. Then, the solvent was gently evaporated with a rotary evaporatorty (Heidolph, Hei-Vap, Germany). The extracted lipid was weighted to determine the oil content of caterpillar. Crude oil was stored at 4 °C in airtight brown sterile glass bottle until further use for physicochemical analysis.

2.4. Analysis

2.4.1. Chemical Composition

The dry matters contents were determined by drying in an oven at 105°C during 24 h to constant weight [24]. The crude protein contents were calculated from nitrogen contents (N×6.25) obtained using the Kjeldahl method by AOAC [24]. The crude fat content was determined by continuous extraction in a Soxhlet apparatus for 8 h using hexane as solvent [24]. The total ash contents were determined by incinerating in a furnace at 550°C [24]. The carbohydrate contents were determined by deducting the mean values of other parameters that were determined from 100. Therefore % carbohydrate = 100- (% moisture + % crude protein + % crude fat + crude fiber + % ash). Energy value was calculated using standard calculations ([gram of crude protein × 4.0] + [gram of crude fat × 9.0] + [gram of carbohydrates × 4.0]).

2.4.2. Specific gravity and refractive index

The specific gravity and the refractive index of extracted oil were determined at 25 °C respectively with a pycnometer and a refractometer (Abbe, Optic Ivymen, Spain) [25].

2.4.3. Acid, peroxide, iodine and saponification values

All these parameters were determined according to AOAC [24] official methods. The acid index was determined by titration using a a solution of KOH (1N) in the presence of phenolphthalein. Iodine value was measured by titration using a sodium thiosulfate (0.1 N) solution. The titrated solution consists of 30 mL carbon tetrachloride, 0.4 g oil, 25 mL of Wijs reagent and 10 mL of acetate mercury. As regards the peroxide value, a mixture of acetic acid – chloroform: 3/2 (v/v) added to a potassium iodine solution were titrated with a solution of sodium thiosulfate (N/100). Concerning the saponification value, after the treatment of 2 g oil using alcoholic potash (0.5 N), the titration was done with a hydrochloric acid (0.5 N) solution in the presence of phenolphthalein.

2.4.4. Fatty acid composition.

The European Communities [26] method was used to determine the fatty acid composition of extracted oil. Fatty acids were converted to their methyl esters (FAMEs) as follow: a mixture of 2 mL of n-heptane and 0.2 mL of a methanolic solution of potassium hydroxide (2N) was made and stirred strongly for 30 s and allow to stand for 5 min. the FAMEs are found in the

upper phase which was used for quantification by gas chromatography. The internal standard (erucic acid) was added to FAMEs and then, 1 µL of the mixture was injected into a gas chromatograph (Shimadzu, GC 14 A, Japan) equipped with a flame ionization detector (FID) and a capillary column TRD1 (60 m X 0.25 mm i.d. X 0.25 µm film thickness). Nitrogen was the carrier gas with a flow rate of 23 mL/min. A temperature of 250°C has been set for detector and injector. For the column, the temperature starts at 100 degrees, then it was programmed to increase by 5°C every minute until reaching 220°C. The internal standard was used to correct chromatographic areas. Fatty acid amounts were estimated as the equation below:

$$\text{Yield of each fatty acid} = \frac{\text{Area of the fatty acid}}{\text{Area of total fatty acid in the oil sample}} \text{ X } 100$$

2.4.5. Functional properties

The water absorption capacity of flours from *C. butyrospermi* larvae were evaluated according to Phillips et al. [27] method. For the oil absorption capacity, the method of Beuchat [28] was used. The foaming capacity (FC) and stability (FS) of flour was studied according to the method of Coffman and Garcia [29]. The dispersibility of flours was measured according to the method of Mora-Escobedo et al. [30]. The volume and bulk density were determined according to the method of Okezie and Bello [31]. The method described by Onwuka [32] was adopted for wettability.

2.5. Statistical Analysis.

All experiments in this study are reported as means of three replicate analyses. One-way analysis of variance (ANOVA) was carried out to compare the mean values. Differences in the mean values were determined using Duncan's multiple range tests (SAS, 1990).

3. RESULTS AND DISCUSSION

3.1. Proximate composition

Table 1 presents biochemical composition of *C. butyrospermi* crude flour. With a moisture value of 4.44 %, these results reveal that *C. butyrospermi* larvae had high dry matter (95.56 %) than those reported for other larvae such as *O. owariensis* (91.59 %), *O. rhinoceros* (83.3 %) and *R. phoenicis* (88.7 %) [33, 5]. The high dry matter content should be advantageous since it is well known that low moisture ensures higher shelf stability of dried product. Thus, microbial proliferation is reduced, and storage life may be prolonged if stored inside appropriate packaging materials under good environment conditions [34].
The ash content of 3.71 % obtained in the present study is not very different from the one reported by Koffi et al. [14] for the palm (*Elaeis guineensis*) weevil *R. phoenicis* larvae. But it is higher than values reported for several edible insects such as *C. forda* (1.50 %), *Oryctes boas* (1.50 %) and *Zonocerus variegatus* (1.20 %) commonly eaten in South-western Nigeria [35]. This indicates that *C. butyrospermi* larvae constitute good source of mineral elements insofar as the ash content indicates a rough estimation of the mineral content of the product.
As regards proteins, the studied larvae could be categorized as protein-rich edible caterpillar. Indeed, with a value of 60.09 %, the protein content of *C. butyrospermi* is greater

than those found for larvae of *C. forda* (20.0 %) [36], *I. oyemensis* (57.77 %) [8], *O. boas* (26 %) [35] and *O. owariensis* (50.64 %) [5]. The high protein content obtained in this study suggests that *C. butyrospermi* larvae can support the protein need of the vulnerable populations such as poor peasants, pregnant woman and children, and solve the problem of malnutrition especially in developing countries where children suffering from kwashiorkor (a protein deficiency condition). Moreover, the fat content of 22.23 % could indicate that this caterpillar as well as several studied larvae constitute an ideal energy food since lipids are the main energy source and the energy value is mainly affected by the proportion of fat in the sample [37]. The obtained energy value (467.79 kcal/100 g DW) shows that the consumption of 100 g dry larva would provide about 25 % the daily energy intakes recommended for a 70 kg person. Therefore, this edible insect could be categorized as a source energy diet and represent a good alternative to prevent the risk of food chain insecurity in developing countries.

It is noteworthy that *C. butyrospermi* larvae are poor in carbohydrates since their content was found to be lower than values reported for many edible insects consumed in Nigeria with values ranged from 7 to 20 % [38]. Koffi et al. [14] found a carbohydrate content of 23.04 % for *R. phoenicis* larvae. As reported by Raksakantong et al. [39], *C. butyrospermi* could be categorized as a low-carbohydrate–high protein (LC–HP) diets. Such diets have a reduced intake of calories, resulting in a predictable degree of weight loss and, a significantly beneficial effect on a variety of cardiovascular risk factors [40].

Table 1. Chemical composition of dry *Cirina butyrospermi* larvae

Parameters	Values (%)
Moisture	4.44 ± 0.02
Dry matter	95.56 ± 0.02
Ash	3.71 ± 0.04
Crude fats	22.23 ± 0.14
Crude proteins	60.09 ± 0.13
Carbohydrates	6.69 ± 0.33
Energy value (kcal/100g)	467.79 ± 0.6

Values given are the averages of at least three experiments ±SE.

3.2. Protein fractions

C. butyrospermi proteins were fractioned from its full-fat and defatted flours based on their solubility in different solvents. The results given in table 2, show that in both full-fat and defatted flours, albumin fraction was predominant, followed by glutelin, globulin and prolamin. Statistical analysis revealed significant difference in values obtained for the two flours suggesting that defatting influence protein fractions, especially for albumin (43.96 % in full-fat flour and 44.83 % in defatted flour) and globulin (25.98 % in full-fat flour and 34.77 % in defatted flour) content which increase. Akpossan et al. [9] found similar results for *I. oyemensis* larvae. As reported by Roche et al. [41], Albumin, the major protein fraction of the studied edible insect, exerts important antioxidant activities. The molecule acts through its multiple-binding sites and free radical-trapping properties. For example, these authors argue that administration of albumin to patients with Acute Respiratory Distress Syndrome (ARDS) confers robust protection against oxidative stress and a favourable influence on redox-signalling processes regulating inflammation. As regards glutelin, the secondary major protein fraction of the studied edible insect, it is generally associated to elasticity and toughness properties in flours [42].

Table 2. Protein fractionation of dry *Cirina butyrospermi* larvae flours

Fractions		Flour samples	
		Full-fat	Defatted
Soluble fraction (%)	Albumin	43.96 ± 0.22[b]	44.83 ± 0.09[a]
	Globulin	12.07 ± 0.65[a]	8.10 ± 0.15[b]
	Prolamin	10.63 ± 1.04[a]	6.01 ± 0.09[b]
	Glutelin	25.98 ± 1.91[b]	34.77 ± 0.99[a]
Insoluble fraction (%)		10.34 ± 1.01[a]	6.28 ± 0.42[b]

Values given are the averages of at least three experiments ±SE. In each line, values assigned with different letters are significantly different at P ≤ 0.05. Those with identical letters are not different.

3.3. Functional properties.

The functional properties of flours from *C. butyrospermi* larvae were summarized in table 3. It is noteworthy that defatting greatly influences functional characteristics insofar as significant ($p \leq 0.05$) differences were observed in all parameters except dispersibility. The dispersibility indicates reconstitutability of a mixture in water. The value obtained (70.90 and 71 %) were higher compared to those found by Dué et al. [43] for wild edible mushrooms *Volvariella volvacea* (48.64 %) and *Armillaria mellea* (37.49 %) indicating the better ability of *C. butyrospermi* flours to reconstitute in water to give a fine and consistent paste. Such a useful functional property in various food product formulations [30].

Bulk density was observed in the range of 0.44 – 0.53 g/mL. Defatted flour shows the highest value. However, bulk density values found in this study are lower than those reported for *I. belina* (0.67 – 0.71 g/mL) and *I. oyemensis* (1.00 – 1.04 g/mL) larvae [11, 9]. This suggests that the studied flours were less heavy and therefore, they would occupy more space and require relatively more packaging materials. Also, bulk density is an indication of porosity and it has been reported to depend on the combined effects of interrelated factors such as the intensity of attractive interparticle forces, particle size, and number of contact points [44].

As suggest by Akpossan et al. [9], results show that the high fat content greatly influences the wettability. indeed, defatted flour wet very quickly (5 s) while wettability for full-fat flour was found to be 180 s. Therefore, the defatted flour would be useful to produce aqueous beverages and batters since wettability was reported to be an important property when protein powders are dispersed to make these products. Also, Wettability of proteins is affected by surface polarity, topography, texture, area and by the size and microstructure of the protein particles [45].

The water absorption capacity represents the ability to bind water molecules under deficient water conditions. This ability is generally attribute to the protein and carbohydrate content. In this study, the water absorption capacities were found to be lower than values observed for various edible larvae flours such as *O. owariensis* (220.33 %) and *R. phoenicis* (281.73 %) [5, 14]. The low values of water absorption capacity might be due to the low carbohydrate content since according to Aremu et al. [46], flours with high water absorption capacity have more hydrophilic constituents such as polysaccharides. As regards the oil absorption capacities, they are in the range of 119 – 150 %. It is an essential parameter since oil increase the mouth feel of food and act as flavour retainer in certain food products. *C. butyrospermi* would be a good sample for this property compared to others edible insects such as *Z variegatus* [47]. Therefore, the studied larvae flours would find useful application in food systems such as ground meat formulations.

Results showed very low foamability (2.09 %) for the full-fat flour while a value of 30.52 % was obtained for defatted flour. This suggests clearly that defatting increase foamability. So, crude flour from *C. butyrospermi* larvae is not a good foaming agent, unlike defatting flour (with Foam stability of 50.05 % after 120 min) that could be useful to improve the texture, consistency and appearance of foods such as cake and ice cream which requires a certain

percentage of foam [48]. Low foamability can be related to highly ordered globular proteins, which resists surface denaturation [49].

Table 3. Functional properties of dry *Cirina butyrospermi* larvae flours

Parameters	Values	
	Full-fat flour	**Defatted flour**
Dispersibility	71.00 ± 0.17[a]	70.90 ± 0.41[a]
Bulk density	0.44 ± 0.06[b]	0.53 ± 0.08[a]
Wettability	180.00 ± 0.00[a]	5.00 ± 0.00[b]
Water solubility index	17.15 ± 0.05[b]	30.00 ± 0.02[a]
Water absorption capacity	71.17 ± 1.43[b]	77.96 ± 0.50[a]
Oil absorption capacity	119.00 ± 1.00[b]	150.00 ± 2.00[a]
Foaming capacity	2.09 ± 0.01[b]	30.52 ± 0.01[a]
Foam stability	2.33 ± 0.01[b]	50.05 ± 0.01[a]

Values given are the averages of at least three experiments ±SE. In each line, values assigned with different letters are significantly different at P ≤ 0.05. Those with identical letters are not different.

3.4. Physicochemical properties of oil

Physicochemical characteristics of *C. butyrospermi* oil are shown in Table 4. The oil from the studied larvae was fluid at room temperature (approximately 16°C). Specific gravity was of 0.91 while refractive index was found to be 1.465. These values were in close agreement with values reported for conventional edible oils [50]. The refractive index of oils depends on their molecular weight, fatty acid chain length, degree of unsaturation, and degree of conjugation. In view of this refractive index, it seems that oil from *C. butyrospermi* larvae has fatty acids with high number of carbon atoms and several double bonds [51]. Moreover, this parameter suggests that the studied oil is of edible quality and is disqualified for varnish manufacturing in chemical industry.

The refractive index is positively related to iodine value, which is a measure of the degree of unsaturation in the oil and gives an idea of their oxidative stability since it could be used to quantify the amount of double bonds present in the oil. For this study, the obtained iodine value was of 115.85 g I_2/100 g, which is higher than the 105.19 g I_2/100 g and 48.35 g I_2/100 g reported for *I. oyemensis* [10] and *Rhynchophorus palmarum* [52] larvae, respectively. The high iodine value implies high nutritional value insofar as unsaturated fatty acids are recommended for human consumption.

The peroxide value of oil from *C. butyrospermi* larvae was 3.12 ± 0.02 mEq/Kg, which is less than the maximum acceptable value of 10 meq KOH/g set by the Codex Alimentarius Commission. It is well known that the peroxide value is used as an indicator of deterioration of oils, thus low peroxide value indicates resistance of the oil to peroxidation during storage. Fresh oils have peroxide values lower than 10 meq O2/kg and before oil becomes rancid, its peroxide value must be between 20 and 40 meq O2/kg [53]. The studied oil is therefore stable and would not easily go rancid.

Acid value recommended for oil to be used in cooking is in the range of 0.00 to 3.00 mg KOH/g. So, with an acid value of 1.97 mg KOH/g, oil from *C. butyrospermi* larvae could be suitable for cooking. Moreover, the free fatty acid value obtained (0.92 %) is very lower than the maximum limit of 5% for free fatty acids in high grade palm oil in Nigeria [54]. This suggests that the studied oil is not much susceptible for fat degradation process during oil extraction too and it could have a long shelf life, which allows it to be consumed as virgin edible oil.

The saponification value of *C. butyrospermi* oil was found to be 299,17 mg KOH/g of oil. This value is higher than that reported for *R. palmarum* (151.79 mg KOH/g of oil) and *I. oyemensis* (184.20 mg KOH/g of oil) respectively by [52, 10]. Saponification value is an

index of average molecular mass of fatty acids in oil sample. High saponification value indicated the presence of greater number of ester bonds, suggesting that the fat molecules were intact. This corroborate the low acid value and free fatty acids obtained. Due to its high saponification properties, the studied oil would be useful in soap making industry.

Table 4. Physicochemical properties of oil from dry *Cirina butyrospermi* larvae

Parameters	Values
Refraction index	1.465 ± 0.002
Specific gravity	0.91 ± 0.10
Acid value (mg KOH/g)	1.97 ± 0.17
Free fatty acid (% oleic acid)	0.92 ± 0.03
Saponification value (mg KOH/g)	299.17 ± 5.42
Iodine value (g I_2/100 g)	115.85 ± 0.8
Peroxide value (meq O_2/kg)	3.12 ± 0.5

Values given are the averages of at least three experiments ±SE.

3.5. Fatty acid composition

Figure 1 depict the fatty acid profile of *C. butyrospermi* larvae oil. Data summarised in Table 5 showed that the oil had similar content of unsaturated (49.33 %) and saturated (49.83 %) fatty acids. The presence of both saturated and unsaturated fatty acids in this insect could be an advantage since they may complement the functions of one another. The major unsaturated fatty acids were linolenic acid (27.83 %), oleic acid (12.14 %) and linoleic acid (6.97 %). Linoleic and linolenic acids are important essential fatty acids required for growth, physiological functions and body maintenance [55]. Also, oleic acid as well as linoleic and linolenic acids had been shown to be hypocholesterolemic [56]. the most abundant saturated fatty acids (SFA) were stearic acid (31.85 %) and palmitic acid (17.16 %). These two fatty acids are often used in food industries to provide texture and softness to products [57]. Moreover, stearic acid has been shown to be free from deleterious effect on plasma cholesterol in young healthy men [58].

The high polyunsaturated fatty acids (PUFA) content (34.80 %) when compared to those of veal (8.22 %), pork (11.81 %), chicken (23.44 %) and eggs (21.98) [59] would corroborate the high iodine value obtained in this study. So, diet with excessive amounts of omega-6 PUFA and a very high omega-6/omega-3 ratio, has been reported to promote the pathogenesis of many diseases, including cardiovascular disease, cancer and inflammatory and autoimmune diseases [60]. *C. butyrospermi* larvae oil shown a ratio omega-6/omega-3 of 0.25 which is extremely lower than the critical ratio of 5.00 recommended by nutritionists to reflect the need for a nutritional equilibrium. In addition, the ratio PUFA/SFA was of 0.70. This value is in close agreement with the ratio of 0.8 associated with desirable levels of cholesterol and reduced coronary heart diseases. Unlike, PUFA/SFA ratio as low as 0.2 has been associated with high cholesterol level with high risk of coronary heart disorders. Therefore, the studied insect oil has the potential of being used in the dietetic management of certain coronary heart diseases. Furthermore, this oil showed very low and desirable ratio omega-6/omega-3 compared to conventional oils such as soybean, walnut, olive, corn and sunflower oils with respective omega-6/omega-3 ratios of 8, 8.1, 34, 72.5 and 670 [50]. This suggests that *C. butyrospermi* larvae oil would be more balance confirming its suitability for human consumption.

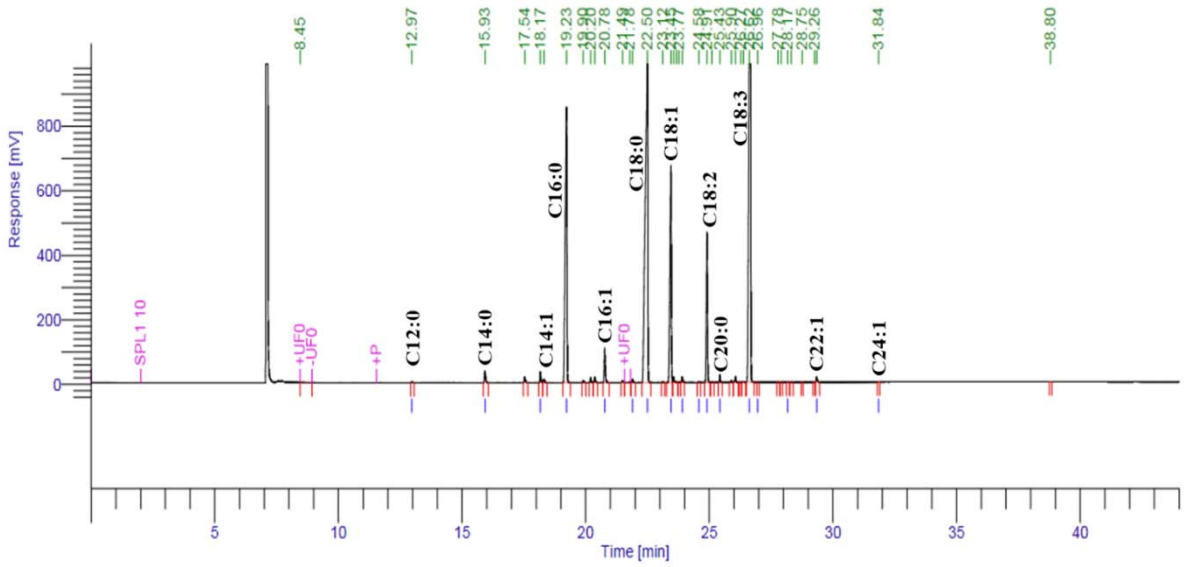

Fig. 1. Gas chromatograms of fatty acids methyl esters of *C. butyrospermi* oil analysed

Table 5. Fatty acid composition of oil from dry *Cirina butyrospermi* larvae

Fatty acid	Saturation	Values (%)
Essential		
Linoleic acid	Omega 6 polyunsaturated	6.97 ± 0.01
Linolenic acid	Omega 3 polyunsaturated	27.83 ± 0.1
Non-essential		
Myristoleic acid	Omega 5 monounsaturated	0.45 ± 0.0
Palmitoleic acid	Omega 7 monounsaturated	1.50 ± 0.0
Margaroleic acid	Omega monounsaturated	0.15 ± 0.0
Oleic acid	Omega 9 monounsaturated	12.14 ± 0.02
Eicosenoic acid	Omega 9 monounsaturated	0.05 ± 0.0
Erucic acid	Omega 9 monounsaturated	0.22 ± 0.0
Selacholeic acid	Omega 9 monounsaturated	0.02 ± 0.0
Lauric acid	Saturated	0.06 ± 0.0
Myristic acid	Saturated	0.48 ± 0.0
Palmitic acid	Saturated	17.16 ± 0.05
Stearic acid	Saturated	31.85 ± 0.02
Arachidic acid	Saturated	0.29 ± 0.0
Behenic acid	Saturated	0.03 ± 0.0
Ratios		
SFA		49.83
MUFA		14.53
PUFA		34.80
PUFA / SFA		0.70
n6/n3		0.25

Values given are the averages of at least three experiments ±SE

4. CONCLUSION

The present study on *C. butyrospermi* larvae suggests that this edible insect could be considered as an alternative and valuable source of protein and oil accounting for more than 80% of nutrients. Proteins are mainly consisting of albumin and glutelin fractions. Functional properties of flours from dried *C. butyrospermi* larva showed good dispersibility, wettability and water and oil absorption capacity indicating their usefulness in food systems such as ground meat formulations. Also, the defatted flour exhibited good foaming properties making it suitable for products where foaming is important. As regards the oil, it contains high amount of unsaturated fatty acids (49.33 %) mainly consisting of linolenic, linoleic and oleic acid which were desirable for a healthy nutrition. Furthermore, the obtained PUFA/SFA and omega-6/omega-3 ratios suggest that the studied oil would be nutritionally more balanced than most of the conventional oils such as soybean, walnut, olive, corn and sunflower. Also, *C. butyrospermi* larvae oil exhibited good physicochemical properties as saponification and stability corroborating its usefulness for nutritional, pharmaceutical and industrial applications.

REFERENCES

[1]. FAO. “Contribution of forest insects to food security: The example of caterpillars in Central Africa”, the Non-Timber Forest Products. Fao, Rome, Italy. 2004.

[2]. West PC, Gerber JS, Engstrom PM, Mueller ND, Brauman KA, Carlson KM, Cassidy ES, Johnston M, MacDonald GK, Ray DK, Siebert S. Leverage points for improving global food security and the environment. Science. 2014; 345: 325-328.

[3]. Raubenheimer D, Rothman JM. Nutritional Ecology of Entomophagy in Humans and Other Primates. Annu. Rev. Entomol. 2012; 58:141–60.

[4]. EFSA Scientific Committee. Scientific Opinion on a risk profile related to production and consumption of insects as food and feed. EFSA J. 2015; 13: 4257-4260.

[5]. Assiélou B, Due EA, Koffi MD, Dabonné S, Kouamé PL. *Oryctes owariensis* Larvae as good alternative protein source : nutritional and functional properties. Ann. Res. Rev. Biol. 2015a; 8 (3): 1-9.

[6]. Kelemu S, Niassy S, Torto B, Fiaboe K, Affognon H, Tonnang H, Maniania NK, Ekesi S. African edible insects for food and feed: inventory, diversity, commonalities and contribution to food security. J. Ins. Food and Feed. 2015; DOI:10.3920/JIFF2014.0016.

[7]. Nowak V, Persijn D, Rittenschober D, Charrondiere UR. Review of food composition data for edible insects. Food Chem. 2016; 193: 39–46.

[8]. Womeni HM, Linder M, Tiencheu B, Tchouanguep MF, Villeneuve P, Fanni J, Parmentier M. Oils of *Oryctes owariensis* and *Homorocoryphus nitidulus* consumed in Cameroon: Sources of linoleic acid. J. Food Technol. 2009; 7 (2): 54-58.

[9]. Akpossan RA, Digbeu YD, Koffi DM, Kouadio. JPEN, Due EA, Kouame PL. Protein fractions and functional properties of dried *Imbrasia oyemensis* larvae full-fat and defatted flours. Int. J. Biochem. Res. Rev. 2015a; 5(2): 116-126.

[10]. Akpossan RA, Due EA, Koffi DM, Kouame PL. Fatty acids, mineral composition and physico-chemical parameters of *Imbrasia oyemensis* larvae oil with unusual arachidonic acid content. Food Environ. Saf. 2015b; 14(4): 358-397.

[11]. Ekpo KE, Azeke MA, Ugbenyen AM. Functional properties of dried *Imbrasia belina* larvae flour as affected by mesh size and pH. Nig. Ann. Nat. Sci. 2008; 8(1): 6-9.

[12]. Alamu OT, Amao AO, Nwokedi CI, Oke OA, Lawa IO. Diversity and nutritional status of edible insects in Nigeria: A review. Int. J. Biodiver. Conserv. 2013; 5(4): 215-222.

[13]. Assiélou B, Due EA, Koffi MD, Kouamé PL. Physicochemical characterization and fatty acid composition of *Oryctes owariensis* larvae oil. Food Environ. Saf. 2015b; 14(3): 320-326.
[14]. Koffi DM, Cissé M, Koua GA, Niamke S L. Nutritional and Functional Properties of Flour from the Palm (*Elaeis Guineensis*) Weevil *Rhynchophorus Phoenicis* Larvae Consumed As Protein Source In South Côte d'Ivoire. Ann. Univ Dunarea de Jos of Galati Fascicle VI – Food Technol. 2017; 41(1): 9-19.
[15]. Odeyemi MO, Olayemi IK, Ukubuiwe AC, Fasoranti JO. Effects of Gamma Irradiation of Egg Cells on Macro and Micro Nutrients Composition of the Edible Larval Stage of *Cirina Forda* (Lepidoptera: Saturnidae). Adv. Bioeng. Biomed. Sci. Res. 2018; 1(2): 1-5.
[16]. Fasoranti JO, Ajiboye OO. Some edible insects of Kwara state Nigeria. Amer. Entom. 1993; 39: 113-116.
[17]. Badanaro F, Amevoin K, Lamboni C, Amouzou K. Edible *Cirina forda* (Westwood, 1849) (Lepidoptera: Saturniidae) caterpillar among Moba people of the Savannah Region in North Togo: from collector to consumer. As. J. Appl. Sci. Engineer. 2014; 3: 13-24.
[18]. Bama HB, Dabire RA, Ouattara D, Niassy S, Ba MN, Dakouo D. Diapause disruption in *Cirina butyrospermi* Vuillet (Lepidoptera, Attacidae), the shea caterpillar, in Burkina Faso. J. Insect. Food Feed. 2018; 1(1): 1-7.
[19]. Odeyemi MO, Fasoranti JO. Distribution of the emperor moth caterpillar, *Cirina forda* (Lepidoptera Saturniidae) on sheanut tree canopy at Ilorin, Nigeria. J. Entomol. 2000; 17: 59-67.
[20]. Omotosho OT. Nutritional quality, properties and anti-nutrient compositions of the larvae of *C. forda*. *J. Zhejiang Univ. Sci*. 2006; 7: 51-55.
[21]. Onimawo IA, Akubor PI. Functional properties of food. In: Food Chemistry, integrated approach with biochemical background. Ambik Press Ltd, Benin City. 2005; 208–221.
[22]. Hu B, Esen A. Heterogeneity of soybean seed proteins: One dimensional electrophoretic profiles of six different solubility fractions. J. Agric. Food Chem. 1981;29:497-501.
[23]. Lowry OH, Rosebrough NJ, Farr AL, Randall RJ. (). Protein measurement with the folin reagent. J. Biol. Chem. 1951;193:265-275.
[24]. AOAC. Official Methods of Analysis of the Association of Official Analytical Chemists, 16th ed. Virginia. U.S.A.; 1995.
[25]. IUPAC. "Standard methods for the analysis of oils, fats and derivatives". Pergamon: Oxford. 1979.
[26]. European Communities, "Determination of free fatty acid methyl esters. In: OJ, (ed). Characteristics of olive oil and the relevant methods of analysis", Geneva, pp. 64-67. 1991.
[27]. Phillips RD, Chinnan MS, Branch AL, Miller J, Mcwatters KH. Effects of pre-treatment on functional and nutritional properties of cowpea meal. J. Food. Sci. 1988; 53(3): 805–809.
[28]. Beuchat LR. Functional and electrophoretic characteristics of succinylated peanut flour protein. J. Agric. Food Chem. 1977; 25:258-261.
[29]. Coffman CW, Gracia VV. Functional properties of amino acid content of a protein isolate from mung bean flour. J. Food Technol. 1977; 12: 473-484.
[30]. Mora-Escobedo R, Paredes-Lopes O, Gutierrez-Lopes G F. Effect of germination on the rheological and functional properties of amaranth seeds. Lebensmittel - Wissenschaft und Technol. 1991; 24, 241-244.
[31]. Okezie BO, Bello AB. Physicochemical and functional properties of winged bean flour and isolate compared with soy isolate. J. Food Sci. 1988; 53:450-454.
[32]. Onwuka GI. Food Analysis and Instrumentation. Theory and Practice. Naphtali Prints, Lagos, Nigeria. 2005; pp 133-137.
[33]. Okaraonye CC, Ikewuchi JC. Nutritional Potential of *Oryctes rhinoceros* larva. Pak. J. Nutr. 2009; 8 (1): 35-38.

[34]. Sanni OL, Adebowale AA, Filani TA, Ayewole OB, Westby A. Quality of flash and rotary dryer dried fufu flour. J. Food Agr. Environ. 2006; 6: 172-175.
[35]. Banjo AD, Lawal OA, Songonuga EA. The nutritional value of fourteen species of edible insects in Southwestern Nigeria. Afr. J. Biotechnol. 2006; 5(3): 298-301.
[36]. Osasona AI, Olaofe O. Nutritional and functional properties of *Cirina forda* larva from Ado-Ekiti, Nigeria. African Journal of Food Sciences. 2010; 4(12): 775–777.
[37]. Aiyesanmi AF, Oguntokun M. Nutrient composition of Dioclea reflex a seed – an underutilized edible legume. Riv. Ital. Sost. Gras. 1996; 73: 521-523.
[38]. Mbah CD, Elekima GOV. Nutrient composition of some terrestrial insects in Ahmadu Bello University, Samaru Zaria Nigeria. Scient. World J. 2007; 2(2): 17-20.
[39]. Raksakantong P, Meeso N, Kubola J, Siriamornpun S. Fatty acids and proximate composition of eight Thai edible terricolous insects. Food Res. Int. 2010; 43: 350–355.
[40]. Kappagoda TC, Hyson AD, Amsterdam AE. Low-carbohydrate–high protein diets is there a place for them in clinical cardiology? J. Amer. Coll. Cardiol. 2004; 43(5): 725–730.
[41]. Roche M, Rondeau P, Singh NR, Tarnus E, Bourdon E. The antioxidant properties of serum albumin", FEBS Letters. 2008; 582: 1783–1787.
[42]. Tatham AS, Shewry PR. The conformation of wheat gluten proteins. The secondary structures and thermal stabilities of a-, b-, gand o-gliadins. J. Cereal Sci. 1985; 3, 104–113.
[43]. Dué EA, Koffi DM, Digbeu YD. Biochemical and functional properties of two wild edible mushrooms (*Volvariella volvacea* and *Armillaria mellea*) consumed as protein substitutes in South Côte d'Ivoire". J. Chem. Biol. Phys. Sci. 2016; 6(4): 1197-1206.
[44]. Peleg M, Bagley EB. Physical properties of foods. *Westport, CN: AVI Pub.Co*, 1983.
[45]. Hagerdal B, Lofqvist B. Wettability and surface pressure of myoglobin treated with acetone. J. Food Sci. 1978; 43: 27-30.
[46]. Aremu MO, Basu SK, Gyar SD, Goyal A, Bhowmik PK, Banik DS. Proximate Composition and Functional Properties of Mushroom Flours from *Ganoderma spp., Omphalotus olearius* (DC.) Sing. and *Hebeloma mesophaeum* (Pers.) Quél. Used in Nasarawa State, Nigeria. Malays. J. Nutr. 2009; 15(2): 233–241.
[47]. Olaofe O, Arogundade LA, Adeyeye EI, Falusi OM. Composition and food properties of the variegated grasshopper, *Zonocerus variegatus*. Trop. Sci. 1998; 38: 233-237.
[48]. Akubor PI, Chukwu JK. Proximate composition and selected functional properties of fermented and unfermented African oil bean (*Pentaclethra macrophylla*) seed flour. Plant Food Hum. Nutr. 1999; 54:227-238.
[49]. Fennema RO. Food chemistry, (3rd edition). Marcel Dekker, Inc. New York, Basel. Hongkong. 1996; pp. 365-39.
[50]. Codex Alimentarius, "Fats and Vegetable oils", FAO/WHO, Geneva, p. 160, 1993.
[51]. Falade OS, Adekunle SA, Aderogba MA, Atanda OS, Harwood C, Adewusi SRA. Physicochemical properties, total phenol and tocopherol of some Acacia seed oils. J. Sci. Food Agric. 2008; 88: 263-268.
[52]. Due EA, Zabri HCBL, Kouadio ENJP, Kouamé LP. Fatty acid composition and properties of skin and digestive fat content oils from *Rhynchophorus palmarum* L. larva. Afr. J. Biochem. Res. 2009; 3(4): 089-094.
[53]. Akubugwo IE, Ugbogu AE. Physicochemical and studies on oils from five selected Nigerian plant seeds. Pak. J. Nutr. 2007; 6: 75-78.
[54]. NIFOR. Nigeria Institute for Oil Research. History, Activities and Achievement. 2nd Ed. Benin City, Nigeria. 1989.
[55]. FAO/WHO. Fats and Oils in human nutrition. Report of a joint expert consultation organised by the Food and Agriculture Organization of the United Nations and the world Health Organization Rome. 1993; 19-26.

[56]. Mensink RP, Katan MB. Effect of a diet enriched with monounsaturated or polyunsaturated fatty acids on the levels of low-density and high-density lipoprotein cholesterol in healthy women and men. New Eng. J. Med. 1989; 321: 436-441.
[57]. Dubois V, Breton S, Linder M, Fanni J, Parmentier M. Fatty acid profiles of 80 vegetable oils with regard to their nutritional potential. Eur. J. Lipid Sci. Technol. 2007; 109: 710-732.
[58]. Hunter K, Crosbie LC, Weir A, Miller GJ, Dutta-Roy AK. A residential study comparing the effects of diets rich in stearic acid, oleic acid, and linoleic acid on fasting blood lipids, haemostatic variables and platelets in young healthy men. J. Nutr. Biochem. 2000; 11: 408-416.
[59]. Ghosh S, Lee S-M, Jung C, Rochow VBM. Nutritional composition of five commercial edible insects in South Korea. J. Asia-Pac. Entomol. 2017; 20: 686–694.
[60]. Simopoulos AP. Evolutionary aspects of diet, the omega-6/omega-3 ratio and genetic variation: nutritional implications for chronic diseases. Biomed. Pharmacoth. 2006; 60(9): 502-507.