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African Edible Insects As Alternative Source of Food, Oil, Protein and Bioactive Components

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https://doi.org/10.1007/978-3-030-32952-5_1

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Chapter 1

Importance of Insects as Food in Africa



Arnold van Huis

Abstract In Africa, about 470 insect species are recorded as edible, of which caterpillars are most consumed followed by grasshoppers, beetles, and termites. Most of those are collected from nature. There are several insect species, such as locusts and grasshoppers, that are pests of crops but which can be eaten at the same time. There are some edible insect species which are harvested in large number contributing to food security. Three of those species are discussed: the mopane caterpillar, the African bush cricket, and the shea caterpillar. However, when we would like to promote insects as food then harvesting from nature is not an option anymore, as overexploitation already occurs. Then we need to rear the insects. That can be done in semi-domesticated systems such as for the palm weevil or by farming insects as mini-livestock such as for crickets. We discuss the nutritional value of edible insects, and how they can contribute to food security. We also give examples of how insects can be processed and marketed. We conclude with the prospects of how edible insects can assure food security and improve the livelihood of the African people.

Keywords Sub-Saharan Africa · Edible insects · Insects as food · Nutrition · Food security · Harvesting insects · Farming insects

1.1 Introduction

The level of prevalence of undernourishment in sub-Saharan Africa aggravated over the last few years. It went first down from 24.3% of the population in 2005 to 20.7% in 2014 but then went up again to 23.2% in 2017, affecting 237 million people, while the number of people experiencing severe food insecurity in 2017 was 346

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A. Adam Mariod (ed.), *African Edible Insects As Alternative Source of Food, Oil, Protein and Bioactive Components*, https://doi.org/10.1007/978-3-030-32952-5_1

million (34%) (FAO et al. 2018). In Africa in 2017, 59 million (30%) of the children under five were affected by stunting (chronic malnutrition) and 14 million (7%) by wasting (acute malnutrition). The influence of climate change on production and livelihoods is strongest in Africa as dryland farming and pastoral rangeland systems dominate livelihood systems for 70–80% of the continent’s rural population (Neely et al. 2009). Conditions of desertification and drought are aggravated by the impacts of human activities. Changes in climate impact heavily on nutrition through (1) impaired nutrient quality and dietary diversity of foods produced and consumed; (2) effects on water and sanitation, with their implications for patterns of health risks and disease; and (3) changes in maternal and child care and breast feeding (FAO et al. 2018).

Meat production in sub-Saharan Africa has been estimated to be 7334 thousand tons in 2005/2007 (only 2.6% of global meat production) and is expected to grow by 2.9% per annum up to the year 2050 (Alexandratos and Bruinsma 2012). Because of environmental reasons, dietary changes are urgently needed (Springmann et al. 2018), and insects, being already an important food source, should be considered.

The recorded number of insect species that are eaten in Africa is 472 (Fig. 1.1) (Jongema 2017). The most abundant group of species eaten are caterpillars (Lepidoptera) (31%), followed by grasshoppers, crickets, and locusts (Orthoptera) (23%). The Coleoptera, in particular the larvae follow (19%), and then termites (Isoptera) (7%), bees, wasps and ants (Hymenoptera) (7%), true bugs (Heteroptera) (6%), aphids, scale insects, cicadas, and leafhoppers (Homoptera) (4%), and flies (Diptera) (1%). The rest (3%) consists of cockroaches (Dictyoptera), mayflies

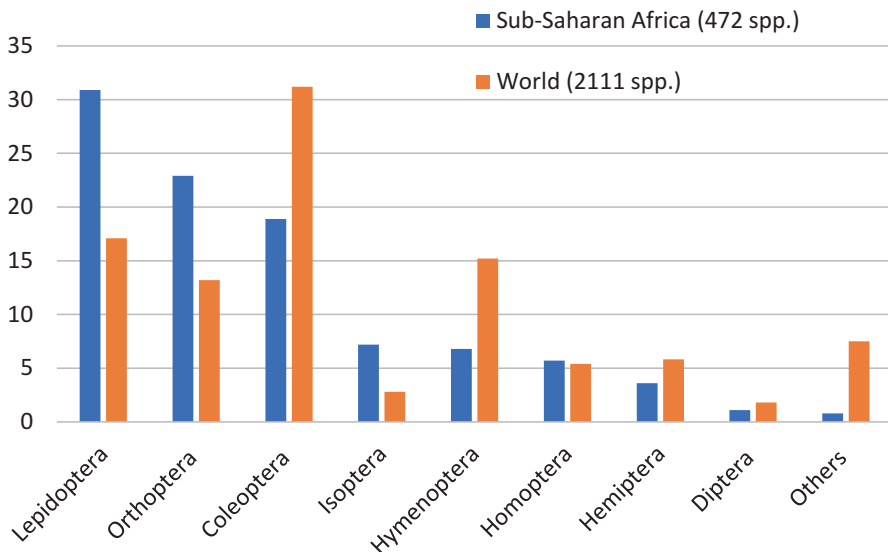


Fig. 1.1 Percentage of recorded edible insect species per insect order in sub-Saharan Africa and the world (Jongema 2017)

(Ephemeroptera), and other arthropod species such as hard ticks (Ixodidae) and spiders (Araneae).

When comparing these figures with those of the world (Fig. 1.1), then it seems that in Africa there are more recorded edible insect species in the Lepidoptera (caterpillars), Orthoptera (grasshoppers, crickets, and locusts), and Isoptera (termites) and less in the Coleoptera (beetles) and Hymenoptera than in the rest of world. There may be several reasons. They are recorded species which means that they have only been included in the database when known from literature. Taking the Lepidoptera, considerable effort has been made by several authors (Malaisse et al. 2017) to categorize those. Another reason is the continental diversity of an insect group; for example, termites have the largest diversity in Africa (38% of all species) (Lewis 2003).

Several review articles have been written about edible insects in Africa: Kelemu et al. (2015); Malaisse (2005) and van Huis (2003). We will deal with recent developments and cover traditional harvesting, semi-domestication, and farming of insects. We mention some economic important (pest) species and briefly deal with insects as feed for animals. Then we discuss nutritional issues, processing and marketing and how insects can contribute to food security. We finish with giving an outlook on insects as food in sub-Saharan Africa.

1.2 Pest Insects as Human Food

Certain insects can be a pest and at the same time are consumed by humans. The most well-known pests are the four locust species in Africa: the desert locust (*Schistocerca gregaria*), the migratory locust (*Locusta migratoria*), the brown locust (*Locusta napardalina*), and the red locust (*Nomadacris septemfasciata*) (Orthoptera: Acrididae). They may cause considerable damage to crops in Africa. When they occur during upsurges and plagues, they are eaten. However, it is a curse and a blessing at the same time. Sometimes it has been suggested that eating them could be used a control method. However, the extent of bands and swarms is so large and often in remote areas that this is not an option. The consumption of those locust may be a health risk as they are often treated with pesticides (Saeed et al. 1993).

The fall army worm *Spodoptera frugiperda* (Lepidoptera: Noctuidae), a serious pest of maize on the American continents feeding on young leaf whorls, ears, and tassels, has been reported for the first time in early 2016 in West and Central Africa (Goergen et al. 2016), and has spread to other parts of Africa (FAO 2017). Would it be an option to eat the caterpillar? Another indigenous pest, the African armyworm, *Spodoptera exempta* is capable of destroying entire crops by feeding on early stages of cereal crops. Mbata (1995) mentioned that this species is eaten by the local population in Zambia. The question is whether *S. frugiperda* can be eaten.

The caterpillar *Cirina forda* (Lepidoptera: Saturniidae) is found in western Africa, including Ghana and Nigeria, but also in Zimbabwe, the Democratic

Republic of the Congo, and South Africa. In Ghana and Nigeria, the larvae may cause heavy defoliation of the African shea tree (*Vitellaria paradoxa*). In southwestern Nigeria, it is widely marketed, and commonly consumed as a cheap delicacy being served as snacks or as an essential ingredient in vegetable soups along with carbohydrate food (Adepoju and Daboh 2013; Paiko et al. 2014). Its nutritional value is high (Akinnawo and Ketiku 2000) and it can be used as human food or animal feed (Omotoso 2006) replacing fishmeal in poultry diets (Amao et al. 2010; Oyegoke et al. 2006). Artificial rearing on the leaves of the African shea tree is possible (Ande and Fasoranti 1998).

Another pest, the variegated grasshopper *Zonocerus variegatus* (Orthoptera: Pyrgomorphidae) attacks food and cash crops such as banana, cassava, cocoa, citrus, cowpea, maize, soybeans, and yam in central and West Africa (Kekeunou et al. 2006). In Nigeria, the control of the variegated grasshopper has been reported as a control method (Iduwu and Modder 1996). In this country the grasshoppers are caught at night during the cold weather (November–February); at low temperatures because inactivity of the cold-blooded animals enables easy catching. After being boiled and roasted, they are displayed in markets and sold like meat (Solomon et al. 2008). Considering the high nutritional content, the grasshopper can both be used as food for humans and feed for animals and fish (Ademolu et al. 2010, 2017; Alegbeleye et al. 2012; Olaofe et al. 1998; Sani et al. 2014; Solomon et al. 2008). This is despite the fact that when molested, both sexes and instars expel an odorous, milky secretion of which the odour is repulsive or unpleasant to human beings (Idowu and Idowu 1999). This is the reason that the insect species is called “criquet puant” in French which means “stinking locust.”

1.3 Economic Important of Edible Insect Species

Although there are quite some edible insect species that are economically important we only discuss the mopane caterpillar, the African edible bush cricket and the shea caterpillar. Some other species were already mentioned in Sect. 1.2.

1.3.1 Mopane Caterpillar

The mopane caterpillar *Imbrasia belina* (Lepidoptera: Saturniidae) (Fig. 1.2) feeds on the mopane tree *Colophospermum mopane*. The larvae are not only popular food in many cultures in southern Africa, they also are often an important source of income for rural households. In South Africa in 1983, it was estimated that 1.6 million kg of traditionally prepared dried caterpillars were traded (Dreyer and Wehmeyer 1982). In Stack et al. (2003) it was mentioned that Styles (1994) estimated that yearly 9500 million caterpillars were harvested in an area of 20,000 km²,



Fig. 1.2 Dried mopane caterpillar *Imbrasia belina* (Lepidoptera: Saturniidae). Photo credits and copyright: Hans Smid—www.bugsinthepicture.com

only in South Africa, for the value of about US\$ 85 million at that time. Approximately 40% goes to producers, who are primarily poor rural women.

The protein content of the larvae is high with large amounts of all of the essential amino acids, essential, fatty acids (linoleic acid, α -linolenic acid), and many minerals (such as iron and zinc) critical to normal growth, development, and health maintenance (Glew et al. 1999). In the Limpopo Province in South Africa, the trade and consumption of mopane caterpillars contributed to rural household food security (Baiyegunhi et al. 2016). However, overexploitation and commercialisation threatens the long-term management of the mopane woodlands, and a balance need to be found between sustainable harvesting of mopane caterpillar and improving the livelihoods of the rural poor (Baiyegunhi and Oppong 2016). Strategies proposed are delaying the supply of the stock to the market and practices to maintain a sufficient number of fifth-instar mopane caterpillars, as well as safeguard the host tree against exploitation and ways to preserve the pupae (Gondo et al. 2010). Also restrictive harvesting periods have been proposed but there are doubts about its effectiveness (Akpalu et al. 2007). As the occurrence of mopane caterpillar is erratic and periodically fails to produce caterpillars of harvestable size, there is now an increased interest in developing domestic farming techniques of the caterpillars at the household level. However, this depends on the technical feasibility as parasitism, predation and diseases proved to be challenge besides that it was costly (Ghazoul 2006). It depends also on a number of other issues, such as farming only becoming interesting when levels of wild populations that can be harvested are low (Hope et al. 2009).

Cereals have low iron and zinc bioavailability, and it has been attempted to enrich cereals with mopane caterpillar in Zimbabwe (Gabaza et al. 2018). However, the bio-accessibility of iron and zinc was not improved, it only increased the iron and zinc content of the enriched fermented cereals. Also the nutritional potential of the mopane caterpillar has been studied in diets through its use in fortified blended foods formulations (Kwiri et al. 2014). Allergic reactions to the consumption of mopane caterpillar are possible (Kung et al. 2011; Okezie et al. 2010).

1.3.2 *The African Edible Bush Cricket*

The African edible bush cricket *Ruspolia differens* (Orthoptera: Tettigoniidae) is considered a delicacy in Uganda and is called by the Lugandan name “nsenene.” It also occurs in Kenya, Rwanda, Tanzania, and Madagascar. The insect species appears in nocturnal flying swarms of a high density, during May–April and November–December and are gathered as a highly prized item of human food (McCrae 1982). *Ruspolia nitidula* locally may be boiled or eaten raw, or sun-dried, fried, and flavored with onions, or used to make a soup (Agea et al. 2008). Sun-dried insects may be kept for several months.

The grasshopper oviposits on the leafage of grasses on which they develop (Bailey and McCrae 1978). Due to their inactivity during cold weather they are collected in the morning by hand from the grasses. As the grasshoppers during their nocturnal flights are attracted by light, women and children often engage in collecting from street lights; however, with the traffic that is a dangerous undertaking. There is homestead collection and harvesting in a more commercial way. Light traps are made by folding corrugated iron sheets into a cone shape. The lights attract the insects, which hit the sheets and then fall in large buckets with a hole on the lid (Mmari et al. 2017). It is also attempted to mass-rear the insects (Lehtovaara et al. 2018; Malinga et al. 2018a, b; Rutaro et al. 2018a, b).

1.3.3 *Shea Caterpillar*

The shea caterpillar *Cirina butyrospermi* (Lepidoptera: Saturniidae) only has the African shea tree as a host. It is highly valued as a human food item in Burkina Faso and Mali (Séré et al. 2018). Caterpillars can be dried, fried or boiled and used in various meals. The insect has exceptional nutritional characteristics, with 63% protein, 15% fat, as well as vitamins and minerals (Anvo et al. 2016b). It has also potential as fish feed (Anvo et al. 2016a, 2017). However, one of the main constraints on the consumption of this insect is its seasonal availability, due to its univoltine cycle. Therefore, it has been studied whether it would be possible to rear the insects by breaking the diapause (Bama et al. 2018; Rémy et al. 2018).

1.4 Insect as Feed

Small farmers in Africa feed chickens and guinea fowls with termites. They do so by breaking open small termite nests such as those of *Microtermes* spp. (van Huis 2017). However, in Togo they also used a method to lure termites to clay containers in which they have placed for example dry stems of sorghum or other cereals. They add some water and then put the pot upside down with the opening on a

termite gallery. Then they wait until there are enough termites (3–4 weeks) and then they empty the pot for the chicks (Farina et al. 1991).

The costs of feeding fish and poultry is often 60–80% of the total production costs, and this is due to the relative expensive protein sources such as fish meal and soy meal (Ssepuuya et al. 2017). These conventional protein sources could be replaced by 10–100% with insects (grasshoppers, house fly maggots, *Cirina forda* larvae, termites) without affecting the growth performance of fish and poultry. Moreover, insect-based feed in some cases performed better than conventional feed.

Worldwide there is a lot of interest to develop insect-based food and in particular the black soldier fly *Hermetia illucens* (Diptera: Stratiomyidae) and the housefly *Musca domestica* (Diptera: Muscidae) are candidates and were also considered of interest for West Africa (Kenis et al. 2014). Roffeis et al. (2018) looked at the economic implications of implementation in this part of Africa. Considering the prices of conventional feeds, there seems to be potential to substitute imported fishmeal with insect-based feeds, but there were no economic advantages over plant-based feeds.

1.5 Farming Insects

Simple rearing methods are sometimes carried out by the local population. It is also called semi-domestication in which the captive state of wild insects in which the living conditions are controlled by humans. Van Itterbeek and Van Huis (2012) gave a number of examples of how to increase the predictability and availability of edible insects such as manipulating shifting cultivation and fire regimes in Africa to improve forest caterpillar exploitation. Below we give an example of the palm weevil. However, when insects are produced as mini-livestock, we can call it farming. We give an example of crickets which can be farmed by households.

1.5.1 Palm Weevil

Palm weevil larvae are one of the edible insects that are popularly eaten in different parts of the world. In Africa, the African palm weevil *Rhynchophorus phoenicis* (Coleoptera: Curculionidae) is considered a delicacy. The larvae (Fig. 1.3) are widely consumed raw, boiled, fried, smoked, and sometimes used in the preparation of stews and soups, as part of a meal or as a complete meal (Nrior et al. 2018). The African palm weevil is common in the humid lowland forest and savannah areas of Africa. It feeds mainly on oil palm, date palm, raffia palm, and coconut palm. The larvae are important pests of these plant species, due to their boring action into plant stems. Oil palms cut down for palm wine production, but also trunks of dead or wounded palms attract adult weevils. The females after mating lay their eggs in the

Fig. 1.3 African palm weevil larvae (*Rhynchophorus phoenicis*; Coleoptera: Curculionidae) sold at a local market in Yaoundé, Cameroon. (Photo by author)



trunks and when the larvae are full grown in about 4 weeks, they are harvested (Muafor et al. 2015). Traditional harvesting methods of African palm weevil larvae are very destructive to the ecosystem, as a single collector can cut down more than 1100 raffia trunks (Ayemele et al. 2016). For this reason it is studied whether the larvae can be reared. Quayea et al. (2018) showed that agro-waste materials from fruits, banana, pineapple, and millet waste can be used as alternative feed resources. Muafor et al. (2017) developed simple rearing techniques using as substrate *Raphia* palms. They were able to produce the insect year round and increase the production at least four times in comparison to the harvest obtained in the wild.

The palm weevil larvae have a high nutritional value (Cito et al. 2017; Edijala et al. 2009; Ekpo 2010; Ekpo and Onigbinde 2005, 2007; Mba et al. 2017; KOFFI et al. 2017; Lenga et al. 2012; Nzikou 2010; Okunowo et al. 2017; Omotoso and Adedire 2007; Quayea et al. 2018). Processing also influences the nutritional value; for example, grilling, roasting, or boiling increased the biological value (Ekpo 2011) and solubility of proteins (Womeni et al. 2012). Adeboye et al. (2016) developed cookies of good quality and acceptability by supplementing wheat

flour with 10% palm weevil larvae flour. Due to the high microbial (bacteria and fungi) load, adequate hygienic practices and proper processing are needed before they can be consumed (Nrior et al. 2018).

1.5.2 Crickets

Among the different species of edible insects, crickets are one of the most interesting as they have shown particular promise in addressing food and nutrition insecurity. Their high nutritional quality makes a variety of cricket species attractive for rearing. Besides their life cycle is considerably shorter than that of traditional livestock species. They also require a reduced-size rearing space and are able to recycle agricultural by-products, while having a high feed conversion ratio (Caparros Megido et al. 2017). Cricket rearing is popular in Thailand where 20,000 smallholder farms produce more than 7500 tonnes a year (Hanboonsong et al. 2013). The Flying Food project, a consortium between partners from Kenya, Uganda and the Netherlands, produced a manual for trainers who will teach small holder farmers how to setup and maintain a cricket rearing production system (Beckers et al. 2019). Also in Kenya, farming of crickets (*Acheta domesticus* and *Gryllus bimaculatus*) have been introduced for households (Ayieko et al. 2016).

In Kenya, a new cricket of the genus *Scapsipedus* (Orthoptera: Gryllidae) has been described (Tanga et al. 2018). This species has been reared for 3 years in the research facility at the International Centre of Insect Physiology and Ecology (icipe), Duduville Campus, Nairobi, Kenya. It has been demonstrated through several research activities that it is a very promising species for mass rearing for food and feed. They named the species *Scapsipedus icipe* n. sp.

1.6 Nutrition

Edible insect species in Cameroon (*R. phoenicis*, *R. differens*, *Z. variegatus*, *Macrotermes* sp., *Imbrasia* sp.) are considerable sources of fat (Womeni et al. 2009). Their oils are rich in polyunsaturated fatty acids, of which essential fatty acids are linoleic and linolenic acids. The “polyunsaturated fatty acid–saturated fatty acid” ratio is in the majority of cases higher than 0.8. The major fatty acids (occurring at more than 10%) of *R. phoenicis* are palmitic acid, oleic acid and linoleic acid while those of *G. belina* and *C. forda* are palmitic, oleic, linoleic, and stearic acids (Amadi and Kiin-Kabari 2016).

Two caterpillar species sold in South Africa and Zimbabwe had high iron and zinc, in particular iron is an important nutrient for combating anaemia (Payne et al. 2015). In the Democratic Republic of Congo the efficacy of a cereal made from caterpillars was assessed on reducing stunting and anaemia in infants at 18 month

of age (Bauserman et al. 2015). It did not reduce the prevalence of stunting, but those infants had higher Hb concentration and fewer were anaemic.

Payne et al. (2016) compared energy and 12 relevant nutrients for three commonly consumed meats (beef, pork and chicken), and six commercially available insect species (the cricket *A. domesticus*, the honeybee *Apis mellifera*, the domesticated silkworm *Bombyx mori*, the mopane caterpillar *I. belina*, the African palm weevil larva *R. phoenicis* and the yellow mealworm *Tenebrio molitor*). They used two models. According to the Ofcom model, no insects were significantly “healthier” than meat products. According to the Nutrient Value Score, crickets, palm weevil larvae and mealworm had a significantly healthier score than beef and chicken. It was difficult to draw general conclusions as there was a large variation between edible insect species in nutrient content. It seems that in the context of overnutrition meat product may be preferred over certain insect species, while in the context of undernutrition certain insects species are a better choice.

1.7 Contribution to Food Security

Niassy et al. (2016) showed a gender bias toward women and children in the collection and consumption of edible insects. Women and children play an active role in the whole value chain of edible insects including collection, processing, and packaging. By collecting they secure stocks of proteins for household consumption and generate income as has been shown for the mopane caterpillar in South Africa (Baiyegunhi et al. 2016). In Zimbabwe, the harvesting and processing of the mopane caterpillar is carried out by women and children while men in general dominate the more lucrative long-distance and large-volume trading chains, but in general the collection and marketing is carried out by relatively poor people (Kozanayi and Frost 2002). In South Africa, where the edible stink bug *Encosternum delegorguei* (Hemiptera: Tesseratomidae) is a traditional delicacy of some ethnic groups in South Africa and Zimbabwe, women control 72% of the market (Dzerefos et al. 2014).

1.8 Processing and Marketing Insects

In Kenya, termites and lake flies were collected and processed in the laboratory under different types of cooking methods such as baking, boiling, and steam cooking under pressure. The processed products, such as crackers, muffins, sausages, and meat loaf, were readily accepted (Ayieko et al. 2010). In the same country a number of processed products with crickets were developed and presented to consumers. Children were particularly attracted to biscuits and the fried foods such as fritters, samosa, and pancakes (Ayieko et al. 2016). Processing can have an effect on the digestibility and vitamin content of edible insects as was shown by Kinyuru et al. (2010) with the termite *Macrotermes subhyalinus* and the grasshopper *R. differens*. In Kenya, it was

also investigated how consumers evaluated the sensory attributes of a common bakery product (buns) that was blended with cricket flour. Providing information on the product could enhance consumer acceptance of the insect-based food (Pambo et al. 2018). However, Kinyuru et al. (2009) also showed that it depends on the concentration of insect flour in the product.

1.9 Conclusions

Although insect consumption is common in Africa, the danger exists that western food habits are copied and that insects as traditional food are being considered as a poor man's diet (Niassy et al. 2016; van Huis 2013). This seems strange as in the western world insects are now increasingly being appreciated as nutritious food and more sustainable than the common meat products (Van Huis and Oonincx 2017). Kelemu et al. (2015) called it for Africa “an overlooked food source” and she mentions with others (Kelemu et al. 2015) that “within the context of sustainable diet, the use of insects as food and feed has a significant role to play in assuring food security and improving the livelihood of the African people.” However, traditionally insects have been harvested from nature and when this food source is going to be promoted than this is not an option anymore. Insects need to be reared and urgently rearing methods need to be developed for a number of species which are highly popular in Africa. This would change the food source from being seasonal to a continuous available food item. Besides also processing methods need to be developed to make them into readily available insect-based products with a long shelf life.

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