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Research Article
Nutritional Potentials of Pachnoda marginata (Kolbe, 1906) and Rhabdotis Sobrina (Gory and Percheron, 1833) Two Insect Species Consumed in Togo

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Abstract

Background and Objective: Several species of Coleoptera are used in diet in Togo. However, data on their nutritional value are not available. This study was undertaken to determine the nutritional value of *Pachnoda marginata* (Kolbe, 1906) and *Rhabdotis sobrina* (Gory and Percheron, 1833) of the *Scarabaeidae* family. **Materials and Methods:** After the samples of *P. marginata* and *R. sobrina* were collected, the ash, protein, vitamin and lipid contents as well as the acid, iodine and peroxide indices were determined according to the AOAC guidelines. The fiber content was obtained by the method of Weende. The minerals were analyzed by atomic absorption spectrophotometry and colorimetry. Fatty acid composition was determined by gas chromatography after separation of the methyl esters. **Results:** The results showed that the average protein content ranges from 48.28±0.1 to 53.89±1.00%. The lipid content is between 12.77±0.7% and 16.62±0.55%. The lipids are rich in monounsaturated fatty acids such as oleic acid (C18:1Δ9), (48.71±0.00% to 54.93±0.04%). Linoleic acid (C18: 2$\Delta^{9,12}$) content ranged from 1.33±0.01% to 5.45±0.01%. Linolenic acid (C18: 3$\Delta^{9,12,15}$) polyunsaturated fatty acid is found in *R. sobrina* at 1.11±0.02%. The Coleoptera studied appeared to be high in energy with calorific values of 1522.31±14.90 kj/100 g to 1681.98±15.58 kJ/100 g. The results showed that the average contents of minerals ranged from 11.59±0.41% to 13.5±0.08%. Vitamins were observed in variable amounts. Overall, *P. marginata* and *R. sobrina* are rich in vitamins, minerals, proteins and fats. **Conclusion:** These Coleoptera are therefore products that could contribute to food security in Togo.

Key words: Energy, fat, minerals, *Pachnoda marginata*, proteins, *Rhabdotis sobrina*, Togo, vitamins

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Insects play an important role in the environment and people's diet around the world[1]. In fact, about 2.5 billion people from 300 different ethnic groups living in the tropical and subtropical regions eat insects daily[2,3]. These people consumed insects either as a dietary supplement[4] or as a substitute product in periods of shortage[5,6]. However, insects are not always eaten in times of famine. They are sometimes an integral part of the diet in many countries of the world, depending on seasonal and local availability[7] or may be part of special meal[8]. They are appreciated for their organoleptic quality and are a source of food diversification[2]. Most of the insects consumed provide energy and nutrients, thus helping to supplement insufficient food rations in developing countries. Former studies have shown that entomophagy cannot only contribute to improving food security but also to conserving biodiversity and protecting the environment[3,9,10]. It can also be a source of income for the poor[11]. Despite the qualities of this resource, its valuation is insufficient in the countries of sub-Saharan Africa[12]. In Togo, lack of knowledge about the availability and nutritional quality of insects forces the consumer to purchase more expensive and less nutritious imported foods[13]. A previous study[14] has identified 25 species of edible insects in the Togolese fauna, including *Pachnoda marginata* (Kolbe, 1906) and *Rhabdotis sobrina* (Gory and Percheron, 1833). This study was therefore aimed at determining the nutritional value of *P. marginata* and *R. sobrina*.

MATERIALS AND METHODS

Biological material: *Pachnoda marginata* and *R. sobrina* specimens were caught in Kparatao (8°57' 151" N, 1° 11' 838" E), Kpéwa (9°16' 978" N, 1°14' 149" E) and Soudou (9°21' 604" N, 1°21' 348" E) villages in Togo. The insects were taken to the laboratory and characterized to confirm the species. They were killed by placing them in a cooler filled with ice[15] and then dried in an oven at 40°C for 7 days before crushing them into a powder for biochemical analysis.

Determination of water content: The SCALTEC electronic moisture analyzer (SM01 Instrument GmH, Germany) was used to determine the water content following the manufacturer's recommendation.

Biochemical assays: The total fiber content of the insect powder was determined using Weende's method [16]. After acid hydrolysis followed by basic hydrolysis, the samples were dried at 150°C for 1 h and then incinerated at 550°C for 6 h. The percentage of total fiber (TF) in the samples was obtained by the following formula[16]:

$$\text{TF} = \frac{\text{Mass of residual after drying} - \text{mass of the ash after incineration}}{\text{Mass of the sample of the trial hold}}$$

The ashes (mineral substances), lipids and protein contents were determined using different methods[17]. Briefly, the ash content was determined by incineration of *P. marginata* and *R. sobrina* samples at 550°C for 5 h. Total proteins were estimated for total nitrogen content using the Kjeldahl method. Lipids were extracted with hexane using Soxhlet and the extracts were evaporated in a vacuum at 35°C using a Buchi R114 type rotavapor.

The acid, iodine and peroxide indices of the extracted lipids were determined by different methods[18]. The phosphorus content was determined using the colorimetric phosphovanado molybdate method[19]. Other minerals were analyzed by atomic absorption spectrophotometry[19].The percentage of total carbohydrates was calculated according to the following formula[20].

$$\text{Carbohydrate} = 100\text{-(moisture+protein+lipid+fiber+Ash)}$$

The metabolizable energy of the samples was calculated from total protein, total fat, total carbohydrate and dietary fiber values by applying energy conversion factors to the formula[20]:

$$E = 17\times\text{carbohydrate}+17\times\text{protein}+37\times\text{lipid}+8\times\text{fiber}$$

Sodium/Potassium and Calcium / Phosphorus ratios were calculated.

The fatty acid composition of the lipids was obtained by separation of the methyl esters using a gas chromatograph (HP 6890 series GC System). At first, the fatty acids were converted to methyl esters by transesterification of the crude lipids using a methanolic solution of boron trifluoride[21]. The percentages of saturated fatty acids and unsaturated fatty acids (monounsaturated and polyunsaturated) of the lipids were obtained by the sum in all the fatty acids. The Omega 6/Omega 3 ratio of the fatty acids was calculated.

The vitamins in the different samples were determined by colorimetric methods[22]. The optical density was measured by a Jenway 6300 Model colorimeter. Calibration curves were obtained from the preparation of a corresponding range of vitamin solutions.

Statistical analysis: All the tests were performed in triplicate. The analysis of variance (ANOVA-1) was used to compare averages using the SPSS 17.0 software. Differences observed between means are considered statistically significant at 5%.

RESULTS AND DISCUSSION

Proximate composition: The determination of the chemical composition gives the proportions of the different components in the two insect species studied as shown in Table 1. The samples of *P. marginata* and *R. sobrina* analyzed contain 5.39±0.37% (*R. sobrina*) and 6.69±0.15% (*P. marginata*) of water. These values are approximately identical to those observed in former studies[23,24]. The low water content correlates with the shelf life of these seasonal species, which can be stored and easily used in periods of scarcity[25]. The average values of the ash contents vary from 11.59±0.41% (*R. sobrina*) to 13.5±0.08% (*P. marginata*). These values are low compared to the results obtained in a former study[26] in *Cirina forda* (Westwood, 1849) (Lepidoptera: *Saturniidae*) but are almost identical to those observed in *Macrotermes subhyalinus* (Rambur, 1842) (Isoptera: Termitidae)[24].

The results reveal that these species can constitute an important source of essential minerals for physiological and metabolic processes in humans[27].

Protein proportions ranged from 48.28±0.1 to 53.89±1.00% in the samples and *P. marginata* contained the highest crude protein. In addition, the values observed indicate that *P. marginata* and *R. sobrina* are better sources of protein than soybean, beans, eggs and meat of poultry, mutton, pork, beef and fish[28]. Therefore, these species can be a solution to protein malnutrition especially in children in developing countries. In comparison, *P. marginata* contains significantly higher levels of water ($p<0.05$), ash and protein ($p<0.001$) than *R. sobrina*. With regard to lipids, *R. sobrina* has significantly higher values (16.62±0.55%, $p<0.002$) than *P. marginata* (12.77±0.7%).

With dietary fiber, we observed an average of 9.78±0.33% for *R. sobrina* and 9.98±0.19% for *P. marginata*. These values are higher than those found in wheat, which is considered a major source of dietary fiber[28]. In this study, the high fiber content of these insect species is of nutritional benefit, since a lack of fiber in diet can lead to digestive disorders[29].

For carbohydrates, *R. sobrina* has significantly higher amounts (8.31±0.88% vs 3.14±1.38%, $p<0.01$). Our results show higher carbohydrate contents than observed in previous studies which showed that their content in insects are generally low[30,31]. Consequently, the consumption of the species studied would be beneficial in reducing the intake of dietary carbohydrates and thus decrease the risk of developing obesity and a cardiovascular diseases risk factor[32]. Considering the proportions of lipids and carbohydrates contained in *R. sobrina*, this specie has more metabolizable energy than *P. marginata* (1655.53±6.70 KJ/100 g vs 1522.31±14.906 KJ/100g). However, the two species are very high calorific value foods and can therefore act as supplement for protein-energy deficiencies in populations. According to previous studies, they are a higher source of energy than most food products (tubers, cereals, vegetables, fruits, etc.), consumed locally in the regions where the insects were collected[28].

Mineral composition: The insect powder studied contains several minerals (Ca, Mg, P, K, Na, Fe, Cu, Zn and Mn). Table 2 shows insect powder value in *R. sobrina* and *P. marginata*. Significant differences ($p<0.001$) were observed between *R. sobrina* and *P. marginata* for Ca, P, K, Na, Fe, Cu, Zn and Mn except Mg. These results confirm the data of previous studies[24,26]. The insects studied have higher mineral contents than beef, pork, rabbit and fish (1-2.5%) consumed in West Africa. These minerals are also higher than those found in fruits and vegetables, which have higher amounts of mineral[20].

The physiological and specific roles of minerals in the body have already been highlighted by several studies[27]. Indeed, Ca and P are involved in bone calcification mechanisms thus promoting skeletal growth and stabilization[33]. In addition, Mg and Ca are essential in most cellular metabolic reactions of organic molecules (carbohydrates, proteins, lipids and nucleic acids)[34]. Iron involved in chromoprotein formation, plays major role in the synthesis of several macromolecules such as hemoglobin for the transport of O_2 and CO_2 between cells and

Table 1: Proximate composition of insect species (%) and their energy value (kJ/100 g)

Species	Moisture	Ash	Protein	Lipid	Fiber	Carbohydrate	Energy
Pachnoda marginata	6.69±0.15^b	13.5±0.08^b	53.89±1^b	12.77±0,7^a	9.98±0,19^a	3.14±1,38^a	1522.31±14.9^a
Rhabdotis sobrina	5.39±0.37^a	11.59±0.41^a	48.28±0,1^a	16.62±0,55^b	9.78±0,33^a	8.31±0,88^b	1655.53±6.70^b
Statistics	p<0.005	p<0.001	p<0.001	p<0.002	NS	p<0.01	p<0.001

*In a column the affected averages of the same letter are not statistically different (ANOVA-1 at the 5% threshold)

Table 2: Mineral composition of studied species (mg/100 g)

Minerals	*Pachnoda marginata*	*Rhabdotis sobrina*	Statistics
Ca	57.350±1.96[a]	60.84±0.05[b]	p = 0.037
Mg	31.780±0.77[a]	32.33±0.60[a]	p = 0.392
P	61.300±0.01[a]	63.46±0.24[b]	p<0.001
K	921.380±1.00[b]	844.22±1.70[a]	p<0.001
Na	111.930±0,92[a]	118.75±0,10[b]	p<0.001
Fe	14.8 4±0.13[a]	24.84±0.12[b]	p<0.001
Mn	3.710±0.28[b]	0.81±0.01[a]	p<0.001
Cu	8.340±0.09[b]	5.48±0.09[a]	p<0.001
Zn	12.310±0.06[a]	16.88±0.05[b]	p<0.001
Na/k	0.12	0.14	
Ca/P	0.93	0.95	

*In a row, the affected averages of the same letter are not statistically different (ANOVA-1 at the 5% threshold)

Table 3: Different lipid indices *Pachnoda marginata* and *Rhabdotis sobrina*

Studied species	Acid indice (mg KOH g^{-1} lipid)	Peroxide indice (milliequivalents of active oxygen kg^{-1} lipid)	Iodine indice (g of iodine/100 g lipid)
Pachnoda marginata	1.30±0.39[a]	7.04±0.02[a]	121.61±1.49[a]
Rhabdotis sorbrina	1.54±0.21[b]	4.08±0.61[b]	79.87±1.26[b]
Statistics	p = 0.002	p<0.001	p = 0.019

*In a column the affected averages of the same letter are not statistically different (ANOVA-1 at the 5% threshold)

extracellular media, myoglobin for the storage of muscle O_2 and the enzymes of metabolic reactions[35]. For this purpose, the consumption of *R. sobrina* and *P. marginata* reduce the effects of iron deficiency anemia, which is very common among pregnant women and children in developing countries[36].

Na and K play a major role in the regulation of fluid balance as well as in most metabolic reactions in the body. The Na/K ratio in *P. marginata* and *R. sobrina* varies from 0.12-0.14.

If this ratio is less than one in food, its consumption improves, physiological reactions and can therefore decrease blood pressure. Thus, the mineral components of these insects can reduce the risk of developing cardiovascular diseases[37].

The ratio of Ca/P, varies from 0.93-0.95 in *P. marginata* and *R. sobrina* and is close to that (1-1.3) recommended by WHO[38]. Given that Ca and P are involved in bone calcification mechanisms, a balanced diet of these minerals is important for bone formation and skeletal integrity[33,39].

Chemical characterization of total lipids: The analysis of the total lipids makes it possible to characterize them and explain their different indices (acid, peroxide and iodine) shown in Table 3.

The free fatty acid content and the degree of resistance of the fats, to hydrolysis are determined by the acid number. Significantly higher values were observed in *R. sobrina* (1.54±0.21 mg KOH g^{-1} lipid, p<0.002) compared to *P. marginata* (1.30±0.39 mg KOH g^{-1} lipids). However, they are both below the recommended limit (4) for a dietary fat by Codex Alimentarius[40]. In fact, the lower the value of this index, the more the free fatty acids concerned are weakly hydrolyzed and therefore in a state of deterioration[41]. This indicates that their consumption is beneficial to the human body.

The amount of peroxides present in the fat is estimated by the peroxide index. In this study, *P. marginata* has a significantly higher peroxide index (7.04±0.02 61 mill equivalents of active oxygen kg^{-1} lipid vs. 4.08±0.61 mill equivalents of active oxygen kg^{-1} lipid, p<0.001). However, the values for *R. sobrina* and *P. marginata* are below the limit recommended (15) by the international reference[40]. This suggests that their fats would be protected, against rancidity during their conservation[42].

The iodine index gives information on the degree of lipid unsaturation. The results obtained in this study show that *P. marginata* has a significantly higher iodine index (121.61±1.49 g of iodine/100 g fat vs 79.87±1.26 g iodine/100 g fat, p<0.019). These values confirm the high content of unsaturated fatty acids in these insects. If the lipid is very rich in unsaturated fatty acids, it is recommended in human diet[43]. The antioxidants such as zinc, liposoluble vitamins are correlated with the low oxidation of the lipids contained in *R. sobrina* and *P. marginata*[44]. Concerning lipid characterization, the results of this study are similar to those observed for the caterpillar *Imbrasia oyemensis*[41]. Therefore considering, their contents in unsaturated lipids, *R. sobrina* and *P. marginata*, constitute food resources of exceptional nutritional quality.

Fatty acid composition and degree of fat saturation: The chemical screening carried out on the lipids of *R. sobrina* and *P. marginata* explains the fatty acid composition and their degree of saturation. The results are shown in Fig. 1 and Table 4. It appears that isopalmitic acid (28.23-34.23%), stearic acid (4.15-32.37%), oleic acid (30.58-54.93%) and linoleic acid (1.33-7.04%) are found in *R. sobrina* and *P. marginata.* However, myristic acid and alpha-linolenic acid are found in *R. Sobrina* alone while elaidic acid is found in *P. marginata* alone. *Rhabdotis Sobrina* contains the two essential fatty acids (linoleic acid and alpha-linolenic acid). The results also show that, with the exception of elaidic acid (with trans configuration, found in small amounts in *P. marginata*), all the

Table 4: Fatty acid profile (g/100 g of all fatty acids) of lipid

Fatty acid	*Pachnoda marginata*	*Rhabdotis sobrina*
Myristic acid (C14:0)	ND	0.71±0.02
Isopalmitic acid (C16:0)	28.87±0.02	28.23±0.00
Stearic acid (C18:0)	8.36±0.01	8.36±0.01
Oléic acid (Cl8 :1 cis (n-9))	53.05±0.02	54.93±0.04
Elaïdic acid (18:1 trans (n-9))	0.94±0.01	ND
Linoleic acid (C18: 2 cis (n-6))	5.45±0.01	4.84±0.02
Alpha-linolenic acid (C18: 2 cis (n-3))	ND	1.11±0.02
No determined	3.32±0.04	1.81±0.05

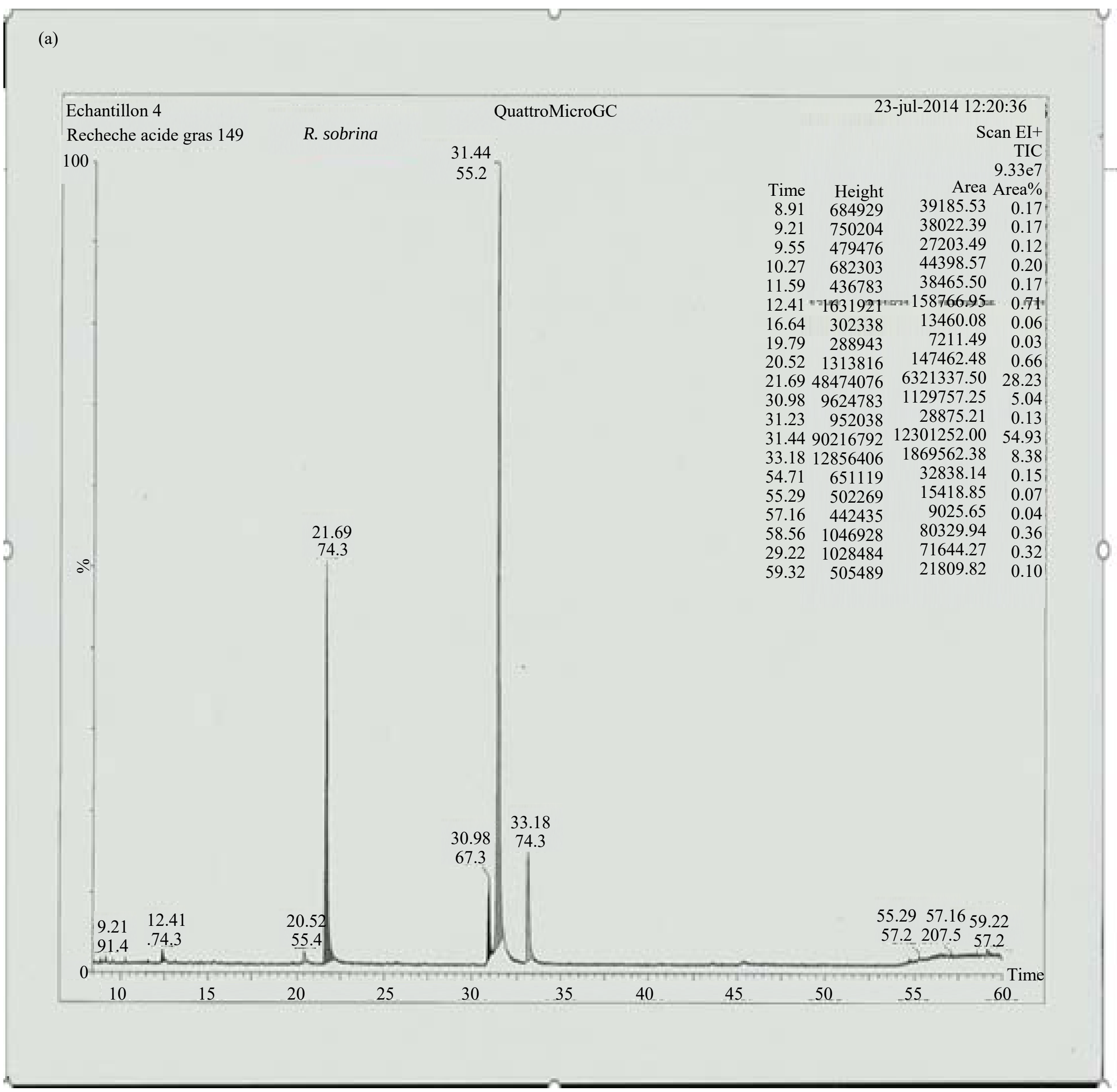

Fig. 1(a-b): Continue

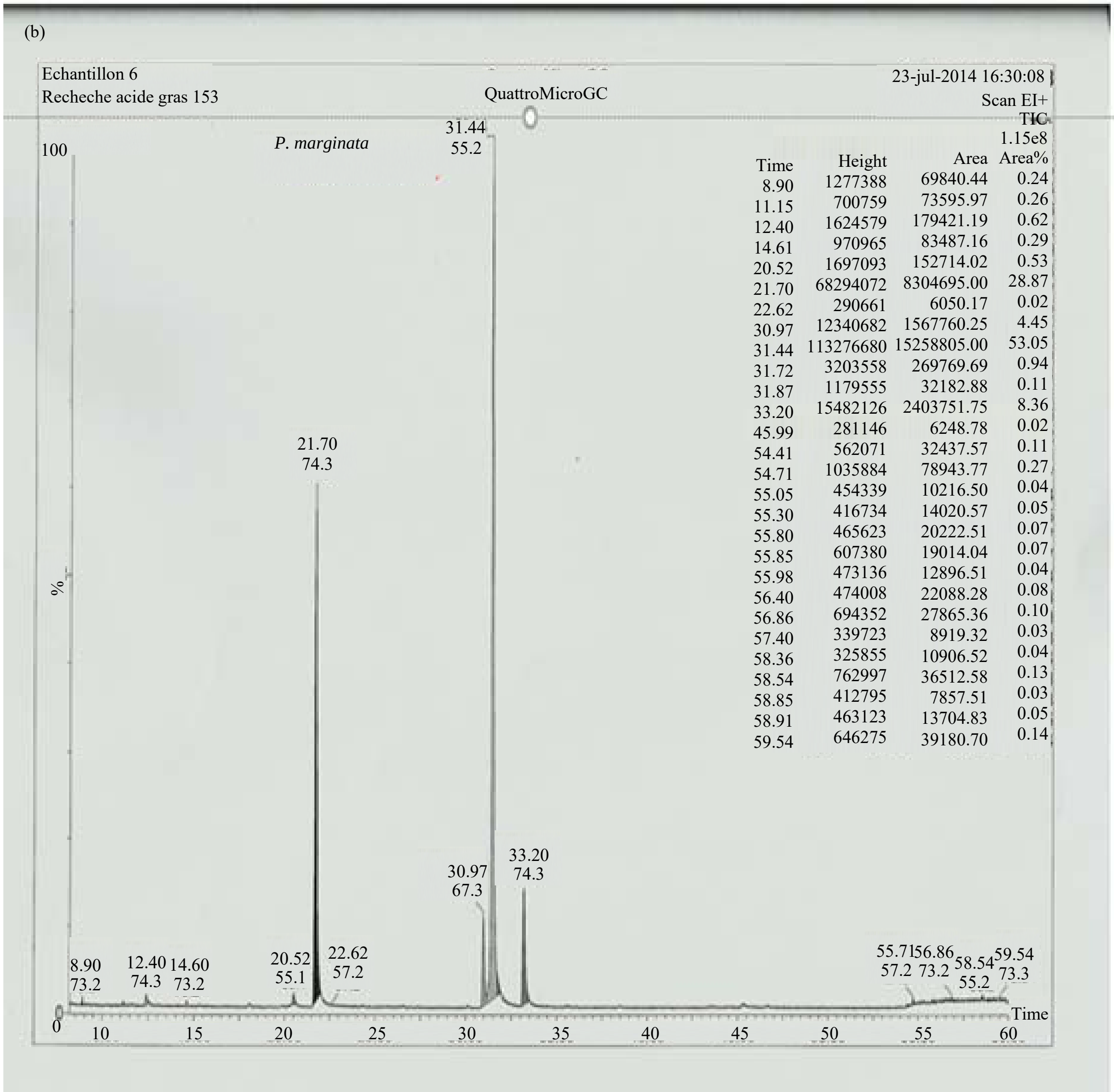

Fig. 1(a-b): Analysis of Fatty acid composition of (a) *Rhabdotis sobrina* and (b) *Pachnoda marginata*

other fatty acids analyzed present cis configuration. Previous studies have already shown that edible insects are rich in cis-fatty acids, which are the components that reduce atherogenic risk[41]. However, trans-fatty acids in very high doses can increase the LDL-cholesterol level and decrease HDL-cholesterol[45]. This constitutes a risk factor for the development of atherosclerosis process responsible for cardio vascular diseases[32,46].

Concerning the degree of saturation of *R. sobrina* and *P. marginata* fatty acids (Table 5), the values show that these insects contain more than 59% of unsaturated fatty acids. Monounsaturated fatty acids represent 53.99-54.93%; polyunsaturated fatty acids 5.45-5.95%. The analysis of fatty acids in both species reveals that omega-6 fatty acid is linoleic acid and omega-3 fatty acid is alpha-linolenic acid. *P. marginata* does not contain Omega 3 fatty acid. The Omega6/Omega3 ratio for *R. sobrina* is 4.36. This value is less than 5, which is a good indicator of the quality of the lipids of these insects[47].

Indeed, in the human body, linoleic acid allows the synthesis of arachidonic acid whose oxidation by cyclooxygenase forms very active and widespread mediators. They are responsible for many physiological reactions (pregnancy, blood pressure, smooth muscle contraction, ion transport across membranes, synaptic transmission, etc.) in small doses.

Table 5: Results of the degree of saturation of fatty acids of the studied insects (%)

Studied species	Saturated fatty acid	Monounsaturated fatty acid	Polyunsaturated fatty acid	Unsaturated fatty acid	Oméga6/Oméga3
Pachnoda marginata	37.23±0.01	53.99±0.02	5.45±0.01	59.44±0.03	-
Rhabdotis sobrina	37.30±0.01	54.93±0.04	5.95±0.03	60.88±0.05	4.36

Table 6: Researched vitamins content of edible insects (mg/100 g dry weight)

Studied species	Retinol (A)	Thiamin (B_1)	Riboflavin (B_2)	Niacin (B_3)	Tocopherol (E)
Pachnoda marginata	0.02±0.00[a]	1.21±0.01[a]	2.54±0.42[a]	7.25±0.23[a]	4.03±0.01[a]
Rhabdotis sobrina	0.03±0.02[a]	1.35±0.29[b]	1.51±0.29[b]	7.20±0.27[a]	4.24±0.14[a]
Statistics	p = 0.143	p<0.001	p = 0.004	p = 1.00	p = 0.099

*In a column the affected averages of the same letter are not statistically different (ANOVA-1 at the 5% threshold)

Vitamin composition: Vitamins in small quantities are essential organic compounds, for metabolic reactions in the human body. Liposoluble vitamins such as retinol (vitamin A) and tocopherol (vitamin E) and water-soluble vitamins such as thiamine (vitamin B1), riboflavin (vitamin B2) and niacin (vitamin B3) were analyzed and their contents in *P. marginata* and *R. Sobrina* were determined and are presented in Table 6. The analysis of the results shows that *P. marginata* and *R. Sobrina* have similar levels of Vitamin A (0.02±0.00 mg and 0.03±0.02 mg), Vitamin E (4.03±0.01 mg and 4.24±0.14 mg), Vitamin B3 (7.25±0.23 mg and 7.2±0.27 mg). Vitamin B_2 was significantly higher in *P. marginata* (2.54±0.42mg vs 1.51±0.29 mg, p<0.004), whereas *R. Sobrina* had a higher content of Vitamin B_1 (1.35±0.29 mg vs 1.21±0.01 mg, p<0.001). The results of this study are different from those obtained in previous studies which showed that Vitamin A was found to range from 3-273 mg/100 g dry matter across insect species[48]. High levels of liposoluble and water-soluble vitamins, of the insects studied show that they can be food supplements for people suffering from vitamin micronutrient deficiency. *P. marginata* and *R. Sobrina* are species that have exceptional nutritional qualities. Indeed, these vitamins have several important metabolic functions in organisms. Vitamins B are co-enzymes, while vitamins A and E are antioxidants, that prevent early aging and improve the functioning of the immune system[49]. Vitamin E is involved in fertility. It is a factor, which decreases atherosclerosis risk and cardiovascular diseases. Vitamin A is essential for vision and growth. Vitamin A deficiency in children causes blindness and increases the risk of infection and digestive disorders[49]. The high vitamin content of these edible insects makes them excellent sources of food supplements for people suffering from malnutrition and micronutrient deficiency.

This study specifies the chemical composition of *P. marginata* and *R. sobrina*. Indeed, these insects have exceptional nutritional value. Because of the high levels of proteins, fats, minerals and vitamins found in them and they can be used as dietary supplements to fight against malnutrition by protein-energy and micronutritional deficiencies. This could be an essential asset for applications in the food industry. Our study focused on the total protein contents without determining the essential amino acids.

CONCLUSION

The present study is the first to evaluate the nutritional value of *P. marginata* and *R. sobrina* in Togo. It has provided reliable information on the nutritional quality of these insects. *P. marginata* and *R. sobrina* are important sources of protein and lipids of high nutritional quality and contain high amounts of minerals and vitamins. They are an appreciable source of energy. The high quality and quantity of nutrients in these edible beetles could contribute to the fight against protein energy malnutrition and micronutrient malnutrition in developing countries.

The results suggest that the consumption of *P. marginata* and *R. sobrina* would slowly improve immunity and mitigate the adverse effects of protein-energy malnutrition and micronutrient deficiency by reducing oxidative stress through vitamins A, C and E. These components would allow the activation of natural resistance mechanisms because of their content of proteins and minerals including zinc.

Given these nutritional benefits of this traditional food resource, the establishment of development programs for its promotion would allow the population to become aware of their benefits.

SIGNIFICANCE STATEMENT

This study discovers the chemical composition (ash, protein, vitamin and lipid) of two edible insect species (*P. marginata* and *R. sobrina*) of Togo, whose data are not available in international scientific literature. The objective is to determine their value and nutritional quality. These informations can be beneficial for population.

This study will help the sanitary authorities and the researcher to promote an alternative non-conventional food resource that is better nutritious in the fight against the malnutrition and the preservation of biodiversity in developing countries.

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