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EDIBLE GRASSHOPPERS *(Ruspolia differens)* AS ALTERNATIVE SOURCE OF PROTEIN FROM INSECTS TO COMBAT MALNUTRITION

Chuwa C[1]*, Ngendello T[1], Saidia P[1] and DP Mlay[1]

Caresma Chuwa

*Corresponding author email: carechuwa@gmail.com

[1]Tanzania Agricultural Research Institute (TARI) Ukiriguru, P.O. Box 1433, Mwanza, Tanzania

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ABSTRACT

One of the most common public health issues affecting both children and adults in poor nations is malnutrition. Malnutrition is frequently attributed to food insecurity or a lack of access to enough food. Malnutrition is a serious issue in Tanzania mainland and Zanzibar, that requires attention. More cases of malnutrition than any other category are caused by protein-energy deficiencies. Compared to plant-based protein, animal protein offers essential amino acids in a better pattern. Nonetheless, it is a significant problem to produce enough animal proteins to feed the expanding global population of 9 billion people. Throughout the months of November and December each year, the Kagera region of Tanzania collects a large number of edible grasshoppers (*Ruspolia differens*) from the Muleba and Bukoba Districts. Grasshoppers processed in different methods are a rich source of nutrients such as protein (7.80-44.70%), fat (36.30-83.00%), fibre (8.70-11.20), ash (2.20-2.40%), total carbohydrates (5.30-12.10%), total energy (614-807 Kcal/100 g), Ca (35.80-55.00 mg/100 g), P (305.40-496.80 mg/100 g), Mg (33.30-56.50 mg/100 g), Fe (12.90-179.10 mg/100 g), Cu (1.60-2.30 mg/100 g), Mn (2.90-5.30 mg/100 g), Zn (8.50-18.40 mg/100 g) and Co (28.60-33.10 mg/100 g). The Kagera region's residents roast these insects and either consume them alone or in combination with other dishes like bananas. A few months after collection, grasshoppers begin to spoil due to their perishability. The shelf life of these products could be increased by at least a year with the right processing methods. In order to battle hunger and raise the community's revenue, these grasshoppers are a great source of nutrients that may be utilized to augment other crops with low nutritional value, such as bananas, cassava, rice, millets, sorghum and maize. In order to combat malnutrition, this review will examine the research on the utilization of edible insects as alternate source of protein and micronutrients.

Key words: Edible grasshoppers, Malnutrition, Protein-Energy Malnutrition, Food security, Edible insects

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INTRODUCTION

Current estimates put the world population at 9 billion people, of which 1.2 billion live in sub-Saharan Africa [1]. Population growth requires a healthy food supply to feed everyone. Animal and plant proteins alone cannot feed everyone, so alternative sustainable protein sources that can feed the entire population at the same time are important. To ensure future food security, The United Nations Food and Agriculture Organization (FAO) recommends a global campaign to improve the use of insects as food and feed [2]. However, most Tanzanians still have a limited level of market approval for products made from insects including edible insects. The prevalence of stunting in children, lactating mothers and pregnant women exceeds 40% in Tanzania, with the regions of Njombe (54%), Rukwa (48%), Iringa (47%), Songwe (43%), Kigoma (42%) and Ruvuma (41%) [3]. Edible insects are expected to become an important source of protein for humans over the next few decades. These insects can be used as an alternative protein source to alleviate malnutrition in developing countries. Due to its low water requirements and potential as a nutritious food source, it is considered a promising solution for food production [4]. Insects have long been consumed in different parts of the world, such as Africa, Latin America, and Asia [5]. Since edible insects contain more protein than traditional sources of protein like meat, dairy products, and nuts, they have been touted as viable sources of dietary protein [6,7,8]. Due to their high feed conversion efficiency, edible insects are also superior to traditional sources of animal protein [2]. Due to their poikilothermia, which causes them to consume far less food energy and nutrients while producing more animal protein than warm-blooded animals. Compared to traditional cattle, insects also reproduce and grow more quickly [9]. Farmers either gather them for sale as food or as fried snacks because grasshoppers are regarded as destructive pests for a variety of crops [10]. The grasshoppers are often harvested in the early winter rainy season, primarily from roofs of houses and fields of corn and beans. Although eating insects may seem like one of the most appealing options for humans, the acceptance of insects as food is determined by a number of factors, including sensory qualities, the social environment, individual beliefs, and contamination hazards, among others [11,12]. Several studies have examined insect macronutrients, protein levels, lipids, and vitamins [13, 14, 15]. In this context, many macromolecules found in edible insects have been investigated to explain the health benefits of eating and using insects. More specifically, many scientists have found that different species of grasshoppers and crickets have protein levels ranging from 43.9% to 77.1%. [16, 12]. Locusts are claimed to have a good fat composition when used as a food source due to their high levels of polyunsaturated fatty acids (PUFAs) [17].

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A polyunsaturated fatty acid concentration of 69.3% was found in *S. purpurascens.* This is a higher concentration compared to 30.6% saturated fatty acids [18]. The lipid content of *S. purpurascens* is relatively low compared to other species such as *R. differens* and food sources, but unsaturated (67–75%) and saturated (29–31%) fatty acids are explaining that this is a potential source of high quality oil [17]. Furthermore, a study on the effect of diet on fatty acid content in East African locusts concluded that diet may influence the fatty acid composition of *R. diffens* [18]. The practice of eating insects by various ethnic groups, called entomophagy, is widespread and well documented in many parts of Africa, Asia and the Americas [18,19,2]. There are nearly 2,000 species known to be edible and eaten by over 2 billion people worldwide [2]. The decision to use insects as a food source is supported by the fact that insects have nutritional values comparable to meat and fish (in terms of relative amounts of protein, fat, vitamins, and calories) [2, 20]. In Tanzania, *R. differens* is traditionally eaten as a roasted, fried or smoked product, depending on the season. The Luo in Kenya and the Baganda in *Uganda R. differens* constitute a major part of food culture, accounting for about 5-10% of the protein intake of rural and urban populations [21, 22]. The bumper harvest of *R. differens* occurs during the period of March to May and October to December in East Africa during rainy season. Most of the swarms are usually concentrated on streetlights in urban areas (they are attracted to the light in the evenings), and on grasses and shrubbery with no apparent damage [23]. These insects are caught during swarming seasons, processed at home, and ingested, thus increasing nutrient intake. Also, they add to the household's sources of revenue, with the surplus being exchanged in nearby marketplaces [24].

Nutritional and health benefits of edible grasshoppers

Beyond basic nutrition, the edible grasshoppers found around Lake Victoria provide a variety of nutritional and health advantages. These include high levels of leucine (80.9-86.5 mg/g), lysine (54.0-69.8 mg/g), and valine (58.1-61.8 mg/g), three of the most abundant amino acids, as well as fat (42.2-54.3%), protein (34.2-45.8%), and fat (42.2-54.3%) [25]. The insect also furnishes copious amounts of essential vitamins: vitamin A (2.1–2.8 µg/g), vitamin E (201.0–152.0 µg/g), niacin (2.1–2.4 mg/100 g), riboflavin (1.2–1.4 mg/100 g), vitamin C (0.1 mg/100 g), folic acid (0.9 mg/100 g), and pyridoxine (0.2-0.04 mg/100 g) and minerals; K (446.0–673.0 mg/100 g), P (429.0–627.0 mg/100 g), Ca (34.9–128.0 mg/100 g), Fe (13.0–16.6 mg/100 g) and Zn (12.4–17.3 mg/100 g) [25, 26]. Unsaturated fatty acids are also reportedly abundant in *R. differens*; oleic acid (38.4–42.7 g/100 g), linoleic acid (19.0–23.0 g/100 g), palmitoleic acid (26.6–27.8 g/100 g) and α-linolenic acid (0.96–1.5 g/100 g) [26].

Despite their great nutritional value, edible insects are frequently processed in order to maintain microbiological safety, lengthen their shelf life, and enhance their sensory appeal [27, 28]. The most popular edible insect processing techniques in Africa are frying, drying, roasting, smoking, boiling, toasting, and steaming [29]. Due to its high rate of spoiling and seasonality, these processing techniques are essential in preserving and extending the shelf life of *R. differens* [30]. Studies demonstrate the value of edible insects in the battle against hunger and food poverty [23]. Eating edible insects may have remarkable health benefits since they contain high quantities of nutrients like protein, fat, fibre, ash, carbohydrates, and total energy. Eating edible insects like grasshoppers could have a number of positive effects on the environment and human nutrition, such as a general decrease in greenhouse gas emissions, a reduction in agricultural land and water use, better chronic disease prevention and management, such as diabetes, cancer, and cardiovascular disease, as well as improved immune function. The advantages of whole insects or insect isolates over traditional animal and plant-based meals should be the subject of future research. The use of insects as food supplements or meat alternatives could ultimately benefit both the environment and human health.

Nutrients composition of edible grasshopper processed with different processing methods and their roles in the body

Moisture

Comparing boiling, blanching, toasting, and deep frying, the moisture level was highest in boiling (Table 1). The shelf life and product quality are greater when the product has a lower moisture content because chemical and physical deterioration are less likely to occur [31]. The study concludes that deep frying is a better strategy for extending the shelf life of edible grasshoppers (*R. differens*) for food and nutrition security. The amount of moisture in a food product affects a number of characteristics, including its physical characteristics (shape, colour, texture, taste, weight (which can affect the price), as well as elements that affect the product's shelf life, freshness, quality, and resistance to bacterial contamination.

Dry matter

The dry matter of *R. differens*, an edible grasshopper, demonstrates the importance of the processing steps. Deep frying produced the items with the highest dry matter content, which was then followed by toasting and blanching. The boiling method revealed a low level of dry materials. The meal loses water due to dehydration when it is deep-fried at temperatures between 150 and 200 ^{o}C. Similar to how moisture leaves holes in food matrixes, oil seeps fast to fill those

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spaces, increasing the amount of dry matter and fat in the food [32]. Boiling *R. differens* causes a constant loss of fat, which is why there is less dry matter and fat visible. The part of the meal that remains after the water has been fully removed is known as dry matter (DM). The dry matter component of food contains all of the following nutrients: energy, protein, fibre, vitamins, and minerals.

Protein

R. differens showed higher protein content when roasted, boiled and blanched than when fried, but there was a significant loss of protein in cooked beetles and crickets due to protein denaturation during cooking. However, the first time I roasted an insect there was no loss [33]. These losses include thermohydrolysis of connective tissue, solubilization of soluble proteins in boiling water, nitrogen shedding due to loss of amines and amides, and complex formation with reactants, especially lipid oxidation products, in food media is related to [28]. In Table 1, the differences in protein and fat content of cooked and blanched *R. diffens* were negatively correlated. Proteins regulate gene expression, make up most of the cell structure, influence immune function, and are an important part of muscle. It also catalyzes nearly every chemical process in the body.

Fat

The frying procedure produced the most fat in the *R. differens* sample, while the boiling procedure produced the least. The difference in this treatment method was significant. Frying has been suggested to affect the nutritional composition of foods by catalyzing many chemical processes. For example, protein denaturation, amino acid damage, and proteins, peptides, and amino groups all contribute to flavour. It is involved in the Millard reaction leading to the compound [33]. This could explain the relatively reduced protein content of *R. differens*. Fat helps the body to produce energy, protects organs, promotes cell growth, regulates blood pressure and cholesterol levels, and facilitates the absorption of essential nutrients.

Fibre

Blanched and boiled *R. diffens* contained more dietary fibre than roasted and fried *R. diffens* [34]. These variations in fibre concentration can be attributed to modifications caused by processing of chemical constituents such as cellulose, hemicellulose, pectin, gums and lignin in the fibre material [35]. Different processing techniques were used in this study, which may have affected the fibre content to varying degrees depending on the time, temperature and medium used. Fibre increases the weight and volume of stool and softens it. The movement of the large intestine becomes smoother, reducing the chance of constipation. Dietary fibre increases the bulk of stools by absorbing water and stabilizes loose stools

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with a lot of water to some extent. Eating a diet high in fibre can reduce the risk of developing colon polyps and haemorrhoids (diverticulitis). Studies show that eating more fibre can reduce the risk of developing colon cancer [36]. Some fibres are fermented in the large intestine. Its potential to prevent colon disease is being studied by researchers. Dietary fibre, especially soluble fibre, has been shown to help control blood sugar levels in people with diabetes by slowing the absorption of sugar. In addition, eating a nutritious diet rich in insoluble fibre can reduce the risk of type 2 diabetes. Not only do high-fibre foods take longer to eat, but they also have a lower "energy density", or fewer calories per unit of food, than other foods. Studies have shown that more fibre, especially in grains, is associated with a lower risk of dying from cancer and cardiovascular disease [37]. The recommended daily allowances for fibre for young and adult men are 38 and 30 grams, respectively, while for young and adult women, are 25 and 21 grams, respectively.

Ash

The ash concentration of *R. differens* was different in blanching, boiling and roasting, but was significantly higher than in frying. This is in contrast to recent studies showing reduced ash concentrations in cooked insects. Leaching loss to water was responsible for the significant ash reduction in boiled insects. Current research findings are different. The term "ash" refers to the minerals and inorganics that remain in food after it has been cooked at high temperatures and all moisture, volatiles, and organics have been removed. The ash concentrations of *R. differens* when blanched, boiled, and toasted were equivalent but substantially greater than when deep-fried. This contrasts with recent research that demonstrated a decrease in ash concentration in boiling insects but an increase in toasted insect products [28, 38]. Leaching losses into the water was the cause of the noticeable ash reduction in boiling insects. Therefore, this effect might have been overwhelmed by the proportional loss of other important components like fat in the boiled, blanched, and toasted *R. differens* in the current study.

Total carbohydrates

The total amount of carbohydrates in *R differens* varies greatly depending on the processing method. Boiled and toasted products had lower total carbohydrate content, while blanched and fried products had higher total carbohydrate content. The carbohydrate concentration of the products is affected by moisture, protein, fat and ash, as differential methods are used. Carbohydrates are the main source of energy for our bodies, fueling our heart, kidneys, brain, muscles and central nervous system. For example, fibre, which is a carbohydrate, aids digestion, makes feel full, and lowers blood cholesterol levels.

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Energy

When it comes to locust processing strategies, the most noticeable change seems to be in overall energy. According to differential techniques, high or low total energy content of a product depends on its protein, carbohydrate and fat content. The macronutrients carbohydrates, proteins, fats and oils in the diet help provide the body with the energy it needs to function and drives the electrical process. Whether one is sleeping, awake, eating, showering, grooming, working, or pursuing one's passion, one needs to get energy in the form of the energy that powers the body also enables external activities that interact with the physical world and allows us to repair, develop and maintain our biological structures and cells. Water, a vital nutrient, assists in the chemical reactions that turn food into energy.

Mineral composition of Edible grasshopper processed with different processing methods

Except for copper and cobalt, the treated *R. differens* showed considerable variations in calcium (Ca), phosphorus (P), magnesium (Mg), iron (Fe), manganese (Mn), and zinc (Zn) (Table 1). Fe, Zn and Mn were the most common trace elements found in all treated *R. differens*, and P, Ca and Mg were the most common macrominerals. Mineral levels of all processed samples of fried *R. differens.* The difference was significantly smaller ($p<0.05$). Except for lower Fe in roasted insects, levels of minerals such as Ca, Mg, and Zn were also significantly higher in blanched, boiled, or roasted *R. diffens*. It corroborates findings by Mutungi *et al.* [29], Ssepuuya *et al.* [38], and Karimian-Khosroshahi *et al.* [39]. The high affinity of Ca and other micronutrients for insect proteins and chitin is associated with their stability in diets subjected to various heat treatments [38]. Published studies have shown that fried foods produce incredibly low levels of protein. This helps explain the low levels of calcium and other micronutrients observed in *R. diffens*. In fact, the general tendency to fry food dramatically reduces Cu, Mn and Co. This is consistent with previous studies of similar nature, in which fried fish significantly increased the Mn and Cu levels [39]. The body uses minerals for a variety of functions, including maintaining healthy bones, muscles, heart and brain. The synthesis of hormones and enzymes requires the presence of minerals including macrominerals such as calcium, phosphorus, magnesium, sodium, potassium, chloride, and sulfur and trace minerals like iron, manganese, copper, iodine, zinc, cobalt, fluoride, and selenium.

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CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

Processing methods of *R. differens* that differ from food have the potential to preserve important factors that are beneficial to both human nutrition and health. Nutrient retention of foods made from *R. Differens* was significantly impaired by frying. The blanching, cooking and roasting processes did not noticeably affect the mineral status of *R. differens*. Overall, the nutritional profile of *R. Differens* appears to confer a wider range of potentially beneficial nutritional and health effects upon its consumption compared to foods of animal origin. Their inclusion as dietary supplements in the human diet leaves several avenues for further research. This analysis accurately maps nutrients in edible grasshoppers that can be harvested in the wild in late November or early December each year. After reading this assessment, governments and non-governmental organizations (NGOs) need to incorporate it into people's diets to promote a balanced diet and combat malnutrition, a problem in many developing countries. Therefore, *R. Differens* can be used as an alternative protein source to increase food and nutrition security and reduce malnutrition.

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Table 1: Nutrients composition of *Ruspolia differens* processed with different processing methods

Nutrient composition								
Processing methods	**Moisture (%)**	**Dry matter (%)**	**Protein (%)**	**Fat (%)**	**Fibre (%)**	**Ash (%)**	**Total carbohydrates (%)**	**Total energy (Kcal/100 g)**
Blanching	1.80 ± 0.05^{b}	98.20 ± 0.05^{b}	40.10 ± 1.33^{b}	43.80 ± 0.41^{b}	11.20 ± 0.01^{b}	2.20 ± 0.00^{b}	12.10±0.02^{c}	603.00±3.18^{a}
Boiling	14.50 ± 0.10^{c}	85.60 ± 0.10^{a}	43.10 ± 1.60b^{c}	36.30 ± 1.06^{a}	10.90 ± 0.19^{b}	2.20 ± 0.00^{b}	5.30±0.04^{a}	614.00±5.22^{b}
Toasting	1.60 ± 0.06^{b}	98.40 ± 0.06^{b}	44.70 ± 1.03^{c}	46.00 ± 0.82^{b}	9.00 ± 0.74^{a}	2.30 ± 0.09^{b}	5.30±0.01^{a}	614.00±4.32^{b}
Deep frying	0.80 ± 0.03^{a}	99.20 ± 0.03^{c}	7.80 ± 0.59^{a}	83.00 ± 1.54^{c}	8.70 ± 0.39^{a}	2.40 ± 0.17^{b}	7.20±0.13^{b}	807.00±6.34^{c}
Minerals composition of *Ruspolia differens* processed with different processing methods								
Processing methods	**Ca**	**P**	**Mg**	**Fe**	**Cu**	**Mn**	**Zn**	**Co**
Blanching	47.9 ± 1.06^{b}	427.8 ± 1.80^{b}	52.8 ± 0.54^{b}	140.90 ± 8.59^{b}	1.9 ± 0.05^{b}	5.30 ± 0.04^{c}	16.8 ± 0.97^{c}	25.6 ± 4.49
Boiling	54.5 ± 1.92^{b}	427.7 ± 14.36^{b}	56.5 ± 1.57^{b}	179.10 ± 14.18^{c}	2.3 ± 0.18^{b}	4.10 ± 0.0003^{b}	18.4 ± 0.08^{c}	33.1 ± 0.005a
Toasting	55.0 ± 5.05^{b}	496.8 ± 27.60^{c}	53.2 ± 7.10^{b}	22.20 ± 0.27^{a}	2.2 ± 0.22^{b}	4.00 ± 0.08^{b}	13.2 ± 1.82^{b}	28.1 ± 5.71^{a}
Deep frying	35.8 ± 0.47^{a}	305.4 ± 18.02^{a}	33.3 ± 1.15^{a}	12.9 ± 2.48^{a}	1.6 ± 0.04^{a}	2.90 ± 0.70^{a}	8.5 ± 0.15^{a}	29.9 ± 1.00^{a}

The same small superscript letters within columns indicate no significant differences in proximate composition at $p < 0.05$. All values are presented as mean ± SD.

Source: [31]

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