The Role of Edible Insects in Diets and Nutrition in East Africa

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Abstract Insects have been used as food, medicine and in rituals by a number of communities in the East African region comprising of Kenya, Uganda and Tanzania over centuries. Progressively, farmed edible insects mainly crickets and grasshoppers are gaining popularity within the region. However the utilization of the edible insects is hampered by lack of storage and preservation facilities in the rural areas leading to high postharvest losses. Sun drying and roasting have been the main processing methods applied for decades by communities consuming edible insects such as the Luo from Kenya. Recently there has been incorporation of insects as an ingredient in processing of baked products and complementary foods. Culture, taboos, customs and ethnic preferences have highly influenced the consumption of edible insects in East Africa. Edible insects such as grasshoppers, mayfly and termites that are consumed in this region have been shown to be source of both macro and micro nutrients and other components such as chitin which has been linked to improved health and better management of chronic diseases. Therefore edible insects promises to be a part of the solution to food and nutrition security within the East African region.

1 Introduction

This chapter will cover edible insects consumed in the East African region and will explore the diversity, nutritional profiles, harvesting and processing and their contribution to food and nutrition security. In Africa, various studies have recorded different number of edible insects, with numbers varying from 246 species from 27 countries (van Huis 2003). A survey conducted by International Centre of Insects Physiology and Ecology (ICIPE), revealed 470 species of edible insects existed in Africa (Kelemu et al. 2015).

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In East Africa insects have been utilized over centuries as food, feed, medicine and in witchcraft. However due to change in eating habits, preferences and food and nutrition insecurity a wider consumption of edible insects have been reported in this region (Ayieko and Oriaro 2008). The key insect orders consumed in East Africa include *Lepidoptera, Coleoptera, Hymenoptera, Orthoptera, Hemiptera, Isoptera* and *Diptera* at different stage of their lifecycle. In Zambia Mopani worm (*Imbrasia belina*) is consumed and sold in the streets of Lusaka usually in dried or roasted form (Ghaly 2009). Tree locust (*Anacridium melanorhodon melanorhodon*) can easily be found in Khartoum, Sudan sold as either flour or fried (Babiker et al. 2007). The Luo community who reside along the Lake Victoria in Kenya have used the mayfly for cultural practices and also as a source of income (Ayieko and Oriaro 2008). Additionally termites (*Macrotermes subhyalinus*) and Longhorn grasshopper (*Ruspolia differens*) are a delicacy in this region of Kenya (Kinyuru et al. 2009, 2010a, b). In Uganda edible Grasshopper (*Ruspolia nitidula*) commonly known as Senene is highly consumed (Ssepuuya et al. 2016).

Furthermore in some of the Eastern African countries, edible insects are roasted and sun dried (Ghaly 2009). In Uganda grasshoppers are fried prior to selling in the market (Agea et al. 2008). Termites are toasted in their own oil for about 5 min and thereafter consumed alone or as a part of a meal by communities in the western region of Kenya (Kinyuru et al. 2010a, b). In Sudan the tree locust are boiled before being sold in the markets of Khartoum (Babiker et al. 2007). Most of these processing procedures are done by women and children. For instance the drying, roasting, packaging, mixing and selling of the mopane caterpillar (*Imbrasia belina*) in Zimbabwe is done by women (Kozanayi and Frost 2002).

A key technical challenge that hampers the utilization of edible insects in East Africa is lack of proper processing, storage and preservation enablers. For instance there is lack of electricity especially in the rural areas where the harvesting of edible insects is done, additionally the high temperature in the tropics causes faster spoilage and as a result there is high postharvest loss (Ayieko 2010). However, sun drying offers a cheap alternative to dry and preserve the harvested insects (Ayieko et al. 2011; van Huis 2015).

2 Harvesting, Handling and Processing of Edible Insects in East Africa

2.1 Harvesting

In the past, most wild-harvested insects were consumed at the household level, and the quantities collected were determined by day to day consumption requirements. Today, insects have become an additional source of income and the portion harvested has increased gradually (FAO 2013; Yen 2015). Edible insects thrive in a variety of habitats such as vegetation, roots, branches and trunks of trees or soils (FAO 2013).

Fig. 1 Day time view of a grasshopper trap ready for harvesting

Most of the insects consumed are often collected by women and children from the wild (van Huis 2015) depending on their seasonality (Ayieko and Oriaro 2008).

Light traps are the most commonly used methods to catch edible insects in Western Kenya (Ayieko and Oriaro 2008; Ayieko et al. 2011). This is particularly so for insects which have a preference to swarm at night such as some species of termites and grasshoppers. In Tanzania for example, traditional traps are made of iron sheets and bright light, so as to attract grasshoppers in the night (Figs. 1 and 2). Caterpillars are harvested from forest trees that form new leaves at the beginning of the rainy season (van Huis 2003).

Insects that inhabit soils such as beetles, are often picked by hand. A researcher observed that during the onset of rains winged termites emerge from tunnels and are collected, additionally the termites are also harvested by placing a bowl of water under a source of light since termites are attracted to light (Kinyuru et al. 2009). Additionally mayflies are collected by villagers along the lake (Ayieko and Oriaro 2008). With the advent of farming of insects such as crickets and grasshoppers, conventional methods of harvesting are now being applied, hence easing the pressure applied on wild edible insect species.

Fig. 2 Night view of a grasshopper light trap during harvesting

2.2 Traditional Processing for Human Consumption

Communities in the East African region consume the insects raw or process them to meet their tastes and preferences. Some of these insects need; removal of appendages, de-winging, degutting, beheading, washing with water to remove any dirt, (Aguilar-Miranda et al. 2002; FAO 2010; Kinyuru et al. 2010a, b) before they are further processed (Fig. 3 and Table 1).

2.3 Industrial Processing

Recently, a lot of interest has been directed to evaluating the production and processing of edible insects and push for its recognition as a food ingredient in food processing. This is especially after studies have shown the safety of edible insects (Konyole et al. 2012). A study concluded that termites and mayfly have a great potential of being utilized as supplements in processing of crackers/biscuits (Ayieko 2010). Similarly incorporation of termite meal in bun production is not only an adoptable

Fig. 3 Women removing appendages and de-winging grasshoppers after harvesting in a market in Tanzania

Table 1 Processing methods of different edible insect species consumed in East African countries

Species	Common name	Stage consumed	Processing method	Country consumed
Acheta domesticus[1]	House cricket	Adult	Toasted and/or dried	Kenya, Uganda
Anaphe panda[2]	Silk worm	Larvae	Fried or roasted	Tanzania
Carebara vidua[3]	Black ants	Adult	Washed and fried, de-headed	Kenya
Chaoborus edulis[4]	Glass worm	Adult	Ground and sun dried	Uganda
Macrotermes spp[5,6]	Termites; white ants	Winged adult (Alates)	De-winged, toasted and/ or dried, salting, boiling	Uganda, Kenya
Ruspolia differens[6]	Long-horned grasshopper	Adult	De-winged, toasted and/ or dried, salting	Kenya, Uganda, Tanzania
Ruspolia nitidula[5,7,8]	Long-horned grasshopper	Adult	De-winged, toasted and/ or dried, salting, boiling	Kenya, Uganda, Tanzania

[1]Ayieko (2010), [2]Defoliart (1995), [3]Ayieko and Kinyuru (2012), [4]van Huis (2003), [5]Agea et al. (2008), [6] Kinyuru et al. (2010a, b), [7] Mbabazi (2011), [8] Ssepuuya et al. (2016)

process but also a way of providing nutrients (Kinyuru et al. 2009). Additionally it has been demonstrated that termites can be used in processing of complementary food with considerably good shelf life (Kinyuru et al. 2015).

Wheat based products have been developed with incorporation of edible insects. For example buns with 5% of wheat replaced with termite meal (Kinyuru et al. 2009) have been developed. Termite and mafly meal have also been used at varying percentages to supplement wheat meal in the production of crackers and muffins that had high nutrient content and consumer acceptance (Ayieko et al. 2010).

A study under the WinFood project funded by DANIDA with the goal of improving nutritional status of infants and young children by utilizing traditional foods in Kenya, involved processing of winged termites, *Macrotermes subhylanus,* into ready to cook extruded complimentary flour (Kinyuru et al. 2015). Industrial processing in East Africa is therefore a possibility, but, it is hampered by lack of adequate amounts from wild harvesting hence necessitating commercial farming of insects. To acquire large quantities of quality insects, automation of both farming and processing methods is vital, which remains a challenge for the development of the sector.

2.4 Storage and Preservation

Edible insects, like any meat and meat products, are highly perishable and prone to microbial and chemical changes upon storage, due to their rich nutrient profile. Microbial contamination mainly occurs during handling, processing and storage (Braide et al. 2011a, b). Bacteria, yeasts and moulds such as *Staphylococcus aureus, Bacillus cereus, Escherichia coli, Enterobacteriaceae, bacterial spores, Proteus mirabilis, Aspergillus, Mucor, Penicillium* and *Fusarium* have been reported to be the major cause of spoilage in edible insects (Braide et al. 2011a, b: Klunder et al. 2012; Opara et al. 2012; Mujuru et al. 2014)., Microorganisms have also been reported to cause quality deterioration of the edible caterpillar of the emperor moth commonly known as *Mophane* (Gashe et al. 1997). Heat based processes have however been found to be effective in eliminating most microbes. Boiled crickets were noted to spoil rapidly while boiled, and dried crickets and grasshoppers were microbiologically stable during storage (Klunder et al. 2012; Ssepuuya et al. 2016).

Insect fats are highly susceptible to both oxidative and hydrolytic rancidity. Ready to eat and vacuum packed longhorn grasshopper (*Ruspolia nitidula)* that were stored at room temperature for 12 weeks, showed a gradual increase in acid value which stabilised at 3.2 mg KOH/g. This was higher than the recommended 2 mg KOH/g acid value of edible oils (Ssepuuya et al. 2016). Processes like freezing and refrigeration have been shown to encourage nutrient retention (Severi et al. 1997) and improve oil absorption and protein solubility hence increasing industrial applications of the insects (Nabayo et al. 2012).

2.5 Cultural Preferences Influencing Consumption of Insects

2.5.1 Appreciation for Edible Insects

Women of Baganda Kingdom in Uganda are prohibited to eat the edible grasshopper though allowed to catch and cook for their husbands. The husbands in return reward their women by giving them traditional dresses called *gomasi*. The more the grasshoppers a woman collects, the better the *gomasi* she gets from her husband. The male kings would exchange edible grasshoppers in a manner that enhanced social ties (Agea et al. 2008).

Among the Kikuyu tribe in Central Kenya, consumption of edible insects is not commonly accepted since they consider the practise uncivilised. Crickets were however considered an important source of food to the guerrilla fighters during the struggle for freedom in the 1950’s as they were freely available in forests of Central Kenya. In Tanzania, the purple grasshopper is considered to be a delicacy for the royalties. It is hence more expensive in the market. Amidst all these cultural barriers, consumption of edible insects has been promoted based on four main points of reference namely high nutritional value, important environmental benefits, economic factors and gastronomic aspects (Ramos-Elorduy 2005).

2.5.2 Barriers to Consumption of Edible Insects

Preference and decision to consume edible insects are dependent on taboos, customs as well as ethnic preferences (van Huis 2003). Such peculiarity of edible insects from normal red and white meat as the absence of blood and such behaviours as swarming has been associated with such taboos (Fasoranti and Ajiboye 1993; van Huis 2003). For example pregnant women in Haya tribe of Tanzania are not allowed to eat the longhorn grasshoppers as they will give birth to children with a cone-shaped head (similar to grasshoppers’ head). Giving the longhorn grasshopper to children is also associated with inability to speak well when they grow up (Musisi 1991).

3 Nutrient Profile of Edible Insects

Protein and fat are the major macronutrients in the reviewed edible insects while available carbohydrate is the least (Table 2). *Schistocerca gregaria* had the highest amounts of protein and *Ruspolia differens* the highest amounts of fat (Table 2). The protein content was within 35.34–61.32% reported by (Rumpold and Schluter 2013) for orders Isoptera and Orthoptera. The protein content of the reviewed edible insects compares to that of conventional livestock (Kinyuru et al. 2010a, b; Nadeau et al. 2014). *Ruspolia nitidula* recorded the highest amount of dietary fibre while *Macrotermes subylanus* the least (Kinyuru et al. 2013; Ssepuuya et al. 2016). A high

Table 2 Macronutrient composition of some edible insects in East Africa (On a dry matter basis)

Edible insects	Protein (%)	Fat (%)	Dietary Fiber (%)	Av. Carbohydrate (%)	Ash (%)
Ruspolia differens (green) fresh [1]	43.1	48.2	4.0	2.0	2.8
Ruspolia differens (green) toasted [1]		20			
Ruspolia differens (green) fresh dried [1]		43.1			
Ruspolia differens (brown) fresh [1]	44.3	46.2	5.0	2.0	2.6
Ruspolia differens (brown) toasted [1]		14.6			
Ruspolia differens (brown) fresh dried [1]		41.2			
Ruspolia nitidula (green) fresh [2]	40.3	42.4	14.3	3.2	4.0
Ruspolia nitidula (brown) fresh [2]	40.4	43.0	13.9	3.1	3.8
Macrotermes subylanus fresh dried [1]		42.3			
Macrotermes bellicosus (dewinged)[3]	39.7	4.0	6.21	2.4	4.7
Macrotermes subylanus (dewinged) [3]	39.3	44.8	6.4	1.9	7.6
Macrotermes subylanus (toasted) [1]		21.4			
Pseudacanthotermes militaris (dewinged) [3]	33.5	46.6	6.6	8.7	4.6
Pseudacanthotermes spiniger (dewinged) [3]	37.5	47.3	7.2	0.7	7.2
Carebara vidua [4]	40.8	47.5			1.6

[1]Kinyuru et al. (2010a, b), [2]Ssepuuya et al. (2016), [3]Kinyuru et al. (2013), [4]Ayieko and Kinyuru (2012)

percentage of the fibre is usually composed of chitin. *Pseudacanthotermes militaris* recorded the highest amount of available carbohydrates while *Pseudacanthotermes spiniger* the least (Kinyuru et al. 2013).

In addition to the macronutrient composition the edible insects vary in mineral and vitamin composition (Tables 3 and 4). The variation in nutritional profiles is attributed to differences in species, metamorphic stages, habitats and diets (van Huis 2003; Ayieko and Oriaro 2008; Ayieko 2010; Kinyuru et al. 2013). Some insects have been shown to have protein with good solubility and biological value (Omotoso 2006; Solomon et al. 2008), with amino acid profile that meets the human requirement (Table 5). The amino acid profile of proteins is a major determinant of protein quality. Leucine was the dominant amino acid in cricket and termites. This demonstrates the good quality of edible insects' proteins. In addition, to amino acid

Table 3 Mineral composition of some edible insects in East Africa

Edible insects	Calcium (mg/100 g)	Magnesium (mg/100 g)	Potassium (mg/100 g)	Sodium (mg/100 g)	Phosphorus (mg/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)	Manganese (mg/100 g)	Copper (mg/100 g)
Ruspolia differens (green) fresh [1]	27.4	33.9	370.6	358.7	140.9	16.6	17.5	5.3	0.6
Ruspolia differens (Brown) fresh[1]	24.5	33.1	259.7	229.7	121.0	13.0	12.4	2.5	0.5
Ruspolia nitidula (green) fresh [2]			0.5		0.5				
Ruspolia nitidula (Brown) fresh [2]			0.6	0.5					
Macrotermes bellicosus (dewinged) [3]	63.6					116.0	10.8		
Macrotermes subhyalinus (dewinged) [3]	58.7					53.3	8.1		
Pseudacanthotermes militaris (dewinged) [3]	48.3					60.3	12.9		
Pseudacanthotermes spiniger (dewinged) [3]	42.9					64.8	7.1		
Carebara vidua [4]	22.2	10.4	51.7	26.2	106.0	10.7	5.7		
RDA for 25 years old male [5]	1000	400	4700	1500	700.0	8.0	11.0	2.3	0.9

[1]Kinyuru et al. (2010a, b), [2]Ssepuuya et al. (2016), [3]Kinyuru et al. (2013), [4]Ayieko and Kinyuru (2012), [5] Bukkens and Poaletti (2005)

Table 4 Vitamin composition and fatty acid fractions of some edible insects in East Africa

Edible insects	Vitamin A (μg/g)	Vitamin E (μg/g)	Vitamin B3 (mg/100 g)	Vitamin B2 (mg/100 g)	Vitamin C (mg/100 g)	Vitamin B9 (mg/100 g)	Vitamin B6 (mg/100 g)	SFA (%)	MUFA (%)	PUFA (%)
Ruspolia differens (green) fresh [1]	2.1	201	2.1	1.2	0.1	0.9	0.4	38.3	26.6	34.4
Ruspolia differens (green) toasted [1]	0.82	139.2	3.3	0.93	0.5	0.6	0.42			
Ruspolia differens (green) fresh dried [1]	0.69	135.9	3.2	0.84	0.35	0.34	0.4			
Ruspolia differens (Brown) fresh [1]	2.8	152	2.4	1.4	0.1	0.9	0.2	39.1	26.3	33.8
Ruspolia differens (Brown) toasted [1]	1.8	160.1	0.12	1.05	3	0.5	0.15			
Ruspolia differens (Brown) fresh dried [1]	1.6	155.5	0.12	0.96	3.01	0.35	0.14			
Macrotermes subylanus fresh dried [1]	1	35.9	2.07	2.3	0.33	0.1	0.24			
Macrotermes bellicosus (dewinged) [3]								49.5	44.6	5.9
Macrotermes subylanus (dewinged) [3]								35.05	52.8	12.2
Macrotermes subylanus (toasted) [1]	1.6	41.4	2.2	2.8	0.5	0.12	0.26			
Pseudacanthotermes militaris (dewinged)[3]								32.2	56.1	11.7
Pseudacanthotermes spiniger (dewinged) [3]								35.8	52.9	11.3
Carebara vidua [4]	0.8	0.6	0.28	20.3	0.03	0.5				

SFA saturated fatty acids, *MUFA* monounsaturated fatty acids, *PUFA* polyunsaturated fatty acid
[1]Kinyuru et al. (2010a, b), [2]Ssepuuya et al. (2016), [3]Kinyuru et al. (2013), [4]Ayieko and Kinyuru (2012), [5] Bukkens and Poaletti (2005)

Table 5 Amino acid profile of selected edible insects in East Africa (mg/g protein)

Edible insects	Histidine	Isoleucine	Leucine	Lysine	Methionine	Cystine	Methionine + Cysteine	Phenylanine + Tyrosine	Threonine	Trytophane	Valine
Acheta domesticus (adult)[6]	21.0	36.0	66.0	53.0	25.0	9.1	25.0	92.0	35.0	9.0	55.0
Macrotermes bellicosus[7]	51.4	51.1	78.3	54.2	27.5	18.7	26.2	74	27.5	14.3	73.3
RDA for 25 years old male[8]	15.0	30.0	59.0	45.0	16.0	6.0	22.0	30.0	23.0	6.0	39.0

[6]Finke (2002), [7]Bukkens (1997), [8]WHO (2007)

profile, food efficiency ratio and protein efficiency ratio (PER) are some of parameters used in evaluating the biological value of proteins. Grasshopper, with a PER of 1.90 is considered superior to soy and crayfish proteins with a PER of 1.33 and 1.66 respectively (Solomon et al. 2008). *Acheta domesticus* protein has been reported to be superior compared to soy proteins (Nakagaki and Defoliart 1991) based on PER. Edible insects therefore have the potential of being utilized as supplements in the promotion of food and nutrition security.

4 Challenges Associated with the Quality of Nutrients from Edible Insects

4.1 Digestibility

Edible insects have abundant essential nutrients for adequate nutritional contribution to human diets. However, availability of these nutrients is challenged by the unanswered questions on digestibility of the insects in the human gut. Processing/cooking methods either increase or decrease digestibility of some components such as proteins (Opstvedt et al. 2003). For instance there was a decline in *in-vitro* digestibility of proteins of boiled and toasted locusts (Nafisa et al. 2008). *In-vitro* protein digestibility of winged termites, grasshoppers ranged between 81.11% and 90.49% with the fresh sample recording higher value than the toasted, toasted and dried and fresh and dried counterpart (Kinyuru et al. 2010a, b). Protein digestibility of dry pan frying, boiling, and boiling followed by sun drying varied between 34% and 67% in grasshoppers and 46–63% in white ants was reported in Uganda (Mbabazi 2011). More studies therefore need to be done to ascertain the question of protein digestibility.

4.2 Mineral Bioavailability

It has been hypothesised that minerals from edible insects are more bioavailable compared to minerals from plant sources (Christensen et al. 2006) hence could potentially help in reducing deficiencies of public health concern such as iron and zinc (Hongo 2003). However the considerably high iron content of edible insects could be as a result of contamination with soil during harvesting, (Kinyuru et al. 2013) therefore not bioavailable. *In-vivo* studies in Kenya and Cambodia involving young children, showed that the iron status of the children consuming insect based complementary foods did not show marked increase compared to plant based complementary foods further adding to the question of bioavailability of the minerals from edible insects (Skau et al. 2015).

5 Edible Insect Opportunities as Food Throughout the Lifespan

5.1 Preventing and Treating Malnutrition in Children

Malnutrition is the largest contributor to disease in the world (Prudhon et al. 2006; Moreki et al. 2012). Among the Sustainable Development Goals, alleviation of malnutrition is key. There is considerably high levels of malnutrition in East Africa. For instance in Kenya chronic malnutrition among children below 5 years stand at 26% and acute malnutrition is at 4% (KDHS 2014). To attain proper nutrition, there is need for continuous access to quality food and dietary diversity which is essential for proper growth (Rytter et al. 2015).

Micronutrient deficiencies are also common among children, therefore necessitating intake of iron, vitamin A, iodine and zinc, which are vital for child growth and mental development (Prudhon et al. 2006). A study concluded that consumption of 100 grams of toasted longhorn grasshopper could aid meet the recommended daily intake for vitamins such as vitamin A, E, B2, B3 and B9 and also minerals for instance potassium, calcium, zinc and iron (Kinyuru et al. 2010a, b). Current studies have shown that insect based complementary foods are of superior quality as compared to commercially produced complimentary food (Kinyuru et al. 2015).

5.2 Contribution of Edible Insects to Health

The fibre content of edible insects in East Africa is shown in Table 2. Much of this fibre is usually chitin which has been associated with immune defence against parasitic and allergic reactions (Brownawell et al. 2012). Chitin may also function as a prebiotic, which enhances growth of probiotic bacteria while suppressing the pathogenic bacteria in the gut. This could potentially contribute to alleviate intestinal dysfunction and Environmental Enteric Dysfunction, which has attained increasing recognition as an underlying contributor to malnutrition in children in poor living conditions (Keusch et al. 2016). This hypothesis needs to be documented.

6 Conclusion

Edible insects show a great potential of being part of the human diet among communities living within the East African region. The nutrient profile of edible insects for instance protein compares well with known sources such as beef, chicken and fish, as a result, they have the potential of reducing cases of malnutrition and promote good health among populations. However the utilization of edible insects is still highly influenced by traditional postharvest practices. Therefore to promote the use of edible insects both at household and industrial levels, modern and suitable farming, processing and storage methods should be applied.

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