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Common edible insects in Africa of therapeutic value - A review of their nutritional composition and their entomoceuticals values

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ABSTRACT: Entomotherapy is fast becoming popular based on the ubiquitous nature of insects. The use of insects in whole form or their derived products is gaining ground worldwide. Insects being ubiquitous makes their extracts easily available for use. Just as therapeutic agents, entomoceuticals, which are derived from pharmaceutical products from insects, play an important role in health improvement. Edible insects have been shown to be important sources for most entomoceuticals. Some species of these insects possess systems capable of generating numerous bioactive components and metabolites, which have major value in the pharmaceutical industry. Although these insects are found in almost all continents of the world, including continents like Europe and Asia, often using them in medicine, less attention has been focused on their use in therapy in most parts of Africa. In this paper, ten edible insects commonly consumed in Africa (African Palm weevil, Cockroaches, Black ants, Termites, Ground beetles, Grasshopper, Black soldier fly, Honeybees, Mole crickets and caterpillars) were selected and evaluated for their chemical and nutritional composition, including their therapeutic benefits. The review comprises a literature search on medicinal insects generated from the Web of Science and Google Scholar databases. Knowledge of these insects will help sensitise communities in Africa to their importance in their rearing for food and exploitation in the field of medicine, which will serve as an easier means of combatting disease plaguing Africa.

1. INTRODUCTION

Diseases still remain a primary concern globally, with adverse effects significantly felt by underdeveloped countries, typically Africa. As such, the search for novel drugs or therapeutic agents remains paramount. Insects are gaining ground in the field of research due to their applications in different sectors. Insects cover most parts of the ecosystem and hence play vital roles. Insects act as human food and animal feed and are effective decomposers and nutrients built in soils (Bulak, 2018) . Although some insects have negative effects on humans and the environment by acting as pests in agricultural and environmental settings, and disease vectors to humans and animals, insects still remain relevant to society. Worldwide, insects are used as food for humans and feed for animals. Some insects also make a positive contribution to diets as they contain dietary components such as proteins, vitamins and minerals. Prepared insects are purchased whole as snacks or powdered supplements from restaurants in most parts of the world (Nonaka, 2009).

Insect products have long been exploited in biotechnological and pharmaceutical industries worldwide. The symbiotic relationship that exists between insects and other microorganisms enables insects to perform several roles in biotechnology, such as the production of enzymes, bioremediation, and the production of important macromolecules and bioactive compounds. Their decomposing ability also makes them play useful roles in agricultural sites. Apart from insects' nutritional value and decomposing ability, their use has also been demonstrated in managing microbial diseases. Studies carried out on various insects show that they possess peptides, fatty acids and chitin, which have been demonstrated to exhibit antimicrobial properties (Dong et al., 2019; Yi et al., 2014). Findings by Correa et al. (2019) documented that some activities of the antimicrobial peptides found in insects include disrupting cell membranes, inhibiting metabolic pathways and destroying cytoplasmic components. Various studies have documented that the bodies of insects possess immunologic, anesthetic, and antimicrobial properties.

There is a paucity of information relating to the exploitation of edible insects in Africa's medical field. This paper looks

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into some common edible insects in Africa (African Palm weevil, Cockroaches, Black ants, Termites, Ground beetles, Grasshoppers, Black soldier fly, Honey bees, Mole crickets and caterpillars) that possess therapeutic properties, most of which are currently been used outside Africa in the treatment of diseases. This knowledge will provide insight to communities in Africa, where most of these insects are found on the possibilities of their exploitation, not only as food but also as medicine in combatting diseases.

2. LITERATURE SURVEY STRATEGY AND INCLUSION CRITERIA

To explore the nutritional composition and therapeutic applications of common edible insects found in Africa, the PRISMA guidelines for systematic review were followed. The Thomas Reuters' Web of Science database (https://apps.webofknowledge.com) and Google Scholar (https://scholar.google.co.za/) were used in sourcing Peer-reviewed literature found in publications on entomoceuticals, nutrient composition of edible insects, insect consumption patterns in Africa and other parts of the world. Keywords and phrases were used in sourcing this information. These included; "entomoceuticals", "edible insects in Africa", "insect extracts", and "nutritional composition of edible insects". References from other selected articles were also screened to identify relevant studies that did not appear in the search. The literature search was limited to articles published from 2000 to 2023. The year 2000 was chosen because it was the era when most researchers began looking into edible insects as nutritional sources and their breakthrough in combatting food insecurity (Illgner & Nel, 2000; Mpuchane et al., 2000).

In generating this review, the inclusion criteria involved original peer-reviewed research articles and review papers that focused on entomology, insect taxonomy, entomoceuticals and nutrient composition of edible insects published only in English. Relevant papers were then further sampled and subjected to further inclusion criteria laying emphasis on the following;

- The paper follows standard methods where possible, with no inappropriate sample preparation.
- The paper reports nutritional results in a form consistent with the wider literature with results analysed and standardised using software packages

A total of 10 edible insects commonly consumed in Africa were studied for their nutritional composition and therapeutic applications.

3. AFRICAN PALM WEEVIL

The African palm weevil (*Rhynchophorus phoenic*) is a beetle larva and a natural pest of plants that live on palm trees. This insect is a member of the family Curculionidae. 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 and Elaeis guineensis. The larva and adult are both in the consumption stages (Amadi & Db, 2016). The larvae are usually fried after seasoning with spices while the adult weevil is roasted after removing the chitinous wings and eaten. The palm weevil larvae is one of Asia and Africa's most famous edible insects (Elemo et al., 2011). Studies from western and Central Africa showed the Palm weevil as a commonly consumed species, seen as a delicacy F. Agbidye and Nongo (2009); Alamu et al. (2013); Kelemu et al. (2015). In Cameroon, Nigeria, Benin and Ghana, the palm weevil is shown to be of major economic importance (Muafor et al., 2014).

3.1. Nutritional Composition

The larva of the palm weevil is an excellent source of proteins, fatty acids, vitamins, and minerals such as zinc, iron, potassium, and phosphorus with a higher fat content (Table 1). Studies document that the larva of the palm weevil is composed of 28.4 % protein, 2.8 % fibre, 2.7% moisture; 2.7 % Ash, 11.3 % Vitamin, 12.3 % iron, 39.6 % Calcium, 26.5 % Zinc and 66.6 % fats (Rumpold & Schlüter, 2013). In addition to this, the palm weevil is a good source of potassium and phosphorus at 1025 and 658 mg/100 g, respectively (Elemo et al., 2011). Other studies carried out in Nigeria show palm weevil being used as snack ingredients to enhance the protein and mineral contents of snacks due to its high nutritional value (Akande et al., 2020).

3.2. Therapeutic Value

In Africa and other parts of the world, the palm weevil does not only serve food purposes but also is therapeutic. In Ghana, where malnutrition is a pressing issue, particularly for women and children, the larvae of the African palm weevil, which is commonly known locally as "a Kokomo," a component of traditional cuisines, is being promoted for preventing protein-energy malnutrition and possibly anaemia in women and children (Parker et al., 2017).

4. COCKROACH

The cockroach is one of the most common household pests. Cockroaches tend to live in dirty spaces like sewers, drains, pipes and bathrooms. As they crawl around, they pick up germs and faecal matter on the surface of their feet and spread to other areas like food surfaces. Hundred species of cockroaches exist in nature, but the Periplana americana is the most significant species in medicine (Xie et al., 2018). This insect is usually attracted to food particles and carries a high load of pathogens, which, when in contact with food, often results in intestinal diseases such as salmonella and other hypersensitivity reactions to humans upon food consumption (Mullins, 2015). Cockroaches pose significant health risks. One of the biggest health risks comes from the faecal matter that they leave behind in their homes.

Cockroaches are consumed at the adult stage. In some parts of the world like China, cockroaches are a food delicacy consumed at home and restaurants. Cockroaches have also been used in the production of cosmetics, as there are cheap forms of

Table 1
Nutritional composition (%) of some common African edible insects

Edible insect	Consumption stage	Crude Protein	Fat	Carbohydrate	Crude fibre	Moisture	Ash	Vitamin	Reference
African Palm weevil (*Rhynchophorus phoenic*)	Larva, adult	28.4	66.6	22.5	2.8	2.7	2.7	11.3	(Rumpold et al, 2013), (Elemo et al. 2011)
Cockroach (*Periplana americana*)	Adult	39.6	NA	NA	13.1	NA	16.1	NA	(Mbah et al. 2010)
Ground beetle (*Analeptes trifasciata*)	Adult	32.8	NA	22.6	6.2	7.6	4.7	11.2	(Zabentungwa et al. 2020)
Termite (*Macrotermes bellicosus*)	Adult (queen)	20.4	NA	NA	2.7	21.2	2.9	2.89	(Banjo et al, 2006)
Black ant (*Carebara vidua*)	Adult	39.79	42.04	19.76	6.13	NA	NA	NA	Ayieko, (2012)
mole cricket (*Gryllotalpa africana*)	Adult	35.06	38.5	22.33	6.3	11.6	3.25	NA	(Agbidye et al 2009)
Honey bee (*Apis millifera*)	Adult	21.0	14.5	NA	2.0	3.82	2.2	12.44	(Banjo et al. 2006)
Grasshopper (*Ruspolia differens*)	Egg, larva, purpa	39.2	20.8	NA	6.4	2.56	5.5	3.0	(Ssepuuya, 2017)
Caterpillars (*Cirina butyrospermi*)	Larva	64.0	12.19	2.36	6.07	3.1	1.50	2.99	(Amadi et al 2014), (Banjo et al. 2006)
Black soldier fly (*Hermetia illucens*)	Larva	50	18.03	NA	NA	9.1	8.3	NA	(Payne et al. 2016)

NA: not available

proteins.

4.1. Nutritional Composition

Cockroaches, though carriers of food-borne diseases, have shown to contain nutrients. Studies carried out in Nigeria by Mbah and Elekima (2010) show that the body of cockroaches is made of 39.6 % protein, 13.1 % crude fibre and 16.1 % Ash (Table 1).

4.2. Therapeutic Value

Apart from it being a food delicacy, its role in medicine is significant. In China, cockroaches are farmed for their traditional medicine. This insect is often sold in whole or powdered form and can be eaten raw for their anti-carcinogenic properties. Their solvent extracts are mostly used for therapeutic purposes. Findings have documented the presence of isoflavones in methanol extracts of cockroaches possessing antibacterial activities (Gao et al., 2016). Similar studies in China, reported by (Zhang et al., 2017), show ethanol extracts being employed in the treatment of chemotherapeutically induced mucositis and gastrointestinal ulcers. Other reports have documented the application of its extracts in the improvement of chronic heart failure (Lu et al., 2018). Research carried out by (Feng et al., 2018) also identified several active components from cockroaches that have been identified as possible drug candidates for wound healing, inflammation reduction, immune system improvement, and the ability to heal gastroenteritis. Generally, in China, the cockroach is considered a miracle insect. Cockroach extracts have also been used in cosmetics for their bacteria-killing effect (Xie et al., 2018).

Numerous non-peptides have been extracted from the bodies of these insects, which play a vital role in the field of oncology. Some of the peptides are currently being evaluated as potential candidates for drugs targeting the proliferation of cancer cells. The identified protein families comprised of cytochrome c, ferritin, superoxide dismutase and hemocyanin (Tan et al., 2019). Reports by Costa-Neto and Oliveira (2000) on zootherapeutic practices in North Eastern Brazil show that cockroaches are used in the treatment of asthma.

5. GROUND BEETLE

The ground beetle (*Analeptes trifasciata*) is a diverse group of insects with more than 40,000 species found in every known habitat, from desert to forest (Yahaya et al., 2019). They share morphological similarities to the cockroach, having both belonging to the order Blattaria (Gonçalves & Paulo, 2017). Ground beetles are known for their distinct appearance, having a hard exoskeleton. Their bodies are usually elongated and shiny, with colours ranging from black to metallic green. Ground beetles live solely at the ground surface and act as bioindicators in checking for chemical runoffs (Gonçalves & Paulo, 2017). However, unlike the cockroach, the ground beetle is less awful to people, as they instead feed on decaying food matter (Hu et al., 2011). The ground beetles act as both predators and prey. As prey, they provide food for other animals such as birds and small mammals. Ground beetle and their larvae are predators too.

5.1. Nutritional Composition

Ground beetles serve as food and nutritional sources in various parts of the world. In Uganda, the larva of ground beetles is highly sought after and combined in other diets (Banjo et al., 2006). In countries outside Africa, for example, China and Thailand, this insect is greatly consumed as it is considered a major source of proteins, lipids and essential fatty acids (Chen et al., 2009). Ground beetles are a rich source of nutrients. Findings documented in South Africa by (Zabentungwa et al., 2020) on the nutritional composition of edible insects

consumed in Africa, show that the bodies of ground beetles consist of 32.8 % protein, 6.2 % crude fibre, 7.6 % moisture, 4.7 % Ash, 22.6 % Carbohydrates, 11.2 % Vitamin A, 1.9 % Vitamin B12, 5.4 % Vitamin C, 14.1 % iron, 43.6 % Calcium, 14.4 % Zinc (Table 1).

5.2. Therapeutic Value

In local communities in Africa, plants have mostly been used in the treatment of human pathogenic diseases (Akwa et al., 2021). However, the use of insects such as ground beetles is now gaining ground in the treatment of pathogenic diseases. Studies carried out in Sokoto-Nigeria as documented by Yahaya et al. (2019) showed that screening of methanol extract of ground beetles identified the presence of bioactive components such as triterpenes, alkaloids, saponins, tannins and flavonoids, which when tested invitro on different human pathogenic microorganisms; Methicillin-Resistance *Stapylloccucuss aureus* (MRSA), *Salmanella typhi*, *Yersinia pestis* and *Escherichia coli,* greatly inhibited their growth. Other findings show that powder preparations of grown beetles have been used to treat blood stasis, cancers, septic joints, rheumatoid arthritis, herpes zoster, and hyperostosis (Putra & Hadi, 2017).

It is worth noting that, extracts from ground beetles also offer protective effects on animals. Protein extracts from ground beetle, when tested on mouse livers, had a protective effect as they induced apoptosis in hepatocarcinoma cells (Z. Liu et al., 2016).

6. TERMITE

Termites (*Macrotermes bellicosus*) nest are found in almost all parts of the world (Ghaly & Edwards, 2011). Some species of termites build nests on the ground, while other species build above. Termites live in colonies, with each member having a specific role. They are abundant and reproduce quickly, compared to traditional livestock, making them sustainable options on the planet. Termites play important roles as decomposers, as they decompose woods and plants, increasing the humus contents of the soil. Their burrowing effects in soils, aerate the soil.

Termites cause a lot of destruction, especially on wood. They are referred to as silent destroyers because they can chew through walls and floors without being detected, causing a lot of damage.

6.1. Nutritional Composition

Termites have been considered an important source of nutrients, as they supply the body with essential amino acids, thereby enhancing brain function and improving immunity (Cu et al., 2012). They are important protein sources, with a protein content comparable to chicken or fish. In some parts of the world, like some tribes in Asia, Africa, Australia, and South America, termites are eaten raw and have been known to cause fewer allergic reactions, unlike other foods (Defoliart, 2009). In many ethnic groups in Southern Africa, termites are an important part of their food culture and also play a major role in rural food security and income generation, as they provide rural people with household income (Kelemu et al., 2015). In most African countries where termites are found, they are considered not only as a source of food but also as a source of income. The research documented by (Banjo et al., 2006) on the nutritional value of edible insects in Southwestern Nigeria shows that the bodies of termites comprise 20.4 % protein, 2.90 % ash, 2.70 % crude fibre, 2.82 % moisture and 2.89 % vitamin (Table 1). They are packed with essential vitamins and minerals, including iron, calcium, magnesium, and B vitamins, thereby supporting strong bones (Cu et al., 2012).

6.2. Therapeutic Value

Termites have a low fat content and are good for the heart and weight management. They also contain an antioxidant boost, thereby helping the body combat oxidative stress and reduce the risk of chronic diseases (J.S. Park et al., 2021). These contain fibre, promoting a healthy digestive system that supports the growth of beneficial bacteria.

Extracts from termites have been used medically in the treatment of respiratory tract infections such as bronchitis, influenza, sore throat, sinusitis and rheumatism (De Figueiredo et al., 2015). Findings by (Lin et al., 2008) showed an inhibition of HIV-1 viral activity from solvent extracts of termites, making this extract a potential candidate for drug synthesis against HIV-1. Other pharmaceutical compounds, such as flavonoids, polysaccharides and heteroglycans, have been found to be present in large quantities in termite nests (Zhao et al., 2019).

Additional studies on the therapeutic application of termites have demonstrated the use of boiled termite paste in the treatment of topical wounds and internal haemorrhages (J.S. Park et al., 2021).

7. BLACK ANT

The edible black ant, scientifically called *Carebara vidua*, is an insect that belongs to the Order Hymenoptera and Family Formicidae (Bolton, 2010). This ant lives in a nest under the ground, similar to the termite mount, with females larger than males (males almost half the size of females). The female black ant has a large round abdomen, filled with eggs and some fatty substances. Black ants can be harmful to health. Their bites can cause skin irritations or even infections. In some cases, they can also carry diseases that can be transmitted to humans.

In Zimbabwe and Kenya, the black ant (*Carebara vidua*) is a food delicacy (Ayieko et al., 2012).

7.1. Nutritional Composition

Nutritionally, the black ant is a full-spectrum bioavailable food supplement, a complete protein source and a natural source of ATP (Feng et al., 2018). Research carried out in Kenya by Ayieko, (2012) using atomic absorption spectrometry analysis showed that black ants contain iron, zinc, calcium, magnesium, potassium, phosphorous, sodium, copper, manganese, vitamin B1, B2, B12, C, D and E and several trace minerals. Additional findings by Ayieko et al. (2012), using gas chromatography of the lipid extracts from this insect, also identified the fatty

acid methyl esters. High-performance liquid chromatography (HPLC) has also shown the presence of fat-soluble vitamins like Retinol and tocopherol.

7.2. Therapeutic Value

In parts of Africa, the black ant is used in different forms of therapy. In Kenya, elderly Luos (a tribe in Kenya) collect and consume black ants to manage several body ailments, probably due to the essential nutrients found in the insect (Ayieko et al., 2012). In other parts of the world such as in China, black ant extract called polyrachis is considered a potent tonic. In both men and women, this extract is a sexual energy tonic, improving fertility and boosting testosterone levels due to its very high level of zinc content (Y.L. Wang & Wang, 2010). The black ant extract is a potent source of protein. It is the highest source of zinc, which is very important in the human diet, such as enhancing the immune system. Zinc is also a potent anti-oxidant which protects our bodies by fighting off free radical damage. Black ant extract is used as an anti-inflammatory and also protects the liver and the kidney. In this regard, black ant extract is used in the treatment of chronic hepatitis B. People most in need of black ant extract include people suffering from fatigue, sexual exhaustion, infertility, hair loss, acne, depression, diabetes, and osteoarthritis.

Studies by Zheng et al. (2012) have documented black ants being a source of dopamine, alkaloids, amino acids, nucleotides, fatty acids, cyclopeptides, and triterpenoids, which are of pharmaceutical and therapeutical value. Other research has identified the black ant to compose at least 70 % unsaturated fatty acid, including leinoleic acid, heptadecenoic acid and octadecenoic acid. These fatty acids have been shown to possess a suppressing effect on cell proliferation and inhibition of tumour growth (Li et al., 2020). In addition to fatty acids, black ant extracts are also rich in aliphatic hydrocarbons, aliphatic alcohols, aliphatic fatty acids, and steroids (Cheng et al., 2001).

8. MOLE CRICKET

The mole cricket, *Gryllotalpa africana*, belongs to the family Gryllotalpidae, which has a worldwide distribution. *Gryllotalpa africana* is an African species occurring in most parts of the Niger Delta, Eastern and Middle Belt regions of Nigeria (F.S. Agbidye et al., 2009). Mole crickets usually spend all their time underground and prefer grassy areas or farmlands. Mole crickets are omnivores, generally feeding on grassroots and any larvae that they come across. They are natural pests to farmers as they eat the roots of plants, causing the plants to die off. The male cricket usually makes chirpy sounds using its wings, which signals the female for a mating call. The female looks the same as the male in structure, except that it contains a long pointy ovipositor, which it uses to lay its eggs underground, as it requires moisture to hatch (Tanga et al., 2021). Only the females can fly. Mole cricket undergoes incomplete metamorphosis. The rapid development of insect farming in East Africa has led to some profitable businesses. Mole cricket breeding is also highly observed in other parts of Africa, like Asia and North America, where they are later milled, packaged and exported as food products (Tanga et al., 2021). Mole crickets are often eaten whole or as ground-up powder incorporated into different foods.

8.1. Nutritional Composition

The mole cricket is one of the most insects consumed around the world, as it is a great source of protein. There are 9 essential amino acids; histidine, isoleucine, leucine, lysine, tryptophan, valine, threonine, phenylamine and methionine. It is high in vitamin B12 and an excellent source of iron (Sun et al., 2011). Studies carried out by F.S. Agbidye et al. (2009) on the nutritional qualities of some edible insects in Nigeria show that the mole cricket is composed of 35.06 % protein, 38.5 % fat, 2.33 % Carbohydrate, 6.3 % fibre, 11.6 % moisture and 3.25 % ash (Table 1). Crickets are also considered a good source of B vitamins, such as thiamine, riboflavin, and folic acid (Kinyuru et al., 2015).

8.2. Therapeutic Value

Mole crickets are rich in protein and fibre and support the growth of beneficial bacteria in the gut. It has also been known to reduce inflammation. This insect has been enormously reared as a vital food supply for animals and has been shown to be an alternative growth promoter with no toxicity (Sun et al., 2011). Methanol extracts from this insect have been observed to possess anti-microbial properties (Q. Liu et al., 2019). Organic solvent extracts from the mole cricket have also been shown to possess anti-inflammatory activity and antioxidant effects against induced lesions caused by oxidative stress (Heo et al., 2008). Studies carried out by Defoliart (2002) show that the mole cricket possesses diuretic and sedative effects. Extracts from crickets have been found to have a regulatory effect on lipid metabolism and blood lipid levels in the body, which in turn has an anti-obesity effect (Ahn et al., 2016). Related studies by Stull et al. (2018) show that the consumption of cricket powder can help probiotics grow and minimize inflammatory responses.

9. BEES

Bees are social insects in the family Apidae, order Hymenoptera. The most important species to humans is *Apis millifera*, the honey bee (Ediriweera & Premarathna, 2012). Bees live in colonies or bee hives. Bees have two pairs of wings and compound eyes. Bees communicate with each other with pheromones (Ediriweera & Premarathna, 2012). Bees are pollinators to plants, thus assisting the production of food. Bees also play a role in biodiversity. Bees produce their homes using wax. The wax from bees is used for a range of things like candles, furniture polish and skin care products like moisturisers. Another significant product of a bee is honey, which many have known and consumed for ages.

9.1. Nutritional Composition

Honeybees have a high nutritional quality. Its larvae and pupae have a very high protein content. Analysis of the

honeybees shows that their body contains 21.0 % protein, 2.0 % fibre, 3.82 % moisture, 2.2 % ash, and 12.44 % vitamin (Banjo et al., 2006) (Table 1).

9.2. Therapeutic Value

The use of bee products in medicine, referred to as apitherapy, has been documented over many years in traditional medicine for the treatment of systemic immune diseases, allergic diseases, viral diseases and organic-specific inflammatory diseases. In Egypt, bee products commonly used in medicine include bee venom, bee pollen, raw honey, royal jelly, wax and propolis (Hegazi, 2012). Honey, which is one of the commonly used bee products, promotes the healing of wounds and is often used as an antiseptic to treat wounds. Honey prevents the development of bacteria and regenerates the skin tissue to have good healing (Hegazi, 2012). This action is due to high osmolarity, which causes honey to attract water, drains lymph and plasma to the outside, removes debris and cleans wounds. Honey softens the throat and has antiseptic properties due to its richness in polyphenols and antioxidant molecules. It also contains gluconic acid and hydrogen peroxide which opposes bacterial proliferation (Ediriweera & Premarathna, 2012). Therefore, ideal for counteracting bronchitis, tonsilitis or nasopharyngitis. Honey can be better suited for diabetic patients because there do not raise blood sugar as it delivers more fructose than glucose (Wytrychowski et al., 2002). Honey has anti-infectious and antibiotic properties.

Honey contains groups of enzymes, including invertase, glucose oxidase, catalase, and acid phosphorylase, some of which, such as glucose oxidase, produce hydrogen peroxide, which is a natural antiseptic (Loveridge, 2001). Honey also has a low protein concentration which prevents bacteria from growing. Its acidity also hinders the multiplication of bacteria, complementing its antibacterial action. Honey possesses an antioxidant action as it comprises flavonoids (Joanna et al., 2018). Antioxidants help protect cells from the effects of free radicals. Flavonoids also help prevent cardiovascular diseases and various neurodegenerative diseases. Honey has a positive effect on cholesterol. Honey promotes the release of insulin, which in turn stimulates tryptophan, leading to drowsiness in humans and, as such, fights insomnia. Due to the presence of polyphenols in honey, honey has been used to increase brain function. The presence of antioxidants in honey helps in the prevention of cancer, with the majority of flavonoids neutralise free radicals in the body responsible for cancerous tumour growth (Needham, 2008). Consuming honey prevents digestion problems and stomach pains, including heartburn sensations (Needham, 2008).

Another bee product is bee venom, which has been used in immunotherapy in the treatment of systemic allergic reactions. Findings from Münstedt et al. (2010) document that bee venom has the ability to activate the levels of basophils in blood, hence boosting immune levels.

Bee pollen, another common bee product, has been shown to have a stimulatory effect on human organs. Studies by Graikou et al. (2011) document several substances in bee pollen inhibiting the development of numerous disease-causing bacteria. Bee pollen also improves mental well-being and memory function (Cheng et al., 2001).

Just as honey, propolis is another very important bee product as it possesses both immunoregulatory and anti-inflammatory properties. Propolis has been shown to exert an antimicrobial effect against human pathogenic organisms such as Salmonella spp. Listeria spp and Enterococcus faecalis (Gomes et al., 2011). In Turkey, studies carried out by Büyükberber et al. (2009) using the *in vitro* model of peripheral blood mononuclear cells showed that propolis had immunomodulatory effects.

10. GRASSHOPPERS

Grasshoppers are present in almost all tropical areas, with several species existing. Although grasshoppers are considered agricultural pests by farmers, their beneficial value cannot go unnoticed. The green form of grasshopper (*Ruspolia differens*) is consumed in most countries in Africa at the adult stage as a food delicacy, with its demands very high which are sold (Malinga et al., 2018). In Eastern Africa, *Ruspolia nitidula* and Ruspolia differens are the most consumed species of grasshoppers (Agea et al., 2008).

10.1. Nutritional Composition

Studies conducted by Ssepuuya et al. (2017) show that this insect is nutritional composed of 39.2 % protein, 20.8 % fat, 6.4 % dietary fiber, 3.0 % Vitamin, 5.5 % ash, 17.3 % Calcium and 11.9 % phosphorus (Table 1). The protein content of this grasshopper is greater than that of most commonly consumed animal and plant protein sources such as veal, lamb, chicken, and herring fish, milk and milk products; whole eggs, common bean and peas (Ssepuuya et al., 2017).

10.2. Therapeutic Value

Grasshoppers have been used by several communities as a source of medicine or therapy. In most cases, the insect is collected, dried and crushed into powder, which is later transformed into a paste and used as a remedy for headaches by applying it on the forehead. Reports have indicated the use of saliva from grasshoppers in the treatment of brain tumours Czaja (2019) . Grasshoppers have also been shown to possess antioxidant activities and antimicrobial activities against several human pathogenic organisms. The crushed hind legs of the grasshopper have been used to generate potent mixtures consumed as diuretics for kidney diseases (Czaja, 2019). There have also been used to reduce swelling and relieve pains as a result of intestinal disorders (Ajobiewe, 2021). Research carried out in Nigeria shows that grasshoppers can be a potential source of drug candidates in the treatment of arthritis (Ajobiewe, 2021). Additional reports documented by Ajobiewe (2021) highlight that extracts from female grasshopper ovipositor facilitate the healing of wounds and scars.

11. CATERPILLAR (TREE CATERPILLAR)

Tree caterpillars (*Cirina butyrospermi*) feeds exclusively on leaves and trees. They are widely distributed and consumed in various parts of Africa, typically South Africa, Uganda, Burkina Faso, Cameroon and Nigeria, where they play important roles in income generation in rural areas (Kelemu et al., 2015). This caterpillar is an example of an edible insect that is crucial for seasonal food security in a widespread agricultural system. Its cultivation has been shown to be positively associated with food security and income generation. This is supported by work carried out by Baiyegunhi et al. (2016) in South Africa. This may mean that regions with caterpillars suffer less from poverty than those without caterpillars.

11.1. Nutritional Composition

Caterpillars are an important source of minerals and nutrients for many households. Findings by Amadi and Db (2016) document that the tree caterpillar comprises 64 % protein, 12.19 % fat, 2.36 % carbohydrate, 6.07 % fibre and 3.1 % moisture (Table 1).

11.2. Therapeutic Value

Ingredients from insects have been shown to possess antioxidant activities. A study examining the *in vitro* antioxidant activity of fat-soluble extracts of some commercially available insects showed that the fat-soluble extracts from caterpillars had a very antioxidant activity, up to twice that of olive oil (Mattia et al., 2019). Caterpillars are high in proteins, fats, iron and zinc contents. This makes their consumption very important in people suffering from malnutrition, anaemia and pregnant women (Petry et al., 2016).

12. BLACK SOLDIER FLY

The black soldier fly (*Hermetia illucens*), which is an ubiquitous African edible insect, is a good example of an insect that plays significant roles in pharmaceutical industries, cosmetic industries and bioremediation purposes (Bulak, 2018). Studies have documented the presence of various endosymbiotic fungi species in the gut microbiota of this fly, giving it a major importance in the decomposition of matter.

The larvae of the black soldier fly to survive and colonise decomposing matter, releasing a wide range of substances beneficial to animal feed (Y.S. Wang & Shelomi, 2017). Some findings have reported the presence of *Trichoderma koningii*, *Aspergillus niger*, *Aspergillus fumigatus*, and *Phanerochaete chrysosporium* to be associated with the larvae of Black soldier fly found in chicken feed and soils which plays a role in synthesis of enzymes for lignification (Müller et al., 2017; Timothy, 2016). The fast-growing larvae of the black soldier fly feed on food waste, converting it into useful biomaterials, which can again be returned to the food production system as fertiliser (frass) and animal feed.

12.1. Nutritional Composition

The black soldier fly larvae serve as food to many as they are rich in various nutrients. Rearing of this larva for human and animal consumption is greatly observed in many parts of Africa, typically Kenya (Spranghers et al., 2017). The black soldier fly is also an excellent source of protein used both in animal feed and human feed (Spranghers et al., 2017). Dried black soldier larvae contain up to 50 % protein, 18.03 % fat, 6 % calcium, 1 % phosphorus, 8.3 % ash and 9.1 % moisture (Payne et al., 2016).

12.2. Therapeutic Value

The black soldier fly is amongst the most common widespread flies, which, in recent discoveries, have shown to contain bioactive components. Their colonisation on matter rich in pathogen suggests that their immune system has the potential to resist and defeat pathogens located in their environment. Additional findings have highlighted the gut of the black soldier fly harbouring beneficial microorganisms with antagonistic activity against pathogens (S.I. Park et al., 2015). The black soldier fly also plays a role in the regulation of the intestinal flora Bruni et al. (2018).

13. LIMITATIONS TO THE STUDY AND AREA FOR FURTHER RESEARCH

There were significant gaps and challenges in the data available on the nutrient composition of edible insects consumed in Africa. Only literature published in English was sorted. This means that vital information that might have been useful in the study but published in other languages has been left out. Most publications focused on a single macronutrient content, typically protein, carbohydrates, fats and fibre. Whereas other nutrients, such as minerals, were not included in analyses. Additionally, although insects are used as food and medicine, various challenges are still faced in achieving human health using insects. This review solely focused on the therapeutic value obtained from edible insects without highlighting their mode of action. It is important to explore in greater detail the modes of action of the active components of edible insects so as to reduce possible allergenicity caused by them.

14. CONCLUSION

In general, edible insects play a significant role in sustaining human health and supplying nourishment. As such, edible insects could represent the future of research in both food and pharmaceutical industries. This review focused on ten common edible insects in Africa and their medicinal applications, which have been relatively extensively investigated in other parts of the world. These edible insects possess bioactive components which could be exploited for therapeutic purposes in communities in Africa rather than just for food consumption.

Also, from the review, it is shown that a majority of these insects of therapeutic value are either agricultural pests (grasshoppers, termites, black ants, crickets, palm weevil,

caterpillars) or vectors for pathogenic diseases to humans (cockroaches). Therefore, transforming these disease carriers and agricultural pests into 'therapeutic treasures' instead of their eradication will be of great boost to the health sector.

15. RECOMMENDATIONS

It is recommended that while designing methods of controlling edible insects in home and agricultural settings, these insects should be reared in large quantities not only for food but also for health purposes. Furthermore, in the hope of increasing the consumption of edible insects in the future, certain setbacks must be resolved. Firstly, a foundation or organisation for the rearing and use of edible insects as food or medicine should be supported or backed by public and international policies and laws. Secondly, since some edible insects are also known to be vectors or a carrier of pathogens, for example, cockroaches, special attention should be paid to their transformation processes to prevent the production of contaminated, toxic or unsafe products while pursuing the goal. Finally, although the efficacy of most of the insect products has been verified as potent remedies or therapeutic agents, limited studies have been done on the toxicological effects of these products. Therefore, more *in vitro*/*in vivo* toxicity assays should be carried out before the approval of these entomoceuticals for clinical trials.

16. CONFLICTS OF INTEREST

The authors declare no conflict of interest in the submission and publication of this research.

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