SEMINAR REPORT

Entomophagy: a step towards food security

By

Laya A. C.

2019-11-070

Presented on 03/01/2020

Submitted in partial fulfilment of requirement of the course

ENT 591 Master's Seminar (0+1)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY
COLLEGE OF HORTICULTURE

KERALA AGRICULTURAL UNIVERSITY

VELLANIKKARA

THRISSUR, KERALA- 680656

CERTIFICATE

This is to certify that the seminar report entitled **'Entomophagy: a step towards food security'** has been solely prepared by **Laya A. C. (2019-11-070)** under my guidance and has not been copied from seminar reports of any seniors, juniors or fellow students.

Vellanikkara
25.01.2020

Dr. Haseena Bhaskar
(Major Advisor)
Professor
Department of Agricultural Entomology
College of Horticulture, Vellanikkara

DECLARATION

I, Laya A. C. (2018-11-070) declare that the seminar entitled **'Entomophagy: a step towards food security'** has been prepared by me, after going through various references cited at the end and has not been copied from any of my fellow students.

Vellanikkara   Laya A. C.
25. 01. 2020   (2018-11-070)

CERTIFICATE

This is to certify that the seminar report entitled **'Entomophagy: a step towards food security'** is a record of seminar presented by **Laya A. C. (2018-11-070)** on 3rd January, 2020 and is submitted for the partial requirement of the course ENT 591.

Dr.Anil Kuruvila
Associate Professor
Department of Agricultural Economics
College of Horticulture, Vellanikkara

Dr. Reshmy Vijayaraghavan
Assistant Professor
Department of Plant Pathology
College of Horticulture, Vellanikkara

Dr. Sangeethakutty
Assistant Professor
Department of Vegetable science
College of Horticulture, Vellanikkara

INDEX

LIST OF TABLES

LIST OF FIGURES

1. Introduction

The world population surges ahead and is expected to reach nine billion by 2050 (FAO, 2012). Food security becomes a challenge due to growing population and limited resources. Hunger and malnutrition is already a perpetual problem in many parts of the world. As nutritional deficiency is the root cause of numerous other pathologies, ensuring adequate nourishment for all, is an urgent need. In this regard, rethinking of our food patterns and habits, particularly those relating to meat consumption is of high importance.

The word entomophagy is derived from Greek word, *Entomon* means 'insect' and *Phagein* means 'to eat.' Thus, the practice of eating insects is known as entomophagy. Insects form part of the human diet in many tropical countries. The high protein content with digestibility as well as some minerals, vitamins, fats and carbohydrates make the insects a perfect food. In fact, insects are the cheapest source of protein compared to animal meat and fish.

2. History of entomophagy

The history of entomophagy is well documented by Bodenheimer in his book, Insects as Human Food; A Chapter of The Ecology of Man (1951). According to him, the history was classified into ancient as well as modern day entomophagy.

2.1. Entomophagy in ancient times

The earliest citing of entomophagy can be found in religious literature of Christian, Jewish and Islamic faiths (Huis *et al*., 2013). In the eighth century BC, locusts arranged on sticks were served to royal banquets in the palace of Asurbanipal of Middle East. Greek literature contains a number of references of eating cicadas. The first reference to entomophagy in Europe was in Greece, where eating cicadas was considered a delicacy. Aristotle (384-322 BC) wrote in his *Historia Animalium*: "The larva of the cicada on attaining full size in the ground becomes a nymph; then it tastes best, before the husk is broken". He also mentioned that, of the adults, females taste best after copulation because they are full of eggs.

In the second century BC, Diodorus of Sicily referred people from Ethiopia as Acridophagi which meant eaters of locusts and grasshoppers. Pliny in his book *Historia Naturalis*, referred to larva of long horned beetle, a dish highly coveted by Romans. Kamal-Ad-Din Ad- Damiri (1341-1408) in his great zoological lexicon discussed the 'lawfulness and unlawfulness' of eating insects. Literature from ancient China also cites the practice of entomophagy. Li Shizhen's Compendium of *Materia Medica* (1368 -1644), a book on Chinese medicine during the Ming Dynasty in China, displays an impressive record of a large number of insects which were used as food as well as for medicinal purposes.

2.2. Modern-day entomophagy

Ulysse Aldrovandi, is considered the founder of the modern-day study of insects. His treatise, *De Animalibus Insectis Libri Septem*, published in 1602, discussed the practice of consuming fried silkworms by German soldiers in Italy. David Livingstone and Henry Morton Stanley featured stories of entomophagy in Africa, which were instrumental in introducing it to the Western countries. In 1857, German explorer Barth Heinrich, wrote in his book Travels and Discoveries in North and Central Africa "enjoy not only the agreeable flavour of the dish, but also take a pleasant revenge on the ravagers of their fields". American entomologist Charles Valentine Riley, appointed in 1868 as the first state entomologist of Missouri, to study the plague of Rocky Mountain locusts (*Melanoplus spretus*), advocated controlling by simply eating them.

V.M. Holt had important role in popularizing entomophagy through his small booklet published in 1885 titled *'Why Not Eat Insects?'* Holding such an opinion in 1885, Holt was clearly ahead of his time and entomophagy was never widely adopted into English food culture.

Since 2003, FAO has been working on topics pertaining to edible insects in many countries worldwide in order to promote the practice of entomophagy.

3. Edible Insects

Providing definitive figures on the number of edible insect species worldwide is difficult. Yet, Jongema (2012) conducted a worldwide inventory and listed 1900 edible insect species.

Fig 1: Distribution of edible insect species of the world

3.1. Major group of edible insects

Globally, 31 per cent of edible insects belong to the Coleoptera which comprises 40 per cent of all known insect species. This include scarab beetle larva, palm weevil grub, mealworm larva *etc*.The consumption of Lepidoptera is estimated as 18 per cent which include silkworm pupa, mopane moth caterpillar, bamboo borer caterpillar, agave red worm. Third comes Hymenoptera (14%) consisting of hornet larva, larva and pupa of weaver ant and leaf cutter ant, grubs and pupa of honey bee. Thirteen per cent of edible insects belong to Orthoptera which include grasshoppers, locusts and crickets, followed by Hemiptera, Isoptera, Odonata and Diptera (Huis *et al.*, 2013).

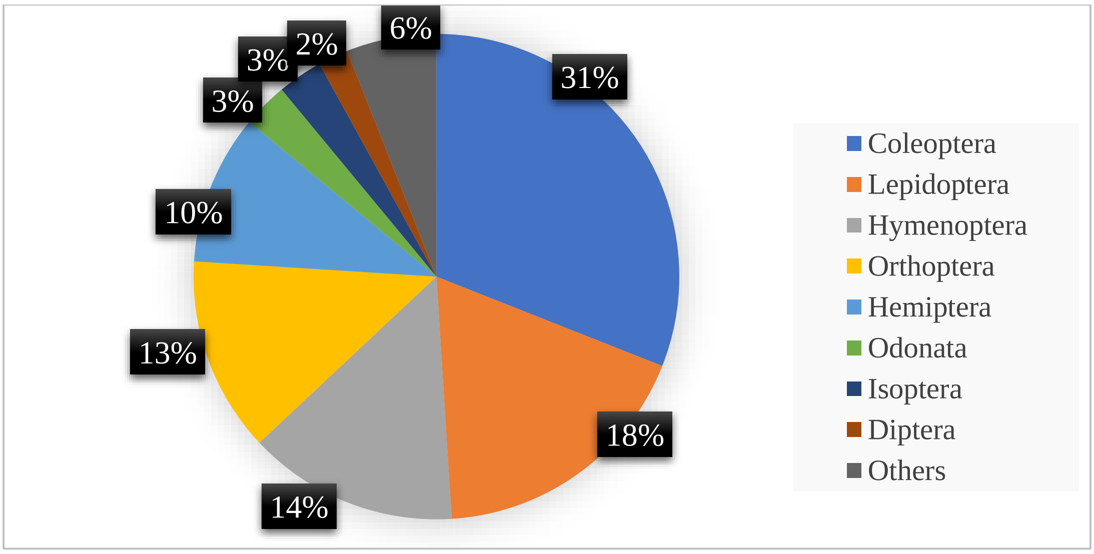

Fig 2: Order-wise distribution of edible insects

3.2. Edible insects in India

According to Chakravorty (2014), Arunachal Pradesh has the highest number of edible insect species in India with 158 species reported. Manipur and Nagaland has 41 edible insect species each, followed by Assam, Meghalaya, Kerala, Karnataka, Madhya Pradesh, Orissa and Tamilnadu. Five edible insect species were reported from Parambikulam region of Kerala, which include larva of *Apis dorsata, Apis cerana indica, Apis floreae,* egg and pupa of *Oecophylla smaragdina* and adult of *Patanga succinata* (Yesodharan *et al.*, 2011).

4. Opportunities for insects in human food

Feeding the growing world population with more demanding consumers will necessarily require an increase in food production. This will inevitably place heavy pressure on already limited resources. In most countries, livestock and fish are considered important sources of protein. Global demand for livestock products is expected to be more than double between 2000 and 2050 (from 229 million tonnes to 465 million tonnes), meeting this demand will require innovative solutions. Large-scale livestock and fish production facilities are economically viable because of their high productivity. However, these facilities incur huge environmental costs. This widens the opportunity for insects as an alternative source of protein. The adoption of insects as a food source can be broadly based on three reasons namely environmental benefits, nutritional benefit and socio-economic benefit.

4.1. Environmental benefits

Environmental benefits of edible insects include, high feed-conversion efficiency, low emission of greenhouse gases and less water as well as land requirement.

4.1.1. Feed conversion efficiency

Feed that is required to produce one kilogram increase in body weight is known as feed conversion efficiency, represented as feed conversion ratio. The feed conversion ratio varies depending on the animal reared and also the production method followed. As demand for meat rises, so does the need for grain and protein feeds. Pimentel and Pimentel (2003) reported that for production of one kilogram of high-quality animal protein, about six kilogram of plant protein was required. Insects require far less feed when compared to conventional livestock.

The advantage of eating insects becomes even greater when feed-to-meat conversion rates are adjusted for edible weight (Huis, 2013). Nakagaki and De Foliart (1991) estimated that, up to 80 per cent of a cricket is edible and digestible compared with 55 percent for chicken and pigs and 40 per cent for cattle. When edible weight is considered, crickets are twice as efficient in converting feed to meat as chicken, at least four times more efficient than pigs, and 12 times more efficient than cattle. This high feed conversion ratio may be due to the fact that insects are cold-blooded and do not require energy expenditure to maintain body temperature.

Table 1: Feed Conversion Ratio (FCR): cricket v/s livestock

Particulars	**Cricket**	**Poultry**	**Pork**	**Beef**	**Reference**
Edible portion (%)	80.0	55.0	55.0	40.0	Nakagaki and De Foliart, 1991
FCR (live weight)	1.7	2.5	3.0	10.0	Huis, 2013
FCR (edible weight)	2.1	4.5	9.1	25.0	

4.1.2. Greenhouse gas (GHG) emission

Livestock rearing is responsible for 18 per cent of GHG emissions, a higher share than the transport sector. Methane (CH_4) and nitrous oxide (N_2O) are produced from livestock rearing, due to enteric fermentation and from farm animal manure respectively. Both methane and nitrous oxide have greater global warming potential than carbon dioxide; CH_4 has 23 times and N_2O 289 times higher global warming potential than carbon dioxide. Among insect species, only cockroaches, termites and scarab beetles were reported to produce CH_4 in a negligible quantity (Hackstein and Stumm, 1994), which is due to bacterial fermentation by Methanobacteria in the hindgut.

Oonincx *et al*. (2012) conducted a study for estimating the contribution of insects, mealworm, *Tenebrio molitor* (5th instar), house cricket, *Acheta domesticus* (5th & 6th instar) and migratory locust, *Locusta migratoria* (3rd & 4th instar) in greenhouse gas (methane and nitrous oxide) production. Additionally, ammonia emissions and average daily gain (ADG) were studied for estimation of feed conversion efficiency.

Insect species was housed in two cages and kept in respiration chamber measuring 80×50×45 cm (volume of 265 litres for three days). Six replications were maintained per species. Humidity, temperature, day length and diets were based on rearing conditions used by commercial insect rearing companies.

Concentrations of CO_2 and CH_4 were measured every nine minutes in the ingoing and outgoing air stream of the respiration chambers. The differences in concentration between ingoing and outgoing air represent the total production of gases by the insects. Non dispersive infrared analyzers were used to measure exact concentration of CO_2 and CH_4. Air samples were taken from respiration chamber, as well as from the incoming air, for N_2O analysis after 24, 48, and 72 hours with a 60 ml syringe and concentration was analysed using a gas chromatograph. Concentration of NH_3 in the respiration chambers were determined twice daily by means of a gas detection tube system. Average daily gain (ADG) was calculated using formula:

$$ADG = \frac{\text{End mass - Start mass}}{3 \times \text{Start mass}} \times 100$$

(where, 3 is the number of days the experiment was running)

Table 2: CH_4, N_2O and NH_3 production per kilogram of mass gain

Insect	**CH_4 (g/kg mass gain**	**N_2O (mg/kg mass gain**	**NH_3 (mg/kg mass gain)**	**ADG (%)**
Mealworm	0.1	25.5	1.00	7.3
House cricket	0.0	5.3	142.0	7.2
Migratory locust	0.0	59.5	36.0	19.6
Pig	1.92-3.98	106-3457	1140-1920	3.2
Beef cattle	114	N/A	N/A	0.3

(Oonincx *et al*., 2012)

The study indicated that, insects had lower emission of greenhouse gases when compared with pigs and beef cattle. Also, the higher average daily gain of insects indicate efficient feed to meat conversion. Insects being poikilotherms, do not use their metabolism to maintain a body temperature within narrow ranges, contrary to homeothermic animals. This is expected to result in higher feed conversion efficiencies.

4.1.3. Water requirement

Water is a key determinant of land productivity. Water scarcity is already constrain in many parts of the world. As per the estimate, by 2025, 1.8 billion people will be living in regions with absolute water scarcity (FAO, 2012). Production of one kilogram of animal protein require 5-20 times more water than to produce same amount of grain protein. This figure approaches 100 times more if the water required for forage and grain production is also included (Pimentel and Pimentel, 2003). According to Pimentel *et al*. (2004), production of one kilogram chicken requires 2,300 litres of water, pork requires 3,500 litres and beef requires 22,000 litres, whereas, crickets require less than 6 litres of water.

4.2. Nutritional benefits

The nutritional values of edible insects are highly variable, not only between the species but varies within the same group of edible insect species, depending on the metamorphic stage of the insect, their habitat and diet. Preparation and processing methods (e.g. drying, boiling or frying) applied before consumption will also influence the nutritional composition of edible insects.

The International Network of Food Data Systems (INFooDS), established in 1984, provide worldwide availability of food analysis data. The version of the INFooDS Food Composition Database for Biodiversity, launched on 15th December 2010, included the nutritional values of some edible insects (Huis *et al*., 2013).

Rumpold and Schluter (2013) compiled nutrient compositions for 236 edible insects. Many of the edible insects provide satisfactory amounts of energy and protein, meet amino acid requirements for human and are high in monounsaturated and/or polyunsaturated fatty acids and are rich in micronutrients such as copper, iron, magnesium, manganese, phosphorous, selenium and zinc (Huis, 2013). A comparative study of amino acids in beef and mealworm larva revealed that mealworms are higher in isoleucine, leucine, valine, tyrosine and alanine, glycine and proline than beef and has comparable amount of threonine, cistene and serine (Huis *et al.*, 2013).

Table 3: Amino acid content - Mealworm larva v/s beef

Essential Amino acid	Meal worm	Beef	**Non-essential Amino acid**	Meal worm	Beef
	g/kg dry matter			g/kg dry matter	
Isoleucine	24.7	16	Alanine	40.4	30
Leucine	52.2	42	Aspartic acid	40.0	52
Lysine	26.8	45	Cysteine	4.2	5.9
Methionine	6.3	16	Glycine	27.3	24
Phenylalanine	17.3	24	Glutamic acid	55.4	90
Threonine	20.2	25	Proline	34.1	28
Tryptophan	3.9	-	Serine	25.2	27
Valine	28.9	20			

(Huis *et al.*, 2013)

Miglietta *et al.* (2015) conducted a study and showed that protein content of mealworm was higher than that of conventional livestock and the energy content was found to be higher in mealworm larvae except in case of beef.

Table 4: Livestock v/s mini-livestock

Particulars	**Meal worm larva**	**Pig**	**Chicken**	**Beef**
Protein (g/ kg edible wt)	186	105	127	138
Energy (kcal/kg)	2056	1520	1190	2820

(Miglietta *et al.*, 2015)

4.3. Socio-economic benefits

Harvesting and raising of insects involves low technology and capital investment, which make it a possible option for even the poorest sections of the society. Raising insects provide opportunities for subsistence for both urban as well as rural population (Govorushko, 2019). These economic and social factors make edible insects more desirable than conventional livestock.

5. How to procure edible insects?

The edible insects can be obtained in three ways namely wild harvesting, semi-domestication and farming. At present, edible insects worldwide are sourced predominantly by wild harvesting and 92 per cent of known species of edible insects are obtained through this method. Six per cent of edible insects species are considered to be semi-domesticated, and only two per cent of the species are reared (Yen, 2009). Even though a lower percentage of the edible insects are obtained by rearing and semi domestication, these methods are considered to be most productive method as they have huge potential to provide a more stable supply (Govorushko, 2019).

5.1. Wild harvesting

Wild harvesting is the most ancient and most labour-consuming method that require experience and awareness of the seasonal and diurnal availability for harvesting. For example, the stink bug *Nezara robusta* in southern Africa are harvested early in the morning when it is not hot and the insects are inactive, they are then shaken down from the branches of trees using a long bamboo stick with a bag attached at the end. Various appliances using light or sound that improves harvesting efficiency are developed.

Bamboo caterpillars were traditionally collected from wild by cutting down entire bamboo clumps which was considered as a destructive and wasteful method. Later, a sustainable method of harvesting of bamboo caterpillars by slicing the specific infested internode without cutting the whole plant is practiced by local people in the north of Thailand. Collection is carried out by cutting rectangular hole approximately 9x13 cm^2 at specific internodes hosting caterpillars. The denseness of an internode indicate the presence of bamboo caterpillars. The best time for collecting bamboo caterpillars is around January to April, when bamboo caterpillars can be obtained from the specific internode and the infested bamboo culm can be harvested for later utilization.

Usually weaver ants, *Oecophylla smaragdina* are harvested from trees in the wild. Eggs, larvae, pupae and sometimes even adults are consumed. In north and northeast Thailand the season for weaver ants' harvesting usually occurs once a year during the dry season between February and May. During this period the arboreal nests of the weaver ants are full of eggs, larvae and pupae. Harvesting of weaver ants is undertaken using a long bamboo pole with a bag or basket attached with strings to the tip of the pole. A hole is poked into the nest with the tip of the pole and it is shaken so the larvae and pupae are emptied into the basket. Then the bag is poured onto a plate or container and some rice or tapioca flour is added to prevent the ants from climbing up to bite the collector.

5.2. Semi domestication

Knowledge on the biology and ecology of an insect species lead to development of better tools to collect them. Insects produced in semi domestication are not isolated from wild populations because it is possible that the insect can infest planted host from the wild population. Thus they are available in the wild and are generally not grown in captivity. Semi domestication enable manipulation of an edible insect's habitat and these manipulations intended for producing edible insects are considered useful as first step towards a more controlled production.

Semi-cultivation has many benefits, most importantly, ensuring the availability and predictability of edible insects. The activities surrounding semi cultivation have the potential to contribute to both edible insect habitat conservation and food security. In the tropics, emphasis should be placed on maximizing the productivity of semi cultivation practices already in place and also developed for other edible insect species.

A classic example of semi-domesticated insects is of palm weevils *Rhynchophorus palmarum* in Central and South America as well as in Africa. Palm weevil prefer to deposit eggs in exposed inner palm tissues rather than on the surface of the palm trunk. Thus manipulating the host plant by making wedge-shape cuts in the palm trunks facilitate the colonization of *R. palmarum* larvae in these trunks. They may return occasionally before the harvest to check on the larval development. Counting the days or examining the colour change of sawdust, which turns a darker orange-yellow colour expelled from the bore hole serve as indicator for harvesting.

In Mexico, the eggs of aquatic true bugs (*Corisella* spp., *Corixa* spp., *Notonecta* spp., *Lethocerus* spp. *etc.)* are considered as a delicacy. These bugs lay eggs on aquatic vegetation. Habitat modification is by providing bundles of twigs or grasses which serve as site for egg laying. These bundles are pressed down to the bottoms of water bodies with the help of stones. After that, the females lay eggs on these bundles; the eggs can easily be harvested by shaking of the bundles.

In Bas-Congo, Democratic Republic of the Congo, locals reintroduce caterpillars such as Emperor moth, *Cirina forda* from wild to Acacia trees near the houses and allow the caterpillars to grow until they are ready to eat. Some of the caterpillars can be left to pupate. These will develop into adult butterflies, which will lay their eggs in the same area. In this way a caterpillar supply is ensured for the following season (Latham, 2003).

5.3. Insect farming

The concept of insect farming is relatively new. Most edible insects are harvested in the wild, but a few insect species have been domesticated because of their commercially valuable products. Insects are reared in a designated area and the insects living conditions, diet and food quality are controlled. Farmed insects are kept in captivity, isolated from their natural populations. Insect farming for human consumption has been undertaken in both tropical and temperate countries. An example of the tropical country is Thailand, one of the few countries in the world which has developed insect rearing sector for food industry. Thailand is well known for its cricket farming with, more than 20,000 insect farming enterprises. Among temperate countries, the Netherlands and France are leaders, and the Netherlands alone having eighteen companies producing edible insects. Kreca, Meertens and vande Ven are the renowned companies which produce insects for human consumption. Some of the commonly farmed insects are grasshoppers, crickets, mealworm, palm weevil *etc.*

According to van Huis *et al.* (2013) characteristic features required for the selection of insects for farming are: (1) Short reproduction cycle; (2) High reproductive rate; (3) High survival rates; (4) High nutritional value; (5) Potential for storage; (6) Possibility to manipulate the habitats; (7) Ease of cultivating host plants; (8) Marketability and (9) Favourable cost-benefit ratio.

5.3.1 Cricket farming

Cricket farming in Thailand was initially started in 1998. The farming technology was developed by entomologists at Khon Kaen University in the northeast. The technology was then disseminated to other parts of the world. At the start of technology development for cricket farming, three common cricket species (*Gryllus bimaculatus*, *Teleogryllus testaceus* and *Teleogryllus occipitalis*) which are all native to Thailand, were introduced to farmers. Later on the native species were replaced by the house cricket, *Acheta dometicus* introduced from temperate regions of Europe and the United States. Even though the period of development of the two cricket species is similar, farmers prefer house crickets rather than native cricket species. This is because house crickets have a better taste, as the females have large number of eggs inside their abdomens and the eggs are delightfully crunchy (Hanboonsong, 2013).

5.3.2. Cricket farming technique

Cricket breeding techniques have not changed much since they were first introduced. Four type of breeding containers are commonly used in cricket farming techniques. These are (1) concrete cylinder pen; (2) concrete block pen; (3) plywood box; and (4) plastic drawers.

Concrete cylinder pens: Concrete cylinders, usually employed for water drainage are used in cricket farming. These are approximately 80 cm in diameter and 50 cm high. The number of units per farm ranges from 20 to 150 pens. They can produce around two to four kilograms of cricket. These are inexpensive, easy to maintain and suitable for small to medium size farms. However, they cannot be moved easily and require considerable space.

Concrete block pens: Concrete pens are popular and commonly used in many farms. They are rectangular in shape and are interconnected. Size of pen depend on space availability, 1.2 x 2.4 x 0.6 m is common. The number of blocks varies from 5 to 100 per farm. Each pen can produce 25 to 30 kg of crickets. They are suitable for medium to large-scale farms. The rectangular shape is an efficient way of using space.

Plywood boxes: These boxes resemble the concrete blocks and are usually made from plywood board. They are about 1.2 x 2.4 x 0.5 metres in size and produce 20 to 30 kilogram of crickets. The box is elevated off the ground by four legs. The unit is movable, easy to clean and does not build up heat as the concrete block pens. The boxes are less durable since plywood is sensitive to heat, cold or damp weather conditions.

Plastic drawers: These are made from plastic sheets and has dimension of 0.8 x 1.8 x 0.3 metres. A set of drawers can be stacked on a shelf and each drawer can produce 6 to 8 kilogram of crickets. They need very little space and are suitable for small and medium size farms. They are easy to maintain and can be moved. But plastic deteriorates and needs replacing. Furthermore, crickets stored in the top drawers have a high mortality rate due to overheating.

After selection of breeding container, bedding is made in the container using a layer of rice husk or cardboard egg cartons. Sometimes the whole setup is covered with mosquito nets to keep crickets in and predators out. In order to start a culture, eggs are either bought from another cricket farmer or by catching adult male and female crickets from the wild and keeping them in a closed container with bowls containing a mixture of husk and sand for egg-laying purposes. The number of egg bowls required depend upon the type, size and number of breeding tank used. Thirty five bowls of egg is required per concrete tank of size 2.2 x 4.8 x 0.6 metres. One egg bowl can approximately produce three kilogram of adult crickets. From hatching up to 20 days chicken feed with 21 per cent protein is provided. And afterwards mixed protein diet having both 14 and 21 per cent protein is given to the crickets. When the male stridulates, which is the mating call for females, bowls containing husk and sand should be provided for egg laying. The duration of egg laying is 7-14 days. The egg bowl should be moved daily to another tank for incubation and hatching, which occur within 7-10 days at normal condition. After mating period is completed it can be harvested, usually after 40-45 days life period. Prior to harvesting (few days before), crickets are fed with vegetables such as pumpkins, cassava leaves, morning glory leaves and watermelons to improve their taste.

6. Processing edible insects

After being harvested, the insects should be processed for human consumption. It can be processed and consumed in three ways: (1) Whole insects; (2) Ground or paste form; (3) Extraction of particular food component like protein (Obopile and Seeletso, 2013).

Whole insects: Eating insects intact is more common in tropical countries. However, for insects such as grasshoppers and locusts and adult beetles, some of their body parts are to be removed before consumption. When insects are consumed in the unchanged form, further processing by frying, roasting, drying *etc.* are practiced. Some insects like stink bugs, crickets, caterpillars, mealworm, grasshoppers, locusts *etc.* can be consumed as whole insects.

Ground or paste form: Processing into the granulated and paste forms is more often used in countries where consumers are not familiar in eating insects as whole. Powdered or paste form is better accepted by the consumers. For instance, Europe has been producing typical foodstuffs from homogenized insects like patties, pasta and bread. Grinding or milling is normal methods for processing of a great number of products. In Thailand and Laos, powder of the ground giant water bug (*Lethocerus indicus*) is the main ingredient of a very popular chilli paste.

Extraction of protein: The average protein content in insects is 60 per cent. Isolating and extracting insect protein is desirable to increase the protein content of a food products. However, supplementing food products with insect protein requires extensive knowledge of the properties of the extracted proteins. These properties include, amino acid profile, thermal stability, solubility, gelling, foaming and emulsifying capacity. In most cases, the proteins are extracted from the insects, but the extraction of fats, chitin, minerals, and vitamins is also possible. As of now, processes for extraction of individual food components are expensive, and the further development of cost-efficient and practical methods for their commercial use is needed.

6.1. Processing technology

The edible insect industry is moving ahead and the demand for new insect products are also growing. Under this scenario, it is necessary to review the main technologies used. Although the number of existing processes in the edible food industry is enormous and varies depending on the species used and the final product to be developed, most of them can be grouped into a relatively small number of operations with the same basic principles. Blanching and drying are two common technology used in processing of edible insects (Lalanne *et al*., 2019).

6.1.1. Blanching

Blanching is a process where insects are placed in boiling water for a short period, removed, and then plunged into ice water or cold running water in order to stop the thermal process. It is used as a pre-treatment for most commercialized edible insects to reduce microbial counts and to inactivate degradative enzymes responsible for food spoilage. Blanching minimizes the microbiological risks associated with the consumption of edible insects. Blanching significantly reduces total counts of mesophilic bacteria and of yeast and moulds; however, it is ineffective at eliminating, or even reducing, mesophilic bacterial spores.

Blanching has also been reported to reduce counts of lactic acid bacteria and total psychrotrophic bacteria (Vandeweyer *et al.*, 2017).

Table 5: Blanching treatments in some common edible insects

Insect	**Treatment**	**Result**
Tenebrio molitor	Boiling water - 10, 20 or 40s	No enterobacteria No yeast or mould
Acheta domesticus	Boiling water - 4 min	Reduced microbial count
Macrotermes spp.	Boiling water - 1 min.	Reduced microbial count No yeast or mould

(Lalanne *et al*., 2019)

6.1.2. Drying

Drying is the commonly used processing technology for increasing the shelf-life of foods. Drying techniques can be traditional methods like roasting, frying and sun-drying. Also modern methods like freeze-drying, microwave-assisted drying *etc*. are also used. Drying reduce the total water content and thus, its availability for degradative reactions and reactions initiated by spoilage microorganism. Microbial growth depends directly on water activity (aw). Most of the microorganisms stop growing at aw less than 0.65. When aw is low, microorganisms show slowed growth, and when water conditions are appropriate, they can start growing again.

Table 6: Drying treatments in some common edible insects

Insect	Treatment	Condition
Rhynchophorus phoenicis	Solar drying Oven-drying Smoke-drying	5 days 50°C/48hr 6hr
Imbrasia epimethea	Oven-drying	80°C/8hr
Ruspolia differens	Freeze-drying	- 50°C/0.40bars/48hr
Tenebrio molitor	Oven-drying (Hot air drying) Freeze-drying	60°C/24hr or 80°C/7hr 0.2mbars/48hr

(Lalanne *et al*., 2019).

6.1.2. Processing method for long term storage of edible insects

Effect of processing technology on storage was studied by Adamek *et al*. (2018) with an aim to detect and compare the microbiological characteristic of long-term storage of edible insect products and to identify the suitable processing method for storage. Insect samples for the determination of microbiological parameters were obtained from Mendel University, Brno in Czech Republic and the insects were: mealworm, *Tenebrio molitor* (larva), field cricket, *Gryllus assimilis* (nymph) and migratory locust, *Locusta migratoria* (adult). Insects were either freshly killed and stored for one year or freezed and stored for five years or killed by boiling water followed by drying at 103^{0}C for 12 hours and homogenization.

To evaluate microbiological parameters, different types of growth media were used specifically. For total count of mesophilic microorganism, Plate Count Agar (PCA) was used. Enterobacteria were evaluated using the Violet Red Bile Agar (VRBA) growth medium, lactic bacteria (*Lactobacillus* spp.) by De Man Rogosa Sharpe Agar (MRS Agar) and yeasts and moulds using growth medium Chloramphenicol Yeast Glucose Agar (CHYGA).

Microbial analysis was conducted by homogenizing the insect sample in 50 ml PPS (Physiological Peptone Solution). Subsequently for homogenization, the insect was put into the homogenization bag with 50 mL of sterile PPS solution. Decimal dilution up to 10^{-5} using these homogenized sample were prepared in PPS solution (1g peptone and 8.5g of NaCl in 1000ml water). Streak-plate inoculation was done out of each dilution, using 0.1 ml of inoculum on specific growth media. Colony forming units, which grew in the petri dishes on the growth media, were counted after the cultivation period.

Table 7: Microbiological characteristic of selected insect species

Insect	**Microbial characteristic**	**Freshly killed cfu / g**	**Frozen cfu / g**	**Dried cfu / g**
Tenebrio molitor (Larva)	TMC	2.2×10^{8}	3.4×10^{7}	5.4×10^{3}
	Ent.	1.9×10^{8}	4.2×10^{6}	<10
	LAB	7.2×10^{7}	2.4×10^{5}	2.6×10^{3}
	Y&M	8.9×10^{3}	3.3×10^{4}	1.5×10^{3}
Gryllus assimilis (Nymph)	TMC	3.3×10^{6}	4.7×10^{6}	7.1×10^{3}
	Ent.	3.5×10^{4}	2.6×10^{5}	<10
	LAB	5.8×10^{6}	5.0×10^{5}	2.2×10^{3}
	Y&M	4.4×10^{5}	5.1×10^{5}	6.0×10^{3}
Locusta migratoria (Adult)	TMC	2.8×10^{5}	1.9×10^{6}	7.3×10^{3}
	Ent.	1.5×10^{5}	6.0×10^{4}	<10
	LAB	1.5×10^{4}	1.5×10^{4}	1.6×10^{4}
	Y&M	$< 2.2\times10^{2}$	1.5×10^{4}	2.6×10^{3}

(Adamek *et al*., 2018)

TMC- Total microbial count, Ent. – Enterobacteria, LAB - *Lactobacillus* spp., Y&M; Yeast and mould

The result revealed that, in *Tenebrio molitor* drying is more effective than freshly killed since it has 10^5 fold reduction of total microbial count. Similarly in *Gryllus assimilis* and *Locusta migratoria*, total microbial count reduces 10^3 fold and 10^2 fold respectively, during drying compared to freshly killed insects. In the case of all species of insect studied, after drying, the number of enterobacteria reduced below the detection limit. Heat treatment reduced the number of lactic acid bacteria in all the samples probably due to the decrease in water activity except in locust. Drying also reduced yeasts and mould count. There is no significant reduction in microbial count when processed by freezing. Also, yeasts and mould were found to be resistant to low temperatures.

The study suggests that, it is not good to consume insect in the freshly killed state. It is possible to reduce microbial risk originating from edible insect by following proper processing techniques along with good storage conditions. It was concluded that, for long-term storage, the most appropriate processing method is to kill the insect using boiling water followed by drying at 103°C for 12 hours and subsequently hermetically pack it.

7. Challenges of using insects as food

Even though use of insects as food brings many advantages, not all insects are safe to eat. In developing and less developed countries, legislation is nearly absent. Thus there is an issue of food safety. Microbial, chemical, physical toxicological risk and allergic risks should be considered when insects are selected for human consumption. Also, there are risks caused by consumption of insects in the inappropriate developmental stage or incorrect culinary preparation. But there are no death reported due to consumption of insects (Ji *et al*., 2009).

7.1. Microbial risk

Some of the edible insects are found associated with microorganism which cause health issues in humans. For example, Cossid moth, *Comadia redtenbacheri* (known in its larval stage as agave red worm) is traditionally used as food in Mexican cuisine. Some larvae show signs and symptoms of infection by various bacteria (*Pseudomonas aeruginosa*, *Acinetobacter calcoaceticus*, *Bacillus cereus etc.*), which carries a potential risk to human health (Hernandez-Flores *et al*., 2015).

7.2. Chemical risk

Also, there are cases of histamine poisoning due to ingestion of fried insects. Histidine, which is present in high concentration in grasshoppers and silkworm pupae, is decarboxylated by bacteria to histamine, a heat stable toxin. The ingestion of histamine is responsible for poisoning (Chomchai and Chomchai, 2018).

7.3. Toxicological risks

Some insect species considered toxic are eaten after taking precautionary measures. Yellow mealworms (*Tenebrio molitor*) can be grown on diets composed of organic by-products. However, when these diets could be contaminated with mycotoxins that can be a reason for poisoning (Broekhoven *et al*., 2017).

Tessaratomid, *Encosternum* (*Natalicola*) *delegorguei* in Zimbabwe and South Africa excretes a pungent fluid (Bodenheimer, 1951) that can cause severe pain and even temporary blindness if it comes into contact with the eyes. Therefore, the insect is consumed after removal of the fluid by squeezing the thorax and placing the bug in tepid water.

7.4. Physical risk

Some edible insects possess physical threat to human beings. For instance, the large spines on the tibia of locusts and grasshoppers may cause intestinal constipation. The legs of such insects must be removed before consumption in order to avoid such risks.

7.5. Allergic risk

Like most protein-containing foods, arthropods can induce allergic reactions in sensitive humans. The potential allergenicity of insects could be associated with body components such as the haemolymph and cuticle, as well as body parts including exuviae, hairs, setae, and scales (Sun-Waterhouseetal., 2016). The species reported to have caused allergic reactions were ghost moths, mopane worms *etc*. In China, allergic reactions after consuming silkworm pupae, cicadas and crickets have been reported which are potential cause of skin itch, urticaria and dizziness (Feng *et al*., 2018).

8. Future of entomophagy

Recent advances in research and development show edible insects to be a promising alternative for the conventional production of meat, for direct human consumption and also as indirect use as feedstock. Nevertheless, a tremendous amount of work still needs to be done by and over many years to fully realize the potential that insects offer for food and nutritional security. In the future, as the prices of conventional animal proteins increase, insects will become cheaper source of protein than conventionally produced meat and fish. For this to occur, there need to be significant technological innovation and changes in consumer preferences. Considering the current protein demand, an immense amount of insect biomass will be required, so automated mass rearing units that produce stable, reliable and safe products need to be developed. Most of the countries do not have any legal or regulatory framework, thus food safety of insects is not assured. Developing of legal framework at the national and international level pave way for easier trade of insect based products. For the success of any venture, close collaboration of government, industry and academia is an essential factor.

9. Conclusion

Insects form part of the human diet in many countries and regions of the world, their consumption is often not promoted and western dietary patterns seem to be dominant. In future, meat centric diets will become increasingly expensive and grain-livestock systems environmentally unsustainable. So, including insects in human diet could contribute to food security and be an effective solution to the meat crisis. As entomophagy is in its early stages, and given due impetus, it can play significant role in quenching world hunger without putting strain on the environment.

10. Discussion

1. How many species of edible insects are reported in India?
   About 300 species are reported from India. Arunachal Pradesh alone has reported to have 158 edible insect species.

2. Which are the major insect species consumed worldwide?

Order	**Insect**	**Stage**
Coleoptera	Scarabid beetle, Palm weevil, Mealworm	Grub
Lepidoptera	Mopane moth, Bamboo borer, Emperor moth Silkworm	Caterpillar Pupa
Hymenoptera	Hornet, Weaver ant, Leaf cutter ant, Honey bee	Larva
Orthoptera	Crickets, Grasshoppers, Locusts	Nymph and adult
Hemiptera	Stink bug Giant water bug	Adult Egg
Isoptera	Termites	Adult

3. What you mean by stridulation?

   Stridulation means sound production. Male crickets when attained reproductive age will produce sound which is considered as the mating call for the female cricket.

4. What are the steps in protein extraction?

   The main steps involved in protein extraction from insects are:

   a) Homogenisation
   b) Defatting
   c) Protein solubilisation
   d) Isoelectric precipitation of the proteins
   e) Protein resolubilisation

5. Why do people not eat insects?

   The reasons of not practising entomophagy may be psychological, social, religious, anthropological *etc.* Food preferences formed in childhood itself and is difficult to change. Also people consider insects as unhygienic.

6. If you got a chance to eat an insect, which one do you eat?

   If I got a chance, I will go for some insect based products like bread or pasta.

References:

Adamek, M., Mlcek, J., Adamkova, A., Suchankova, J., Janalikova, M., Borkovcova, M., and Bednarova, M. 2018. Effect of different storage conditions on the microbiological characteristics of insect. *Potr. S. J. Food Sci*. 12: 248-253.

Bodenheimer, F. S. 1951. Insects as Human Food; A Chapter of the Ecology of Man. Dr. W. Junk Publishers, The Hague, 69p.

Broekhoven, S., Gutierrez, J. M., De Rijk, T. C., De Nijs, W. C. M., and Van Loon, J. J. A. 2017. Degradation and excretion of the Fusarium toxin deoxynivalenol by an edible insect, the yellow mealworm (*Tenebrio molitor* L.).*World Mycotoxin J.* 10(2): 163-169.

Chakravorty, J. 2014. Diversity of edible insects and practices of entomophagy in India: an overview. *Biodivers. Biopros. Dev*. 1(3): 1-6.

Chomchai, S. and Chomchai, C. 2018. Histamine poisoning from insect consumption: an outbreak investigation from Thailand. *Clin. Toxicol*. 56(2): 126-131. Available: https://doi.org/10.1080/15563650.2017.1349320.

FAO [Food and Agriculture Organisation]. 2012. Water and poverty, an issue of life & livelihoods. Available: hppt://www.fao.org/nr/water/issues/scarcity.html. [Accessed 24 Oct. 2019].

Feng, Y., Chen, X. M., Zhao, M., He, Z., Sun, L., Wang, C.Y., *et al*. 2018. Edible insects in China: utilization and prospects. *J. Insect Sci.* 25(2):184-198.

Govorushko, S. 2019. Global status of insects as food and feed source: a review. *Trends Food Sci. Technol.* 91: 436-445.

Hackstein, J. H. and Stumm, C. K. 1994. Methane production in terrestrial arthropods. Proceedings of the National Academy of Sciences of the United States of America 91(12): 5441-5445.

Hanboonsong, Y., Jamjanya, T., and Durst, P. B. 2013. *Six-legged Livestock: Edible Insect Farming, Collection and Marketing in Thailand.* RAP publishers, Bankok, 57p.

Hernandez-Flores, L., Llanderal-Cazares, C., Guzman-Franco, A. W., and Aranda-Ocampo, S. 2015. Bacteria present in *Comadia redtenbacheri* larvae (Lepidoptera: Cossidae). *J. Med. Entomol.* 52(5): 1150-1158.

Huis, A. 2013. Potential of insects as food and feed in assuring food security. *Annu. Rev. Entomol*. 58:563-583.

Huis, A., Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G., and Vantomme, P. 2013. Edible insects: future prospects for food and feed security. *Int. Forestry Rev.* 16(1): 1-187.

Jongema, Y. 2012. List of edible insect species of the world. Wageningen University, Netherland. Available: http:/www.ent.wur.nl/UK/Edible+insects/ Worldwide+species+list/. [Accessed 25 Nov. 2019].

Ji, K. M., Chen, J. J., Li, M., Liu, Z. G., Wang, C. B., Zhan, Z. K., *et al*. 2009. Anaphylactic shock and lethal anaphylaxis caused by food consumption in China. *Trends Food Sci. Technol.* 20: 227-231.

Lalanne, G., Hernandez-Alvarez, J., and Castro, A. S. 2019. Edible insects processing: traditional and innovative technologies. *Compr. Rev. Food Sci.* 18: 1666-1911.

Latham, P. 1999. Edible caterpillars of the Bas Congo region of the Democratic Republic of Congo. *Antenna* 23(3): 135-139.

Miglietta, P. P., De Leo, F., Ruberti, M., and Massari, S. 2015. Mealworms for food: a water footprint perspective. *Water* 7: 6190-6203.

Nakagaki, B. J. and De Foliart, G. R. 1991. Comparison of diets for mass-rearing *Acheta domesticus* (Orthoptera: Gryllidae) as a novelty food, and comparison of food conversion efficiency with values reported for livestock. *J. Econ. Entomol.* 84(3): 891-896.

Obopile, M. and Seeletso, T. G. 2013. Eat or not eat: an analysis of the status of entomophagy in Botswana. *J. Food Secur*. 5: 817-824.

Oonincx, D. G. A. B., van Itterbeeck, J., Heetkamp, M. J. W., van den Brand, H., van Loon, J., and Huis, A. 2010. An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. *PLoS One* 5(12): e14445. Available: http://doi:10.1371/journal.pone.0014445 [Accessed 20 Oct. 2019].

Pimentel, D. and Pimentel, M. 2003. Sustainability of meat-based and plant-based diets and the environment. *Am. J. Clin. Nutr*. 78: 660-663.

Pimentel, D., Berger, B., Filiberto, D., Newton, M., Wolfe, B., Karabinakis, E., Clark, S., Poon, E., Abbett, E., and Nandagopal, S. 2004. Water resources: agricultural and environmental issues. *Bioscience* 54: 909-918.

Rumpold B.A. and Schluter O. K. 2013. Nutritional composition and safety aspects of edible insects. *Nutr. Food Res.* 57(5): 802-823.

Sun-Waterhouse, D., Waterhouse, G. I. N., You, L., Zhang, J., Liu, Y., and Ma, L. 2016. Transforming insect biomass into consumer wellness foods: a review. *Food Res. Int.* 89: 129-151.

Vandeweyer, D., Lenaerts, S., Callens, A., and Van Campenhout, L. 2017. Effect of blanching followed by refrigerated storage or industrial microwave drying on the microbial load of yellow mealworm larvae. *Food Control* 71: 311-314.

Yen, A. L. 2009. Entomophagy and insect conservation: some thoughts for digestion. *J. Insect Conserv.* 13: 667–670.

Yesodharan, K., Padmanabhan, P., and Cini, N. U. 2011. Wild food traditionally used by indegeneous people of parambikulam wildlife sanctuary, Western Ghats, Kerala, India. *J. Bombay Nat. Hist. Soc.* 108(1): 41-46.

KERALA AGRICULTURAL UNIVERSITY
COLLEGE OF HORTICULTURE, VELLANIKKARA
Department of Agricultural Entomology
ENT 591: Master's Seminar

Name	**:**	Laya A. C.	**Venue**	**:**	Seminar hall
Admission No.	**:**	2018-11-070	**Date**	**:**	03-01-2020
Major Advisor	**:**	Dr. Haseena Bhaskar	**Time**	**:**	10.00 am

Entomophagy: a step towards food security

Abstract

Food security is emerging as a global challenge necessitating rethinking about food patterns and habits, particularly those relating to meat consumption. Loaded with proteins, fats and minerals, insects offer enormous scope as an alternative source of food. About 31 per cent of all edible insects around the world belong to the order Coleoptera followed by Lepidoptera, Hymenoptera, Orthoptera and Hemiptera.

The opportunities of insects as alternate food sources are due to their environmental, nutritional and socio-economic benefits. The major environmental benefits include high feed conversion ratio, lower emission of greenhouse gases and lower water as well as land requirement (Huis, 2013). Higher feed conversion efficiency as well as lower emission of methane, nitrous oxide and ammonia have been reported in the edible insects *Tenebrio molitor*, *Acheta domesticus*, *Locusta migratoria*, *Pachnoda marginata* and *Blaptica dubia*, when compared to conventional livestock (Oonincx *et al*., 2010).

Edible insects are highly nutritious as they are rich in carbohydrates, proteins, amino acids, fatty acids and micronutrients. A comparative study of amino acid content in beef and mealworm larva revealed that mealworms had higher isoleucine, leucine, valine, tyrosine, alanine, glycine and proline content (Huis *et al*., 2013). Harvesting and raising of insects involve low technology and capital investment and provides opportunities for subsistence for both urban and rural population, which makes it socio-economically viable.

Edible insects can be obtained by wild harvesting, semi-domestication and farming. Bamboo caterpillar, *Omphisa fuscidentalis* and weaver ant, *Oecophylla smaragdina* are collected from the wild, while the palm weevil, *Rhynchophorus palmarum* serve as a classical example of semi-domestication (Govorushko, 2019). Rearing of insects in captivity, isolated from their natural populations and provided with controlled living conditions and diet is

referred to insect farming. House crickets, palm weevils and mealworms are being successfully farmed in Thailand (Hanboonsong *et al*., 2013).

Edible insects are processed and consumed as whole insects, in ground or paste form or as extracted protein. Blanching and drying are the common processing techniques followed, which minimizes the microbial risk and increases the shelf life of edible insect products. The effect of processing technology and storage conditions on the microbial characteristics of mealworm larva, field cricket nymph and migratory locust adult revealed that storage after drying at 103^0C for 12 hours reduced the total microbial count, as well as counts of enterobacteria, yeast and mould significantly (Adamek *et al*., 2018).

Even though use of insects as food confers many advantages, not all insects are safe to eat. Microbial, chemical, physical and allergic risk should be considered while selecting insects for human consumption.

In future, meat centric diets will become increasingly expensive and grain-livestock systems environmentally unsustainable. Though entomophagy is still in its early stages, given due support, it can play a significant role in assuring global food security.

References:

Adamek, M., Mlcek, J., Adamkova, A., Suchankova, J., Janalikova, M., Borkovcova, M., and Bednarova, M. 2018. Effect of different storage conditions on the microbiological characteristics of insect. *Potr. S. J. Food Sci*. 12: 248-253.

Govorushko, S. 2019. Global status of insects as food and feed source: a review. *Trends Food Sci. Technol.* 91: 436-445.

Hanboonsong, Y., Jamjanya, T., and Durst, P. B. 2013. *Six-legged Livestock: Edible Insect Farming, Collection and Marketing in Thailand.* RAP publishers, Bankok, 57p.

Huis, A. 2013. Potential of insects as food and feed in assuring food security. *Annu. Rev. Entomol*. 58: 563-83.

Huis, A., Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G., and Vantomme, P. 2013. Edible insects: future prospects for food and feed security. *Int. Forestry Rev.* 16(1): 1-187.

Oonincx, D. G. A. B., van Itterbeeck, J., Heetkamp, M. J. W., van den Brand, H., van Loon, J., and Huis, A. 2010. An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. *PLoS One* 5(12): e14445. Available: http://doi:10.1371/journal.pone.0014445 [Accessed 20 Oct. 2019].