SURVIVABILITY AND NUTRIENT COMPOSITION OF AFRICAN PALM WEEVIL (*RHYNCOPHORUS PHOENICIS* FABRICIUS) REARED ON FIVE DIFFERENT AGRO-PRODUCTS

Fadeyibi B. T[1]., Omojola A. B[1]. and *Awodoyin, O. R[1].
Department of Animal Science, University of Ibadan, Oyo State.
**Email: kasyem@yahoo.com*
https://dx.doi.org/10.4314/gjansci.v15i1.8

ABSTRACT
African palm weevil larvae (APWL) (Rynchophorus phoenicis F.), a relished traditional food but major pest of oil palm, coconut, raffia palm, sago palm and occasionally sugarcane causes death and economic loss of these plants. Availability of feedstock is crucial for sustainable insect production however, nutrient, palatability and cost of ingredients is also essential. Thus, the need to develop nutrient efficient and cost-effective feed substrates to produce industrially safe insects. Four hundred (400) pieces third instar of APWL from the wild in Igbokoda, Ondo state, Nigeria, weighing 0.8-1.5 g were placed in perforated plastic cages, and fed palm yolk for 48 hours. After acclimatization, similar weights larvae were allotted to five substrates (palm yolk + sugarcane, young unripe coconut husk, sugarcane, honey syrup, water melon) in a completely randomized design with four replicates (n=20). After 30 days, adult insects were placed together (1 male: 5 females) and eggs laid fed dietary treatments ad libitum for 12 weeks. Survivability, weight, proximate and mineral (larvae), length, width and circumference (adult) from treatment with highest survivability were assessed. Data were analyzed by ANOVA at p<0.05. Larvae (young unripe coconut husk) had 91.25% survivability and significantly higher (p<0.05) than 68.75% (PalmYolk+Sugarcane), 38.75% (sugarcane), 38.75% (water-melon) and 18.75% (honey-syrup). Larvae weighed 8.10 g, contain 63.41% (moisture), 2.20% (ash), 12.17% (crude protein), 18.45 mg/g (sodium), 5.00 mg/g (iron), 2.42 mg/g (copper), 0.02 mg/g (calcium), 0.04 mg/g (magnesium) and 0.13 mg/g (phosphorus). The adult body was 4.20 cm (length), 2.02 cm (width) and 5.40 cm (circumference). The study highlighted that Palm weevil larvae can be reared on artificial feed substrates. Larvae and adult insects performed best on young unripe coconut husk.

Keywords: *African Palm weevil larvae, biomass, sustainability, unripe coconut husk, palm yolk, insect farming*

INTRODUCTION
Traditional food particularly in sub-Saharan Africa have been reported to be sustainable with economic, nutritional and ecological benefits (Van, 2003) and among various cultures of the world, insects remain a vital and preferred traditional food (Durst and Shono, 2010). In many cultures, edible insects are popular source of food and the emphasis on their production and consumption is not only because of the nutrition-

al security they proffer but they also help in reducing poverty thus increasing the overall well-being of the household (Commendar *et al*., 2019; Parker *et al*., 2020).

Edible insects depend largely on forest for their survival as they are associated with one or more host plants and their collection depends on the season in which the consumption stage is available (Alamu *et al*., 2013). The nutritional value of some of these edible insects could be compared with that of meat and fish, while higher proportions of proteins, fat and energy value are recorded in others (De Foliart, 1992). One of such insects is the larvae of *Rynchophorus phoenicis* F. (African palm weevil larvae) (APWL) which is usually available during the wet season. The matured larva is about four inches long and two inches wide, fleshy and grub-like (Elemo *et al*., 2011). They are traditional cuisines that can serve as occasional delicacy, food replacement especially in times of shortages (Adedire and Aiyesanmi, 1999; Mutungi *et al.,* 2019) or merged with other foods (Ayensu *et al*., 2019). It is rich in nutrient (25.04% protein, 50.23% fat, 12.60% fiber and 3.91% ash) (Rumpold and Schluter, 2013) and provide a good source of energy, minerals and vitamins (Zielinska *et al*., 2015; Nongonierma and FitzGerald, 2017; Kohler *et al*., 2019). They are notably known for their high level of unsaturated fatty acid which is rich in essential fatty acids. These nutritional potentials of African palm weevil larvae have endeared them to man despite their destructiveness.

The life cycle of *Rynchophorus phoenicis* usually takes place within their host trees (Thomas *et al*., 2004). The insect is occasionally found in sugarcane plants (Hoddle, 2015) but it is a well-recognized menace and secondary pest of oil palm, coconut and raffia palm as well as sago palm where its larvae are found burrowing deeply in the palm trees (Sánchez and Cerda, 1993; Thomas *et al*., 2004). During the developmental stages, the cavities excavate by the larvae can be more than a metre in length which may eventually lead to the death of the host tree after three to four months of infestation (Faleiro *et al*., 1999).

Many small-scale businesses have flourished through the gathering in small quantities of wild edible African palm weevil larvae (Thomas and Briyai, 2019). In most African countries, the unsustainable practice of wild collection, which is characterized by low yield and seasonality problems has remained the only means of harvesting the larvae (Ebenebe *et al.*, 2017). This is because the larvae are only available during the wet season due to availability of their host plants on which they feed voraciously on and grow robust with food store up in their fat bodies (Alamu *et al*., 2013). However, the exploitation of these larvae from the wild is irregular and cannot satisfy the increasing market demand (Fogoh *et al*., 2015) and this had reduced its availability for consumption (Laar *et al*., 2017).

One way of re-introduction of this edible larva into the modern food supply and meeting the high demand that comes with it is through its micro-farming. Furthermore, with the indiscriminate felling of palm trees during their wild collection, it becomes more important to explore ways of cultivating them intensively. This will facilitate more consistent seasonal availability and greater ease of procurement. It is therefore imperative to promote its farming by developing artificial diets and adopting the necessary management techniques in order to meet consumer demands and also lessen its wild collection. Therefore, in order to obtain and maintain high production yield of the weevil, adequate substrate should be available to meet the daily feeding demand of the insects (Asomah *et al*., 2023). However, in livestock feed formulation process, ingredients are selected not on availability alone but also on their nutrient content, palatability and cost (www.poultryhub.org/nutrition/feed-formulation/).

This research therefore aimed at developing and automatizing cost effective, nutrient and energy efficient feed substrate by assessing the survivability, nutrient compositions and morphology of larvae and adult of African Palm weevil on different agro products substrates.

MATERIALS AND METHODS

Sample collection and Experimental design

Third instar of APWL were procured from the main jetty market at Igbokoda, Ondo state, South West, Nigeria. They were transported to Ibadan in perforated plastic containers with wet palm yolk. On arrival, the larvae, 400 pieces were randomly allotted to five experimental diets in a completely randomized design with four replicates of 20 larvae each.

Experimental site, house, diets and management

The study was carried out at the Teaching and Research Farm University of Ibadan. Perforated (in order to let out moisture) plastic containers of 30 cm diameters and 40 cm height were used for rearing in order to mimic the natural environment of the APWL. The plastic containers were covered with mosquito net to keep away insects and other parasites. The containers were elevated in order to collect the juice or pulp resulting from feeding activity of the larvae on the substrate (Ebenebe, *et al.*, 2017). To minimize accumulation of microbes and other parasites, fresh feed substrates were replaced with the old ones in each container every week.

Rearing of *Rynchophorus phoenicis* F. on diets

On arrival, the larvae were fed with palm yolk (their natural feed) for 48 hours for acclimatization after which they were fed the experimental diets. The diets were Palm yolk + sugarcane, Young unripe coconut husk (YCH), Sugarcane, Honey syrup (HS) and Water-melon. For sugarcane, small holes were made at the end of each piece of sugarcane stem using a cork borer so that the larvae can burrow inside it. The containers were checked daily for any dead larvae in which they were removed. After 10-14 days of feeding, cocoons (where available) were collected (where this is not formed, the larvae were transferred with a camel brush hair) and placed in another containers cages, wet with water as needed and closed with lids. After two weeks of cocoon/larvae collection, they were monitored daily as they metamorphosed/emerged into adult weevil. This phase lasted for four weeks.

Adult insects were collected and sexed into male and female, (this was possible by close observation of the length of the rostrum and presence or absence of tuft of hairs on the rostrum. Longer, curved rostrum without tuft of hairs were identified as female while shorter less curved rostrum were identified as the male (Ebenebe, *et al.*, 2017). The adults were placed in perforated plastic cages at ratio 1 male to 5 females. Eggs were laid between 2-3 days and cotton wicks holding laid eggs were removed from the oviposition sites and placed inside another perforated plastic cages containing wet cotton wicks for incubation. After 2 to 6 days (eggs hatched between this periods), larvae from hatched eggs were removed to separate containers and fed with the dietary treatments *ad libitum*. The rearing room was maintained at 26±2°C and 65-75% relative humidity with a photoperiod of 12:12. This phase lasted for 12 weeks.

Data Collection

Survivability was monitored by counting and recording the number of larvae alive and mortality in each feeding substrate. The weight was also monitored on weekly basis using a sensitive weighing scale (CAMRY model EK5055).

Morphometric evaluation and laboratory analyses of the larvae were carried out only on the larvae with the best survivability potentials.

Survival rate and percentage survivability of larvae on different feed

This was obtained by subtracting number of dead larvae from live larvae in each treatment per week for a period of four weeks.

% survivability of larvae =

$$\frac{\text{No. of surived larvae at the end of experiment}}{\text{No. of larvae at day 0}} \times 100$$

(Ebenebe *et al.*, 2017).

Morphometric evaluation

A total of five pieces of fifth larvae instar were evaluated and the mean calculated. Parameters evaluated were: length (cm), width (cm), circumference (cm) and head length (cm) with a precision digital Vernier caliper 150 mm (6”) and larvae body weight (g).

Proximate composition
Approximately thirty grams (30 g) of larvae from each dietary treatment was sampled and the following parameters: moisture, protein, ash, fat and crude fibre were determined using AOAC (2005).

Mineral composition
This was carried out in triplicates through an atomic absorption spectrophotometer. The samples were dry-ashed in a muffle furnace at 550°C until a grey to reddish brown colour of the ash was observed (approximately 6 hours). The ash was then dissolved in a mixture of nitric acid (65%), hydrochloric acid (37%) and hydrogen peroxide (30%) (Manditsera *et al*., 2019).

Fatty acid profile
The triglyceride profile was determined by HPLC. The analysis was carried out using a HPLC (Infinity Series 1260, Aligent Technologies, Germany) fitted with an auto sampler and a Refractive Index Detector. The Hypersil ODS C-18 column at ambient temperature was used with mobile phase of Acetonitrile: Acetone (37.5: 62.5) at flow rate of 1.5. The elution program was isocratic. The purpose of this analysis was to characterize the fatty acid composition. Using mole ratio, the concentration of each component fatty acid was calculated for each triglyceride (Ortiz *et al*., 2016). All samples were analyzed in triplicate and the fatty acids assessed were lauric, stearic, palmitic, oleic, linoleic, linolenic, myristic, palmitoleic acids.

Statistical analysis
All the experiments were conducted in triplicates. Data obtained were subjected to analysis of variance (ANOVA) using SAS package (2012). Significance of mean differences was accepted at $p < 0.05$ using Duncan’s multiple range test.

RESULTS
Survivability
The biomass of survived larvae (African Palm Weevil Larvae) on different diets after four weeks as displayed on figure 1 showed survived biomass ranging from 15-73. The survival ability

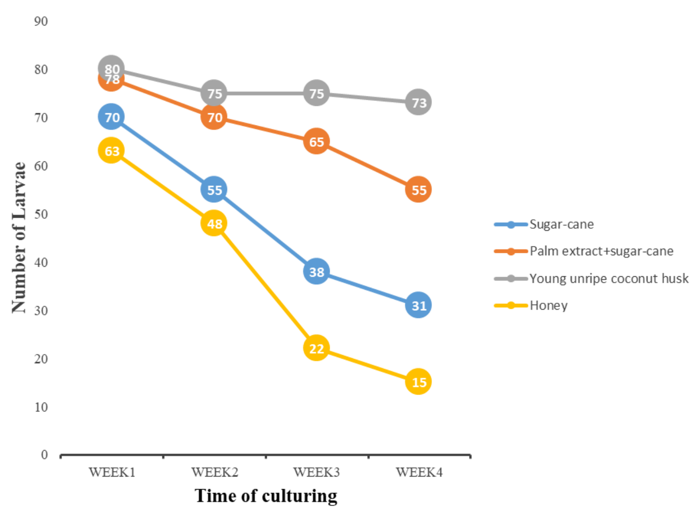

Figure 1: Survival rate of *Rhynchophorus phoenicis* F. on five dietary feed treatments

SC= Sugarcane, PY + SC= Palm yolk+sugarcane, YCH=Young unripe coconut husk, WM=Water melon

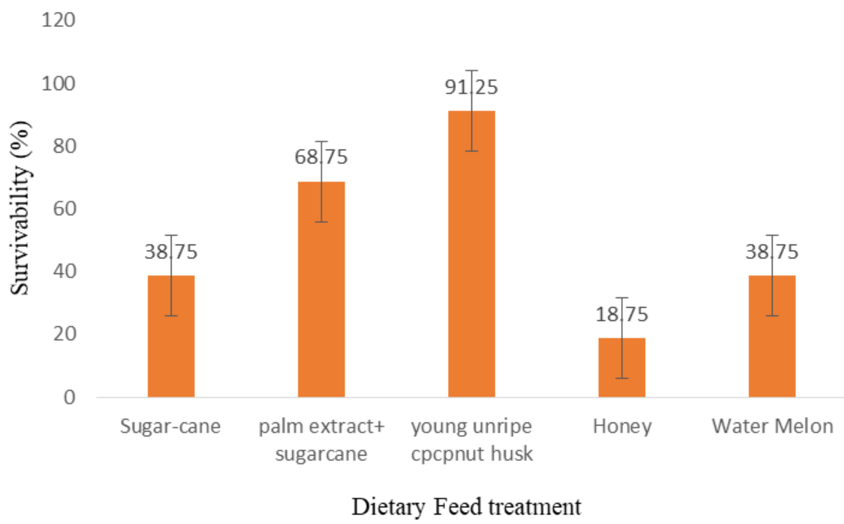

Figure 2: Survivability percentages of *Rhynchophorus phoenicis* F. on different dietary treatments

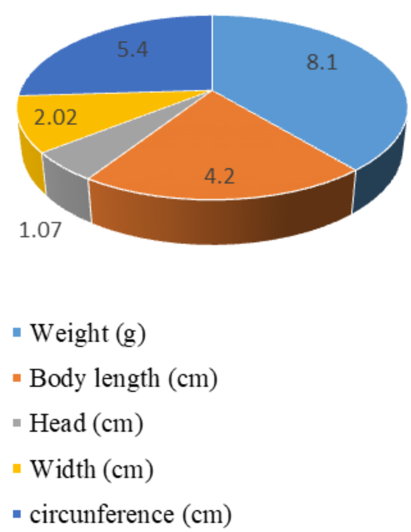

Figure 3: Morphometric characteristics of *Rhynchophorus phoenicis* F. fed young unripe coconut husks

(figure 2) (91.25%) of larvae fed YCH was significantly higher ($p<0.05$) than 68.75%. (Palm extract+ sugar-cane), 38.75% (sugar-cane and water-melon separately) and 18.75% (honey).

Morphological evaluation

The adult African Palm weevil dimensions as presented in figure 3 indicated that the weight of survived matured adult palm weevil had an average weight of 8.10 g while the average body length was 4.20 cm. The mean head length was 1.07 cm with a body width of 2.02 cm while a mean of 5.40 cm was recorded for the body circumference.

Proximate and mineral compositions of *Rhynchophorus phoenicis* F. fed with young unripe coconut husks

The proximate composition of APWL (head inclusive) that survived best on YCH as displayed on Table 1 showed that the larvae contained 63.41% (moisture), 2.20% (ash), 12.17% (crude protein) and 0.01% (crude fibre).

Table 1: Proximate and mineral compositions of *Rhynchophorus phoenicis* F. fed with young unripe coconut husks

	Proximate composition (%)							
	Moisture	Ash	Crude Protein	Ether Extract	Crude Fibre			
Larvae with head	63.41	2.20	22.17	9.92	0.01			
				Minerals (mg/g)				
Larvae	Ca	Fe	Cu	Na	K	Mn	Mg	P
	0.02	5.00	2.42	18.45	0.25	2.30	0.04	0.13

Ca= Calcium; Fe= Iron; Cu= Copper; Na= Sodium; P= Phosphorus; K= Potassium; Mn= Manganese; Mg= Magnesium

The mineral analysis (mg/g) of APWL fed YCH depicted on Table 2 showed that APWL is rich in sodium (18.45), iron (5.00), copper (2.42) and manganese (2.30). Other minerals present were calcium (0.02), magnesium (0.04), potassium (0.25) and phosphorus (0.13).

Fatty acid profile

The fatty acid composition of APWL fed YCH compared with lard as displayed on figure 4 highlighted that the percentages of lauric (4.2%), oleic (43.40%), linolenic (4.74%), myristic (4.79%) and palmtoleic (5.34%) acids found in APWL were higher than 1.50% (lauric), 32.60% (oleic), 0.08% (linolenic), 1.70% (myristic) and 1.50% (palmtoleic) found in lard. A higher percentage ($p<0.05$) of stearic (11.50%), palmitic (24.50%) and linoleic (9.90%) was obtained in lard compared with 0.93% (stearic), 5.35% (palmitic), 5.89% (linoleic) found in APWL.

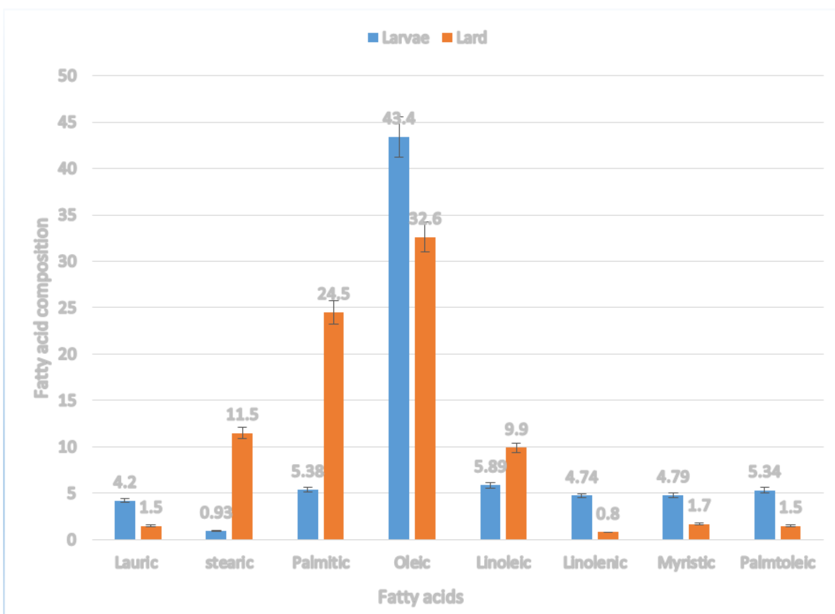

Figure 4: Fatty acid composition of raw *Rhynchophorus phoenicis* F. fed young unripe coconut husks and lard

DISCUSSION

The APWL were fully developed on the various dietary feed substrates however, the survival rate in terms of average biomass of larvae at various instar stages, percentages of larvae that went into cocoon, biomass and percentage of emerged adults varied greatly among the tested diets. This is contrary to the reports of Monzenga *et al.* (2017), Quaye *et al.* (2018) and Walid *et al.* (2020) who opined that African Palm weevil larvae could not be reared outside their natural environment. However, the results from this study highlighted that African Palm weevil larvae could be micro farmed for commercial purposes for maximum profit on low cost feeds.

Low biomass number and percentages were recorded for larvae on honey and water melon diets irrespective of the days of growth. This could be as a result that these larvae failed to construct cocoons because of the unavailability or not enough of fibers in these diets as opined by Kaakeh *et al*. (2001). It could also be attributed to the fact that these larvae could not burrow in these diets very well as they did in other diets because palm weevil larvae are concealed tissue borer (Murphy and Briscoe, 1999) which is one of their feeding properties. Again, it is expected that larvae on sugarcane diets will survive better as observed by Kaakeh *et al*. (2001) but a higher percentage of survivability of the larvae was recorded on young unripe coconut diets.

The high number of larvae that metamorphosized into adults when fed young unripe coconut husk could be due to the fact that this diet was able to mimic the natural environment of the larvae. It might also be the fact that the diet possesses some feeding properties such as softness, burrowing characteristics, cocoon forming ability which are some characteristics that contributes to their growth. For instance, burrows are used for seasonal mating, oviposition, and hibernation (Rodriguez-Muñoz *et al*., 2010; Bretman *et al*., 2011) all of which aid their growth.

The dimensions such as the weight, width and circumference of the adult African Palm weevils with highest survivability obtained in this study during the feeding trials were higher than 6.89 g (weight), 2.20 cm (width) and 4.49 cm (circumference) while the linear body measurement (5.70 cm) and head length (2.88 cm) were lower than the dimensions reported by Omotoso and Adedire (2008). Also, some of the values obtained in this study were similar to what was obtained by Tambe *et al*. (2013) when larvae were fed different feed substrates.

The chemical composition revealed that these larvae composed mostly of water as also observed by Ekpo and Onigbinde (2005) and Womeni *et al*. (2012) who reported a lower water content of 61%. The crude protein, fat and ash contents recorded in this study for larvae fed YCH were lower than 32.83% ; 32.39% (crude protein) and 50.29%; 42.43% (fat) and 3.23%; 3.18% (ash) reported by Parker *et al*. (2020) when palm weevil larvae (akokono) larvae were reared on palm pith and pito mash respectively. The values obtained here were also lower than 30.46% (crude protein), 22.24% (fat) and 7.64% (ash) contents found in red palm weevil (*Rhynchophorus ferrugineus*) reported by Ash *et al*. (2017). However, values obtained in this study were slightly comparable to 53.80% (moisture), 1.00% (ash), 15.36% (fat) and 25.30% (crude protein) found in *Rhynchophorus phoenicis* larvae reported by Okunowo *et al*. (2017). Furthermore, the crude protein obtained here was similar to what was found in larvae fed sugarcane tops and spoilt water melon but lower than when fed spoilt pineapple and higher than when fed raw pawpaw (Ebenebe *et al*., 2017). These researchers also reported a higher ash and lower ether extracts contents compared with larvae fed YCH. Although there are inconsistencies in the literature reports but the crude protein, 28.42% (Banjo *et al*., 2006) and 71.63% (Braide and Nwaoguikpe, 2011) of African palm weevil larvae that grew completely in the raffia palm were high when compared to the values obtained in this study.

Various results of the mineral analyses showed that mineral salts are persistently present in *Rhnchophorus phoenicis* larval stage. The

Rynchophorus phoenicis fed YCH examined in this study is found to contain manganese, magnesium, calcium, phosphorus, copper, potassium and very rich in sodium and iron while other studies reported richness in potassium and phosphorus (Elemo *et al.*, 2011). The levels of minerals present in the samples indicate that they are good sources of minerals and daily requirements of essential minerals can be derived from their consumption (Ash *et al*., 2017). For instance, the high sodium content and other essential microminerals such as Fe, Mn and Cu recorded in the present study represents a high potential of the nutrient-rich larvae as suitable for several purposes such as regulation of fluids in the body and its inclusion in diet of anemic patient.

The mineral composition of African palm weevil recorded in this study compared with other studies showed greater differences particularly in micronutrients contents which varies between studies. Multiples studies from Nigeria showed that there is significant variability in mineral contents (Ekpo and Onigbinde, 2005; Okaraonye and Ikewuchi, 2008) of larvae even when they were fed only raphia palm pith. This variation is reported to be dependent of sources of procurement of the larvae (Rumpold and Schlüter, 2013) of the larvae geographical locations, ecological factors and diets as the minerals are obtained from the dietary sources and not synthesized in the animal body (Meyer-Rochow *et al*., 2021).

Consistent with existing research, this study has shown Nigeria APWL to be a nutrient-rich, protein food and are also a better sources of protein compared with other protein-rich foods as reported by Okunowo *et al* (2017). This implied that the insect larvae could serve as a novel alternative source of protein and other nutrients supplement in human and animal diet (Ash *et al.*, 2017) and its inclusion as food can help improve dietary quality when including animal sourced protein in the diet (Van-Huis *et al*., 2013). This also confirmed that the insect larvae could form a base for food product of considerable nutritive value as opined by Ekpo and Onigbinde (2005) and its inclusion in the diet will also boost the cereal based diets common in developing countries. The nutritional composition of African palm weevil larvae recorded in this study as compared to other studies showed greater differences and this varies between studies which could be as a result of differences in their feed/diet, age and the location/environment where they are indigenously sourced (Zielinska *et al*., 2015).

Lipids represent the second main component in palm weevil larvae (Fogang Mba *et al*., 2018). The fatty acid composition analysis of *Rynchophorus phoenicis* larvae compared with lard revealed that it contains higher levels of unsaturated fatty acids. This study is in consistent with reports of Dué *et al*. (2009) and Gbogouri *et al*. (2013). The oleic and linolenic found in the African palm weevil in this study is higher than what Okunowo *et al*. (2017) reported. These authors also find a total of 47.36% saturated and 52.35% unsaturated fatty acids in the African palm weevil larvae they researched on. The unsaturated fatty acids levels especially oleic, linolenic and palmtoleic acids found in APWL is higher than what is obtained in lard. This further implied that the larvae can replace lard in food where lard is used as fat.

CONCLUSION

This study has revealed that insect farming is an efficient alternative to rearing pigs, cows and goats for protein. This study further confirmed that African Palm weevil larvae can be microfarmed on other sources of feed such as young unripe coconut husks or sugarcane. This will reduce reliance on economic felled trees and cost of production thus increasing its production sustainability. Also, a successful farming of this insect will increase its availability for local subsistence, providing increased opportunity for alternative protein sources in the area of study, thereby assuring a year-round availability of this resource.

REFERENCES

Adedire, C.O. and Aiyesanmi, A. F. (1999). Proximate and mineral composition of the adult and immature forms of the variegated grasshopper, *Zonocerus variegatus* (L) (Acridoidea: Pygomorphidae). *Bioscience Research Communications,* 11(2): 121-126.

Alamu, O.T., Amao, A.O., Nwokedi, C. I., Oke, O. A. and Lawal, O. (2013). Diversity and nutritional status of edible insects in Nigeria: a review. *International Journal Biodiversity Conservation*, 5(4):215-222.

AOAC (2005), AOAC, Official methods of analysis of AOAC international (17th ed.), AOAC International, Gaithersburg, MD, USA.

Ash, A., El-Kholy, M. Y. and Wea, E. (2017). The Red Palm Weevil, *Rhynchophorus ferrugineus* Olivier, As Edible Insects for Food and Feed a Case Study in Egypt. *Research Journal of Pharmaceutical, Biological and Chemical Sciences,* 8(3): 1653-1658.

Asomah, S., Anankware, J. P., Debrah, K. S. and Obeng-Ofori, D. (2023). Evaluation of different substrates on the life history parameters of African palm weevil, *Rhynchophorous phoenicis* (*Coleoptera: Curculionidae*) in Ghana. *Cogent Food & Agriculture,* 9: 2232170 https://doi.org/10.1080/23311932.2023.2232170

Ayensu, J., Lutterodt, H., Annan, R. A., Edusei, A. and. Loh, S. P. (2019). Nutritional composition and acceptability of biscuits fortified with palm weevil larvae (*Rhynchophorus phoenicis Fabricius*) and orange-fleshed sweet potato among pregnant women. *Food Science and Nutrition,* 7 (5):1807-1815.

Banjo, A. D., Lawal, O. A. and Songonuga, E. A. (2006). The nutritional values of fourteen species of edible insects in South Western Nigeria. *African Journal of Biotechnology,* 5 (3): 208-301.

Braide, W. and Nwaoguikpe, R. N. (2011). Assessment of microbiological quality and nutritional values of a processed edible weevil caterpillar (*Rhynchophorus phoenicis*) in Port Harcourt, Southern Nigeria. *International Journal of Biological and Chemical Sciences*, 5(2): 410- 418.

Bretman, A., Rodriguez-Muñoz, R., Walling, C., Slate, J.and Tregenza, T. (2011). Fine-scale population structure, inbreeding risk and avoidance in a wild insect population. *Molecular Ecology* 20: 3045-3055.

Commander, T.N., Anankware, J.P., Onwugbuta, O.R. and Obeng-Ofori, D. (2019). Econometrics of domestication of the African palm weevil *(Rhynchophorus phoenicis* F.) production as small-scale business in Ghana. Intech Open, London, UK. http://dx.doi.org/10.5772/ intechopen.90259

De Foliart, G. R. (1992). Insects as human food. *Crop Protection*, 11(5): 395-399

Dué, E. A., Zabri, H., Kouadio, J. and Kouame, L. P. (2009). Fatty acid composition and properties of skin and digestive fat content oils from *Rhynchophorus palmarum* L. larvae. *African Journal of Biochemistry Research,* 3: 89-94.

Durst, P. B. and Shono, K. (2010). Edible forest insects: exploring new horizons and traditional practices. Proceedings of a workshop on Asia-Pacific resources and their potential for development, 19-21 February 2008, Chiang Mai, Thailand. Bangkok: Food Agriculture Organisation United Nations, Pp. 1-4.

Ebenebe, C. I., Okpoko V.O., Ufele A. N. and Amobi M. I. (2017). Survivability, growth performance and nutrient composition of the African Palm Weevil (*Rhyncophorus phoenicis* Fabricius) reared on four different substrates. *Journal of Bioscience and Biotechnology Discovery,* 2: 1-9.

Ekpo, K.E. and Onigbinde, A. O. (2005). Nutritional Potentials of the larva of *Rhynchophorus phoenicis* (F). *Pakistan Journal Nutrition*. 4(5): 287-290.

Elemo, B.O., Elemo, G.N., Makinde, M. A. and Erukainure, O. L. (2011). Chemical evaluation of African palm weevil, *Rhychophorus phoenicis*, larvae as a food source. *Journal of Insect Science* 11(146): 1-6.

Faleiro J. R., Al-Shuaibi, M. A., Abraham V. A. and Kumar, T. P. (1999). A technique to assess longevity of the pheromone (Ferrolure) used in trapping *Rhynchophorous ferrugineus*. *Journal Scientific Research in Agricultural Science* 4: 5-9.

Fogang Mba, A. R., Kansci, G., Viau, M., Ribourg, L., Muafor, J. F., Hafnaoui, N., Le Gall, P. and Genot, C. (2018). Growing conditions and morphotypes of African palm weevil (*Rhynchophorus phoenicis*) larvae influence their lipophilic nutrient but not their amino acid compositions. *Journal of Food Composition and Analysis* 69: 87-97

Fogoh J. Muafor, Gnetegha, A. A., Le Gall, P. and Levang, P. (2015). Exploitation, trade and farming of palm weevil grubs in Cameroon. Working Paper 178. Bogor, Indonesia: CIFOR. DOI: http://dx.doi.org/10.17528/cifor/005626

Gbogouri, G., Maxwell Beugre, G., Brou, K., Atchibri, O. and Linder, M. (2013). *Rhynchoporus palmarum* L. larva, an edible insect in Cote D'Ivoire: nutritional value and characterization of the lipid fraction. *International Journal of Chemical Science* 11: 1692-1704.

Hanboonsong, Y., Tasanee, J. and Durst, P. B. (2013). Six-legged livestock: edible insect farming, collection and marketing in Thailand. Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific Bangkok, 2013

Hoddle, M. S. (2015). Red Palm Weevils – Food or Foe? Palms, 59(1): 21-30

Kaakeh, W., Aboul-Anour, M. and Khamis, A. A. (2001). Mass rearing of the red palm weevil, *Rhynchophorus ferrugineus* Oliv. on sugarcane and artificial diets for laboratory studies. In Proceedings of the Second International Conference on Date Palm (refereed), Al-Ain, UAE. Pp. 344-357.

Kohler, R., Kariuki, L., Lambert, C. and Biesalski, H. K. (2019). Protein, amino acid and mineral composition of some edible insects from Thailand. *Journal Asia Pacific Entomology,* 22:372-378.

Laar, A., Megan Parker, M., Kotoh, A., Tawiah, C., Peiman Milani, P., Anankware, J. P., Shobhita Soor, S., Kalra, N., Tandoh, A. Manu, G., Engmann, C., Zobrist, S. and Pelto, G. (2017). An Exploration of Edible Palm Weevil Larvae (Akokono) as a Source of Nutrition and Livelihood: Perspectives from Ghanaian Stakeholders. *Food and Nutrition Bulletin,* 38(4) 455-467

Manditsera, F. A., Luning, P. A., Fogliano, V. and Lakemond, C. M. M. (2019). The contribution of wild harvested edible insects (Eulepida mashona and Henicus whellani) to nutrition security in Zimbabwe. *Journal of Food Composition and Analysis,* 75: 17–25.

Meyer-Rochow, V.B., Gahukar, R.T., Ghosh, S. and Jung, C. (2021). Chemical Composition, Nutrient Quality and Acceptability of Edible Insects Are Affected by Species, Developmental Stage, Gender, Diet, and Processing Method. *Foods*, 10 (1036) 1-36 https://doi.org/10.3390/foods10051036

Monzenga, L. J. C., Le Goff, G. J., Bundo, K. and Hance, T. (2017). Influence of substrates on the rearing success of *Rhynchophorus phoenicis* F. *African Journal of Food Science Technology,* 81: 7-12.

Murphy, S. T. and Briscoe, B. R. (1999). The red palm weevil as an alien invasive: biology and the prospects for biological control as a component of IPM. *BiocontrolNews and Information* 20 (1): 35N-46N

Mutungi, C., Irungu, F.G., Nduko, J., Mutua, F., Affognon, H., Nakimbugwe, D., Ekesi, S. and Fiaboe, K. K, M. (2019). Postharvest processes of edible insects in Africa: A review of processing methods, and the implications for nutrition, safety and new products development. *Critical Review Food Science Nutrition,* 59:276-298.

Nongonierma, A. B. and FitzGerald, R. J. (2017). Unlocking the biological potential of proteins from edible insects through enzymatic hydrolysis: A review. *Innovation Food Science Emergency Technology,* 43: 239-252.

Okaraonye, C. C. and Ikewuchi, I. J. (2008). *Rhychophorus phoenicis* (F) larva meal: Nutritional value and health implications. *Journal of biological sciences,* 8(7): 1221-1225

Okunowo, W. O., Olagboye, A. M., Afolabi, L. O. and Oyedeji, A. O. (2017). Nutritional Value of *Rhynchophorus phoenicis* (F.) Larvae, an Edible Insect in Nigeria. *African Entomology,* 25(1):156-163.

Omotoso, O. T. and Adedire, C. O. (2008). Potential Industrial Uses and Quality of Oil of Palm Weevil, *Rhynchophorus phoenicis* F. (Coleoptera: Curculionidae). *Pakistan Journal Science Ind. Res.* 51(2): 93-97.

Ortiz, E. G., Quintero, I. and Arévalo, K. (2016). Biodiesel production from three mixes of oils with high free fatty content: quality evaluation and variable analysis. *International Journal Environment, Science and Technology*, 13(5):1367-76

Parker, M., Zobrist, S., Mansen, K., Soor, S., Laar, A., Asiedu, C. and Lutterodt, H. (2017). Nutrient analysis of farmed palm weevil larvae for the advancement of edible insects in Ghana. *The FASEB Journal*, 31 (1):636-639.

Parker, M.E., Zobrist, S., Lutterodt, H.E., Asiedu, C.R., Donahue, C., Edick, C., Mansen, K., Pelto, G., Milani, P., Soor, S., Laar, A. and Engmann, C.M. (2020). Evaluating the nutritional content of an insect-fortified food for the child complementary diet in Ghana. BMC Nutrition 6: 7-22. https://doi.org/10.1186/s40795-020-0331-6

Quaye, B., Donkoh, A., Adjei M. B., Opoku, O., Amankrah, M. (2018). Nutritional potential and microbial status of African Palm Weevil (*Rhynchophorus phoenicis*) larvae raised on alternative feed resources. *American Scientific Research Journal for Engineering, Technology and Sciences,* 48: 45-52.

Rodriguez-Muñoz, R., Bretman, A., Walling, C., Slate, J. and Tregenza, T. (2010). Natural and sexual selection in a wild insect population. *Science,* 328: 1269-1272.

Rumpold, B. A. and Schlüter, O. K. (2013). Nutritional composition and safety aspects of edible insects. *Molecular Nutrition and Food Research,* 57: 802-823.

Sánchez, P. and Cerda, H. (1993). The Rhynchophorus palmarum (L.) (Coleoptera: Curculionidae), Bursaphelenchus cocophilus (Cobb) (Tylenchidae: Aphelenchoididae) complex in Palmeras. *Boletin de Entomologia Venezolana,* 8: 1-18.

SAS Institute. 2012. *Statistical Analysis System. Version 9.1.3*. Cary, North Carolina.

Tambe, J. T., Riolo, P., Okolle, J. N., Pietro, N. I., Fanciulli, P., and Dallah, R. (2013). Sexual size differences and colour polymorphism of *Rhynchophorus phoenicis* in the Southwest region of Cameroon. *Bulletin of Insectology*, 66(1): 153-159.

Thomas C. N., Ogbalu O. K. and Okwakpam, B. A. (2004). Oviposition of *Rhynchophorus phoenicis* (f.) (Coleoptera: curcuuonidae) in Palms of the Niger delta. *Indian Journal Agricultural Research,* 38: 126 - 130.

Thomas, C. N. and Briyai, F. O. (2019). Traditional consumption of Rhynchophorus phoenicis larvae (F) as human food in Niger Delta area, Nigeria. *Journal of Biology and Genetic Research*, 5(1): 39-45.

Van Huis, A., Van Itterbeeck, J. Klunder, H. Mertens, E. Halloran, A. Muir, G. and Vantomme, P. (2013). Edible insects: future prospects for food and feed security. FAO Forestry Paper 171. (http://cisr.ucr.edu/ pdf/ fao-entomophagy-report.pdf

Van, H. A. (2003). Insects as food in Sub-

Saharan Africa. *Insect Science Appl.* 23 (3): 163-185

Walid, K., Mahmoud, A., Ahmed, K. (2020). Mass rearing of the Red Palm Weevil, *Rhynchophorus Ferrugineus* Oliv., on sugarcane and artificial diets for laboratory studies: Illustration of Methodology. Department of Plant Production, Faculty of Agricultural Sciences, UAE University, Al-Ain, U.A.E.

Womeni, H. M., Tiencheu, B., Linder, M., Chouatcho Nabayo, E., Tenyang, N., Tchouanguep Mbiapo, F., Villeneuve, P., Fanni, J. and Parmentier, M. (2012). Nutritional value and effect of cooking, drying and storage process on some functional properties of *Rhynchophorus phoenicis*. *International Journal of Life Science and Pharma Research,* 2 (3): 203-219.