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Marketability and Amino Acid Composition of Edible Insects in Zaria and Surrounding Areas, Kaduna State, Nigeria

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Abstract
This study investigated the marketability and Amino Acid composition of two species of edible insect in Zaria and its environs. Data collected were from two Local Government Areas of Kaduna State and two major markets were covered for data collection. Kraussaria angulifera (Grasshopper) were more marketed and consumed than Macrotermes natalensis (termites) because of their availability in the ecosystem. Amino acid profiles of edible insects marketed in the study areas was determined. Results was presented in terms of the dispensable and indispensable amino acids that of termites was higher in most of them than that of grasshopper. The total protein composition of termites was 29.12mg/100g Protein, higher than that of grasshopper 18.72mg/100g Protein. In general, edible insects have a high protein contents with a satisfactory Amino Acid (A.A) profiles for humans' nutrition, when you juxtaposed with conventional animal based foods. Entomophagy is one of the viable alternatives as source of protein in the 21st century.

Keywords: Marketability, Amino Acid, Edible Insects

Introduction

The features of insects are chitinous exoskeleton, a three-part body namely head, thorax, and abdomen, three pairs of jointed legs, compound eyes, and two antennae. Insects belong to the class Insecta within the arthropod group in the kingdom Animalia. With over a million species described, they make up more than half of all known living organisms, making them one of the most diverse groups on Earth. According to the FAO (2014), insects may represent more than 90% of the various animal life forms on the planet, with an estimated 6–10 million species. While only a few species inhabit water, where crustaceans, another group of arthropods, dominate, insects can be found in nearly every environment. Eating insects is called entomophagy. This term was coined from the Greek words "entoma," meaning "insect," and "phagin," meaning "to eat." This practice likely originated with early hominid ancestors and has been passed down to modern humans. Similar to today's bush babies and marmosets, the habit probably began with much earlier primate ancestors who primarily ate insects.

Discovery of insect's chitin in human coprolites dating back nearly 10,000 years provides strong evidence that humans consumed insects (Dossey et al., 2016). Ancient Chinese texts and recent Western sources have promoted insect consumption in modern diets for over 3,000 years (Sudakaran et al., 2015; Dossey *et al*., 2016; Williams & Williams, 2017). By 2050, the number of people eating insects could grow to nine billion, up from the current two billion (FAO, 2010). The practice of eating insects as food is known as entomophagy (Paiko et al., 2012) . Across the globe, people have incorporated insects into their diets for thousands of years. While the practice is not common in many Western societies, it is not new in many parts of the world. It's estimated that at least two billion people regularly eat insects, from crispy-fried locusts and beetles in Thailand to ants and beetle larvae consumed by tribes in Africa and Australia as part of their diets (FAO, 2014). Edible insects can be classified into two groups: those used as condiments and those used as nutrient sources. Historically, insects have played a vital role in human diets across Africa, Australia, Asia, and America.

Namely grasshoppers, caterpillars, beetles, grubs, and sometimes adult winged termites are among the many insect species consumed by humans. This includes wasps, ant brood (larvae and pupae), winged ants, cicadas, and various aquatic insects like damselflies, stoneflies, dragonflies, and caddis flies. Insects are generally part of regular diets throughout the year or when in season, rather than being saved only for times of famine. Although edible insects remain a food source in many developing countries, many forest managers consider most insects as pests since they can severely damage and kill valuable trees (De Foliart, 2002). The pale emperor moth, *Cirina forda*, which is often enjoyed in many African homes, defoliates the shea butter tree, *Vitellaria paradoxa* (Nongo, 2005; Akanbi & Ashiru, 2002; Odeyemi & Fasoranti, 2000). This moth's larvae damage trees like *Parkia biglobosa, Prosopis africana*, and *Khaya senegalensis*, they remain prized in many Nigerian households (Akanbi & Ashiru, 2002). In many Nigerian and African homes, termites, *Macrotermes natalensis*, are delicacies (Adepoju, 2020). According to Akanbi and Ashiru (2002), the largest African cricket, *Brachytrupes membranaceus*, is highly valued in many Nigerian households yet acts as a pest in forest nurseries and can cause significant tree damage. It is not surprising that many edible insect species have become popular in African towns and village markets, boosting livelihoods in both rural and urban areas. In most cases only the larvae of species like *R. phoenicis, T. molitor*, and *I. belina* are usually consumed due to their high lipid content, which enhances flavour. Given the importance of *T. molitor* to humans, its production has become industrialised. Thus, even when only low-nutritional waste is used as food, they can grow rapidly (Tang et al., 2019). Typically, only adult Orthopterans, such as crickets, are eaten. Harvesting them from swarms is relatively easy. However, concerns about pesticide residue affecting food quality exist since they are significant pests and often exposed to pesticides during their life cycles (Tang et al., 2019).

As those with higher education may be less likely to recognise that traditional practices like eating insects still exist in Africa, many Nigerians have either first hand or second experiences with entomophagy, which is often more common in rural areas than urban ones (Sun-Waterhouse et al., 2016). They believe that education should promote entomophagy, as insects can significantly help address protein shortages in the nation. They also emphasised the need for developing mass-rearing techniques rather than continuing reliance on harvesting wild populations. Most insects consumed by Nigerians are collected during the rainy season.

Whether as a rare treat or a substitute during times of scarcity, drought, flood, or conflict, insects serve as essential food in many cultures worldwide. Both meat and insects fulfil similar roles in the diet. Generally insects are important non-wood forest product that poor people, especially women and children, gather, according to Adeoye et al. (2014). In many villages, caterpillars are common, while meat is not as familiar. A wide variety of insects provide lysine, an amino acid often lacking in grain-based diets. Insects also reproduce more quickly than cattle and generally have better food conversion rates than most traditional meats. Producing protein for humans from insects would be more sustainable than from vertebrates (Van Huis et al., 2013).

Raising insects demands much less land compared to other livestock. Dunkel and Payne (2016). It is important to note that only 10% of the land required for beef production is necessary to produce 1 kilogram of mealworms (*T. molitor*). Although the differences may be less striking compared to pork or chicken production, mealworm farming still uses 29% to 50% less farmable land because edible insects are smaller. They can also be grown vertically, eliminating the need to clear more land for expansion (Van Huis et al., 2013). Water supply is also at risk due to land scarcity. The FAO (2010) reports that by 2025, water shortages will stress two-thirds of the world. Since water is essential for producing forage and feed, it takes 100 times more water to produce the same weight of animal protein compared to 1 kg of grain protein (Tao & Li, 2018). While estimates of water usage for growing edible insects are not yet available, the results are likely to be promising, similar to the results for greenhouse gas and ammonia emissions. Raising cattle consumes much land and water and requires feed, which contributes to land clearing.

Thus, only a portion of an animal's weight is edible, decreasing the actual availability of meat protein and minerals. For example, beef accounts for only 40% of edible weight, while chicken and pork offer 55% (Tao & Li, 2018). In contrast, *Brachytrypes membranaceus* (*A. domesticus*) provides 80% of its live weight for consumption, resulting in a remarkably efficient feed conversion. Overall, insects boast clear nutritional advantages. Their nutritional content is

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quite similar to that of conventional animal protein (Raubenheimer et al., 2015). They hold great potential as a nutrient and active ingredient source for both poultry and humans.

It's important to recognise that all life stages of insects are rich in animal protein. Although they have comparable amino acid profiles, mostly edible insects often contain higher crude protein levels than traditional meats. They contain a high concentration of essential amino acids, with 76% to 96% digestibility (Lee et al., 2020). The essential and semi-essential amino acid levels of common edible insect species are shown in the World Health Organisation's published adult amino acid requirements (Wiedemair et al., 2020). While some insects are limited in methionine, cysteine, and tryptophan, these must be balanced in diets if insects are the primary food source. Besides these species, most insects typically meet the WHO's amino acid guidelines. By mixing different food items, many can provide sufficient essential amino acids. An insect can be consumed if it contains substantial amounts of isoleucine, leucine, lysine, phenylalanine, threonine, valine, arginine, histidine, and tyrosine. Compared to other protein sources, Coleoptera are particularly high in leucine. Nymphs often provide the highest concentration of amino acids compared to insects at other stages.

Insects are generally high in fat. Their fat content varies depending on dry weight and developmental stage. All insect families show similar fatty acid profiles (Manditsera et al., 2019). The larvae are typically the best source of fatty acids or oils, as triacylglycerol constitutes most insect fat (Güney et al., 2021). Adult insects in most cases contain higher amounts of saturated fatty acids (SFAs) than Monounsaturated Fatty Acids (MUFAs). Oleic acid is the most common monounsaturated fatty acid in insects and a typical part of human diets. It can help lower blood pressure and has potential benefits for treating cardiovascular, immune, and inflammatory conditions (Tang et al., 2019). However, while adult insects supply more Polyunsaturated Fatty Acids (PUFAs) than beef, pork, and insects at other life stages, they risk replacing SFAs as food sources. Linoleic acid, the main PUFA in insects, has been linked to anti-inflammatory effects, acne reduction, and skin-lightening properties. Among insect orders, Orthoptera is the best source of linoleic acid (Tang et al., 2019). Humans require linolenic and α-linolenic acids, which we cannot produce ourselves. These acids are necessary for healthy eyesight and are precursors for generating prostaglandins, thromboxanes, and leukotrienes. Insufficient intake of linolenic and α-linolenic acids can lead to problems affecting the kidneys, liver, nervous system, and vision, as well as growth delays, reproductive issues, and skin damage. The medical field could greatly benefit from extracting these nutrient-rich compounds from edible insects.

The aim of this study is to assess the marketability and amino acid composition of edible insects in the area. Once the nutritional values and amino acid profiles of these edible insects are determined, more exploitation is needed to meet the protein demands in rural regions. For many years, people in Africa, Asia, Australia, and Latin America have relied on edible insects as a nutrient-rich staple food. Generally, insects provide high energy, protein, and various vitamins and minerals. Interest in using insects as food has grown, likely due to their significant nutritional, economic, and environmental benefits (Ojinnaka et al., 2013). Many Nigerian families earn a respectable living by selling insects (Mbata & Chidumayo, 2003). The country also produces a fair amount of edible insects and caterpillars, the majority of which are collected by women and children from bushes and farmlands and processed and consumed to prevent hunger and malnutrition (Sun-Waterhouse *et al*., 2016) or sold in open markets and school buildings to generate income.

Materials and Methods

Study Area

Zaria and its nearby areas are the focus of this research. The two local governments in Zaria are Sabon Gari Local Government Area, which consists of seven wards, and Zaria Local Government Area, which has thirteen wards. Geographically, Zaria is located at latitude 11.0855° N and longitude 7.7199° E. It experiences an average rainfall of 155.9-182.1 mm and a temperature range of 25-30.2 °C. The area has a low evaporation rate of 154.2-163.91 mm, resulting in a relative humidity that ranges from 63.2 to 68.8%. Zaria's vegetation is characteristic of the Guinea Savannah (Kaduna State Government, 2006).

Entomophagy Status or Marketability of Edible Insects in Zaria

The consumptions of insects in Zaria and its surrounding areas has not been studied in any published research. Still, people in Zaria eat insects for their unique flavor, cultural significance, and nutritional benefits. They also serve as a backup food when access to regular foods is limited. The people of West Africa use various insect species or their products as food. Originally, grasshoppers were the most popular insects eaten in Zaria. However, other tribes in the

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area mixed with local tribes and consumed a range of insects, either directly or as part of their meals, which are known for being nutritious. Termites, caterpillars, locusts, dung larvae, and crickets are some examples of these insects. Due to their nutritional value, many insects were eaten in Zaria.

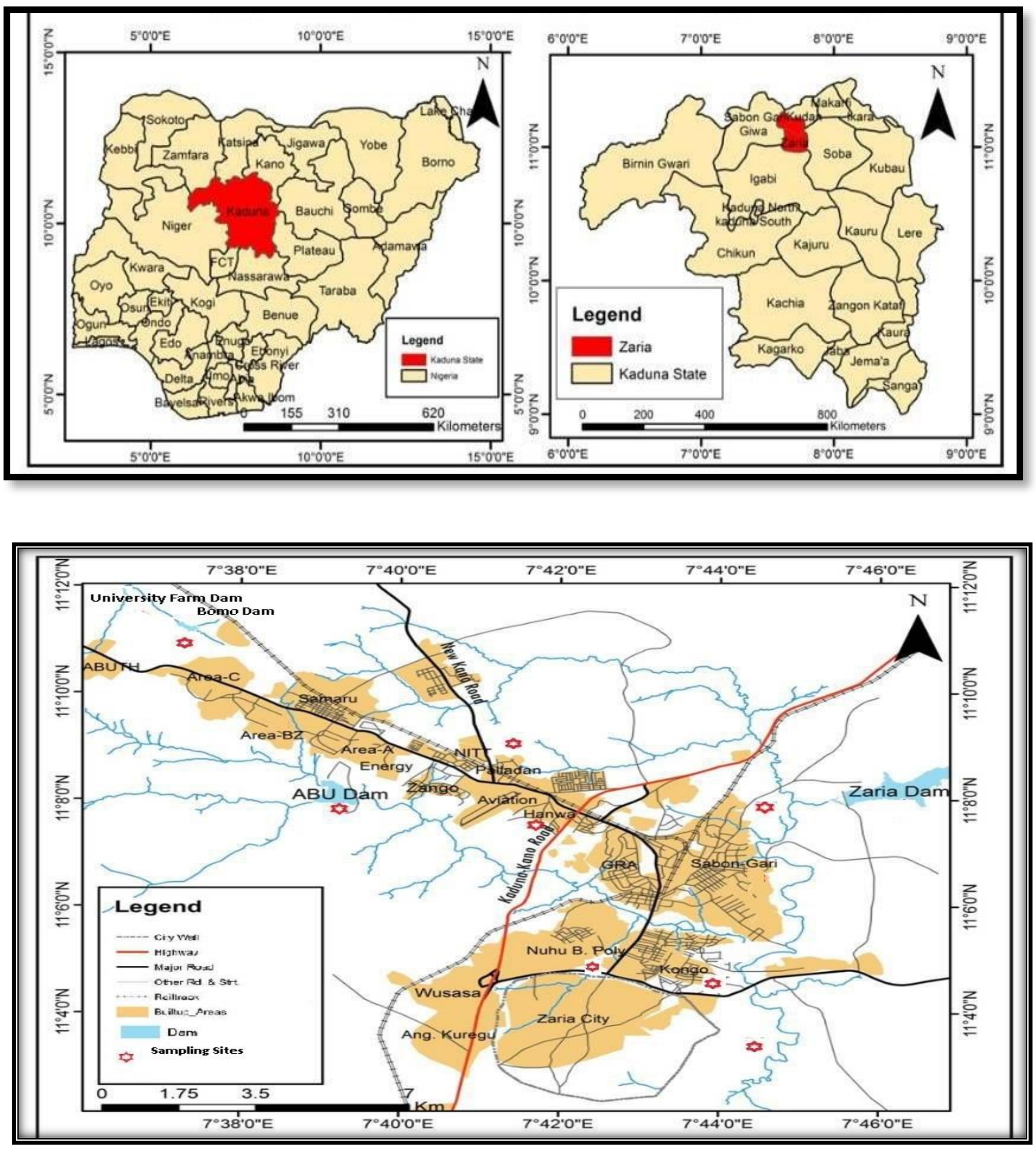

Fig. 1: Map Showing Sample Sites of the Study Area
Source: Adapted and Modified from the Administrative Map of Kaduna State (Ahmad, 2017)

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Insect species Collection Sites

Some edible insects previously identified as safe for consumption by Banjo *et al*. (2006), Mba & Elekina (2007), and Agbidye et al. (2009) make up the study population. The locations where the insects were collected were taken into account. To make sure there is a fair representation of the region, eight locations in Zaria were specifically selected. From these, four were randomly chosen for the sampling process and insect collection. Sampling process was based on agro-ecosystem areas (Shika Area), open fields (Nuhu Bamali Polytechnic Annex Campus Gaskiya), residential areas (Tudun Wada Area), and wetlands around the Kongo/Dakace Areas (Ibrahim, 2021).

Experimental Design

The experiment took place from early June to November. The sampling locations were randomly selected in Zaria and its environs. Chosen edible insects were collected in duplicate from several sample sites at least once a week. We used flight interception, pitfall, and bottle traps to obtain equal samples of the selected edible insects. In some cases, we attracted them with small bits of honey, a sweet treat.

Samples Analyses

The following labs looked at each milled sample of edible insects that was collected: Central Research Laboratory, University of Ilorin; National Research Institute for Chemical Technology (NARICT) Zaria; Parasitology and Entomology Laboratory, Department of Zoology, Ahmadu Bello University, Zaria.

Amino Acid Composition of Edible Insects in Zaria

The following reagents were used to extract proteins from the samples after grinding them on ice: 30.0 mmol/L Tris-HCl (pH 8), 0.1 mmol/L EDTA, 6.0 mmol/L ascorbic acid, 5.0 mmol/L MgCl2, 1% polyvinyl pyrrolidone, 0.02% β-mercaptoethanol, and 1% glycerol. After vortexing, the homogenate was incubated for 40 minutes at -20°C. It was spun at 13,000 rpm for one hour. The 2D-cleanup kit was used to remove contaminants and collect supernatants. The protein sample was then moved to a microcentrifuge and centrifuged for five minutes at 13,000 rpm. The protein mixture was vortexed and then incubated for 15 minutes at 4-5°C on ice. After adding 300 µL of co-precipitate to the reaction mixture, it was centrifuged again for five minutes at 13,000 rpm. The supernatant was then removed and disposed of with a pipette tip. The pellet was covered with distilled water. The tube was vortexed for several seconds. After that, the pellet was cleaned for at least one hour at -20°C using 1 milliliter of wash buffer and 5 microliters of wash additive buffer. After drying and dissolving the pellet with rehydration buffer, the supernatant was disposed of. The buffer contained 2% 3-((3-cholamidopropyl)-dimethylammonio) and 8.0 mol/L urea, 0.002% bromophenol blue, 2.0 mmol/L dithiothreitol, 0.8% immobiline pH gradient gel buffer, and CHAPS. The Bradford (1976) assay was used to measure protein concentrations. Next, the samples were hydrolyzed for 24 hours at 105°C in 6M HCl under vacuum. Based on the Manufacturer's Instructions from the Waters AccQ-tag Chemistry Package (Instruction Manual Waters Corp, Water Corporation, Milford, MA), amino acid analyses were performed using reversed-phase LC with pre-column derivatization using AccQ-fluor reagent. This was carried out with Hitachi's L-8900 model (Sharma et al., 2014).

Results

Marketing of Edible Insects in Zaria, Kaduna State – Nigeria:

Only two of Nigeria's many edible bug species were available for purchase during the study period (Table 1). These species were *Macrotermes natalensis* (termite) and *Kraussaria angulifera* (grasshopper). Grasshoppers consume more and have the highest average quantity per marketer ($P<0.05$). The prices of these edible insect treats varied based on the market, the insect species, and the unit of measure. They were either piled up or sold using spoons, milk tins, and local mudus. For instance, in Tudun-wada market, a tin of milk containing 0.8 kg of dried grasshopper was sold for ₦470, while a mudu of the same product weighing 0.8 kg was priced at ₦2, 500. The same goods were sold for ₦2, 600 in another market and ₦480 at the Sabon-gari market. Since edible insects were sold in different containers with prices based on the contents, there was no standard unit of measurement in many of the rural markets around Zaria. In many cases, snacks made from edible insects were offered for sale alongside other meat products, such as chicken eggs.

Table 1: Mean Quantities in Kilogrammes (Kg) of Edible Insects offered for sale in Zaria markets

Species of Insect	Mean Quantity (Kg) per Marketer
Kraussaria angulifera	13.2+-1.1^{a}
Macrotermes natalensis	3.5+-0.5^{b}

Values are mean quantity + SEM of edible insects offered for sale in Zaria markets. Means with the same superscripts are insignificantly (P>0.05) different

Plate 1: Showing dried alate of Grasshopper (*Kraussaria angulifera*)

Plate 2: Showing dried alate of Termite (*Macrotermes natalensis*)

Amino Acid Composition (mg/100gProtein) of Insects Studied

Amino acid composition of the insects was examined is presented in Table 2. Termites, *Macrotermes natalensis*, and grasshoppers, *Kraussaira angulifera*, were analyzed. The aspartate content was higher in *Kraussaira angulifera* (3.17) than in *Macrotermes natalensis* (2.42). *Macrotermes natalensis* (8.02) had a greater glutamate content than *Kraussaira angulifera* (0.23). The serine amino acid was more abundant in *Macrotermes* species, specifically *Kraussaira*

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angulifera (0.19), which had a value of 2.11. Glycine and histidine had little impact on both species: termites (0.98 & 0.03) and grasshoppers (0.30 & 0.01). Termites showed a higher level of arginine (1.28) compared to grasshoppers (0.59). Termites had a low level of threonine (1.43), an important essential amino acid, while grasshoppers had a higher level (2.03). Termites exhibited a high level of alanine (3.27), whereas grasshoppers had a low level (1.88). The proline content was low in termites (0.27), but grasshoppers had a high level (0.75). Termites had low amounts of tyrosine (1.13), while grasshoppers had high amounts (1.68). Termites (0.20) and grasshoppers (0.18) had low valine contents, with low methionine levels in termites (0.08) and higher levels in grasshoppers (0.15). Termites (0.68) and grasshoppers (0.61) had similar cysteine levels. Termites had low isoleucine levels (1.71), while grasshoppers had higher levels (4.16). Termites showed a high leucine content (4.71), in contrast to grasshoppers, which had a low level (0.61). Termites (0.10) and grasshoppers (0.08) had comparable levels of phenylalanine. Termites showed low lysine levels (0.10), while grasshoppers had higher levels (1.08). Termites had low levels of tryptophan (0.34), whereas grasshoppers had higher levels (0.71). *Macrotermes natalensis* (termites) had the highest total protein content at 29.12, while *Kraussaira angulifera* (grasshoppers) had the lowest at 18.72.

Table 2: Showing Amino Acid Composition of Two Edible Insect Species (mg/100gProtein)/FAO/WHO Reference Value

Insect Species Amino Acid Profile	Kraussaria angulifera (Grasshopper)	Macrotermes natalensis (Termite)	FAO/WHO 2013 Ref. Value (mg/100gProtein)
Aspartate	3.17	2.42	-
Glutamate	0.23	8.02	-
Serine	0.50	2.11	-
Glycine	0.30	0.98	-
Histidine	0.01	0.03	1.60
Arginine	0.59	1.28	-
Threonine	2.03	1.43	2.50
Alanine	1.88	3.27	-
Proline	0.75	0.27	-
Tyrosine	1.68	1.13	-
Valine	0.18	0.20	4.00
Methionine	0.15	0.08	2.30
Cysteine	0.61	0.68	2.30
Isoleucine	4.16	1.71	3.00
Leucine	0.61	4.71	6.10
Phenylalanine	0.08	0.10	4.10
Lysine	1.08	0.10	4.80
Tryptophan	0.71	0.34	0.60
Total Protein	18.72	29.12	-

Keys: Food and Agricultural Organization/World Health Organization (FAO/WHO)
Recommended Amino Acid scoring patterns for Older Children, Adolescents and Adults

Discussion

According to the study's findings shown in Table 2, edible insects are a common commodity in Zaria, Kaduna state, and they improve the socioeconomic status of rural and urban residents. The results show that edible insects are sold alongside other meat products because they compete well with these products in Zaria and the surrounding area. The variety of edible insect species in Zaria and its surroundings is clear, as there are many available for both domestic use and commercial sale. These findings support the work of Agbidye et al. (2009), Dagevos (2021), Zuk-Gotaszewska et al. (2022), and Alhujaili et al. (2023). They found that edible insects are important commodities in many communities around the world, helping to reduce poverty and meet people's protein needs.

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Generally amino acids are essential for protein synthesis and other metabolic functions in insects, as they are in all living things. The contents of essential and non-essential amino acids in insects varies by species and even among different life stages of the same species. Achtigall et al. (2025) studied four (4) edible insect species approved as novel foods in the European Union namely lesser mealworm (*Alphitobius diasperinus*), house cricket (*Acheta domesticus*), migratory locust (*Locusta migratoria*), and yellow mealworm (*Tenebrio molitor*). These insects contain a high percentage of protein (48–67%) with a good profile of essential amino acids, a significant amount of fat (21–39%) with a high level of saturated fatty acids based on Dry Matter (DM), and a decent amount of vitamins and minerals. This supports the study's findings presented in Table 2. Their protein composition ranges from 35.3% (Isoptera, including termites) to 61.3% (Orthoptera, including crickets and locusts) based on DM weight. All insect species tested contained significant levels of protein, with the migratory locust having 72.36g/100g and the house cricket having 67.49g/100g.

Miankeba et al. (2022) study examined protein levels in ten (10) edible insect species, focusing on the amino acid profiles of six (6) important commercially viable species. According to their findings, protein contents ranged from 46.1% to 52.9% DM, Orthoptera species showing the highest protein content and highest levels of three Essential Amino Acids (EAAs). The study indicated that the six (6) selected species contained 18 Amino Acids (AAs), with EAA profiles close to the FAO's recommended levels. The concentrations of EAAs and non-essential amino acids differ among edible insect species. This study aligns with previous research on the amino acid profiles of edible insect species, despite environmental variations and other factors.

Conclusion

This study examined the marketability and amino acid composition of common edible insects in Zaria and its environs. It found that edible insects are sold in Zaria, with *Kraussaria anguilifera* (Grasshopper) being the most popular. All twenty (20) naturally occurring amino acids, both essential and non-essential, are present in edible insects, making them a good source of amino acids. The specific amino acid composition varies among insect species, as well as between developmental stages like larva, pupa, and adult, depending on factors like nutrition and environmental conditions. Generally, edible insects can provide humans with a valuable source of high-quality protein. The study showed that *Macrotermes natalensis* (Termite) had a higher total protein or amino acid profile at 29.12 mg/100g protein, compared to *Kraussaria anguilifera* (Grasshopper), which had 18.72 mg/100g protein. Over the past ten years, scientific interest in edible insects has grown significantly as a possible alternative source of high-value protein for human diets.

Recommendations

From the scientific and economic importance of edible insects in Zaria and its environs, the study offers the following recommendations: Individuals should set up farms to cultivate edible insects palatable in such areas, this will make it abundantly available for human consumption as cheapest source of proteins. The government should enforce laws against illegal tree-cutting and bush-burning to protect these insects' habitats. Rigorous plantations that support the growth of edible insects, such as the African oil palm (*Elaeis guineensis*), Locust bean tree (*Parkia biglobosa*), *Khaya senegalensis*, *Prosopis africana*, and *Crossopteryx febrifuga*, should be established. More research is needed to maximize the use of edible insects in human nutrition and to understand their unique amino acid compositions.

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