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Fats and major fatty acids present in edible insects utilised as food and livestock feed

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ABSTRACT

Common food sources including meat, fish and vegetables are the main source of fats and fatty acids required by human body. Edible insects such as worms, locusts, termites, crickets and flies have also been identified as a potential source of essential fatty acids since they are highly documented to be rich in unsaturated fatty acids such as α-linolenic and linoleic acids which are vital for the normal functioning of the body. The approval of insects as edible food by the European Union has sparked research interest in their potential to form part of human and animal diets due to their abundant protein, amino acids, fats, and minerals. However, little attention has been given to the importance and health benefits of lipids and fatty acids present in edible insects consumed by human and animals. This article aims to review the biological significance of essential fatty acids found in edible insects. The accumulation of fats and essential fatty acids present in edible insects were identified and described based on recommended levels required in human diets. Furthermore, the health benefits associated with insect oils as well as different processing techniques that could influence the quality of fats and fatty acid in edible insects were discussed.

1. Search strategy

A literature search was conducted to identify recent peer-reviewed journals and book chapters based published from 2009 to 2023 on fats and fatty acids composition of edible insects as food and feed. The accessed publications were searched using the electronic databases including Google Scholar, ScienceDirect, ResearchGate, Scopus, Web of Science and the Directory of Open Access Journals. Keywords used in the search box were “fats and fatty acids”, “edible insects”, “insect oils”, “entomogaphy”, “livestock diets”, “health benefits” and “food security”. Approximately 11700 were obtained and thoroughly checked and evaluated. A total of 9676 papers were nonrelated articles in which others were written in other languages except English. 1954 articles were excluded on the basis that they were duplicates, had missing information or articles were not specifically focusing on edible insects as a source of fats, oils and fatty acids. Thereafter, a total of 70 articles related to the topic and keywords were selected and included in the current review.

2. Introduction

As the global population continue to rise, malnutrition remain a serious challenge in most undeveloped countries faced with poverty and hunger, particularly in Africa, Asia and the Middle East (Atinmo et al., 2009; Adeyeye et al., 2023). Over decades, poor communities, especially in rural areas opt for foods materials harvested in the wild including edible insects orders namely Orthoptera (locusts and crickets), Isoptera (termites), Lepidoptera (caterpillars), Hemiptera (stinkbugs) and Diptera (flies) to cope with undernutrition since they possess nutritional and health benefits (Tang et al., 2019; Elahi et al., 2022). These lists of traditionally harvested and farmed insects are rich in nutrients mainly protein, fats and minerals. However, fats and fatty acid contents are the second major dominant nutrient in edible insects after protein (Kinyuru et al., 2015; Dobermann et al., 2017; Kuntadi et al., 2018). They comprises of about 10 to 50g/100g DM of fats (Xiaoming et al., 2010), with considerable amount of Omega-3 (n-3) and Omega-6 (n-6) polyunsaturated fatty acids which are the main essential fatty acids required for the normal functioning of the human body cells (Tilami et al., 2020; Adli, 2021; Hermans et al., 2021). Hence, they could be potentially

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utilised as a source of essential fatty acids in replacement of conventional edible oils for human and animal feeding.

As reported by previous studies, fish, poultry, pork, beef and vegetable oils such as sunflower soybean, and palm are the most common food materials rich in fats and fatty acids (Kuntadi et al., 2018; Monter-Miranda et al., 2018; Tang et al., 2019). However, poor communities in rural areas and smallholder livestock farmers have little or no access to food and by products that supplies essential oils. Hence, insects could prove to be a vital alternative source of essential fatty acids when incorporated in diets. According to Abdullahi et al. (2021), the importance of lipids and their constituents present in edible insects have not been fully explored despite their high global recognition as functional food and feed, thus, limiting their global demand and acceptability by consumers. Moreover, there is less information documented about the availability and significant contribution essential fatty acids such as linoleic and linolenic acids found in edible insects (Dobermann et al., 2017; Feng et al., 2018). Hence, this review aims to assess and evaluate the significant role of essential fatty acids present in edible insects to promote global consumption, acceptability and rearing of edible insects as a source of edible oils.

3. Description of fats and essential fatty acids present in edible insects

As in animal tissues, the lipid profile of insects comprises of phospholipids, triglycerides, sterols, waxes, and lipophilic vitamins but mainly dominated by phospholipids and triglycerides as depicted in Fig. 1. Examples of phospholipids include phosphatidylcholine, phosphatidylethanolamine, phosphatidylinositols, phosphatidylserine, sphingomyelin, and cardiolipins which are most common in insects such as locusts (Mariod, 2020). They are generally responsible for smooth absorption of fat-soluble substances and also function to lubricate joints, heart and lung membrane layers to maintain their functionality in human and animals (Li et al., 2015). The triglycerides on the other hand, are a group of fatty acids and glycerols. They make up most of the fat content found in food materials such as edible insects, meat, fish and vegetable oils (Kinyuru, 2014; Kinyuru et al., 2015; Tang et al., 2019). The fatty acid profile in insects comprises of saturated fatty acids (SFAs) and unsaturated fatty acids (UFAs), in which UFAs are further divided into monounsaturated (MUFAs) and polyunstaunsaturated fatty acids (PUFAs) (Kouřimská, and Adámková, 2016; Akullo et al., 2018; Kuntadi et al., 2018; Elahi et al., 2022). As shown in Fig. 1, the most common examples of SFAs includes palmitic, stearic and arachidic acids (Mishyna et al., 2020). Moreover, myristoleic, palmitoleic and oleic acids are the commonly found MUFAs within the lipid fraction, whereas n-6 (linoleic and arachidonic acids) and n-3 (linolenic and eicosapentaenoic acids) are the commonly found PUFAs within the lipid fraction (Kinyuru et al., 2015; Musundire et al., 2016; Tao and Li, 2018). The palmitic acid, oleic acid and linolenic acid are the most common SFA, MUFA and PUFA that are found in abundance in various insects, respectively (Kouřimská, and Adámková, 2016; Mariod, 2020; Meyer-Rochow et al., 2021). However, humans and other mammals including most livestock are unable to synthesize essential fatty acids particularly α-linolenic and linoleic acids, hence, insects as a functional food could be a suitable dietary supplement to supply these vital amino acids for utilisation by human (Saini and Keum, 2018).

4. Accumulation of fats and fatty acids in edible insects

4.1. Fats/oil content

Edible insects are rich in fats mainly reserved as energy for growth throughout the stages of development (Mariod, 2020). Table 1 describes fats and fatty acids composition of various the commonly reared and harvested edible insects (caterpillars, locusts, termites, crickets and flies) including *Gonimbrasia belina* (mopane worms), *Tenebrio molitor* (yellow mealworms), *Rhynchophorus phoenicis* (African palm weevil larvae), *Schistocerca gregaria* (Desert locusts), *Locusta migratoria* (Migratory locust), *Macrotermes* spp. (Winged termites), Gryllus spp. (Field crickets), Acheta spp. (House crickets), *Hermetia illucens* (Black soldier fly) and *Musca domestica* (House fly). The caterpillars, locusts, termites contain high fat content ranging from 11.49 to 69.78 g/100g. The highest fat content is observed in caterpillars and termites species. Similar results were reported by Hlongwane et al. (2020a,b), who observed higher fat content in insect species from Lepidopteran order (caterpillars) compared to other insect orders. Hence, the larvae from the Lepidopteran order are regarded as a good source of fatty acids and contain more fat content than other edible insects at any growth

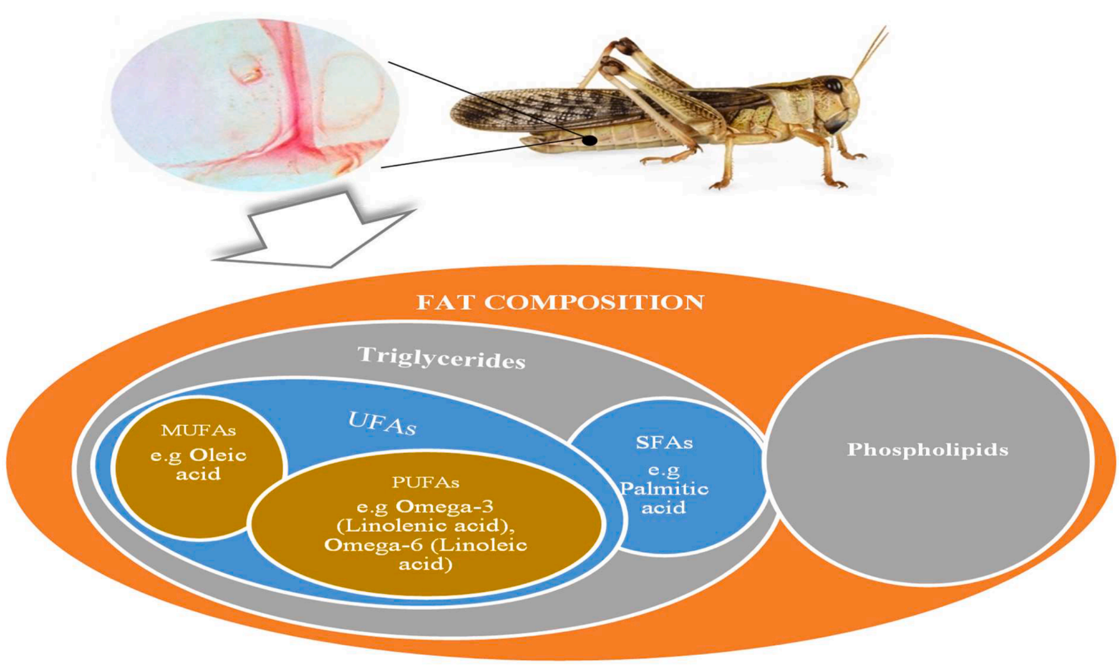

Fig. 1. Fats and fatty acids composition of edible locust; *Locusta migratoria*.

Table 1
Fatty acid composition (g/100 g) of selected edible insects.

Insect species	Stage	Compositions										References
		Fats (%)	SFA	Palmitic acid (C16:0)	UFA	MUFA	Oleic acid (C18:1)	PUFA	Linoleic acid (C18:2)	Omega 3 (n-3)	Omega 6 (n-6)	
Caterpillars (Lepidoptera)												
Gonimbrasia belina	L	15.15-23.38	32.50-46.50	3.20-31.90	-	7.60-36.00	34.20	26.12-48.17	6.0	3.70	1.60	Tang et al., 2019; Mariod, 2020; Ghosh et al 2020; Meyer-Rochow et al., 2021; Orkusz, 2021
Tenebrio molitor	L	24.70-43.08	25.35-30.12	18.00-28.20	-	43.27-66.77	40.86-60.63	3.11-31.37	2.84-29.68	1.61	29.68	Zielińska et al., 2017; Tang et al., 2019
Rhynchophorus phoenicis	L	21.10-69.78	39.90-54.07	27.13-34.20	-	41.78-55.00	35.05	2.79-22.85	2.20-19.50	0.00	2.20	Tang et al., 2019; Mariod, 2020; Anankware et al., 2021
Locusts (Orthoptera)												
Schistocerca gregaria	A	12.97-35.30	35.30-42.37	23.26-26.90	63.05	38.35-42.37	31.70-40.87	20.68-34.80	10.10-14.04	11.35-13.40	7.28-14.04	Fombong et al., 2021; Zielińska et al., 2017; Egonyu et al., 2021
Locusta migratoria	A	30.52	46.70-56.85	39.00-43.01	43.15	25.70-28.00	22.85-26.20	17.45-25.20	3.38-9.32	6.74	10.71	Sanchez-Muros et al., 2014; Fombong et al., 2021
Termites (Isoptera)												
Macrotermes bellicosus	A	26.30-48.00	46.72-49.46	38.35-46.54	50.54-53.20	14.93-44.64	12.84-41.74	4.90-38.27	5.03-34.42	0.00	8.16	Kinyuru et al., 2013; Tang et al., 2019; Meyer-Rochow et al., 2021; Anankware et al., 2021
Macrotermes nigeriensis	A	34.23-50.90	39.40	31.40	60.64	53.10	52.45-52.50	7.57-7.60	7.60-8.84	-	-	Fombong et al., 2018; Meyer-Rochow et al., 2021
Macrotermes subhyalinus	A	44.82-47.00	35.05-35.40	27.65-33.00	64.95-89.00	42.50-52.77	9.50-48.60	12.18-46.5	10.75-43.1	-	-	Kinyuru et al., 2013; Meyer-Rochow et al., 2021
Crickets (Orthoptera)												
Gryllus assimilis	A	7.00-32.00	43.72	25.85	56.29	27.49	25.03	28.80	26.13	1.99	26.81	Magara et al., 2021
Gryllus bimaculatus	A	11.90-20.74	3.25-38.02	2.16-27.73	7.46-62.46	3.13-32.91	2.91-31.76	4.33-29.54	4.16-27.33	0.08-1.15	4.25-27.92	Magara et al., 2021; Fombong et al., 2021
Acheta spp.	A	12.20-22.96	32.22-32.80	5.50-22.65	64.36-67.40	21.72-33.50	20.18-31.10	33.90-42.64	32.20-41.30	0.01-0.39	2.08-42.63	Tang et al., 2019; Magara et al., 2021; Orkusz, 2021
Flies (Diptera)												
Hermetia illucens	L	18.03-32.60	61.36-67.93	9.44-13.25	-	17.39-26.06	2.59-12.84	9.18-14.67	6.43-13.91	0.00	8.16	Makkar et al., 2014; Tang et al., 2019; Anankware et al., 2021
Musca domestica	L	11.49-24.31	33.40-44.74	9.63-27.60	-	29.46-47.67	18.30-21.75	16.11-17.00	8.84-16.44	2.94	13.17	Makkar et al., 2014; Tang et al., 2019; Anankware et al., 2021
Fatty acid requirements												
Humans		-	26.90	-	-	30.85	-	16.90	14.95	-	-	Tang et al., 2019
Poultry species (broilers, layers, turkey)		-	-	-	-	-	-	-	-	-	0.83-2.00	NRC, 1994

Key: L-larvae; A- adult; '-' Not reported; SFA-Saturated fatty acids; TUFA- Total unsaturated fatty acids; MUFA- Monounsaturated fatty acids; PUFA- Polyunsaturated fatty acid5. Significant role of fats and fatty acids available in edible insects.

development stage (Tang et al., 2019). For that, insects at early developmental stages have high levels of total lipid fraction than at adult stage (Mariod, 2020). Thus, the larvae and pupae stage contain a higher total fat content compared to the adult stage, and this content ranges from 1 to 70 g/100g DM (Mlček et al., 2014). Again, insects with a soft bodied skeleton (termites) comprises of more lipids than those with hard body skeleton (locusts) (Dobermann et al., 2017). Other studies also concluded that dried insects contain more fat content of up to 77 g/100g DM with large proportion of essential fatty acids (Tao and Li, 2018; Mutungi et al., 2019). However, the accumulation of lipid and fatty acid contents in different insect species depends on a combination of factors such as species type, sex, reproduction stage, developmental stage, living temperature, season, feed substrates, geographical origin, and processing methods as well as biological factors including enzymatic activity (Akullo et al., 2018; Monter-Miranda et al., 2018; Kim et al., 2019; Mutungi et al., 2019).

4.2. Fatty acids content

The existence of essential fatty acids determines the quality of insect oils, therefore, it is important to distinguish and evaluate various types of fatty acids detected in edible insects (Kinyuru, 2014). The most predominant fatty acids in insects such as crickets, locusts, flies, stinkbugs, and termites includes oleic acid (SFA), palmitic acid (MUFA) and linoleic acid (PUFA), respectively (Kinyuru et al., 2013; Akullo et al., 2018; Mariod, 2020). Table 1 shows the fatty acids composition of different edible insect species and their recommended levels in human and poultry diets. In terms of total SFAs, locusts, termites and files contain about 32.22 to 64.53 g/100g DM) of total SFAs, which is above the recommended levels required in human diets. Moreover, the lipid profile of termites comprises of higher SFAs than locust species (Kinyuru, 2014; Kim et al., 2019).

Nonetheless, the lipid fractions of all edible insects in Table 1 are highly dominated by UFAs with 16 and 18 carbons including α-linolenic and linoleic acid (PUFAs) (Monter-Miranda et al., 2018), which, are some of the essential fatty acids required by human and livestock

(Kinyuru et al., 2013;2015). Despite that, eicosapentaenoic acid (EPA) (C20:5) and docosahexaenoic acid (DHA) (C22:6) remain the primary PUFA required for good health in humans (Doberman et al 2017). The reported insects contain total UFAs ranging from 32.22 to 64.53 g/100g DM. However, *Tenebrio molitor* and *Rhynchophorus phoenicis* larvae seem to be rich MUFAs and oleic acid levels than other insect species. More so, *Gonimbrasia belina, Schistocerca gregaria, Locusta migratoria* and *Acheta* spp. contain high of PUFAs with *Acheta* spp. having the largest proportion of linoleic acid (32.20 to 41.30 g/100g DM). Similar findings were also reported by Tang et al. (2019). The elevated PUFA levels in insects apparently modifies their lipid structure to exist in the form of oils, thus becoming liquid at room temperature (Mariod, 2020). Despite that, all edible insects contains sufficient linoleic acid content above the required levels by human and poultry species (broilers, layers and turkey). Furthermore, the n-3 and n-6 fatty acids in orthopterans such as locusts and crickets ranges from (26.81 to 42.63 g/100g DM) and (11.35 to 13.40 g/100g DM) (Table 1). Fombong et al. (2021), also observed that the n-3 fatty acids such as α-linolenic acid is highly accumulated in locusts than common plant oils such as sunflower, olive and soybean. This indicates that edible insects as functional foods could be supplemented in human diets to supply essential fatty acid required in the body. However, *Macrotermes nigeriensis* and *Hermetia illucens* reported in the table had the lowest PUFAs content below the recommended levels in human diets. Hence, knowledge about the accumulation of fatty acids in various insects and their safe consumption could help promote farming of insects as an alternative to common foods meant to supply essential fatty acids (Kuntadi et al., 2018).

The lipids and fatty acids present in edible insects play a major role in their structural and biological functioning. The SFAs found in insects including palmitic acid and stearic acid have been reported to improve insect flavour, whereas, UFAs, mainly n-3 and n-6 in insects assist in regulating fluidity of membranes and are also involved in the synthesis and formation of waxes, pheromones, eicosanoids and defence secretions (Musundire et al., 2016). Again, common essential fatty acids (α-linolenic and linoleic acids) on the other hand, have great influence the nutritional value of insects oil by lowering their cholesterol levels relative to oleic acid (Akullo et al., 2018). In humans, however, lipids and fatty acids obtained from consuming insects and insect oils provide support, protection and insulation to various organs and further aid in transportation of essential fat-soluble vitamins in the body (Musundire et al., 2016; Seni, 2017). Kuntadi et al., (2018) also observed that PUFAs from edible insects such as stinkbug species promote cell viability, mitogenesis and help protect β-cells from glucose and palmitic acid-induced apoptosis.

The oleic acids found in common foods such as meat, eggs and fish is also present in edible insects. Its main function is to for lower human blood pressure and also has the ability to cure inflammatory, immune and cardiovascular diseases (Sales-Campos et al., 2013). Nonetheless, the α-linolenic acid (PUFA) found in insects such as caterpillars is responsible for acting as a nutraceutical substance that protects the brain and provides anti-inflammatory, acne reductive and skin-lightening benefits in humans (Tang et al., 2019). The n-6 and n-3 (PUFAs), however, produces enzymes required for the synthesis of long chain fatty acids (Akullo et al., 2018). In addition, the n-3 fatty acids act as the lipids membrane structure, especially in nerve tissue and the retina. Previous literature reported that the accumulation of n-3 and n-6 fatty acids present in edible insects further help lower the cholesterol levels and other sterols whose build-up can lead to heart diseases such as atherosclerosis in humans (Musundire et al., 2016; Kuntadi et al., 2018; Kinyuru, 2021). More so, the high amounts of phytosterols present in insect species such as locusts have also been reported to be associated with reducing cholesterol levels in the human body (Egonyu et al., 2021). Nevertheless, it has been reported that the incorporation of fatty acids in livestock diets provide hypocholesterolemic, anticoronary and antiarthritic effects, which consequently promote their health (Musundire et al., 2016).

Fig. 2 below compares the fatty acid composition of edible insects with common food materials including sunflower, soyabean and palm oils, fish oil as well as fat contained in chicken, pork, and beef. Insects seem to contain more fatty acids than common food materials (vegetable oils and animal fats/oil). Their PUFA levels are higher than those from animal fats/oil but slightly lower and comparable that of vegetable oils. Hence, they could be a good source of essential fatty acids that are vital in growth and health of human and livestock.

5. Benefits of fats and fatty acids from edible insects

5.1. In human diets

The fats and essential fatty acids in edible insects are required by humans for better nutrition and health. As reported in Fig. 2, they make up most of the fat content of common food materials such as meat, eggs, and vegetable oils (Kinyuru, 2014). It has been reported that high levels of fat present in edible insects could be utilised as a source of energy in human diets to alleviate malnutrition problems resulting from energy deficiencies (Hlongwane et al., 2020b). Edible insect oils have low SFAs than beef and pork meat (Kinyuru, 2014). Hence, they could be a good supplement, insects contain more UFAs which are desirable for human consumption than SFAs (Akullo et al., 2018). Moreover, it has been reported that edible insects such as stinkbugs (Musundire et al., 2016) and termites (Kinyuru et al., 2013) as a source of PUFAs could aid in reducing deficiencies associated with lack of α-linolenic and linoleic acid in diets of poor households with limited access to basic foods containing sufficient essential fatty acids (Kinyuru et al., 2015; Khalil, 2018). In addition, PUFAs found in edible insects have a direct effect on the flavour of food materials, in which they improve food palatability by enabling their flavour retention (Mishyna et al., 2021).

The oil extracted from various edible insects could further be purified and added in human diets as cooking oil or processed into a by-product (margarine) as a substitute for vegetable oils rich in n-3 and n-6 fatty acids since (Smetana et al., 2020; Cheseto et al., 2020). Other studies also found that essential fatty acids are responsible for the health and development of children and infants (van Huis, 2013; Anankware et al., 2015; Khalil, 2018; Akullo et al., 2018). Hence, the dietary inclusion of edible insects in human diets could help improve the livelihood of many communities exposed to malnutrition (Dobermann et al., 2017; Hlongwane et al., 2020a,b). Tao et al .(2018), also reported that lipids from edible insects could be potentially used to improve dietary energy intake in both human and animal diets. Again, insect oil could further be utilised as a lotion or hand cream to moisturize dry skin (Verheyen et al., 2018). Thus, edible insects could play a very significant role as a source of oil and essential fatty acids.

5.2. In livestock diets

The consumption of insects by farm animals have an indirect effect on human health via the food chain (Nyangena et al., 2020). Hence, previous studies reported that edible insects contains large proportion of UFAs sufficient enough to meet the essential fatty acids requirements for both humans and animals (Seni, 2017; Tao and Li, 2018; Feng et al., 2018; Kim et al., 2019). The inclusion of insect meal in livestock diets could aid in improving the quality of poultry meat by elevating the concentration of essential fatty acid in the meat (Selaledi et al., 2020). Edible insects could, therefore, be considered as a suitable alternative source of PUFAs utilised in animal diets (Mishyna et al., 2021; Żuk-Gołaszewska et al., 2022). According to Elahi et al. (2022), a 15% dietary inclusion of black soldier fly meal improved MUFAs levels and but sightly lowered the PUFAs content of broiler chicken breast meat. Furthermore, the oil content extracted from insects could be directly supplemented in livestock diets to supply PUFAs which are unavailable in plant-based oil ingredients such as full fat soya and sunflower oil (Longvah et al., 2011; Monter-Miranda et al., 2018). However, a high

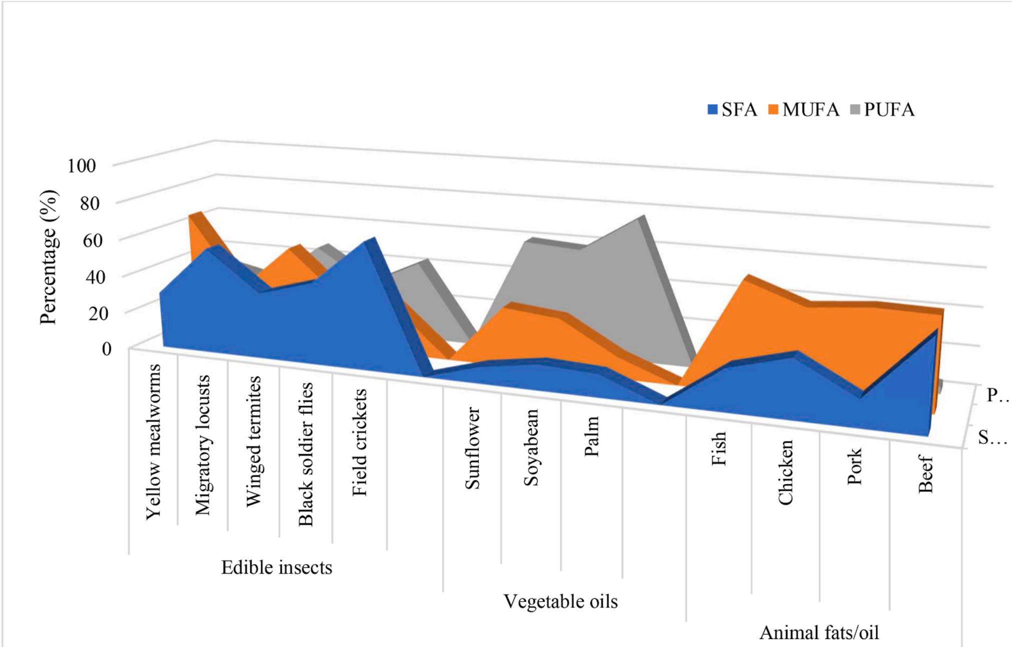

Fig. 2. Comparison of the fat and fatty acid profile (%) in common food materials and edible insects. Sources: (Abbas et al., 2009; Kostik et al., 2013; Mishra et al., 2012; Muzolf-Panek et al., 2021; Awogbemi et al., 2019).

accumulation of fats in meat leads to lipid oxidation which results in an undesirable taste and colour and reduced shelf-life (Kinyuru et al., 2015). Hence, there is a need to balance lipids and fatty acid contents when including fat-rich ingredients such as edible insects in animal diets. Despite that, as reported by (Tao and Li, 2018), the information about the potential use of lipids and essential fatty acids present in edible insects and their requirement levels in animal diets is very limited.

6. The effect of processing methods on the fatty acid composition of edible insects

Processing methods are highly considered as one of the main factors influencing the quality and concentration of fats and fatty acids present in various insect species (Fombong et al., 2021). Examples of techniques used in processing of edible insects includes cooking (steaming, roasting, smoking, frying, stewing, curing etc.), solar drying, oven-drying, freeze

Table 2
Effect of processing methods on fatty acid profile in common African edible insects.

Processing method	Temperature and	Duration	Insect species	Effects	**References**
Freeze-drying	-20 or -50°C	72 hours	Mealworm *T. molitor* L.	Significantly affected fatty acid content and resulted in the promotion of undesirable oxidation of fats and total PUFAs which caused bad smell and taste, thus accelerating insect spoilage with poor nutritional value, stability, and shelf life of various insect products	Khalil, 2018; Melgar-Lalanne et al., 2019; Mariod, 2020; Hernández-Álvarez et al., 2021
Freeze and oven-drying	-	-	-	Has been reported to result in herbal and fishy odours in insects	Mishyna et al., 2020
Cooking or heating	55 to 95°C	20 to 60 minutes	*Rhynchophorus phoenicis*	Slow cooking or smoke-drying affected the fatty acid profile by slightly reducing fat contents and total MUFAs. However, it is the best method for stabilising lipid content of African palm weevil	Musundire et al., 2016; Melgar-Lalanne et al., 2019; Lee et al., 2019
Oven-drying	60°C	19 hours	*Imbrasia epimethea*	Significantly affected the lipid profile of edible insects such as mopane worm caterpillar by decreasing UFA content, especially the MUFAs levels and increasing their SFAs such as stearic acid	Tiencheu et al., 2013; Melgar-Lalanne et al., 2019; Nyangena, 2021; Keil et al., 2022
Solar or Sun-drying	20 to 38°C	8 hours for 7 days	*Polyrhachis vicina*	Had a slight increase or no effect on fatty acids within the lipid profile	Melgar-Lalanne et al., 2019; Nyangena, 2021
Frying and solar drying	-	-	Termites and grasshopper species	Elevated SFAs and reduced UFAs content of the edible insects	Kinyuru, 2014
Toasting	120°C	-	*Gryllus bimaculatus*	Negatively affected the lipid fraction by reducing the linoleic acid as compared to other UFAs	Nyangena, 2021
Microwave drying	-	-	Locusts	Causes an imbalance in ratio of fatty acid types hence, reducing the UFAs content and exposing the insects to lipid oxidation	Mariod, 2020; Mishyna et al., 2020
Fat extraction	60°C	15 to 35 seconds	Various insect powders	Slightly improved PUFA levels including the ratio between linoleic and 6n fatty acids. It could also improve insect storage and shelf life by stabilising lipid oxidation, hence, preventing undesirable small caused by certain pigments and off-odour compounds	Melgar-Lalanne et al., 2019; Indriani et al., 2020; El Hajj et al 2023

drying, microwave drying and fat extraction using oil pressor. Table 2 indicates the findings of previous reported on the effects of various processing techniques on fatty acid availability and shelf life of edible insects. According to Kinyuru et al. (2013), heating and drying could significantly improve insect nutritional quality and flavour without altering their fatty acids profile, mainly the UFAs composition in (*Macrotermes* spp.) termite alates. Although, processing techniques such as freeze drying have been reported to increase fatty acid contents of insects, it result in lipid oxidation which, consequently, reduces the stability and shelf life of edible insects (Mutungi et al., 2019). Similar findings were made by Mishyna et al. (2020) who reported that high lipid oxidation in insects and insect meals could adversely affect their fat content in terms of quality and availability. Again, linoleic acid has been observed to oxidize rapidly when exposed to different processing methods than other PUFA groups (α-linolenic and arachidonic acids) (Anankware et al., 2015; Nyangena, 2021). In contrast, Akullo et al. (2018) reported that insects oils with low PUFAs including linoleic and linolenic acid have high oxidative stability that act against lipid oxidation. Hence, knowledge about the desirable processing method needed to stabilize fats and fatty acids in insects and insect products is very crucial to maintain nutritional quality and prolonged the shelf-life for consumption of both human and livestock (Kinyuru et al., 2015).

7. Legal regulations of using insects as a source of edible oil

Although entomogaphy has no legal regulations in Africa Grabowski et al. (2020), the ban for utilisation of insects by European Union (EU) existed until 2017. The ban was thereafter lifted since edible insects poses less heath risk when consumed by human or animals. Hence, insect oils could be successfully administered or supplemented in both human and animal diets since they are safe for consumption According to Żuk-Gołaszewska et al. (2022). The lifting of this ban will play a significant role in promoting insect farming as a source of essential fats and fatty acids for humans and livestock. However, reported that although the utilisation of fats from invertebrates such as insects has been permitted by EU the approval is restricted to certain number of edible insects including such as crickets, flies and caterpillars which has been tested for safe consumption (Lähteenmäki-Uutela et al., 2017). Nevertheless, the optimal inclusion levels of insects as a source of fats and fatty acids in diets must still be taken into consideration since any food material with SFAs such as palmitic acid and stearic acid at high levels are reported to be undesirable for consumption (Musundire et al., 2016; Akullo et al., 2018).

8. Conclusion

Lipids and fatty acid composition of edible insects incorporated in human diets could play a crucial role in acting as a source of energy and providing essential PUFAs required for the normal functioning of human body cells. This is mainly because they are found in abundance within the common edible insects such that they meet the recommended fats and fatty acids levels required by humans. Although the lipid profile of insects could be manipulated through various processing techniques to improve their nutrient content, techniques such as freeze-drying increases lipid oxidation, consequently, reducing stability and shelf life of insects kept in storage for future consumption. Therefore, the knowledge about the dietary health benefits of insect and insect oils as an alternative food source could help improve the global insect market demand and farming practices in communities with limited access to fish, meat, eggs, and plant-based oils responsible for supplying essential fats and fatty acids. It will also help spark the attention and acceptability of edible insects as food and feed, more especially in the Western countries. It could, therefore, be concluded that based on good nutritional profile and high fats and fatty acid content, edible insects could be a good alternative food source for human consumption. Moreover, further research is necessary to evaluate the optimal inclusion level and safe consumption of insect as a source of fats and fatty acids in diets.

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SDK; Substantial contributions to the conception and design of the work, SDK and MM; Drafting and editing of manuscript, EM, NAS and TGM; Revising the review article critically for important intellectual content. All authors approved the final version of the manuscript to be published.

Ethics statement

None. This is a review article and it does not require ethical approval.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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