Comparative Study on Fatty Acid Profiles of Selected Edible Insects and Animals in Africa: A Review

Thomas C. N[1]., Kiin-Kabari D. B[2]
[1]Department of Biological Sciences,
Niger Delta, University, Ammassoma, Bayelsa State, Nigeria
[2]Department of Food Science and Technology,
Faculty of Agriculture,
Rivers State Science University, Nkpolu, Port Harcourt, Nigeria
thomascommander9@gmail.com

Abstract
The quality of fats of eight (8) edible insects: Crickets (CK), Grasshoppers (GH), African palm weevil larvae (APWL) (Rhynchophorus phoenicis), Caterpillars of Imbrasia spp. (CIS), Soldier termite (ST) (Macrotermes bellicosus), Longhorned beetle larvae(LHBL) (Apomecyna parumpunctata), Palm beetle larvae (PBL) (Oryctes monoceros) and Compost beetle larvae (CBL) (O. boas) were evaluated by collating their fatty acid profiles and compared with fats from four (4) conventional animal sources (beef, pork, poultry and fish. Results showed that crickets had the highest quality of fats with higher Ps value of 105.75 having greater proportion of healthy polyunsaturated fatty acids: linoleic acid (45.63%) omega-6, linolenic acid (16%) omega-3 which combined with lower amount of myristic acid (0.5%) SFA. R. phoenicis had average fat conent (61.74%) with lower Ps value of 16.70, high amount of linoleic acid (45.46%) and lower amount of linolenic acid (4.19%) which combined with small proportion of saturated fatty acid (3.05%) to produce Ps value of 16.70. Grasshoppers have lower average fat content (6.44%) with linoleic acid (21.07%) plus two isomers of linolenic acid: γ- linoleic acid (22.5%) and α-linolenic acid (14.76%), without saturated fatty acid, having Ps-value of 58.37. Caterpillars of Imbrasia spp had Ps value of 5.33 contained low palmitic acid (8.42%) SFA, possessed high amount of polyunsaturated fatty acids (44.89%) which consisted of linoleic acid (6.88%) omega-6 and ∝ - linolenic acid (38.01%) omega-3. Apomecyna parumpunctata larvae, M. bellicosus Orcytes monoceros and compost beetle (O. boas) contained higher amount of saturated fatty acids (SFA) ranged between 30.91 - 57.04% and lower amount of polyunsaturated fatty acids ranged between 0.85% - 13.3% with lower Ps values of 0.43, 0.35, 0.108 and 0.016, respectively. The crickets, grasshoppers, R. phoenicis larvae and caterpillars of Imbrassia spp. provided higher quality of fats than beef, pork, chicken and fish; which were in turn better than the fats of A. parumpunctata, M. bellicosus, O. monoceros and O. boas.

Keywords: *fatty acids, Ps value, edible insects and animal*

1.0 Introduction

Insects constitute over 70% of the animal kingdom (Yoloye, 1988). In Africa, out of 500 species of edible insects, about 236 species have been investigated to know their nutritional status. In Ghana, Zambia, Cameroon and Nigeria plus other developing countries in tropical Africa, there is scarcity of foods which supply enough proteins, essential fatty acids and minerals, hence people resort to harvesting of edible insects from the wild as supplementary sources of these nutrients to reduce the prevalence of some common nutritional diseases (Anthonia and Isoum, 1982; Fasoranti and Ajibola, 1993). Currently, the consumption of healthy unsaturated fatty acids is advocated to reduce the incidence of cardiovascular diseases associated with hypertension, obesity and diabetes in Africa, America and European countries (Womeni *et al*, 2009). About ten years ago, the North American populace was found to have high rate of obesity caused by the excessive consumption of foods containing high proportion of saturated fats. Therefore, the most critical problem of human nutrition is how to reduce the intake of saturated fatty acids and increase the intake of foods that contain high amount of polyunsaturated fatty acids to provide enough energy and still sustain good health of humanity (Defoliart, 1991; Thomas *et al*, 2018). The objective of this review was to collate available data on the fatty acid profiles of some commonly eaten edible insects in some Africa countries and compared it with few conventional animal fats such as poultry, beef, pork and fish which provides high calories of energy with satisfactory amounts of essential fatty acids that boost the health of consumers (Defoliart, 1991). This was important because, there was paucity of information on utilization of insects as food for humans and animal feed. However, the main challenge militating against the utilization of edible insects is the seasonality of their availability and in some cases, the difficulty to determine the quantity that can be consumed at a time to satisfy the required amount of nutrients by children whose digestive system cannot digest the hardened "chitinous" parts of the adult and some larval stages of the edible insects (NRC, 1988; Defoliart, 1991). In any case, there is steady increase in research on edible insects in recent times. The essence of the study was to identify the species of edible insects that are rich sources of healthy fats when utilized as food by humans to reduce protein-energy malnutrition, as well as mitigate against hunger for above 1.2 billion malnourished people in the world (FAO 2009; Premalata *et al*, 2011, Alamu *et al*, 2013 and Rumpold and Schluter, 2013).

Explanatory Notes:

SFA =Saturated fatty acid
MUFA=Monounsaturated fatty acid
PUFA=Polyunsaturated fatty acid
PS ratio=Degree of Unsaturation
ALA =Alpha linolenic acid

EPA=Eicosapentanoic acid (omega-6 (C_{20}:$_5$)
DHA=Docosahexaenoic acid (omega-3 ($C_{22:6}$)
LA=Linoleic acid (omega-6 fatty acid)
AA=Arachidonic acid

2.0 Materials and methods

In this review, eight (8) edible insects that are commonly eaten by the indigenes of rural communities in different ethnic groups in Nigeria, Cameroon, Ghana and other African countries were evaluated to ascertain the level of saturated and unsaturated fats. The list of edible insects investigated included: crickets, grasshoppers; African palm weevil (*Rhynchophorus phoenicis* larvae), soldier termite (*M. bellicosus*), caterpillars of *Imbrasia* spp; palm beetle (*Oryctes monoceros*) compost beetle (*O. boas*) and a lesser known tree beetle called *Apomecyna parumpunctata*. The average fat content of these insects were obtained from existing data. In the cases were the data was reported on wet weight basis, it was converted to dry matter for uniformity (Womeni *et al*, 2009; Rumpold and Schluter, 2013; Thomas and Kiin-Kabari, 2018). Furthermore, the fatty acid profiles of these insects were re-examined with a view to properly decipher the level of saturated and unsaturation in the fats, so that consumers can appreciate the health implications of the insects they are consuming (Payne *et al*, 2015). The quality of fats of the selected edible insects were assessed by calculating their Ps values and compared with the Ps values of four common animal fats (poultry, beef, pork and fish) (NRC, 1988; Defoliart *et al*, 2009). The Ps ratio of the fat of each insect was calculated using the formula: Ps = $\frac{tPUFA}{tSFA}$ = degree of unsaturation (Womeni *et al*, 2009). Finally, the Ps values of the edible insects and the common animal fats were ranked to rate their health potentials when consumed as food by humans.

3.0 Results and Discussion

The result (Table 1) showed that the average fat content was higher in *R. phoenicis* (61.74%), crickets (60.15%), *M. bellicosus* (47.73%), *Imbrasia species* (24.90%), *A. parumpunctata* (13.26%), grasshoppers (6.44%). The least were the palm beetle (*Orcytes monoceros*) and compost beetle (*O. boas*) which contained 2.66% and 1.70% of fats, respectively (Thomas and Kiin-kabari, 2018; Womeni *et al*, 2009). These results agreed with earlier report (Rumpold and Schluter, 2013) which stated that fat is usually the second highest proportion of the nutrient content of edible insects. According to Fox and Cameroon (1989) and Harvard (2018) which reported that a gramme of fatty food yields about nine (9) calories of energy, whereas a gramme of carbohydrate and protein food yields only four (4) calories of energy. It also reported that the average fat content of edible insect per order ranges from 13.4% in orthoptera, including the grasshoppers, crickets and locusts, while the coleoptera (beetles weevils) and isoptera (termites) contained an average fat content of 32.74%; while cockroaches (Blattodea) had 27.66% and hemiptera had 30.2% of fat, respectively (Bhulaidok *et al*, 2010). However, the highest amount of fat was found in the caterpillars of a lepidoptera (*P. triangularis*) which range between 77.0-77.13% and the palm weevil (coleoptera) had 69.78% of fat content (Ramos-Elorduy *et al*, 1997; Omotoso and Adedire, 2007). The report also corroborated the findings of this study by stating that the lowest fat content was observed in the larvae of *O. rhinoceros* with fat content ranged between 0.66-38.12% (Ekpo *et al*, 2009; Olowu *et al*, 2021).Similarly, the larvae of *O. boas* contained 1.50% of fat in dry matter. The orthoptera (*Braschytrupes* species) had fat content ranged between 3.24-53.05%. The report commented that variations in the fat content of edible insects was attributed to the type of food it feeds on, the location and development stage at which it was taken for analysis. Generally, studies have revealed that the larvae were higher in fat content than the adults (Chen *et al*, 2009). For instance, in the *Orcytes* species, the larvae of *O. monoceros* were richer in fat content than the larvae of *O. boas* due to the fact that the larvae of *O. monoceris* feeds continuously on the decayed tissues of the young oil palm trunk after it had been used by *R. phoenicis* adults, larvae and pupae to complete its life cycle; whereas, the larvae of *O. boas* feeds on the manure from the decomposed organic wastes in the soil.

Table 1: Fat content of some common edible insects

S/N	Common Name	Order/Suborder	Scientific names of common species	Fat Content (% Dry Matter)
1.	African palm weevil+	Coleoptera: Cucurlionidae	*Rhynchophorus phoenicis*	61.47±3.86
2.	Crickets+	Orthoptera: *Gryllotalp*	*Gryllotalpa africana*	60.15±3.55
3.	Soldier termite+	Isoptera: Termitidae	*Macrotermes bellicosus*	47.73±1.67
4.	*Imbrasia spp.*+	Lepidoptera	*Imbrasia belina,*	24.90±0.56
5.	Tree beetle*	Coleoptera: Cerambycidae	*Apomecyna parumpunctat*	13.26±0.13
6.	Grasshoppers+	Orthoptera: pyrgomorphidae	*Zonocerus variegatus*	6.44±2.66
7.	Palm beetles**	Coleoptera	*Oryctes monoceros*	2.66±1.20
8.	Compost beetle**	Coleoptera	*Oryctes boas*	1.70±1.20

Sources: +Womeni *et al*, (2009) and *Thomas, (2018); **Thomas and Kiin-Kabari, (2018).

3.1 Fatty Acid Composition of Some Selected Edible Insects

3.1.1 Crickets:

The results (Table 2) revealed that the crickets (order orthoptera) contained low amount of saturated fatty acid and three monounsaturated fatty acids, namely; palmitolei acid (27.59%), oleic acid (6.89%) and trace amount of gondoic acid (0.28%) which combined to have total monounsaturation of 34.70%. An additional unique feature of the circkets was the possession of highest proportion of polyunsaturated fatty acids predominated by linoleic acid (45.63%) which is known as omega-6, plus high amount of ∝-linolenic acid (16.19%) known as omega-3 and trace amount of γ-linolenic acid (0.58%), which combined to have total polyunsaturation of 62.40%. Therefore, crickets contained the highest Ps value of 105.15 that was most desired by nutritionists due to the excellent health benefits derived this group of edible insect represented by *Braschytrupes species and Gryllotalpa africana* which are found in different parts of tropical African countries including Nigeria, Ghana, Cameroon and others (NRI, 1996; Womeni *et al*, 2009).

3.1.2 Grasshoppers

Although, the grasshoppers are ortheoptera found in the same order as the crickets, the results (Table 2) showed that the fat content of grasshoppers did not show any any saturated fatty acid (Womeni *et al*, 2009), but it contained fairly high amount of two monounsaturated fatty acids such as palmitoleic acid (23.83%) and oleic acid (10.7%) which combined to have high total monounsaturation of 34.53%. The fat content of grasshoppers also contained high amount of two different isomers of polyunsaturated fatty acids known as γ-linolenic acid (22.54%) andα-linolenic acid (14.76%), in addition to the presence of relative high amount of linoleic acid (21.07%) which formed total polyunsaturation of 58.37%. The cumulative effect of the rich content of these essential fatty acids produced a high ps value of 58.37% for the grasshoppers which portend excellent nutritional benefits to the consumers. Common examples of edible insects in this group were the *Zonoceros variegatus* and the short horned grasshoppers called *Cytacanthacris naeruginosus* and *Ruspolia differens which was formerly called Homoroloryphus nitidulus vicinus* known as long horned grasshoppers found in tropical African environments *(*NRI, 1996*;* Womeni *et al, 2009).*

3.1.3 R. phoenicis

The results (Table 2) show that the African palm weevil (*R. phoenicis*) is a coleoptera belonging to the sub-order cucurlionidae which contained small amounts of four saturated fatty acids: lauric acid (0.12%), myristic acid (2.50%), palmitic acid (0.20%) and stearic acid (0.23%) which combined to have total saturation of 3.05% which is quite low as desired (Defoliart, 1991). The monounsaturated fatty acids consisted of high amount of palmitoleic acid (37.60%), low amount of oleic acid (5.24%) and trace amount of gondoic acid (0.79%), which combined to have total monounsaturation of 43.63%. However, it possessed high content of linoleic acid (45.46%) omega-6 and low amount of α-linoleic acid (4.19%) omega-3 and γ-linolenic acid (1.215%) which combined to have total polyunsaturation of 50.82%. Therefore, it had high Ps value of 16.70 which provide good health benefits to humans who consume it as food. The larvae, pupae and adults of the palm weevils are highly appreciated as traditional delicacies but the fried larvae are most cherished in many tribes in Africa (Thomas, 2003; Womeni *et al*, 2009;Thomas and Briyai, 2019).

3.1.4 Imbrasia spp.

The results (Table 2) showed that the edible caterpillars of the *Imbrasia* species which is a lepidopteran that contained low amount of saturated fats such as palmitic acid (8.42%), two monounsaturated fatty acids, namely: oleic acid (9.06%) and erucic acid (0.94%), which combined to have low total monounsaturation of 10.00%. The polyunsaturated fats consisted of low amount of linoleic acid (6.88%) and rich content of α-linolenic acid (38.01%) which made high total polyunsaturation of 44.89%. Therefore, it had appreciable Ps value of 5.33 which is beneficial in supporting the health and wellbeing of people who eat this insects as food. Common examples of the edible species found in Africa include *Imbrasia belina* (larvae) found in Nigeria and *I. oyemensis* and *I. truncta* caterpillars found in Ivory coast and Zaire (Rumpold and Schluter, 2013; Womeni *et al*, 2009).

3.1.5 Soldier termite (*M. bellicosus)*

The result (Table 2) further revealed showed that the soldier termite (*M. bellicosus*) (order Isoptera), contained relatively high amount of saturated acids such as myristic acid (0.18%), palmitic acid (8.51%) and stearic acid (34.40%) and enoic acid (3.24%) which had total saturated fatty acids content of 46.33%. It contained trace amounts of palmitoleic acid (0.05%) and high amount of oleic (32.49%), which made total monounsaturated fat content of 32.55%. The polyunsaturated fraction consisted of low amount of linoleic acid (0.72%) and little amount of α-linolenic acid (8.10%) omega-3, and eicosatrienoic acid (7.48%) which combined to have low total polyunsaturation of 16.30%. Therefore, it had low Ps value of 0.23 which does not offer much health benefits to consumers of this insect as food. They are obtained from the common ant-hills or castes in tropical African environment (Thomas *et al,* 2021).

3.1.6 Long horned beetle (*Apomecyna parumpunctata.)*

The results (Table 2) showed that the larvae of the longhorned beetle is (acoleopteran), contained relatively high content of saturated fatty acid which consisted of myristic acid (1.83%), palmitic acid (24.60%), stearic acid (2.45%) and behenic acid (2.03%), which combined to have total saturation of 30.91%. The monounsaturated fats comprised of palmitoleic acid (1.40%) and nervonic acid (2.57%) which combined to have total monounsaturation of 56.80% which was higher than other insects in this study. There was low amount of polyunsaturated fats which consisted of linoleic acid (12.28%), α-linolenic acid (0.21%), eicosadienoic acid (0.25%) and docosahexaenoic acid (0.16%) which combined to form total polyunsaturation of 13.3%. Therefore, it had low Ps value of 0.43 which does not promote the health of humans who consume it as food. However, it is very tedious to collect sizeable number of this insect from the wild which makes it unsuitable domestication (Thomas, 2019).

3.1.7 Palm beetles larvae (*Oryctes monoceros*) larvae

The palm beetles which belong to the order coleoptera; family scarabaeidae and genus *Oryctes* has two edible species (*O. owariensis* and *O. monoceros*) which are pests of mature oil palms, raphia and coconut. The larvae of *O. monoceros* contained high amount of saturated fatty acids which consisted of myristic acid (6.21%), palmitic acid (50.8%) and arachiedilic acid (0.03%) which combined to have total saturation of 57.04%. However, it contained low amount of monounsaturated fatty acids such as palmioleic acid (36.42%) and trace amount of oleic acid (0.11%) which form total monounsaturation of 36.42%. Also, there were low amount of polyunsaturated fatty acids which included linoleic acid (0.30%) omega-6 and linolenic acid (0.31%) omega-3, plus eicosandienoic acid (0.19%) and arachidonic acid (5.37%) which made up total polyunsaturation of 6.17%. Therefore, the *Oryctes* larvae had low Ps value of 0.108 which does not offer health benefit to consumers (Thomas and Kiin-Kabari, 2014).

3.1.8 Compost beetles larvae (*O. boas*) which is a coleoptera, family scarabaeidae and genus *Oryctes* are edible species that are found in organic wastes. The edible larvae of *O. boas* contains high content of saturated acids fatty acids which consists of palmitic acid (53.58%), and stearic acid (0.11%) that combined to have total saturation of 53.69%. It possessed high amount of monounsaturated fatty acid, mainly palmitoleic acid (53.58%) and little amount of oleic acid (0.10%) which formed total monounsaturation of 53.68%. There were trace amounts of four (4) polyunsaturated fatty acids which included linoleic acid (0.21%), linolenic acid (0.03%), eicosadienoic acid (0.04%), eicosatranoic acid (0.52%) and arachidonic acid (0.05%) which combined to have low total polyunsaturation of 0.85% with a low Ps value of 0.016 which provides no health benefit in people who eat it as food. They are harvested by digging heaps of manure from organic wastes in tropical Africa (Thomas and Kiin-Kabari, 2014).

Table 2: Fatty acid profiles of some common edible insects

Food insect	Fatty acid	Concentration (%	Characterization	Ps value
Crickets[+]				
	myristic acid (c14:0)	0.59	SFA	
	palmitoleic acid (c16:1)	27.59	MUFA	
	oleic acid (c18:1n-9)	6.89	MUFA	
	linoleic acid (c18:2n-6)	45.63	PUFA (omega – 6)	
	α-linolenic acid (c18:3n-3	16.19	PUFA (omega – 3)	
	γ- linolenic acid (c18:3n-	0.58	PUFA (omega – 6)	
	gondoic acid (c20.1)	0.28	MUFA	
	PS ratio			**105.75**
Grasshoppers[+]				
	palmitoleic acid (c16:1)	23.83	MUFA	
	oleic acid (c18:1n-9)	10.7	MUFA	
	linoleic acid (c18:2n-6)	21.07	PUFA (omega – 6)	
	α-linolenic acid (c18:3n-3	14.76	PUFA (omega – 3)	
	γ- linolenic acid (c18:3n-	22.54	PUFA (omega – 6)	
	gondoic acid (c20.1)			
	Ps ratio			**58.37**
R. phoenicis[+]				
	lauric acid (c12:0)	0.12	SFA	
	myristic acid (c14:0)	2.50	SFA	
	palmitic acid (c16:0)	0.20	SFA	
	palmitoleic acid (c16:1)	37.60	MUFA	
	stearic acid (c18:0)	0.23	SFA	
	oleic acid (c18:1n-9)	5.24	MUFA	
	linoleic acid (c18:2n-6)	45.46	PUFA (omega – 6)	
	α-linolenic acid (C18:3n-	4.19	PUFA (omega – 3)	
	γ- linolenic acid (C18:3n	1.215	PUFA (omega – 6)	
	gondoic acid (C20.1)	0.79	MUFA	
	Ps ratio			**16.70**
Imbrasiaspp. [+]				
	Palmitic acid (C16:0)	8.42	SFA	
	Oleic acid (C18:1n-9)	9.06	MUFA	
	Linoleic Acid (C18:2n-6)	6.88	PUFA (omega – 6)	
	∝-linolenic acid (C18:3n-	38.01	PUFA (omega – 3)	
	Erucic acid (C22.1)	0.94	MUFA	
	Ps ratio			**5.33**
M. bellicosus[++]	myristic acid (c14:0)	0.18	SFA	

	myristoleicacid (c14:1)	0.01	MUFA	
	palmitic acid (c16:0)	8.51	SFA	
	palmitoleic acid (c16:1)	0.05	MUFA	
	stearic acid (c18:0)	34.40	SFA	
	oleic acid (c18:1n-9)	32.49	MUFA	
	linoleic acid (c18:2n-6)	0.72	PUFA (omega – 6)	
	α-linolenic acid (c18:3n-3	8.10	PUFA (omega – 3)	
	Eicosatrienoic acid ($C_{20:3}$	7.48	PUFA (omega-3)	
	Enoic acid ($c_{22:0}$)	3.24	SFA	**0.351**
	Ps ratio			
Apomecyna parumpuntata*				
	myristic (c14.0)	1.83	SFA	
	myristoleic (c14:1)	-	-	
	palmitic (c16:0)	24.60	SFA	
	palmitoleic (c16:1)	1.40	MUFA	
	stearic (c18:0)	2.45	SFA	
	oleic (c18:1)	50.26	MUFA	
	Linoleic (C18:2)	12.28	PUFA(Omega-6)	
	α-linolenic (C18:3)	0.21	PUFA (Omega -3)	
	arachidic (c20:0)	-	-	
	eicodenoic (c20:0)	-	-	
	eicosadienoic (c20:3)	0.25	n-3 PUFA	
	behenic (c22:0)	2.03	SFA	
	erucic (c24:1)	2.57	MUFA	
	nervonic (c24:1)	2.57	M UFA	
	docosahexaenoic (c22:6)	0.61	PUFA	
	Ps ratio			**0.43**
Oryctes monoceros	Myristic acid (C14:0)	6.21	SFA	
	Myristoleic acid (C14:1)	0.1	MUFA	
	Palmitic acid (C16:0)	50.8	SFA	
	Palmitoleic (C16:1)	36.42	MUFA	
	Stearic acid (C18:0)	-	MUFA	
	Oleic acid(C18:1)	0.11	SFA	
	Linoleic acid (C18:2)	0.30	MUFA	
	Linolenic acid(C18:3)	0.31	PUFA (Omega-6)	
	Arachiedilic acid(C20:0)	0.03	PUFA (Omega -3)	
	Pallinic acid (C20:1)	-	SFA	
	Eicosadienoic acid (C20:2	0.19	MUFA	
	Eicosatranoic acid (C20:3	-	PUFA	
	Arachidonic acid (C20:4	5.37	PUFA	
	Ps ratio			**0.108**
O. boas*	Myristoleic acid (C14:1)	0.14	MUFA	
	Palmitic acid (C16:0)	53.58	SFA	
	Palmitoleic (C16:1)	45.22	MUFA	

	Stearic acid (C18:0)	0.11	SFA
	Oleic acid(C18:1)	0.10	MUFA
	Linoleic acid (C18:2)	0.21	PUFA (Omega-6)
	Linolenic acid(C18:3)	0.03	PUFA (Omega-3)
	Arachiedilic acid(C20:0)	-	-
	Pallinic acid (C20:1)	-	SFA
	Eicosadienoic acid (C20:2	0.04	PUFA
	Eicosatranoic acid (C20:3	0.52	PUFA
	Arachidonic acid (C20:4	0.05	PUFA
	Ps ratio		**0.016**

Sources: [+]Womeni *et al*, 2009; **Thomas and Kiin-Kabari, 2014; *Thomas, 2018;[++]Thomas *et al* ,2021

3.2 Quality of Fats from Common Animal Sources

The fatty acid composition of four commonly consumed animal fats (Table 3) showed that poultry products were higher in quality of fats, followed by salmon (seafish), pork and beef was the least were ps values of 2.38, 1.66, 0.7 and 0.26, respectively (Vizcarrondo *et al*, 1998). Poultry products are more beneficial to health of consumers due to the presence of low amount of stearic acid (8.22%) which is a saturated fatty acid (SFA); while it contained higher amount of essential fats such as linoleic acid (19.54%) omega-6. Poultry product had ps value of 2.38 which supports effective functioning of the human hearts (Mann, 1993). Although, the fats of the salmon (seafish) had lower ps value of 1.66, it is beneficial to the health of consumers due to the presence of appreciable amount of the two most essential fats known as linoleic acid (11.0%) omega-6, and linolenic acid (17.6%) omega-3, in addition to oleic acid (19.3%) which is a monounsaturated fatty acid that is of moderate benefit to health. The quality of fats of salmon seafish was reduced by the presence of palmitic acid (17.2%) which is a saturated fat that negatively affect the heart of humans as it contains high cholesterol content which induces increased blood pressure. According to a recent report (Tasbozan and Gokce, 2017), stated that salmon and other seafishes are more reliable sources of essential fats for sustainable health of consumers because it satisfies the ratio of 1:1 or more of the presence of n-3 PUFA (EPA and DHA) as recommended by the World Health Organization. Furthermore, they reported that fatty acids composition in fishes differs based on the species of fish, environmental influence (salinity, temperature, season, geographical location) and whether it is obtained from the wild or farmed. The fat obtained from Pork with lower ps value of 0.47 is also recommended for human consumption as it contain high amount of oleic acid (42.83%) MUFA and average amount of linoleic acid (11.85%) PUFA, which jointly neutralizes the negative effect of the high content of palmitic acid (24.15%) SFA. This implies that fat from pork contains low cholesterol, hence it does not solidify at room temperature (Mann, 1993; Harvard, 2018). Therefore, it is higher in quality than the common edible palm oil and margarine which has ps value of 0.2. The fats from beef cuts are not good for human health due to the high content of saturated fats; including stearic acid (20.97%) and palmitic acid (25.67%) which combine to have high total SFA of 46.64%. Beef contained lower amount of polyunsaturated fatty acids (PUFA) such as linoleic acid (12.09%), plus oleic acid (36.21%) MUFA. The resultant effect of combination of total saturated fatty acid of 46.64% with high unsaturated fatty acids (UFA) (48.30%) produced lower ps value of 0.26 for beef, which was almost equivalent to the ps value of common edible palm oil and margarine which had ps value of 0.2.

Table 3: Lipid composition of Beef, Pork, Poultry and Fish

Amino acid	**Beef cuts (**	**Pork (%)**	**Poultry (%)**	**Salmon fish**	**Characteriza**
Stearic acid	20.97	NA	8.22	NA	SFA

Palmitic acid	25.67	24.15	NA	17.2	SFA
Oleic acid	36.21	42.83	NA	19.3	MUFA
linoleic acid	12.09	11.85	19.54	11.0	PUFA (Omeg
Linolenic acid	NA	NA	NA	17.6	PUFA (Omeg
SFA	46.64	24.15	8.22	17.2	
MUFA	36.21	42.83	NA	19.3	
PUFA	12.09	11.15	19.54	28.6	
Ps ratio	0.26	0.47	2.38	1.66	

Sources: Vizcarrondo *et al*, (1998); Tasbozan and Gokee, (2017)

3.3 Health Benefits of polyunsaturated fats from Edible insect and animals

The results (Table 4) further confirm that the crickets which have the highest Ps value of 105.75 possessed the most healthy fats that guarantees efficient functioning of the human heart. People who have the opportunity to consume large quantity of these edible insects would not have any risk of cardiovascular diseases of the heart, obesity nor hypertension. Essentially, the quality of fats obtained from crickets was better than fats from poultry, beef, pork and fish (Rumpold and Schluter, 2013). The grasshoppers were ranked as the second best quality of fats because it had Ps value of 58.37, while the larvae of African palm weevil (*R. phoenicis*) was the third best in quality of fats, as it had Ps value of 16.70. The fats from crickets, grasshoppers and *R. phoenicis* were considered as the best grade of fats which sustains optimum functioning of the human heart, because they have higher proportions of polyunsaturated fatty acids (PUFA) that ranges between 50%-63%, plus average monounsaturated fatty acids (MUFA) that ranged between 30-43%, while there was low saturated fatty acids (SFA) that ranges between 0.59%-3.05% (Defoliart, 1991). The second category was made of fats from caterpillars of *Imbrasia* species, poultry and salmon fish which had ps values of 5.33, 2.38 and 1.66 respectively; hence they were ranked as the 4th, 5th, and 6th in quality of fats that provide adequate health benefit to consumers. They contain polyunsaturated fatty acids (PUFA) that range between 19.54-44.81% ; monounsaturated fatty acids (MUFA) ranged between 10.0-19.3% and relatively lower amount of saturated fatty acids (SFA) that range between 8.22 – 17.2%. Therefore, people who are having any heart-related diseases are advised to make their choices of fats from this group of animals. The remaining six sources of fats which included the pork, longhorned beetle larvae (*A. parumpunctata*), *M.bellicosus* beef, and the edible palm beetle larvae (*O. monocerus* and *O. boas*) are not recommended for consumption because they had the lowest quality of animal fats based on their corresponding lower Ps values of 0.47, 0.43,0.35 0.26, 0.108 and 0.016, respectively (Thomas and Kiin-Kabari, 2014; Thomas, 2018). These animal fats provide little or no health benefit to consumers because they contained less amount of polyunsaturated fatty acids (PUFA) that range between 0.85-12.75% but contained high content of saturated fatty acids SFA (24.15-57.04%) with greater amount of monounsaturated fatty acids (MUFA) ranging between 36.21% – 45.35%, which offers moderate health benefit, hence they were ranked as 7th - 12th in the quality of fats of health of consumers.

Table 4: Qualitative categorization of fats of some edible insects and animals

Sources	SFA	MUFA	PUFA	Ps Values	Ranking
		CATEGORY I			
Crickets^{+}	0.59	34.75	62.37	105.75	1st
Grasshoppers^{+}	2.34	34.96	58.36	58.37	2nd
R. phoenicis^{+}	3.05	43.63	50.86	16.70	3rd
		CATEGORY II			

***Imbrasia* spp.**	8.42	10.00	44.81	5.33	4th
Poultry++	8.22	NA	19.54	2.38	5th
Salmon fish+++	17.2	19.3	28.6	1.66	6th
		CATEGORY III			
Pork products++	24.15	42.83	11.15	0.47	7th
Long horned beetle (*A. parumpunctata*)*	31.01	56.80	12.74	0.43	8th
Soldier termite+ **(*M. bellicosus*)**	46.64	36.21	12.09	0.35	9th
Beef cuts ++	46.33	32.55	16.30	0.26	10th
Palm beetle (*O. monoceros*)**	57.04	36.53	6.17	0.108	11th
Compost beetle (*O. boas*)**	53.69	45.35	0.85	0.016	12th

Sources:+(NRC, 1988), ++(Defoliart, 2009),+++(Vizcarrondo et al, 1989); *(Thomas, 2018); **(Thomas and Kiin-Kabari, 2014);
Womeni *et al*, (2009),NA – Not available

The findings of this work has revealed some similarities in the distribution of fatty acids in edible insects such as crickets, grasshoppers, *R. phoenicis* and fish which possessed the highest proportion of polyunsaturated fatty acids and monounsaturated fatty acids, thus their fats are able to support efficient functioning of the human heart without coronary diseases (Defoliart, 1991). These findings agreed wih earlier workers who stated that the pattern of distribution of fatty acids of pupae of the housefly (*Musca domestica)* used to feed broiler chicks, had great resemblance with the fatty acids of fish oils. Fast (1970) also reported that the quality of fats in coleopterous insects (beetles and weevils) and lepidopterans (butterflies and moths) possessed high concentration of polyunsaturated fatty acids. However, the coleoptera contained more linoleic acids (omega-6), whereas the Lepidoptera contained more linolenic acid (omega-3) which are beneficial to the human heart when it had undergone metabolism in the body. These essential oils are always obtained by consuming some special foods including vegetables (flaxed canola) and fresh salmon fish, because these oils cannot be synthesized in the human body (Harvard, 2018). Recently, some polyunsaturated fatty acids were extracted from the salmon fish and processed into omega-3 supplements been recommended to be taken, at least twice in a week in North America, as a natural way of controlling heart diseases by the America Heart Association (AHA) (Defoliart, 1991). The consumption of these edible insects is preferred to some common animal fats because these insects provides higher quality of polyunsaturated fats which are more beneficial to health and supply adequate calories of energy to consumers than the conventional animal foods. The sustained consumption of foods that contains these essential fatty acids also promotes maternal and fetal health during pregnancy, newborn and childhood development (Umhau and Dauphinais, 2007). It claimed that the intake of these essential fatty acids in the right amounts would relieve dementia hyperactivity and some psychiatric disorders (Umhau and Dauphinais, 2007). Consequently, the rich content of n-3 and n-6 PUFA (DHA + EPA) can be obtained from insects and be processed into supplements to be taken by people to solve some nutritional diseases including obesity and diabetes (Malciciks *et al*, 2018).

CONCLUSION

This review had revealed that crickets, grasshoppers and *R. phoenicis* are excellent sources of healthy polyunsaturated fat because they have high Ps values of 105.76, 58.37 and 16.70 respectively; whereas the catapillers of *Imbrasia* species are also good for consumption because they guarantee efficient functioning of the heart of consumers. The fats from poultry and salmon fish are also acceptable source of healthy polyunsaturated fatty acids because they have moderate ps values of 2.38 and 1.66 which are higher than the Ps value of palm oil (0.2) WHICH is the bench mark for rejection because it contains too much saturated fatty acids. Therefore the fats from pork, beef, *M. bellicosus*, *A. parumpunctata* , *O. monocerus* and *O. boas* which have the lowest quality of fats with Ps value ranging from 0.016- 0.47 are not recommended for consumption by people who are having heart related diseases because they contain too much saturated fatty acids that do not support the health of the heart due to high cholesterol. The Ps value was defined as the ratio of total polyunsaturated fatty acids which combined with total saturated fatty acids. The constraints against commercialization of edible insects is the unavailability of the edible species at sometimes of the year and difficulty of obtaining the daily required among of 500mg of the most essential fatty acids (EPA + DHA) from optimum health benefits. In other to overcome this dilemma, people resort to the consumption of greater quantities of sea fishes (Salmon, mackerel herring and others) which supplies these essential fatty acids in a sustainable manner for sound health. Therefore, different species of edible crickets, grasshoppers, *R. phoenicics* and *Imbrasia* sp should be investigated to confirm the content of essential fatty acids with the primary objective of processing them as supplement of omega 3, 6, and 9 to boost the health of consumers. These findings are aspects of ongoing studies on the nutritional values of edible insects.

REFERENCES

Alamu O. T, Amgo A. O, Nwakedi C. I., Oke O. A. and Lawal I. O. (2013). Diversity and nutritional status of edible insects in nigeria: a review. *International Journal of Biodiversity and Conservation.* 5 (4): 2015-222

Anthonia H. O and Isoum M. (1982). Nigeria Cookbook. London: Macmillian Press

Bhulaidok, S. Sihamala, O. Oshen L. and Li. D (2010): Nutritional and fatty acid profiles of sun-dried black ants (*Polyrhachisvicina* Roger). *Maejo Int. J. Sci. Technol. 4:*101-112

Chen, X., Feng, Y., Chen, Z., (2009). Common edible insects and their utilization in China. *Entomol. Res.*, 39: 299-303.

Defoliart G. R. (1991). Insects fatty acids: similar to those of Poultry and Fish in their Degree of Unsaturation but higher Polyunsaturates. *Food Insects News Letter. 4:1-4*

Ekpo K.E, Onigbinde A.O and Asia I.O (2009): Pharmaceutical Potentials of the oils of some popular insects consumed in southern Nigeria. *Afr J. Pharmacy X Pharmacology*, 3; 51-57

FAO (2010): Review of Food consumption data on edible insects: *Food and Agricultural Organization. The International Network of Food Data Systems* (INFOOD).

FAO. (2009): The State of Food and Agriculture. Rome: *Food and Agriculture Organization of the United Nations;* 2009

Fasoranti J. O and Ajiboye D. O. (1993): Some edible insects of Kwara State. *American Entomologist*, 39(2):113-116.

Fast P. G. (1970): Insects lipids. In progress in the chemistry of fats and other lipids (R. T. Holman, ed.) vol. 11 pt 2: 181-242.

Fox B. A. and Cameroon A. G. (1989): Food science, nutrition and health 5th edition. Edward Arnold, the educational academic medical division, hodder and Stoughton ltd, 41 bedford square London, WC133DQ.

Harvard Heart Letter (2018): Harvard Health Publishing, Harvard Medical School (https://www.healthharvard.edu).

Mann J. (1993): Diseases of the Heart and Circulation: The role of Dietary Factors in aetiology and management. In: Garrow JW, James eds. *Human Nutrition and Dietetics, London*: Churchill, Living Stone: Pp 619-650

Natural Resources Institute (1996): A Guide to Insect Pests of Nigerian Crops: Identification, Biology and control. Federal Ministry of Agriculture and Natural Resources, Nigeria and Overseas Development Administration, UK.

NRC (1988): National Research Council (1988). Designing Foods. Animal Products Options in the Market Place Washington D. C. National Academy press.

Olowu, R. A. Moronkola B. A. Tovide, O. O., Denloye, A. A., Awokoya K. N., Sunday C. E. and Olujimi O. O. (2021)., Assessment of Proximate and minerals status of Rhinoceros beetle larva, *Oryctes rhinoceros* Linnaeus (1758) (Coleoptera: Scarabaeidae) from Itokin, Llagos State, Nigeria. *Res. J. Environmental Sci.*, 6: 118-124

Omotoso O. T and Adedire C. O. (2007): Nutrient composition, mineral content and solubility of the proteins of palm weevil (*Rhynchophorus phoenicis*) (Coleoptera: Curculioidae), J. *Zhejiang Univ. Sci. B.*7:51-55.

Payne C. R. L, Scarborough P, Rayner M. and Nonaka K. (2015): Are Edible insects more or less "Healthy" than commonly consumed meats? A comparison using two nutrient profiling models developed to combact over and under-nutrition. European Journal of Clinical Nutrition, *United kingdom*. (www.nature.com/ejcn)

Premalatha M, Abbasi T, Abbasi T, Abbasi SA (2011). Energy-efficient food production to reduce global warming and ecodegradation: The use of edible insects. *Renewable and Sustainable Energy*. Rev. 15: 4357–4360.

Ramos Elorday J. Prado E. E. Perez M. A., Otero J. L and de Guevera O. L. (1997): Nutritional value of edible insects from the state of Qaxaca, Mexico. *Journal of Food Composition and Analysis*, 10:142-157

Rumpold B. A. and Schluter O. K (2013): Nutritional composition and safety aspects of edible insects. *Nutri. Food Res.* 57:802-823

Tasbonzan O. and Gekcee A. M. (2017): Fatty Acids in Fish Intech Open: Submitted: October 14th 2016, Reviewed: Feb. 21st 2017, Published: June 21st, 2017, DOI: 10.5772/68048

Thomas C. N. (2018) Nutritional Potentials of Edible Larvae of Longhorned beetle (*Apomecynaparumpunctata*) (Coleoptera:Cerambycidae) in Niger Delta, Nigeria. *International Journal of Agricultural and Earth Science.* 4(3):46-51

Thomas C.N, Owuno F.A, and Kpe J.J (2021). Nutritional Value and Quality of Fats of Soldier termite (*Macrotermes bellieosus*; Isoptera) in Bayelsa state, Nigeria. *Annuals of Applied Sciences*, 7(2):15-22.

Thomas C.N, Kiin-Kabiri D.B and Briyai O.F (2014); Fatty Acid Composition of Edible larvae of Beetles (*Oryctes* spp) utilized as Human food in Niger Delta Area of Nigeria. *African Journal of Biomedical Sciences,* 5; 1-6

Thomas C. N. and Kiin-Kabari D. B. (2018): Protein Quality of Edible Larvae of Beetles (*Orycte spp.)* from Palms and Compost in Niger Delta, Nigeria; *International Journal of Food Bioscience* 1(2):1- 4.

Thomas CN. (2003) Biology utilization and rearing of African palm weevil (*Rhynchophorus phoenicis* F) in palms of the Niger Delta, Nigeria [PhD Thesis]. Nkpolu, Port Harcourt, Nigeria: Department of Biological Sciences, Rivers State University.S

Thomas Commander N., Jacob P. Anankware, Onwugbuta O. Royal and Daniel Obeng-Ofori (2019): Econometrics of Domestication of the African Palm Weevil (*Rhynchophorus phoenicis* F) Production as Small-Scale Business in Ghana: IntechOpen, DOI: http://dx.doi.org/10.5772/intechopen.90259

Vizcarrondo C. A., Padilla FC, and Martin E. G. (1998). Fatty acid Composition of Beef, Pork and Poultry fresh cuts and some of their processed products. *Arch Latinoam Nutrition Dec. 1998;* 48(4):354-358

Womeni, H. M. ; Linder, M. ; Tiencheu, B. ; Mbiapo, F. T. ; Villeneuve, P. ; Fanni, J. ; Parmentier, M., (2009). Oils of insects and larvae consumed in Africa: potential sources of polyunsaturated fatty acids. *Oléagineux, Corps gras, Lipides* 16: 230-235.

Yoloye L. Victor (1988): Invertebrates 3rd edition Ilorin University Press, P.M.B 1515, Ilorin, Nigeria

Umhau J. C. and Dauohinais K. M. (2007). Omega-3 Polyunsaturated fatty acids and health, Chapter in Book: Low Cost Approaches to promote physical and mental health (pp. 87-101). (https://www.researchgate.net.2261)

Malcicks M., Bertane V. and Jacintha E. (2018): An Evolutionary Perspective on Linoleic Acid Sythesis *Evolutionary Biology*, 45: 15-26.