Technical brief #2:
Insect production systems for food and feed in Kenya

GREEiNSECT
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Communities within the Lake Victoria region of Kenya have a long history of consuming insects as food (Kinyuru *et al.,* 2012, Kelemu *et al*., 2015). Insect species have traditionally been harvested seasonally from the wild. This method of collection can be unsustainable for the wider ecosystem due to overharvesting or destructive techniques (Ayieko *et al.,* 2010). Production systems that can provide consistent supply and other kinds of sustainable techniques are currently under investigation in order to establish a stable market for insects as food and feed. Currently cricket, black soldier fly and grasshopper farming for human food and animal feed has been developed by Kenyan institutions in collaboration with international partners.

This brief provides an overview of rearing systems for two cricket species (*Acheta domesticus* and *Gryllus bimaculatus*) and black soldier fly (*Hermetia illucens*). It provides an outline of facilities and management practices as well as how to rear insects under the prevailing local conditions.

Indigenous cricket species in Kenya

Research has been undertaken to learn more about wild cricket species. A survey in Nairobi County, found that the common house cricket (*Acheta domesticus*) is the most abundant cricket species. In order to obtain a more complete picture of cricket species in Kenya an extensive survey is taking place at three different elevations (Low altitude, Mid-altitude and high altitude).

Table 1: Cricket species found in Kenya and their local names

Common name	Scientific name	Local name (Kiswahili)	Local name (Luo)	Local name (Meru)	Local name (Kisii)	Local name (Luhyia)	Local name (Kikuyu)	Local name (Kamba)
House cricket	*Acheta domesticus*	Nyenje wa nyumba	Onjiri mar ot OR Onjiri matindo	Ngiriama ya nyomba	Egesiriri kia nyomba	Sistilily vyo Munzua	Ngiria ya nyumba	Ngili ya nyumba
Camel cricket	*Diestrammena japanica*	Nyenje	Onjiri mokiko rateng' gi rachar	Ngiriama ya ngamira ya mutitu	Egesiriri nyangamia nyasamo Kia orosana	Sistilily vyo muritu	Ngiria ya ngamira makanyakanya	Ngili ya Kiwanza
Two-spotted cricket	*Gryllus bimaculatus*	Nyenje	Onjiri Wenge ang'wen mar pap	Ngiriama ya meto mana	Egesiri Nyamaiso ane	Sistilily vyo tsimoni tsine	Ngiria ya maitho mana ya muritu	Ngili ya Kiwanza
Black field cricket	Teleogryllus chorpad	Nyenje	Onjiri mar rateng	Ngiriama muiru ya mutitu	Egesiri ekemwamu	Sistilily mwamu vyo muritu	Ngiria mwiru	Ngili ya Kiwanza
Giant cricket	*Brachytrupes membreneus*	Nyenje	Onjiri maduong mar kuoyo	Ngiriama munene ya mutitu	Egesiri rinani	Sistilily gunani vyo malova	Ngiria nene	Ngili nene vyu ya kithangathi
Spider cricket	*Homeogryllus reticulatus*	Nyenje	Onjiri ma bungu	Ngiriama mbuimbui ya mutitu	Egesiriri nyarombobe	Sistilily vyo muritu	Ngiria ya kiharo	Ngili ya Kiwanza
Brown Giant mole cricket	*Gryllotalpa robusta*	Chungu	Onjiri oyiech maduong ma rabuor	Ngiriama mbuko ya mutune	Egesiriri nyang'uko ekebariri	Sistilily imbuku	Ngiria huko ya gitiria	Ngili mbuku nene vyu
Rain cricket	*Gymnogryllus miorus*	Nyenje	Onjiri ma koth	Ngiriama ya mbura	Egesiri ki embura	Sistilily vyo imbula	Ngiria yambura	Ngili ya mbua
Dwarf black cricket	*Gryllus mori*	Nyenje	Onjin ma rateng'	Ngiriama munini ya mutitu	Egesiriri ekieng'e ekemwamu	Sistilily mwamu vyo muritu	Ngiriaya kiharo	Ngili ya Kiwanza

Cricket farming in Kenya

Cricket species that have shown viability in the Lake Region for both small/medium and large scale production are the Common house cricket (*Acheta domesticus*) and Field cricket (*Gryllus bimaculatus*). The two species have different advantages. Field crickets are larger in size (1.014g and 0.803g, for females and males respectively, whilst the average adult size of *Acheta domesticus* is 0.608g and 0.599g, for females and males respectively. The life cycle of *Gryllus bimaculatus* is between 6-8 weeks; however, they are more vulnerable to slight changes in environmental conditions. The Common house cricket, though smaller in size and slower in growth (10-12 weeks), is more resilient to changes of conditions in rearing environment. Some of these attributes make the two species viable for medium and large scale production. Two other local species were initially tested, but the Black field cricket (*Teleogryllus chopad)* is highly vulnerable to changes in the environment, while the Giant cricket (*Brachytrupes membreneus)* takes long to reach maturity, which makes it not yet viable for commercial production.

Production Systems

Caging System

Crickets can be reared in containers of various types such as glass cages, wooden boxes, concrete blocks or cylinders, and plastic drawers or crates. The size and number of such containers depends on the availability of space as well as the scale of production. In all systems egg cartons are used as hideouts and dry feed is placed in small plates for ease of access. The containers are covered with netting material (e.g. mosquito netting) to contain the crickets and secure them from predators such as lizards.

Figure 1: Bucket system (Photo: M. Orinda)

Figure 2: Concrete pen system (Photo: M. Orinda)

Bucket Cages for Medium-Scale Production

In this system, crickets are confined within 80 L or 100 L buckets. These buckets allow for air circulation (when ventilation is provided through small holes) and maintains temperature and humidity suitable for optimal cricket growth. The buckets are placed on elevated racks to keep away predators like spiders and lizards. Different kinds of shelters can be used for the bucket system. At the JOOUST (Jaramogi Oginga Odinga University of Science and Technology, Bondo) experimental site, trials are conducted with a basic shelter and a greenhouse. Farmers also use traditional mud houses or concrete houses. So far, mud houses provide better results due to the ability to maintain optimal temperatures during the dry and rainy seasons which, in turn, promotes cricket growth. For generating an income of up to 5000 Kenyan Shilling from cricket farming a farmer needs to have at least 30 buckets, to establish a two weeks harvesting cycle. Currently, a farmer can fetch 230 Kenyan Shilling per kg of crickets, which is comparable to the price of omena (*Rastrineobola argentea*) a species of fish found in Lake Victoria.

Figure 3: Greenhouse structure for cricket farming (Photo: M. Orinda)

Figure 4: Prefabricated housing structure (Photo: M. Orinda)

Pens for Large-Scale Production

In this system, concrete is used to build square pens that mimic small cattle dips. Trials at the JOOUST rearing facility show that it is a cost effective system and yield larger amounts of crickets in the long-term. However, unlike Thailand, where production units have to be low enough to counter high humidity and temperatures, there are variations in temperature and humidity in the current cricket farming regions of Kenya. Therefore, adaption to local climatic conditions will be required during construction of the pens.

Collaboration with farmers has shown that farmers are more reluctant to establish the pen system due to the higher initial cost of building materials and the fact that it requires more horizontal space. Few farmers use a cheap and easily available alternative to concrete (compacted soil used in construction of mud houses). By starting off with a few pens, farmers can experiment with the differences between bucket and pen systems, choosing which system works best for their household.

Table 2: Comparison of the two rearing systems

Bucket system	Pen system
Advantages: ▪ Most suitable for household and small scale cricket production. ▪ Medium carrying capacity (up to 2,5 kg per bucket per cycle. ▪ Low capital requirement compared to the pen system. ▪ Easy to disassemble for cleaning, disinfection and harvesting. ▪ Fully enclosed system that protects the crickets from predators. ▪ Lower risk of losing an entire colony in the case of disease outbreak. ▪ Retains warmth that is much needed thus boosting cricket growth during the wet season. ▪ Easy to transfer crickets in buckets from one place to another when selling or disinfecting the production unit.	**Advantages:** ▪ Suitable for especially large scale cricket production for commercial purposes. ▪ Carrying capacity up to 10 kg per cycle in a 1.5m by1.5m by 0.5m size pen. ▪ Crickets have reduced contact with faeces and are allowed some freedom of movement. ▪ Durability of well-constructed pens is high. ▪ Efficient utilization of space in pens. ▪ Fully enclosed system that protects the crickets from predators.
Disadvantages: ▪ Limited accessibility and affordability of plastic buckets for rural farmers. ▪ Plastic buckets need replacement as they depreciate. ▪ Higher possibility of overheating. ▪ Crickets have increased contact with faeces and are allowed less freedom of movement. ▪ Humidity during the wet season can cause losses among smaller crickets, due lower temperature in the buckets. ▪ Not cost-effective if farmer wants to produce beyond 30 buckets. ▪ Difficult to maintain cleanliness when too many crickets are raised in the same bucket.	**Disadvantages:** ▪ High initial cost of building materials thus more difficult to be established by most rural farmers. ▪ Running costs are higher and can be unaffordable for small scale farmers. ▪ Higher risks for whole colony in case of disease and pests. ▪ Does not make use of vertical space when land availability is a limiting factor. ▪ Cleaning and disinfecting the units requires movement of entire cricket stock.

Cricket Feed and Formulations

Feed is a significant challenge in livestock systems around the world. Providing affordable, nutritious and safe feed to crickets is an ongoing area of research, not only in Kenya, but also in other countries like Thailand (Hanboonsong et al, 2013) and Cambodia (Megido et al, 2016). The optimal composition of feed depends on the growth stage of the cricket and locally available sources of feed. Feeding trials for the GREEiNSECT project are carried out under laboratorialry conditions at ICIPE (International Center for Insect Physiology and Ecology) and under commercial conditions at JOOUST in order to identify and optimize cricket feeds based on local substrates. Experience from Thailand shows that the major constraint of rearing crickets is the high cost of commercial protein chicken feed, which constitutes around half of the production costs (Hanboosong et al., 2013).

Recent research on 42 existing cricket farms in the region of Bondo, Kabondo and Kisumu in the Lake Victoria area assessed the management and constraints of cricket feed resources. Feed substrates commonly utilized by farmers include conventionally compounded meals made from seasonally available cereals and legumes like maize, sorghum and soybeans, and indigenous vegetables such as collards, jute mallow, amaranth leaves, black night shade, cow pea leaves and spider plant.

Farmers also use forage leaves to substitute vegetables during the dry season. These include cassava, banana, sweet potato, tomato, pawpaw and moringa leaves. These feed items face high competition from other farming ventures and also compete with hungry stomachs as they are used as food for humans.

The substrates used during the laboratorial trials include: corn meal (which serves as a control as it is commonly used by the farmers), wheat bran, pumpkin leaf powder, carrot meal, fish meal and soya meal (all as treatments). The developmental time and survivorship significantly varied between food substrates. The wheat bran meal, pumpkin leaf powder meal, soya meal and fish meal gave the good results on development and survivorship, while carrot and maize meal had the slowest development and survivorship in crickets.

Way forward

The final results of the GREEiNSECT project should provide medium and large scale farmers with options for an efficient and cost effective feed regime as well as caging systems that are adaptable by using only locally available materials that are cost effective.

Cricket farming can be embraced as a mini-livestock by farmers in varied agro-ecological conditions in the lake region in Kenya (Ayieko *et al* 2016). While cricket farming can help rural communities in Kenya to build more sustainable livelihoods, it is important to note that issues such as appropriate and affordable cricket feed and rearing systems and their cost implications can prevent households from entering into production. The development of feeds that meet the crickets' nutritional requirements using locally available feedstuffs will be valuable for cricket farmers and ultimately a significant determining factor in the acceptance of this livelihood strategy.

- The bucket and pen system have advantages which offer optimal production and reduce labour costs for farmers. However the buckets are costly and their suitability for different agroecological conditions needs to be investigated.
- Cricket farming can be knowledge intensive, especially concerning cricket feed management. In order to obtain optimal production, training of farmers is required on the importance of nutritious and safe feed composition.
- Farmers are still hesitant to enter into cricket farming due to a lack of training and a lack of market outlets to sell their crickets.
- A preliminary analysis found that radio, community development organizations and chief's barazas are popular sources of information about new agricultural technologies, like cricket farming. Further outreach to rural farmers is needed in order to inform and develop interest in this livelihood strategy. This must go hand in hand with the development of domestic markets, an issue that will be the center of the next information brief.

Black Soldier Fly Farming in Kenya

Introduction:

The Black Soldier Fly (*Hermetia illucens*) is a tropical fly found in warmer regions worldwide, but considered to be a native of South America. The insect has been reported in almost 80% of the world (Dilone *et al.,* 2014). Their larvae are common detritivores/saprophytes, mostly found in compost heaps, pit latrines, human and animal cadavers and other decomposing organic matter. The larvae have significant potential uses in organic waste management, supplementing animal feeds, house fly control in homesteads and animal rearing facilities, and in forensic entomology.

Fig 1: Black Soldier Fly (*Hermetia illucens*), (Photo: A. Halloran)

Black Solder Fly in Kenya (BSF)

BSF production is not yet developed commercially in Kenya. The GREEINSECT study (conducted at JOOUST) intends to fill this void by developing a system for the farming of BSF under local conditions and using local substrates. The study intends to identify suitable organic wastes substrates that can be used for optimized production of BSF larvae for feed, and generally develop a protocol for BSF farming in Kenya.

Feeding substrates:

Trials have been on going on several locally available substrates for their potential to produce BSF larvae. Among those considered in the study include banana peelings, avocadoes, brewery waste, human faeces, potato peelings, market vegetable and fruit wastes, restaurant remnant foods. Also investigated was the effect of using mono substrates vis-à-vis combination of substrates. Variation of the nutrient content of larvae produced on different substrates is an ongoing investigation. Though the results are still raw, they are however promising. Again, the preliminary findings indicate that combining substrates performs better than using pure stock substrates due to a more balanced diet for the larvae.

Black soldier fly (larvae) farming systems:

Two general farming systems of BSF production are currently on trial at JOOUST namely:

a) An open farming system: An open larvae production structure called a larvarium is filled with rotting organic waste. The smell from the waste attracts the adult flies to lay eggs on the egg laying vessels placed on top, or at the corners of the larvarium (Figure 2). Upon hatching, the larvae neonates fall into the organic waste to feed on it and change into pre-pupa, which then instinctively crawl out of the feedstock from the slanting end of the larvarium (Figure 3). This production system was initially designed to find out the availability of BSF in the natural wild at JOOUST and it proved very successful. It has also proved to be suitable for small holder farmers of fish and or poultry, who can supplement the protein needs of their livestock with the biomass of the produced larvae without going into the complexities of feed formulation since they mostly depend on free range chicken feeding and the natural fertility of the ponds. However, the system is very much dependent on the natural availability/nativity of BSF in the area. The system is also prone to several challenges including flooding from the rains since the larvarium cannot be completely covered, predation from birds lizards, snakes and rats and therefore suffers from low volume of harvests.

Figure 6: Grooved plastic pipe (Photo: A. Halloran)

Figure 7: Carton strips for egg laying (Photo: E. Nyakeri)

Figure 8: A open wooden larvaria (Photo: A.Halloran)

Figure 9: A open plastic larvaria (Photo: E.Nyakeri)

b) Captive production system: In this system**,** a colony is maintained in captivity inside a closed building (e.g greenhouse, basic shed, see Figure 4). Adult flies are kept in a separate breeding structure to inhibit mating. The ambient temperatures within the enclosure structure should range between 26-37 ^{0}C. Under these conditions, the adult females will lay eggs within oviposting material such as grooved plastic piping material or cardboard boxes (Figure2). The eggs can be collected at regular intervals every two days and incubated in nursing containers for hatching. In the nursery, the eggs are put on substrate material. At a temperature of 30-35 ^{0}C they will hatch into small neonates after 3-4 days. The hatched neonates then drop onto the substrate and start feeding immediately. After 7-8 days (when all the eggs shall have hatched) the neonates are transferred into another part of the enclosure (known as the grow-out area) for further feeding until they reach pre-pupal stage and are ready for harvesting. The grow-out area contains larval feeding structures (Figure 5) in which the larvae are mixed with the main organic waste substrate. The moisture content should range between 40-70% humidity. The grow-out area should be as dark as possible as the larvae are photophobic.

Figure 10: A netted structure for captive breeding of a colony of Black soldier flies established at JOOUST campus, Bondo. (Photo: E. Nyakeri)

Figure 11: Small containers for farming BSF in an enclosed environment. (Photo: E. Nyakeri)

Black Soldier Fly practical applications

Though BSF larvae consume all types of organic matter, substrates for feeding BSF depends on the aim of the bioconversion process: 1) Getting rid of organic waste or 2) Production of larval biomass for animal feed. In case of animal feed production, it is necessary to use safe substrates, which minimize a risk for the food chain. Substrates under investigation include banana peelings, brewery waste, vegetable and fruit waste and restaurant food remains.

Production of larval biomass for animal feed In order to produce fresh larvae for animal feed, many small compartments/vessels may be used for production (Figure 5). The vessels are inclined at an angle of 30-45^0 in order to easily separate the mature larvae (now called prepupa) at the desired development stage. Harvesting BSF larvae prior to this stage, adds complexity to the process as they will not separate from the substrate before. To produce larvae whose skins have not yet hardened yet, the following methods are used: filtering, adding water to the larvarium, manual sorting by hand, or use of a rotating drum with a mesh screen have to be used. Pre-pupae and pupae which have a hardened skin, which is anti-nutritional due to its high chitin content.

Production of larvae for waste management: If the main goal is to dispose bio-waste and produce pre-pupae and bio-fertilizer in the process. The advantage of this system is that less monitoring is required. Feed stock can be added and pre-pupae collected continuously until the vessel is full. The system uses the natural behaviour for BSF pre-pupae to self-harvest by leaving the feed medium when mature, in search of a dark, dry place to pupate. When all larvae of the cohort have matured, the vessel can be cleaned, removing the frass and residual feed. In order to ensure continuous production, more than one holding vessel will be needed. However one incurs much loss of larval biomass as some will prefer to pupate within the dark and dry areas of the vessel and not self-harvest. These eventually emerge as adults and disappear to the wild.

Challenges for BSF production in Kenya

There are several challenges for BSF production in Kenya.

- Lack of awareness on the potential value of BSF larvae. Potential benefits as a feed source or waste manager are not yet known policy makers and the private sector.
- Breeding technology and substrate management adapted to Kenyan environmental conditions is still under investigation.
- Lack of knowledge of the management practices to employ in order to successfully raise a productive colony.
- There are no established sources of starter colonies and awareness of initiation of a colony from nature is lacking.
- Culturally, insects and, in particular, flies are looked down upon as they are associated with filth and are considered disease or pathogen carriers. Eliminating this negative attitude and association to successfully encourage breeding and embrace BSF as a useful resource.

Potential for BSF production in Kenya

- Climatic conditions prevalent in most of Kenya are suitable for the BSF production.
- An ongoing study has confirmed of the presence of natural colonies of BSF in western Kenya (Kisumu and Bondo area).
- Kenya, being primarily an agricultural country, is naturally rich in potential substrates required for BSF larvae farming.
- An informal fact finding inquiry among Kenyan feed manufacturers showed interest and readiness for an alternative source of protein for animal feeds in response to scarcity of *Rastrionela argentea* (omena in Luo).

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References

Kinyuru J.N., Konyole S.O., Kenji G.M., Onyango C.A., Owino V. O., Owuor B.O., Estambale B.B., Friis H and Nanna Roos. (2012). Identification of traditional foods with public health potential with complementary feeding in western Kenya. *Journal of Food research.* **1** (2).

Kelemu, S., Niassy, S., Torto, B., Fiaboe, K., Affognon, H., Tonnang, H., Maniania,N.K, Ekesi, S. (2015). African edible insects for food and feed: inventory, diversity, commonalities and contribution to food security. Journal of Insects as Food and Feed, 2015; 1(2): 103-119.

Ayieko M.A, Ndonga M.F.O, Tamale A. (2010). Climate change and the abundance of edible insects in the Lake Victoria region. *Journal of Cell and Animal Biology.* **4**(7): 112-118.

Hanboonsong, Y., Jamjanya, T., & Durst, P. (2013). Six-legged Livestock: Edible Insect Farming, Collecting and Marketing in Thailand. FAO, Bangkok.

Caparros Megido, R., Alabi, T., Nieus, C., Blecker, C., Danthine, S., Bogaert, J., Francis, F. (2016). Optimisation of a cheap and residential small-scale production of edible crickets with local by-products as an alternative protein-rich human food source in Ratanakiri Province, Cambodia: Local production of edible crickets in Cambodia. *Journal of the Science of Food and Agriculture*, *96*(2), 627–632. http://doi.org/10.1002/jsfa.7133

Ayieko M.A.,Ogola H.J.,Ayieko I.A. (2016), Introducing rearing crickets (gryllids) at household levels: adoption, processing and nutritional value*; Journal of insects as Food and Feed***,** Wageningen Academic Publishers, DOI: http://dx.doi.org/10.3920/JIFF2015.0080

Dilone, P.D., Habbab, M., Yanikara, F. S., and Jesus, F.K (2014). Development of a food waste compositing system using Black Soldier Fly larvae: 3rd Annual Research and Development student competition, Greenovate, NYS.

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