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# Nutritional Composition and Microbiology of Some Edible Insects Commonly Eaten in Africa, Hurdles and Future Prospects: A Critical Review

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## Abstract

An overview of the microbiology and nutritional composition of eight (8) insects, *Bunaea alcinoe*, *Rhynchophorus phoenicis, Gonimbrasia belina, Gryllotalpa africana, Cirina forda, Brachytrupes membranaceus*, *Macrotermes natalensis*, and *Anaphe venata* used as food is presented. All the edible insects whose microbiological flora is known have mixed population of bacteria with *Bacillus* and Staphylococcus persistently occurring. The Gram-negative population is more diverse and included members of the genera, *Acinetobacter, Enterobacter, Klebsiella, Proteus, Pseudomonas* and *Serratia*. Available data show that edible insects contain protein concentrations ranging from 22.06 to 74.35% (*Lepidoptera* (≥ 38+ to 74.35%), *Coleoptera larva* (22.06 to 30.30%), *Coleoptera adult* (26.85 to 32.71%), *Isoptera* (35.06%) and *Orthoptera* (65.62%). The larval forms seem to have a high fat content compared to the adult forms. The ten essential amino acids are present in varying amounts while the major fatty acids are palmitic, oleic and linoleic, which is highly unsaturated. Different species of Rhynchophorus species may have different quantities of amino acids or indeed, domestication may affect the quantities of amino acids of *Rhynchophorus species*. The major fatty acids (occurring at more than 10%) of *R. phoenicis* (*Coleoptera*) are palmitic acid, oleic acid and linoleic acid while those of *G. belina* and *C. forda* (*Lepidoptera*) are palmitic, oleic, linoleic and stearic acids. Macro-elements and micro-elements of *R. phoenicis* occur at significant amounts. Iron and magnesium occur in the order, *Coleoptera*, more than in *Isoptera*, *Lepidoptera* and *Orthoptera*. There seems to be a dearth of information on the macro- and micro-elements, amino acid and fatty acid compositions of some insects. A more comprehensive, standardised and universally acceptable method for estimating proximate composition of edible insects is advocated so that values obtained can be scientifically compared. Further work on comprehensive nutritional studies and microbiological flora of edible insects and insect husbandry/farming are also advocated.

**Keywords:** Edible insects; Nutritional composition; Microbiological flora; Husbandry

## Introduction

Many parts of the world use insects as human food and the use of insects as food is becoming attractive, constituting an emerging new area of study [1-3]. Countries where insects serve as food include Australia, Cambodia, China, Columbia, Mexico, New Guinea, Thailand Vietnam and some African countries [4-7]. A comprehensive list of edible insects of the world has been given by Jongema [8]. The comprehensive review of insects from a food safety and nutrition perspective by Belluco, et al. [9] highlighted that insects constitute a good source of protein and are safe for human consumption. A review of the diversity and nutritional status of insects used as food in Nigeria was given by Alamu et al. [10] but it did not cover their microbial load, a critically important consideration when used as food. Insects are eaten in their adult or larval form. For instance, in Nigeria, the larvae and the adult *Rhynchophorus phoenicis* are eaten. In Indonesia larvae of rhinoceros beetle is a delicacy and the larvae of *Anaphe venata* is preferred in some parts of Nigeria. A major barrier for the use of insects as human food is repulsion, particularly strong among consumers in most Western countries. This may reflect their view of insects as pests and not as a human food source [11-13].

## Rationale for use of Insects as Food

The nutritional values of insects have long been recognised. The choice of insects as food is strengthened by the fact that they constitute about 80% of the entire animal kingdom and therefore an enormous biomass, insects have high fecundity [7]. Insects life cycle is short as they reach adulthood within days as compared to other animals [7], edible weight of insect larva is close to 100% and around 80% for the adult species, eg. *Rhynchophorus phoenicis* Nakagaki and Defoliart; Amadi, et al. [2,14]. Other attributes that favour the use of insects as food are – insects are potential candidates for providing animal protein Collavo, et al. [15,16], insects have proven to be good candidates in feeding experiments Finke, et al. [17], insects protein are highly digestible 77 to 98%, Ramos-Elorduy, et al. [18], caterpillars and termites rank among the highest in fat [19,20], some insects have higher essential fatty acids (linoleic and linolenic acids) than meat [21] and animal proteins have higher nutritional value than plant proteins because the former have higher amounts of essential amino acids for human development [22]. Furthermore, insects can also provide the same nutritional benefits as bushmeat [23]. Insect proteins are also better than plant proteins because of the possibility of contamination of the latter with mycotoxins, particularly, aflatoxin. Aflatoxins can be produced in agricultural commodities like maize and cowpeas and can subsequently infect man [24].

### Microbiological Flora

Insects are rich in nutrients and moisture and therefore provide a favourable environment for microbial growth Van-Huis, et al. [1]. During the entire sequence of food handling, from producer to the final consumer microorganisms can be introduced causing food spoilage or disease outbreaks Prescott, et al. [25]. Intrinsic factors (e.g., pH, moisture content, water activity, available nutrients, etc) and extrinsic factors (e.g., temperature, relative humidity, number and type of microorganisms present and gases) influence microbial growth in foods Prescott, et al. [25]. The number and type of microorganisms present is influenced, to a large extent, by the environment from where the food was originally obtained and the sanitary conditions under which the food is handled and processed Jay, et al. [26]. Other sources of microorganisms in food include the adequacy of subsequent handling, packaging and storage conditions of the product. The selection of microbial inactivation, packaging and storage technologies requires knowledge of the microbial flora of the food material involved. Therefore, knowledge of the microbial load of edible insects would assist in the selection of these technologies. It should be noted that no significant health problem has arisen as a result of the consumption of edible insects Banjo, et al. [27].

## Brief Resume of some Insects

### *Bunaea alcinoe Stoll* (Order: Lepidoptera)

This is one of the monarchs of the Niger Delta and belongs to the family Saturniidae. In its immature stage it is a serious defoliator of some economic plants of the Niger Delta. They occur seasonally and infest *Gmelina arborea* and *Terminalia cattapa* (African almond tree). The larvae feed causing defoliation and loss of photosynthetic activities of the host plants. There are about three to four generations a year, appearing in January/April, May/July, August/October and November/January, depending on the availability of the host plant [28]. In parts of Nigeria, including Rivers State, some saturniid larvae are harvested as food supplement [28]. The larvae are a delicacy among some parts of Rivers State and the Tivs of the Middle Belt of Nigeria. The larvae are either salted and roasted or fried with salt and onions and eaten as a snack.

### *Rhynchophorus phoenicis* (Order: Coleoptera)

This insect belonging to the family Curculionidae is the adult palm-wine weevil. It can reach a body length of 25 mm and is considered a serious pest in palm plantations, damaging young palms such as Raphia species, *Elaeis guineensis*. The adult weevil lay eggs in wounds in the stems of dying or damaged parts of palms. After hatching, the weevil larvae excavate tunnels in the trunk and feed on the shoot and young leaves leading to the death of the host plants. Just like *B. alcinoe* it is a delicacy in Rivers, Delta, Edo, Oyo, Imo, Anambara, and Akwa Ibom states [29]. The larvae are usually fried after seasoning with spices while the adult weevil is roasted after removing the chitinous wings and eaten. Palm wine tappers harvest the weevil from fresh palm-wine. In fresh palm-wine the weevil remain in a state of stupor as result of intoxication by alcohol in palm-wine. Thirty to forty minutes after removal from the palm-wine and exposure to air, the effect of alcohol weans and they fly off Amadi et al. [2].

### *Imbrasia belina* (Order: Lepidoptera)

The mophane worm is the larval stage of the emperor moth, *Imbrasia belina*, commonly known as "phane" in Botswana belongs to the family Saturniidae. Other vernacular names for the caterpillars include sepedi (South Africa), muyaya (Zambia), ndebele (Zimbabwe) and oshiwambo (Namibia). The herbivorous larvae feed on the leaves of the mophane tree, *Colophospermum mopane*, from which they derive their name Mpuchane, et al. [30]. It is an important food source in Botswana Simpanya, et al. [31]. The larvae appear twice a year, October to January and March to April, on mophane tree. After harvesting, the larvae are degutted, the intestinal contents squeezed out and and the larvae without the intestinal contents is introduced into boiling saline for preservation. Thereafter they are boiled for 15 to 30 minutes and spread out on a level patch of ground to dry for 5 days. For the purposes of this review, mopane will be used in all references to the larva of *I. Belina*.

### The Mole Cricket, *Gryllotalpa africana* (Order: Orthoptera)

The mole African cricket, *Gryllotalpa africana* belongs to the family *Gryllotalpidae* which has a worldwide distribution. Insects in this family are best known for their different digging forelimbs modifications. *Gryllotalpa africana* is the African species, occurring in most parts of the Niger Delta, Eastern and Middle Belt regions of Nigeria. *Gryllotalpa africana* is a small mole cricket species native to Africa. The mole lives underground, making burrows and feeding on plant roots, larvae and other insects and only goes to the surface at night during the mating season.

### The insect *Cirina forda* (Order: Lepidoptera)

Commonly known as the Pallid emperor moth or Shea defoliator, *C. forda* larva is a heavy defoliator of Shea tree ( *Vitellaria paradoxa*). The Shea tree is a traditional African food plant indigenous to Africa, the larvae of *C. forda* feed on Shea causing heavy defoliation. The larva is eaten in many homes in Africa [32-34]. It is the most widely marketed edible insect in Nigeria.

### The insect *Brachytrupes membranaceus* (Order: Orthoptera)

This large African cricket is a delicacy in many homes in Nigeria and a pest of crops, especially yam. It lives entirely underground, is nocturnal and digs burrows that may be 50 to 80 centimetres deep. This insect feeds on grasses, succulent parts of plants and suckers of trees such as *Brachystegia* and *Isoberlinia* [35]. The genus, Brachytrupes seems to occur in the tropical and subtropical belt of Asia and Africa [36]. It lives entirely underground and is nocturnal. Breeding takes place once a year in February and March and the adults die off between February and April [35]. During the mating season the singing of the males attract the females. The newly hatched crickets emerge between October and December leaving the burrow of the parent mother to the immediate vicinity, preferring uneven or broken-up surfaces as these facilitate digging. The new adults dig burrows which may be 50-80 centimetres deep leaving a sand mould of up to 30 centimetres in height that betray their presence. The diet includes grasses, succulent parts of plants and suckers of trees such as *Brachystegia* and *Isoberlinia* [35]. In Nigeria, *B. membranaceus* is known by different local names such as apina (Eleme), pina (Ogoni) and gyare (Hausa).

### The insect *Macrotermes natalensis* (Order: Isoptera)

The termite, *Macrotermes natalensis* is the most destructive group of insect pests of trees in Nigeria. This winged termite which is a delicacy in Nigeria and most African countries is collected mostly by women and children and strongly attracted to light sources.

### The insect *Anaphe venata Butler* (Order: Lepidoptera)

This is a moth of the Notodontidae family, the African silk worm. The larvae feed on the Obeche tree (*Triplochiton scleroxylon*), known in Ghana as wawa and Cameroon as ayous. The moth lives in Angola, East and West of Africa.

## Nutritional Composition

The nutritional composition of the insects here reviewed is shown in Table 1. Most are rich in protein with varying quantities of carbohydrate, fat, ash, fibre and moisture. *Imbrasia belina* contains ≥ 38+ % protein, 16+ % fat, ca 13% carbohydrate and some chitin Ohiokpehai et al. [37,38] gave the nutritional composition of *I. belina* as 56.8% protein, 16.4% fat, 6.9% ash and 9.6% fibre. Moisture content of *I. belina* was estimated at 83.1% [25].

| Food Insect | Crude Protein | Ash | Fat | Carbohydrate | Moisture | Fibre | Dry Matter |
|---|---|---|---|---|---|---|---|
| *Bunaea alcinoe Larvae*[*](Lepidoptera) | 55.2 | 7.7 | 25 | 3.8 | 8.3 | NA | 91.7 |
| *Cirina forda larva*[††](Lepidoptera) | 74.35 | 3.1 | 14.3 | 2.36 | 32.15 | 6.01 | 67.85 |
| *Anaphe venata larva*[b] (Lepidoptera) | 60.03 | 3.21 | 23.22 | NA | 6.61 | NA | 93.39 |
| *Gonimbrasia belina* caterpillar[odwq] | ≥ 38 + to 56.8 | 6.9 | 16.4 | 13 | 83.1 | 9.6 | NA |
| *Rhynchophorus phoenicis* Adult weevil[*](Coleoptera) | 32.71 | 0.98 | 4.17 | 0.88 | 56.82 | 8.59 | 43.18 |
| *Rhynchophorus phoenicis* Adult weevil without chitin[*] (Coleoptera) | 26.85 | 0.58 | 9.15 | 1.69 | 52.88 | 6.4 | 47.12 |
| *Rhynchophorus phoenicis* Larvae[†] | 22.06 | 5.79 | 25.3 | 5.53 | 61.85 | NA | 38.15 |
| *Rhynchophorus phoenicis* Larvae[**](Coleoptera) | 30.3 | NA | 81.6 | 2.5 | NA | NA | NA |
| *Rhynchophorus palmarum* Larvae[+] (Coleoptera) | 25.8 | 2.1 | 38.5 | 33.2 | NA | NA | NA |
| *Brachytrupes membranaceus*[††] (Orthoptera) | 35.06 | 3.25 | 53.05 | 2.33 | 11.6 | 6.3 | 88.4 |
| *Macrotermes natalensis*[††] (Isoptera) | 65.62 | 4.05 | 21.35 | 1.13 | 31.56 | 7.85 | 68.44 |

**Table 1:** Nutritional composition (%) of some edible insects, [*]From Amadi, et al. [2,4]; [+]Reared under laboratory conditions Cerda, et al. [5]; [b]Bukkens [19]; Quin [25]; [†]Ekpo and Onigbinde [29]; [odwq]Ohiokpehai, et al. [37]; Dreyer and Wehmeyer [38]; [**]Wachukwu, et al. [39]; [††]Agbidye, et al. [40] and ND: Not Determined.

A careful look at the Table 1 data reveals flaws in the proximate composition reported for *C. forda, M. natalensis*, *B. membranaceus* and *R. phoenicis* larvae. Also the carbohydrate value of 33.2% given for *R. palmarum* by Cerda, et al. [5] is extremely and the 13% for *I. belina* by Ohiokpehai, et al. [37] is high. Furthermore, reports do not specify whether values are on a wet or dry matter basis. The data for *B. membranaceus* by two groups is a good indication of data limitations. The values for crude protein, fat, moisture and fibre show considerable disparity. A similar disparity is also evident in the proximate composition values presented by Wachukwu, et al. [39] and Ekpo and Onigbinde [29] for *R. phoenicis* larvae. All future proximate composition should be reported on dry weight basis.

Available data, however, show that edible insects contain protein in the range 22.1 to 74.4% Amadi EN, et al.; Ekpo and Onigbinde ; Dreyer and Wehmeyer ; Wachukwu, et al.; Agbidye, et al.; [2,4,29,38-40]. This protein range by Order translates to: Lepidoptera (≥ 38 + to 74.4%), Coleoptera larva (22.1 to 30.3%), Coleoptera adult (26.9 to 32.7%), Isoptera (35.1%) and Orthoptera (65.6%). Moisture data for *C. forda* larva, *B. membranaceus* and *M. natalensis* are derived from their respective dry matter values. The fat values for the larvae of *R. phoenicis* shows a similar disparity.

The amino acid and fatty acid compositions of *R. phoenicis* are given in Tables 2 and 3. The ten essential amino acids are present in varying amounts while the major fatty acids are palmitic, oleic and linoleic which is highly unsaturated. For laboratory-reared *R. palmarum* the ten essential amino acids are not only present in varying amounts but in much more lower quantities. It would seem, therefore, that different species of *Rhynchophorus* may have different quantities of amino acids. Or indeed, domestication may affect the amino acids of *Rhynchophorus* species. The amino acids, methionine and tryptophan are not present in the amino acid profile of *A. venata* [41]. The essential amino acids are higher in insects compared to what is obtainable in animals such as beef meat, pork meat and chicken meat. *Rhynchophorus phoenicis* provides 3.44 g/100 g of histidine, 3.99 g/100 g of lysine and 2.05 g/100 g of methionine [29] as against 0.82 g/100 g of histidine, 1.94 g/100 g of lysine and 0.61 g/100 g of methionine in beef meat, 0.82 g/100 g of histidine, 1.80 g/100 g of lysine and 0.59 g/100 g of methionine in pork meat and 0.69 g/100 g of

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histidine, 1.79 g/100 g of lysine and 0.62 g/100 g of methionine in chicken meat Longvah, et al. [42].

| Amino acid | Food Insect | |
|---|---|---|
| | *R. phoenicis* larva* | *Anaphe venata*† |
| Lysine | 3.99 (1.72) | 0.88 |
| Histidine | 3.44 (1.02) | 0.78 |
| Arginine | 5.06 (1.62) | 0.32 |
| Aspartic acid | 7.02 (2.29) | NA |
| Threonine | 3.10 (1.15) | 0.38 |
| Serine | 3.27 (1.33) | NA |
| Glutamic acid | 12.91 (3.09) | NA |
| Proline | 2.11 (1.12) | NA |
| Glycine | 2.95 (1.04) | NA |
| Alanine | 3.05 (1.37) | NA |
| Cysteine | 2.20 (0.23) | 0 |
| Valine | 2.80 (0.81) | 1.76 |
| Methionine | 2.05 (0.27) | 0 |
| Isoleucine | 3.45 (0.75) | 2.14 |
| Leucine | 6.22 (1.62) | 1.31 |
| Tyrosine | 2.02 (0.97) | 2.49 |
| Phenylalanine | 4.13 (0.73) | 2.14 |
| Tryptophan | 2.51 (0.25) | 0 |

**Table 2:** Amino acid composition of *R. phoenicis* larva and *Anaphe venata* (g/100 g protein), Figures in brackets are data for *R. palmarum* reared under laboratory conditions, Cerda, et al. [5]; † From Bukkens [19]; *Ekpo and Onigbinde [29];

Cereal proteins that are key staples around the world are often low in lysine, tryptophan and threonine [20] and can, therefore, be used for food fortification.

Fatty acids composition of the insects included in this study here is not comprehensive and appears to reflect the specific objective of the work reported. *Imbrasia belina* contains 31.9%, 15%, 21% and 18% of palmitic acid, stearic acid, oleic acid and linolenic acid, respectively. These fatty acids are a combination of saturated and unsaturated fatty acids whose fractions occur in almost equal proportions. *Cirina forda* is rich in palmitic acid (17.2%), stearic acid (27.4%), oleic acid (12.9%) and linolenic acid (33.8%), a high unsaturated fraction [44]. The high linolenic acid of *Cirina forda* larva makes it a valuable candidate for use in infant food formulation since this fatty acid has been shown to be important in the healthy development of infants and children Michaelsen, et al. [45]. Unsaturated fatty acid is the predominant fatty acid of Coleoptera and Lepidoptera. However, in one Lepidoptera both saturated and unsaturated fatty acids occur in almost the same quantity.

Macro-elements and micro-elements of *R. phoenicis* occur at significant amounts. Thus sodium, calcium, potassium, copper, cadmium and zinc occur at 773.49 ± 1.02 mg/100 g, 60.81 ± 0.32 mg/100 g, 26.65 ± 0.24 mg/100 g, 1.26 ± 0.04 mg/100 g, 0.039 ± 0.022 mg/100 g and 10.57 ± 0.89 mg/100 g, respectively [29]. The mineral contents of five other insects are given in Table 4. Thus the five insects contain appreciable amounts of calcium, phosphorus, iron and magnesium. Iron and magnesium occur more in coleoptera than the other orders of insects. Vitamins A and E also occur in *R. palmarum* at 1.8% and 34.7%, respectively Cerda, et al. [5].

| Fatty acid | % Composition | | |
|---|---|---|---|
| | *Rhynchophorus phoenicis* larva* (Coleoptera) | *Imbrasia belina*+ (Lepidoptera) | *Cirina forda* larva** (Lepidoptera) |
| Total unsaturated fatty acid | 61.1 | 47.5 | 54.9 |
| Total saturated fatty acid | 38.9 | 48.9 | 45.23 |
| Monounsaturated fatty acid | 43.4 | NA | NA |
| Polyunsaturated fatty acid | 17.7 | NA | 41.65 |
| Lauric (C12:0) | 0.20 ± 0.03 | NA | NA |
| Myristic (C:14:0) | 3.20 ± 0.12 | NA | 0.66 |
| Palmitic (C16:0) | 32.40 ± 0.58 | 31.9 | 17.15 |
| Palmioleic (C16:1) | 3.30 ± 0.20 | NA | 0.32 |
| Stearic (C18:0) | 3.10 ± 0.13 | 15 | 27.42 |
| Oleic (C18:1) | 40.10 ± 0.72 | 21 | 12.93 |
| Linoleic (C18:2) | 13.00 ± 0.20 | 8.5 | 7.81 |
| Linolenic (C18:3) | 3.50 ± 0.10 | 18 | 33.84 |
| Arachidonic (C20:4) | 1.20 ± 0.04 | NA | NA |

**Table 3:** Fatty acid compositions of three edible insects (% fatty acid), *Ekpo and Onigbinde [29]; +Zinzombe and George [43], taken from Allotey [7]; **Ande [44]; NA: Not Available.

| Food Insect | Ca | P | Fe | Mg | Ash |
|---|---|---|---|---|---|
| *Macrotermes natalensis* | 18 | 114 | 29 | 0.26 | 1.9 |
| *B. membranaceus* | 9.21 | 126.9 | 0.68 | 0.13 | 1.82 |
| *A.venata* | 8.57 | 100.5 | 2.01 | 1.56 | 3.2 |
| *C.forda* | 8.24 | 111 | 1.79 | 1.87 | 1.5 |
| *R. phoenicis* | 54.1 | 685 | 30.8 | 131.8 | 2.7 |

**Table 4:** Mineral and ash contents of five insects (mg /100 g)*; *Taken from Alamu, et al. [10]

There seems to be a dearth of information on the macro- and micro-elements, amino acid and fatty acid compositions of the other insects so far studied.

## Microbiological Flora

The bacterial flora of the insects under review is a mixed population of both Gram-positive and Gram-negative bacteria with *Bacillus* and *Staphylococcus* species predominating. All the bacterial species isolated from the insects are not known to cause food-spoilage during storage and, therefore, pose no health problem [26,46].

The microbial load of the skin and intestinal contents of *B. alcinoe* are $8.16 \times 10^6$ and $5.70 \times 10^5$cfu/g while the fungal populations are $2.07 \times 10^6$ and $1.32 \times 10^6$ cfu/g, respectively. The predominant bacteria belonged to the genera *Acinetobacter*, *Bacillus*, *Micrococcus* and *Staphylococcus* (Table 5). Total heterotrophic bacterial, coliform and fungal counts of the skin of adult *R. phoenicis* are $9.20 \times 10^5$, $5.30 \times 10^5$ and $7.30 \times 10^5$ cfu/g, respectively. The microbial loads of the gut for the same group of microorganisms are higher at $1.83 \times 10^7$, $4.20 \times 10^6$ and $3.60 \times 10^6$ cfu/g. The skin microbial flora are heterogeneous and belong to the genera *Bacillus*, *Klebsiella*, *Pseudomonas*, *Saccharomyces*, *Serratia* and *Staphylococcus* while the gut content is predominantly *Bacillus sp*, *Enterobacter sp*, *Serratia sp* and *Staphylococcus sp*. Yeast population in the intestinal contents of mopane range from $2 \times 10^1$ cfu/g to $5 \times 10^3$ cfu/g while molds range from $1 \times 10^1$ cfu/g to $2 \times 10^2$ cfu/g [31]. However, there appears to be a dearth of information on the bacterial flora of phane.

| Insect | Associated Microbial Genera | Reference |
|---|---|---|
| *Bunaea alcinoe larva* | *Acinetobacter, Bacillus, Micrococcus,* and *Staphylococcus* | Amadi, et al. [4] |
| *Rhynchophorus phoenicis* Skin | *Bacillus, Klebsiella, Pseudomonas, Saccharomyces, Serratia* and *Staphylococcus* | Amadi, et al. [2] |
| *Rhynchophorus phoenicis* Gut | *Bacillus, Enterobacter, Serratia* and *Staphylococcus* | Amadi, et al. [2] |
| *Gryllotalpa africana* | *Bacillus, Corynebacterium, Micrococcus, Proteus* and *Staphylococcus* | Ogbalu and Renner [47] |
| *Rhynchophorus phoenicis* Fresh larvae | *Bacillus, Enterobacter, Serratia, Staphylococcus* | Wachukwu, et al. [39] |
| *Rhynchophorus phoenicis* Fried larvae | *Bacillus, Staphylococcus* | Wachukwu, et al. [39] |
| *Rhynchophorus phoenicis* Roasted larva | *Bacillus cereus, Enterococcus faecalis, Escherichia coli, Pseudomonas aeruginosa* and *Staphylococcus aureus, Aspergillus, Mucor, Rhizopus* | Ekrakene and Igeleke [48] |

**Table 5:** Microbial flora of some edible insects.

Total heterotrophic bacterial populations of the skin of *G. africana* range from $5.12 \times 10^7$ to $8.0 \times 10^7$ cfu/g while the fungal count is $1.0 \times 10^6$ cfu/g. The predominant bacterial flora of *G. africana* belongs to the genera *Bacillus*, *Corynebacterium*, *Micrococcus*, *Proteus* and *Staphylococcus* [47,48] isolated a more diverse group of microorganisms than Wachukwu, et al. [39] from the larva of *R. phoenicis*. The fungal isolates were predominated by Aspergillus while the bacterial isolates were more heterogeneous and included *Bacillus cereus, Enterococcus faecalis, Escherichia coli, Pseudomonas aeruginosa* and *Staphylococcus aureus*. We find it difficult to explain the discrepancy between the results of Wachukwu, et al.; Ekrakene and Igeleke [39,48] because both workers obtained their samples from areas of high human traffic and therefore exposed to heavy human and environmental contamination. However, with the exception of *S. aureus* and *B.cereus*, all the other microorganisms isolated from the larvae of *R. phoenicis* are known to be associated with palm and palm sap [49]. This heterogeneous collection of microorganisms isolated from the larvae of *R. phoenicis* calls for concern in the handling of the larvae during processing. Hazard Analysis Critical Control Points (HACCP) is, therefore, advocated to ensure quality assurance, identifying, evaluating and controlling physical, chemical and biological hazards throughout the production process.

The predominant bacterial genera in all the insects studied are *Bacillus* and *Staphylococcus*, mainly coagulase-negative species. However, Wachukwu, et al. [39] also isolated *S. aureus* and *B. cereus* which were not toxigenic strains. The bulk of the microbes isolated are mainly saprophytes. The deterioration of the mopane quality was attributed to the presence of *Chaetomium*, *Aspergillus*, *Fusarium*, *Cladosporium* and *Penicillium* Mpuchane, et al. [30]. The same workers also pointed out that there were bacterial isolates which were proteolytic and chitinolytic and mostly spore-formers. However they did not go further to identify them. *Chaetomium*, *Aspergillus*, *Fusarium* and *Mucor racemosus* were the most prevalent in the intestinal contents of phane whereas *Aspergillus*, *Penicillium* and *Mucorales* were predominant in laboratory-stored mopane Simpanya, et al. [31].

All the bacterial species isolated from the insects are not known to cause food-spoilage during storage and, therefore, pose no health problem Jay, et al.; Prescott, et al. [26,46].

Microbiological data exist for only three (3) out of the eight (8) insects under review. Based on the data available conclusive conclusion cannot be made. We, therefore, call for the determination of the microbial flora of all edible insects so that conclusive conclusion (s) can be made.

## Hurdles

Edible insects are not only used as human food but are also used as animal feed and in feeding experiments. They also constitute a source of income for a section of the population where the consumption of insects is in vogue as well as a source of protein in areas where animal protein is expensive. However, the changing consumer pattern is affecting the use of insects as food in Africa as traditional culinary culture is being replaced by imported foods. Traditional African diets are rich in roughage (edible insects have reasonable quantities of fibre) and the change to Western culinary culture may be responsible to the prevalence of various types of cancer hitherto unknown to Africa. These assertions are in agreement with Illgner and Nel [50] who sees globalization as the use of more fast foods and pre-prepared foods and the loss of traditional ways of life. A major set-back, therefore, for the use of insects as food is the repulsion felt by Western people Belluco, et al. [9] and the change in consumer habits. When these two factors are reconciled, the practice of eating insects and arachnids, i.e., entomophagy, will begin to take its place in food science research.

## Future Prospects

Another major problem associated with the use of insects as food is sustainability. Edible insects are becoming difficult to find as their habitats are being destroyed at an alarming rate. Crop rotation, a traditional agricultural practice in Nigeria and most African countries has almost given way to the use of fertilizers, pesticides and herbicides, a factor that may contribute to the disappearance of edible insects because crop rotation disrupts disease cycles and the lifecycles of insect pests [51]. For those insects that are crop pests, the use of insecticides has compounded the problem. An important question arises then – How do we control those edible insects that are pests and at the same time preserve them as a source of protein? We must strike a balance between the two!

In Africa, in particular, the ecological niche of these insects is being destroyed at an alarming rate due to deforestation, urbanisation and the changing climate. For instance, *B. membranaceus*, usually common during the yam harvesting season (August to October) and the mating season (February to March) is now rare to find. We must therefore aggressively pursue insect husbandry/farming with vigour. For entomophagy to succeed as an emerging science and constitute an alternative source of protein for the increasing/teeming world population, therefore, there must be a way of preserving these insects. Insect farming is already practised in countries like Thailand, Singapore and China Hanboonsong, et al. [52] Insect husbandry is the ultimate answer. The potential health risks that may be associated with rearing insects have been extensively and brilliantly discussed by Van-Huis, et al. [1] and should be consulted by any group interested in insect husbandry.

## Conclusion

The nutritional composition of the edible insects so far known is not comprehensive as various workers only provide a handful of data. Current knowledge indicates that edible insects are good sources of protein. However, more work is needed to provide information on the macro- and micro-elements, amino acid and fatty acid compositions of the other edible insects as well as sustainability of their uses. With the exception of *R. phoenicis* and *I. belina* for which the microbial flora of the fresh and processed insects exist such data for other insects are rare to find. A more comprehensive, standardized and universally acceptable method for estimating proximate composition of edible insects is advocated so that values obtained can be scientifically compared. Further work is required to provide a comprehensive nutritional and microbiological data and apply HACCP during processing.

Although there does not seem to be any recorded account (s) of food poisoning as a result of the consumption of insects, a good way to check the sanitary status of the insect is to compare the microbial flora of fresh and finished product. This is because extraneous microorganisms can be introduced into the insect during processing.

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