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Nutrient contributions of *Rhynchophorus phoenicis* Fabricius, 1801 (Coleoptera: Curculionidae), very appreciated larvae in Côte d'Ivoire compared with beef (N'Dama breed) and thon (*Thunnus thynnus*)

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ABSTRACT

In Côte d'Ivoire, the larvae of the oil palm weevil, *Rhynchophorus phoenicis*, are appreciated and consumed by rural and urban populations. However, many people are unaware of the nutritional qualities of these larvae. The objective of this study was to compare the nutritional value of these larvae with that of the beef and fish usually consumed. The different nutritional components of late stage larvae, beef and fish were determined from standard analytical methods. Moisture contents of 25.66 ± 0.05; 60.47 ± 0.08 and 39 ± 0.28 mg / 100 g, lipid 39.14 ± 0.01; 12.47 ± 0.05 and 1.26 ± 0.005 mg / 100 and protein of 29.9 ± 0.11; 25.56 ± 0.02 and 22.16 ± 0.15 mg / 100 g were obtained for R. phoenicis, beef and fish, respectively. The ash content was 5.02 ± 0.01; 1.5 ± 0.1 and 0.46 ± 0.57 mg / 100 respectively for *R. phoenicis*, beef and fish. These three samples are characterised by respective iodine numbers of 161.86 ± 0.1; 142.83 ± 0.2 and 45.5 ± 0.4 I2 / 100 g and saponification of 159.53 ± 0.61; 69.33 ± 0.00 mg KOH / g. Larvae, beef and fish oils have acid values of 3.06 ± 0.01; 6.43 ± 0.05 and 6.33 ± 0.057 KOH / g and peroxides 4.56 ± 0.11; 8.56 ± 0.16 and 7.03 ± 0.05 meq O 2 / kg low. This study shows that late stage *R.phoenicis* larvae have significant nutrients that are able to balance diets.
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Keywords : *Rhynchophorus phoenicis*, nutritive composition, edible insects, Côte d'Ivoire.

INTRODUCTION

Accelerated growth of the world's population remains a concern in developing countries. More than one billion people, or 12% of the world's population, live on a low-protein diet with trace elements (Mignon, 2002 ; FAO, 2013). The majority of people suffering from chronic hunger are 98% in third world countries (Programme alimentaire mondial, 2011 ; Lavalette, 2013). However, there are already several sources of underutilised food that could be exploited to improve this nutritional deficiency. Edible insects have long played an important role in

feeding many peoples around the world. They are used either as emergency food or as a staple to replace meat and fish (Cerda et al., 2001). In Africa, Asia and Latin America, for example, insects are used to prepare many specialties (Van-Huis et al., 2013). According to (Jongema, 2015), the latest estimates have revealed that 2037 species of insects are consumed by humans worldwide. Insects contain a satisfactory amount of nutrients such as proteins, carbohydrates, fatty acids and minerals important for the functioning of the body (Ayieko and Oriaro, 2008 ; Rumpold and Schlüter, 2013). Larvae of the palm weevil are commonly consumed in different parts of the world. It is a parasite of oil palm, coconut palm, date palm and occasionally sugar cane plants (Naji et al., 2016). Larvae of *Rhynchophorus species* are well appreciated in some African countries (Ekpo and Onigbinde, 2005 ; Gbogouri et al., 2013).

In Côte d'Ivoire, the larvae of the weevil *Rhynchophorus phoenicis* are among the most popular edible insects in rural and urban populations (Ouali-N'goran and Ehounou, 2017). This consumption of *R. phoenicis* larvae remains purely cultural without knowing the nutritional quality (Gbogouri et al., 2013). In addition, the literature mentions little study on the nutritional value of the larvae of this species. The overall objective of this study is to compare the nutritional potential of *R. phoenicis* larvae with those of beef and fish. Specifically, it is a question of determining the biochemical and nutritive compounds contained in the meals of larvae of *R. phoenicis* and of comparing them with those of the beef and tuna usually consumed by the Ivorians.

MATERIALS AND METHODS
Collection and conditioning of animal material
The animal material used is larvae of *R. phoenicis weevil*, N'Dama beef and tuna fish, Thunnus thynnus (Figure 1). Live larvae were collected from decomposing oil palms (*Elaeis guinéensis*) after extraction of palm wine from the locality of Ebimpé in Anyama commune in Côte d'Ivoire. These live larvae were transported to the laboratory in a transparent plastic bucket (275 x 25 x 45 cm) with a perforated lid for aeration of the larvae. This bucket contained palm fibers that served as food for the larvae. Before the various manipulations, the larvae were asphyxiated in a freezer (Womeni et al., 2012). Fresh beef and tuna were purchased at the Adjamé market in Abidjan at the rate of five kilograms per sample and transported in an ice-cold box.

Biochemical characterization of flours of larvae, beef and fish
Preparation of the meal of *R. phoenicis*, beef and fish
The first step was to prepare the flour of each fresh sample according to the method of Asiedu (1991). Three kilograms of each fresh sample were weighed and placed in an oven set at 105 ° C. After 24 hours, the samples thus dried were ground in a RETSCH type mill, SM100. The ground material obtained was then screened with a 500 μm mesh screen and the flour produced was stored in a desiccator for the various analyzes.
Nutritional properties of larvae of *R. phoenicis*, beef and fish
The contents of water and dry matter of the flours were determined according to the method described by Okangola (2016). For each sample, five (5) grams of flour were weighed in previously known mass capsules. The assembly was placed in an oven set at 105 ° C.

Removed from the oven after 24 hours, the whole was cooled in a desiccator and weighed to a constant weight. The contents of water and material were obtained according to the following formulae:

$$\textbf{Humidity rate (\%)} = \frac{m1 - m2}{m1 - m0} \times 100$$

Dry matter content (%) = 100 − Humidity rate

m0: mass of the empty crucible; m1: mass of the empty capsule + sample; m2: mass of the empty capsule + sample after drying

The ash content is that described by AOAC (1980). Five (5) grams of dry matter obtained previously were weighed, placed in a muffle furnace and then incinerated at 550 ° C until white ash was obtained. The whole was

removed from the oven and cooled in a desiccator and weighed. The ash content was expressed as a percentage of mass as follows:

$$Tc = \frac{m1 - m0}{m1} \times 100$$

Tc: ash rate (%); m: mass of flour (g); m0: mass of empty crucibles (g); m1: mass of crucibles + ash

The crude proteins were determined from the total nitrogen assay using the Kjeldhal method (AOAC, 1997) (Figure 2). This method includes a phase of mineralization, distillation and titration with sulfuric acid. The protein content has been expressed as a mass percentage by the following formulae :

Protein (%) = ((V1 -V2) X 14 * N * 6.25) / me)

N: normality of the sulfuric acid solution; me: mass (g) of the flour sample.

The carbohydrates were evaluated by calculation according to the method recommended by FAO (1947) which takes into account the moisture, lipids, proteins and ash contents according to the following

Total Carbohydrate (%) = 100 - (% Fat +% Protein +% Ash +% Moisture)

formula :

The energy value (E) was calculated by applying the thermal coefficients of (Atwater and Rosa, 1899) with 4 kilocalories per 1 g of protein, 9.3 kcal for 1 g of lipids and 3.75 kcal for 1 g of carbohydrates. The formula is as follows:

Energy (kcals / 100 g) = 9.3 lipids + 4 proteins + 3.75 carbohydrates

The mineral content was determined by atomic absorption spectrophotometry (AOAC, 1997). A quantity of 0.5 g of each flours sample was weighed and incubated in a muffle furnace at 650 ° C for five hours. After cooling, five (5) ml of nitric acid was added to the resulting ash, and then it was brought to total evaporation on a sand bath. Five milliliters of hydrochloric acid was added to the residue which was returned to the oven at 400 ° C for 30 minutes. The final residue is recovered with 10 ml of hydrochloric acid (1 mol / l) and then poured into a 50 ml flask. The crucible was rinsed twice with 10 ml of hydrochloric acid. The flask was made up to 50 ml with hydrochloric acid. The mineral content with the exception of phosphorus was obtained by atomic absorption spectrophotometer spectrometry with air-acetylene flame. The values were read in mg / l. The values read were then converted to mg / kg according to the relationship below:

Ce: Concentration of the sample in mg / L;
Cb: White concentration in mg / L;

$$Teneur \ (mg/kg) = \frac{(Ce - Cb)}{m} \times V$$

V: Volume of the ash solution (50 ml); m: mass of the test sample (0.5 g).

Characterization of meal oils of *R. phoenicis* larvae, beef and fish
Extraction of the oil

The lipid content was determined by hexane extraction in a Soxhlet extractor (AOAC, 1997). Ten (10) grams of flour from each sample were taken from an empty pre-weighed Wathman (CV) cartridge. The cartridge was put in the Soxhlet extractor, to which was connected a previously weighed 500 ml flask (m1). In this flask was introduced two hundred and fifty (250) ml of hexane. Evaporation of the solvent was carried out on a rotary evaporator (Rotavapor). The traces of solvent in the oil sample were evaporated in an oven at 105 °C for one hour.

The flask was removed from the oven, cooled and weighed to a constant mass (m2). The proportion of oil contained in each sample was obtained according to the formula below:

$$\textbf{Proportion of oil} \ (\%) = \frac{m2 - m1}{me} \times 100$$

Chemical properties of the three flour samples

Determination of the acid value of larval, beef and fish meal was done according to the method (AOAC, 1997). Two (2) grams of oil were dissolved in 10 ml of ethanol-

diethyl ether in respective proportions 1 : 1 (v / v). The mixture was then titrated in the presence of 3 drops of phenolphthalein with a solution of 0.5 N alcoholic potassium hydroxide contained in a burette until the pink turn. The acid number was calculated according to the following formula:

$$Ia = \frac{56,1 \times (V - V0)}{me}$$

Ia: acid number in mg KOH / g of oil. ; 56.1: normality of the alcoholic potash solution;
V0: volume (ml) of alcoholic potash equivalents for the blank test;
V: volume (ml) of alcoholic potash acid equiva- lent to the sample. ;
me: mass (g) of the oil sample (test sample).

The peroxide value of larval, beef and fish meal was determined by the method described in (AOAC, 1997). One gram (1 g) of oil of each sample was dissolved in 30 ml of chloroform-acetic acid in the ratio of 3: 2 (v / v). To the previous content, 1 ml of saturated solution of potassium iodide was added. The vial was capped, shaken for 1 min and protected from light for 5 min. After this time, 30 ml of distilled water was added thereto. The mixture obtained was titrated with a solution of 0.01 N sodium thiosulfate contained in a burette in the presence of starch pits until complete decolorization. The peroxide number was calculated as follows:

$$Ip = \frac{(V - V0) \times 10}{m}$$

Ip: peroxide value in meq of O2 / kg of oil; V: volume (ml) of sodium thiosulfate equivalents for the sample. ; V0: volume (ml) of sodium thiosulfate poured at equivalence for the blank test; m: mass (g) of the oil sample (test sample).

Determination of the iodine value of larval, beef and fish meal was carried out using the Wijs method (AOAC, 1997). A mass of 0.5 g of oil of each sample was dissolved in 15 ml of chloroform. To the above mixture, 20 ml of Wijs reagent was added thereto. The Erlenmeyer flask was then capped, shaken and protected from light for 1 hour. After this time, 10 ml of a 10 % potassium iodide solution and 150 ml of

distilled water were added successively to the mixture. The new mixture was then titrated with a solution of 0.1 N sodium thiosulfate contained in a burette in the presence of starch paste until complete decolorization. The iodine value was determined from the following expression:

$$Ii = \frac{12,69 \times N \times (V - V0)}{m}$$

Ip: peroxide value in meq of O2 / kg of oil; V: volume (ml) of sodium thiosulfate equivalents for the sample. ; V0: volume (ml) of sodium thiosulfate poured at equivalence for the blank test; m: mass (g) of the oil sample (test sample)

The saponification value of larval, beef and fish meal is determined by the method (AOAC, 1997). Two grams (2 g) of oil were solubilized in 25 ml of 0.5 N alcoholic potassium hydroxide. The mixture was then boiled in a water bath for one hour under a reflux condenser. After cooling, the excess of alcoholic potassium hydroxide was titrated with a solution of 0.5 N hydrochloric acid contained in a burette in the presence of 3 drops of phenolphthalein, until the turn to colorless. The saponification number was calculated according to the following formula:

$$Is = \frac{56,1 \times (V0 - V) \times N}{m}$$

Is : indice de saponification en mg KOH/g d'huile ; N : normalité de la solution d'acide chlorhydrique ; V0 : volume (ml) d'acide chlorhydrique versé à l'équivalence pour l'essai à blanc ; V : volume (ml) d'acide chlorhydrique versé à l'équivalence pour l'échantillon ; m : masse (g) de l'échantillon d'huile (prise d'essai)

Statistical analyses
All analyzes were performed in triplicate, and the results are presented as mean ± standard deviation (SD). The ANOVA tests followed by Duncan found significant differences were used for comparing the averages from the Statistica 7.1 software. The level of significance was 5%.
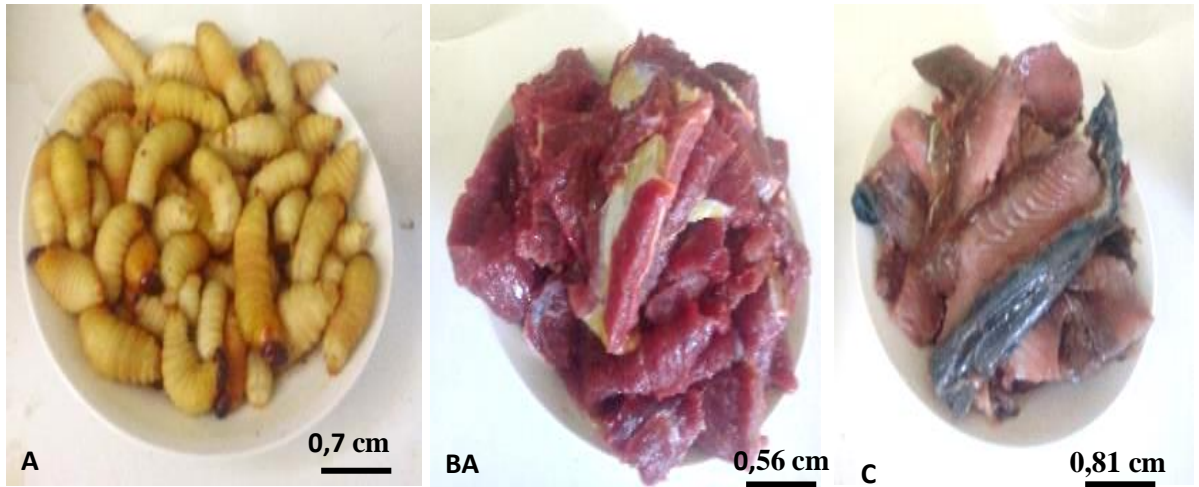
Figure 1: Animal biological material: A: palm caterpillar; B: beef; C: chopped tuna fish.
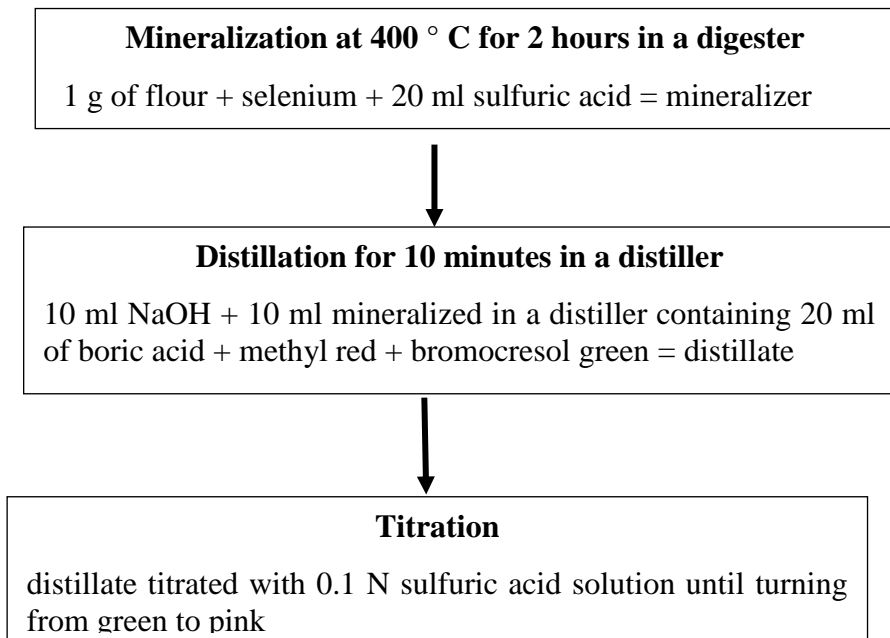

Figure 2 : Steps for determining the level of proteins by the method from Kjeldhal.

RESULTS

Biochemical and mineral composition of larval, beef and fish

Humidity was lower for larvae than for beef and tuna (Table 1). The larval flour is distinguished by a dry matter content of 74.36 ± 0.05 mg / 100 g against 38.46 ± 0.02 mg / 100 g and 25.77 ± 0.15 mg / 100 g respectively for beef and tuna. The inorganic fraction of the dry matter, represented by the ashes, was in proportion higher for the larval meal (5.02 mg / 100 g) than that of the fish (0.46 ± 0.57 mg / 100 g) and beef (1.5 ± 0.1 mg / 100 g). These dry matter contents are statistically different for the three samples (F = 59.21, P < 23 0.05). Compared with beef meal (25.56 ± 0.02 mg / 100 g) and fish (22.16 ± 0.15 mg / 100 g), larval meal showed the highest protein level (29.56 ± 0.02 mg / 100 g) and fish (22.16 ± 0.15 mg / 100 g). , 9 ± 0.11 mg / 100 g). The oil contents were 39.14 ± 0.01; 12.47 ± 0.05 and 1.26 ± 0.005 mg / 100 g respectively for larval, beef and tuna meal. These fat contents are statistically different for the three samples (F = 59.21, P <0.05). Compared to beef (0.81 ± 0.02 mg / 100 g) and tuna (1.73 ± 0.1 mg / 100 g), the carbohydrate content of the larval meal was 0.28 ± 0.02 mg / 100 g. From the energy point of view, larval flour contains on average 471.51 ± 1.4 kcal / 100 g of material and is twice the energy value obtained for beef flour (213.1 ± 0.5 kcal / 100 g).

Mineral content of the flours of the three samples

Potassium content was higher in the larval meal (75.26 ± 0.78 mg / 100 g) than in the beef and tuna meal (F = 36.48, P < 0.05). The sodium composition was 72.66 ± 0.57 mg / 100 g for beef, 60.13 ± 0.11 mg / 100 g for tuna and 56.49 ± 0.01 mg / 100 g for larvae.

The highest amount of calcium was observed in the larval meal with a value of 56.38 ± 0.45 mg / 100 g. This mineral was less important in beef flour (2.86 ± 0.05 mg / 100 g). The iron content varied between 6.03 ± 0.36 and 69.33 ± 0.00 mg / 100 g after the flours analyzes of the three samples. Largest value was obtained in larval flour (69.33 ± 0.00 mg / 100 g) and the lowest value (6.03 ± 0.36 mg / 100 g) in beef flour (F = 56.49, P <0.05). The overall content of the other minerals such as zinc, copper and manganese from the flours studied is between 0.13 and 4 mg / 100 g (Table 2).

Chemical properties of the oils of the three samples

For the acid values of the oils of the three samples, the lowest value was obtained with the larvae oil (3.06 ± 0.01 KOH / g). This index was high for beef and fish oil with respective values of 6.43 ± 0.05 and 6.33 ± 0.057 KOH / g (Table 3). The oils extracted from the flours studied showed low peroxide index values ranging between 4.56 ± 0.11 and 8.56 ± 0.16 meq O2 / kg. Tuna and larvae oils were characterized by elevated iodine value (142.83 ± 0.2 and 161.86 ± 0.1 g I / 100 g), whereas beef (45. 5 ± 0.4 g I / 100 g). Regarding the saponification index, a significant difference was observed (F = 48.29; P <0.05) between the average values obtained for the three samples. The saponification number of the larvae is 159.53 ± 0.61 mg KOH / g and that of the beef is 69.33 ± 0.00 mg KOH / g. Tuna obtained the highest saponification number with a value of 181.5 ± 0.7 mg KOH / g (Table 3).

Table 1: Biochemical parameters of larval meal of palm weevil, fish and beef.

Parameters	Flour		
	Palm tree larvae	Fish	Beef
Humidity (mg /100 g)	$25,66 \pm 0,05^a$	$74,39 \pm 0,28^b$	$60,47 \pm 0,08^c$
Dry matter (mg /100g)	$74,36 \pm 0,05^a$	$25,77 \pm 0,15^b$	$38,46 \pm 0,02^c$
Ash (mg /100 g)	$5,02 \pm 0,01^a$	$0,46 \pm 0,57^b$	$1,5 \pm 0,1^c$
Carbohydrate (mg /100 g)	$0,28 \pm 0,02^a$	$1,73 \pm 0,1^b$	$0,81 \pm 0,02^c$
Protein (mg /100 g)	$29,9 \pm 0,11^a$	$22,16 \pm 0,15^b$	$25,56 \pm 0,02^c$
Lipid (mg /100 g)	$39,14 \pm 0,01^c$	$1,26 \pm 0,005^a$	$12,4 \pm 0,05^b$
Energi kcal /100 g	$471,51 \pm 1,4^a$	$105,68 \pm 0,8^b$	$213,1 \pm 0,5^c$

The values in the table are averages of three tests, assigned standard deviations. At each column, the statistical differences from Duncan's test between these 95% average confidence levels are indicated by the different letters a, b, and c

Table 2 : Mineral content of flours of larvae, beef and tuna.

Minerals (mg / 100 g)	Farines		
	Beef	Fish	Larvea
Copper	$0,52 \pm 0,01^b$	$0,39 \pm 0,00^c$	$1,13 \pm 0,02^a$
Calcium	$0,61 \pm 0,01^b$	$2,86 \pm 0,05^c$	$56,38 \pm 0,45^a$
Fer	$6,03 \pm 0,36^b$	$4,13 \pm 0,05^c$	$69,33 \pm 0,00^a$
Manganèse	$1,56 \pm 0,11^c$	$2,76 \pm 0,05^b$	$4,9 \pm 0,00^a$
Magnésium	$71,57 \pm 0,00^b$	$47,64 \pm 0,05$	$141,26 \pm 0,15^a$
Potassium	353 ± 1^b	$314 \pm 0,4^c$	$675,26 \pm 0,78^a$
Zinc	$0,13 \pm 0,01^c$	$4,3 \pm 0,05^b$	$16,3 \pm 0,1^a$
Sodium	$60,13 \pm 0,11^b$	$72,66 \pm 0,57^a$	$56,49 \pm 0,01^c$

The values in the table are averages of three tests, assigned standard deviations. At each column, the statistical differences from Duncan's test between these 95% average confidence levels are indicated by the different letters a, b, and c.

Table 3 : Chemical properties of palm tree larva, fish and beef oils.

Indices	Farines		
	Larvae	Fish	Beef
Peroxide indices (meq O2 / kg)	$4,56 \pm 0,11^c$	$8,56 \pm 0,16^a$	$7,03 \pm 0,05^b$
Iodine indices (g I_2/100 g)	$142,83 \pm 0,2^b$	$161,86 \pm 0,1^a$	$45,5 \pm 0,4^c$
Saponification indices (mg KOH / g)	$159,53 \pm 0,61^c$	$181,5 \pm 0,7^a$	$69,33 \pm 0,00^a$
Acid indice (%)	$3,06 \pm 0,01^c$	$6,33 \pm 0,057^b$	$6,43 \pm 0,05^a$

The values in the table are averages of three tests, assigned standard deviations. At each column, the statistical differences from Duncan's test between these 95% average confidence levels are indicated by the different letters a, b, and c.

DISCUSSION

Edible insects play an important nutritional role in the diet of humans and animals in many parts of the world (Elemo et al., 2011; Rumpold and Schlüter, 2013 ; Zieliska et al., 2015)**.** The comparative study of the nutritional value of *R. phoenicis* larvae with that of beef and tuna revealed that the moisture content of larval flours (25.66 ± 0.05 mg / 100 g) is lower. This moisture content is lower than previously reported for *R. ferrugineus* larvae (Ekpo and Onigbinde, 2005 ; Womeni et al., 2012 ; Edijala et al., 2009). Lenga et al. (2012) obtained a moisture content of 28.20% in the same species at 26.6 ° C and 72.71% RH in Brazaville.

This low value of moisture allows a good physical and qualitative conservation of the larvae slowing considerably their degradation (Muvundja et al., 2012 ; Mabossy et al., 2013). The ash content of *R. phoenicis* larvae flour (5.02 ± 0.01%) was higher than that of beef (0.46 ± 0.57%) and tuna (1.5 ± 0.1 %) indicates that the larvae of this insect contain a lot of minerals. Concerning the protein content of the larvae studied, it was high (29.9 ± 0.11 mg / 100 g) compared to beef (25.56 ± 0.02 mg / 100 g) and tuna (22.16. ± 0.15 mg / 100 g). This value is higher than that obtained by Ekpo and Onigbinde (2005) for the same species (22.06 ± 0.26 mg / 100 g) in Nigeria. Akposson et al. (2009) found a higher protein level (55.77 ± 0.02 mg / 100 g) in *Imbrasia oyemensis*. The crude protein content of 29.9 ± 0.11 mg / 100 g is similar to that reported by Akinnawo and Ketiku (2000) which is 33.12 ± 0.87 mg / 100 g. This protein content is similar to that obtained by Banjo et al. (2006) in the same species in Nigeria. Since the essential function of a food protein is to satisfy the amino acid requirements, the regular consumption of *Rhynchophorus phoenicis* larvae could compensate for the important amino acid requirements and thus improve the nutritional quality of the meals (Van Huis, 2013). The lipid fraction of *R. phoenicis* larvae at 39.14 ± 01 mg / 100 g is greater than that of 25.30 ± 0.25 mg / 100 g reported by Elemo et al. (2011) for larvae of the same species at

Nigeria. Lipids provide energy to the body and allow the transport of fat soluble vitamins. The lipid content of these larvae could be an advantage. Comparing the energy value of *R. phoenicis* larvae meal (471.51 ± 1.4 kcal) with that of beef and tuna, it is found that *R. phoenicis* larvae are a more energetic food. This value is also higher than that of the caterpillars of *Burina aurantiaca* (433 kcal) and *Cirina forda* (375 kcal) recorded by Agbidye et al. (2009). This value (471.51 kcal) is higher than that recommended (413 kcal) for edible caterpillars (FAO, 2004). The meal of oil palm weevil larvae could therefore be a promising alternative in the incorporation of infant flours. As for the mineral elements, they are part of the essential micronutrients because they contribute to the good functioning of the organism by their implication in the physiological and metabolic functions.

They must be taken in very small amounts in the diet to stimulate cell growth and metabolism (Oyewole and Asagbra, 2003). For example, the calcium and magnesium contents of the palm weevil larvae are important compared to those of beef and fish. The concentration of the larval flours in these two minerals is higher than the nutritional reference values of EFSA Scientific Committee, (2015) whose requirements are estimated in adults at 10 mg / kg / day for calcium and 5 to 7 mg / kg / day for magnesium. In fact, this high calcium content for larvae is particularly advantageous for children since this element is involved in the constitution of bones and teeth, while magnesium is an important cofactor in many cellular metabolism reactions (Soetan et al., 2010). Type 2 diabetes has been reported to be associated with low levels of magnesium in the body (OMS, 2005). These insect larvae would be a better source and cheaper means to obtain this vital mineral. The high potassium content of the larvae (675, 26 ± 0.78 mg / 100 g) compared to those of beef (314 ± 0.4 mg / 100 g) and fish (353 ± 1 mg / 100 g) is an asset, as this compound plays an important role in the regulation of cellular osmotic balance (Murray et al., 2000). In addition, the potassium content of these larvae is higher

than that of *R. palmarum* (Gbogouri et al., 2013), termites and locusts according to Ajai et al. (2013). In addition, the mineral composition of the flours studied revealed the absence of heavy metals such as lead and cadmium which have a toxic effect by increasing oxidative stress and negatively affecting the reproductive function (Soetan et al., 2010). Iron is a trace element essential for the functioning of cells and is a fundamental constituent of red blood cells because it allows the transport of oxygen. The larvae studied have an iron concentration close to that reported by Foua Bi et al. (2015) for the larvae of Imbrasia oyemensis. It is higher than the average iron content recommended by l'EFSA (2015) and FAO (2004). Iron deficiency is common worldwide, especially in pregnant women and people with anemia (WHO, 2006). This deficit could be easily compensated by insect species such as the larvae of *Rhynchophorus phoenicis* but also by species such as *Imbrasia oyemensis* which are richly provided (FAO, 2004). The high zinc content of the palm weevil larvae studied (16.3 ± 0.1 mg / kg) could be used to supplement the daily requirement of an adult 60 kg zinc estimated at 15 mg / day (OMS, 2005). Considering the importance of sodium in human metabolism, FAO has recommended a daily dietary intake of 2400 mg of sodium (FAO, 2010). The sodium concentration of the larvae studied (56.49 ± 0.1 mg / 100 g) is higher than those of the caterpillar *Cirina butyrospermii* obtained by Yapo et al. (2017). The high content of this trace element is an asset that could be capitalized in view of the significant presence of other micronutrients. The iodine value observed for palm larvae (142.83 ± 0.61 mg KOH / g) is higher compared to that of beef (45.5 ± 0.4 g / I2 / 100 g). Apart from beef, the iodine value of these larvae is higher than that of the corn oil grown in Pakistan (Qasim et al., 2013) and flour from *Imbrasia oyemensis* (Foua Bi et al., 2015). Indeed, the iodine index is an essential trace element that is directly related to the thyroid gland which it ensures the proper functioning. It is found in very small amounts in the body. The consumption of these larvae could fill this lack at the level of the body. As

for the saponification index value of larvae (159.53 ± 0.61 mg KOH / g), it is higher compared to that of beef (69.33 ± 0.00 mg KOH / g). The saponification value of the *R. phoenicis* larvae obtained is lower than that of the raspberry seed oil (*Rubus idaeus*) of between 191 and 192 mg KOH / g (Oomah *et al.*, 2000). However, this index is close to that reported by Abdulkarim et al. (2005) for *Mounga oleifera* seed oils (163 ± 0.98). The high value of the saponification index of an oil indicates its value in the cosmetics industry (Akbar et al., 2009). The dietary value of a fat is related to the acid number and the peroxide index which constitute parameters of alterability. The oil of the larvae of *R. phoenicis* has an acid number (3.06 ± 0.01 mg KOH / g) of less than 6 mg KOH / g, which is the recommended limit value for the use of fat in the diet. culinary purposes (Onyeike et Acheru, 2002). The lower peroxide value of the oil of *R. phoenicis* larvae shows that this oil is not very sensitive to oxidative rancidity (Akbar et al., 2009). In addition, the potential use of this oil in the feed is also favored by the peroxide index of less than 10 meq O2 / kg; FAO recommended limit value for oils for human consumption (Fernandez-Lopez et al., 2008).

Conclusion

The comparative study of the nutritional value of *Rhynchophorus phoenicis* palm weevil larval meal with that of beef and fish reveals that the late-stage larvae of this insect species are rich in various nutrients. Larvae of *R. phoenicis* are likely to provide humans with essential nutrients for their diet. Larvae of this species have significant macronutrient potential such as proteins and lipids and micronutrients such as iron, zinc, calcium and many other elements. These larvae can thus be nutritional supplements for populations whose diets are constantly deficient in protein, fat and trace elements.

COMPETING INTERESTS

The authors declared that they have no competing interest.

AUTHORS' CONTRIBUTIONS

GPE, S-WMO-N'G, DS and MEB were the promoters of this work and approved the final version of this manuscript after having integrated their observations.

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