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Insects as an Alternate Source for Food to Conventional Food Animals

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ABSTRACT

A section of people in India and all over the world consuming edible insects and are highly nutritious with high fat, protein and micronutrients depending on the species and thus represent a valuable alternative food to protein rich animal foods. With the increasing demand in alternative protein rich food sources world-wide, insects represent an innovative food and source of high quality protein as well as other beneficial nutrients such as fat, minerals and vitamins. Despite traditional knowledge about insects and their harvest in the wild, for the industrial mass production of safe insects and insect products for consumption and for processing into food and feed, the development of rearing, harvest as well as post-harvest technologies is required. This paper outlines different edible insects and its mass production and processing technologies. It also emphasis on nutritional benefits and organoleptic attributes of processed insects.

Key words: *Insects, Nutritional benefits, Food, Minerals and Vitamins*

INTRODUCTION

In the face of growing threats to global food security from climate change and depletion of natural resources, insects are being considered as a new source of human food and animal feed in the world[27]. Insects are consuming in India and 113 countries all over the world[16] and more than 2,000 insect species that are considered edible have been counted to date[13]. The eggs, larvae, pupae and adults of insects were used in prehistoric times in India as food ingredients in humans, and this trend has continued into modern times. Man was omnivorous in early development and ate insects quite extensively. Before people had tools for hunting or farming, insect constituted an important component of the human diet. Moreover, people lived mainly in warm regions, where different kinds of insects were available throughout the year. Insects were often a welcome source of protein in the absence of meat from vertebrates. Eating insects is not only exciting, healthy and tasty, but almost inevitable. The way we currently produce meat and poultry food, has the adverse impact on agricultural production resources. Currently, the production of meat requires 70 percent of global agricultural land and to produce 1 kg chicken, 1 kg mutton and 1 kg beef requires 4325 liters, 5520 liters, 13000 liters of water respectively[10].

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Compared with livestock, breeding insects seems to be more environmentally friendly because of lower greenhouse gas emissions; water pollution and land use[27]. Insects show higher feed conversion efficiency (i.e. a measure of the animal's efficiency in converting feed mass into body mass) in comparison with mammalian livestock. The feed conversion of house cricket (*A. domestica*) to be twice that of chickens, 4 times higher than in pigs and more than 12 times higher than in cattle[27]. The nutritional value of insects flesh is similar to that of ordinary meat, while for the production of one kilogram of edible product, the cold-blooded insects much less feed is needed than warm-blooded animals: four times less than for a pig, and 12 times less than for a bovine animal[9]. Globally, the most frequently consumed species are beetles, caterpillars, bees, wasps and ants. They are followed by grasshoppers, locusts and crickets, cicadas, leafhoppers and bugs, termites, dragonflies, flies and other species[13]. The largest consumption of insects is in Africa, Asia and Latin America[13]. The reported benefits of the human consumption of insects as an alternative to conventional food animals are numerous, including comparable levels of protein[25] and relatively high although variable e levels of nutrients and unsaturated fat[3,27] coupled with a lower environmental impact due to lower emissions of greenhouse gases[27,25] and lower land requirements during production[17]. The number of edible species eaten in India is around 24 [6]. Increasing population growth in the India increases demand for protein sources but the amount of available farmland is limited. In 2050 the India population is estimated at more than 1.66 billion people, resulting in an additional need for food of half the current needs. Conventional protein sources may be insufficient and we will have to focus on alternative sources, which may be edible insects.

An interesting positive aspect of entomophagy is its help in reducing pesticide use. Indian farmers are using huge pesticides for crop production and it leads to adverse effect on environment and farmers health. Collection of edible insects considered as pests can contribute to reduced use of insecticides and a decreased financial burden on farmers. Furthermore, the economic benefits of collecting insects as compared with the cultivation of plants should also be taken into account[14].

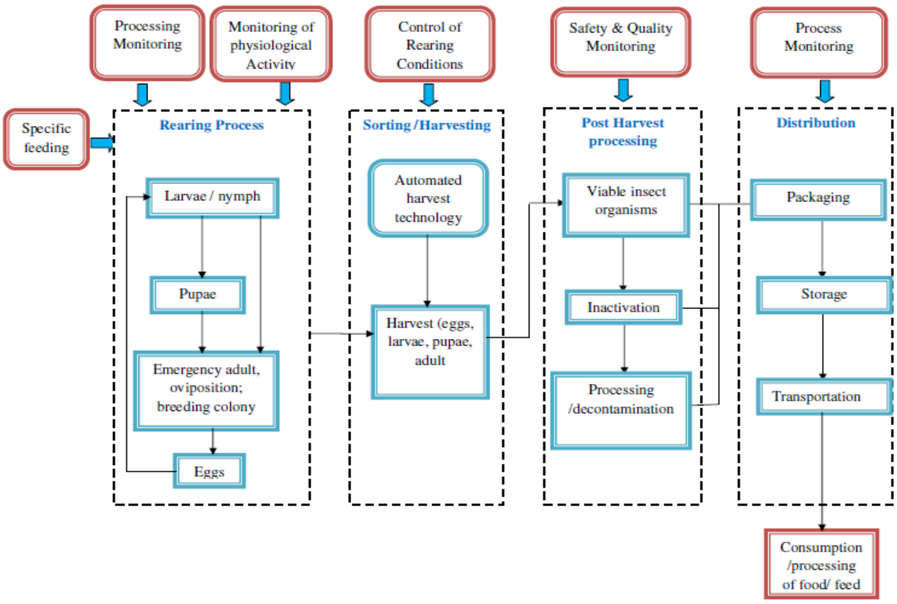
Table 1: Consumption of Insect in Different Countries

Country	Consumption of Insect
South America	Butterfly, Grasshoppers, crickets, Cicadas, Ants, Flies, Bees and Wasps.
Colombia	Giant queen ants, Palm grubs and Caterpillars.
Asia	Grasshoppers, Crickets, Silk worm pupa, Dragonflies, Termites, and Beetles .
Thailand	Giant water beetle.
Africa	Caterpillars, Mopane worm, Termites and Locusts.
Pacific Islands	Papua, Palm grubs, Grasshoppers, Crickets, Stick insects, Mantids and Locust.
Australia	Honey ants, Grubs, Moth, Bardi grubs and Cerambycid beetle.
China	Silkworm pupa, Fly larvae, Cricket, Blattaria, Termites and Locusts.
India	Termite, Dragonfly, Grasshopper, Ants, Eri and Mulberry silkworm, Honey bee, Cricket.
Source: Insects Cambridge World History of Food	

Mass production of edible insects/processing technologies

The rearing of insects has been practiced for at least 7,000 years e.g. for the sericulture (silk), the production of shellac and later on also for apiculture (honey) and for the production of medicinal products. In 1936 the first mass production of a screwworm in a factory on an artificial diet had been accomplished paving the way for the sterile insect technique (SIT). A lot of research has been conducted and progress made regarding the development of artificial diets and the mass rearing of insects as biological weapons for various pest control programs since then[21,22].

For marketing edible insects on an industrial scale while preserving the forests it is therefore preferable to establish cost-effective but safe farming systems of edible insects. A schematic process for the production of ready-to-eat and easy-to-prepare food products from insects is shown in flow chart.



Flow Chart 1. Schematic production process of food derived from edible insects (Source: Birgit[4] *et al*.,) In order to make the mass production besides the purchase and consumption of insects more attractive as well as more competitive with regard to meat, it is therefore necessary to develop rearing and harvest as well as post-harvest processing technologies including safety and quality monitoring for the automation of insect (protein) production to decrease its production costs and ensure food and feed safety[4]. For a maximum meat and/or protein yield, a suitable edible insect species to be raised has to be selected, in doing so also the consumer acceptance (human or animal) has to be taken into consideration. Candidate insects are selected based on their size, social behavior, safety, epidemic tendencies, reproductive and survival potential, nutritional benefits, potential for storage, and marketability[23]. It is aimed for a high egg production, high egg hatchability, short duration of larval stage, optimum synchronization of pupation, high weight larvae or pupae, a high productivity i.e. high conversion rate and high potential of biomass increase per day, low feed costs, low vulnerability for diseases, ability to live in high densities, and a high quality protein. Depending on the species to be reared and the current developmental stage of the insect`s life cycle specific feeding might be required. Other factors influencing the rearing process include temperature, light/illumination, humidity, ventilation, rearing container properties, larvae/population density, oviposition site, food and water availability, food composition, food quality as well as microbial contamination[4]. These rearing conditions need to be controlled throughout the rearing process along the production chain (Flow chart 1). Caterpillars have been recommended as prime candidates since they are coldblooded and wingless and convert plant biomass to animal biomass 10 times more efficient than cattle and on much less land[23]. Furthermore, the farming of Orthoptera (grasshoppers, locusts, and crickets) as food and feed has been suggested[4].

Nutritional value of edible insect

The nutritional value of edible insects is heterogeneous in nature because of the large number and variability of species. Nutritional values can vary considerably even within a group of insects depending on the stage of metamorphosis, origin of the insect and its diet (Finke M.D *et al.*, 2014). Similarly the nutritional value changes according to the preparation and processing before consumption (drying, cooking, frying etc.) [27]. The Nutrient Value Score of crickets, palm weevil larvae and mealworm was significantly healthier than in the case of beef and chicken and none of six tested insects were statistically less healthy than meat. Most edible insects provide sufficient energy and proteins intake in the human diet, as well as meeting the amino acid requirements[14].

Insects also have a high content of mono- and polyunsaturated fatty acids; they are rich in trace elements such as copper, iron, magnesium, manganese, phosphorus, selenium and zinc, as well as vitamins like riboflavin, pantothenic acid, biotin, and folic acid in some cases[19].

Table 2: Nutritional content of insects compared with beef and fish

Insect and Animal	Energy (kcal)	Protein (g)	Iron (mg)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)
Termites (Macrotermes subhyalinus)	613	14.2	0.75	0.13	1.15	0.95
Caterrpillar (Usata Terpsichore)	370	28.2	35.5	3.67	1.91	5.2
Weevil (rhynchophorus phoenicis)	562	6.7	13.1	3.02	2.24	7.8
Beef	219	27.4	3.5	0.09	0.23	6.0
Fish	170	28.5	1.0	0.08	0.11	3.0
Source: Finke, 2012						

Energy:

The energy value of edible insects depends on their composition, mainly on the fat content. Larvae or pupae are usually richer in energy compared to adults. Conversely high protein insect species have lower energy content[14].

Proteins:

Total protein content is relatively the same in most of the insects except for the waxmoth (*G. mellonella*) where the protein content (based on dry matter) was only 38.4%. The percentage of other species ranged from 50.7% for yellow mealworm (*T. molitor*) to 62.2% for the African migratory locust (*L. migratoria*). Considering the amino acid composition of edible insects, they contain a number of essential amino acids including high levels of phenylalanine and tyrosine. Some insects contain large amounts of lysine, tryptophan and threonine, which is deficient in certain cereal proteins. Analysis of almost a hundred edible insect species showed that the content of essential amino acids represents 46–96% of the total amount of amino acids[3].

Lipids

Edible insects contain on average 10 to 60% of fat in dry matter. This is higher in the larval stages than in adults[30]. Caterpillars belong among insects with the highest fat content. The fat content of insects generally ranges from less than 10 to over 30% fat based on fresh weight[6] and is higher in larval and pupal stages than at the adult stage[5]. Isoptera (termites) and Lepidoptera (caterpillars) are among the insects with the highest fat contents[6]. There is a relatively high content of C18 fatty acids including oleic, linoleic and linolenic acids in the fat of insects[26]. Palmitic acid content is also relatively high. Fatty acid profile is affected by food, which the insects feed upon.

Table 3: Nutritional Value of Insects per 100 Grams

Insect	Protein (g)	Fat (g)	CHO (g)	Calcium (mg)	Iron (mg)
Giant water beetle	19.8	8.3	2.1	43.5	13.6
Red ant	13.9	3.5	2.9	47.8	5.7
Silk worm pupae	9.6	5.6	2.3	41.7	1.8
Dung beetle	17.2	4.3	0.2	30.9	7.7
Cricket	12.9	5.5	5.1	75.8	9.5
Large grasshopper	14.3	3.3	2.2	27.5	3.0
Small grasshopper	20.6	6.1	3.9	35.2	5.0
June beetle	13.4	1.4	29	22.6	6.0
Caterpillar	28.2	n/a	n/a	n/a	35.5
Termite	14.2	n/a	n/a	n/a	35.5
Weevil	6.7	n/a	n/a	n/a	13.1
Source: <http://www.ent.iastate.edu/Misc/insectnutrition.html> 26 Nov. 2010					

Fibre

Edible insects contain a significant amount of fibre. Insoluble chitin is the most common form of fibre in the body of insects contained mainly in their exoskeleton[27]. Chitin in commercially farmed insects ranged from 2.7 to 49.8mg per kg of fresh weight (from11.6 to 137.2mg per kg of dry matter). Chitin is considered as an indigestible fibre, even though the enzyme chitinase is found in human gastric juices. Chitin of insect exoskeletons acts in the human body like cellulose and because of this effect it is often called “animal fibre” [2].

Minerals

The majority of insects contains high amounts of potassium, calcium, iron, magnesium, and selenium. Few insects partially contain much more iron and calcium than beef, pork and chicken[23]. Caterpillars of mopane could be a good source of zinc (14mg per 100 g of dry matter) together with palm weevil larvae Rhynchophorus phoenicis (26.5 mg per 100 g of dry matter).

Vitamins

Insects provide with several vitamins. For example, Bee brood is rich in vitamin A and D, caterpillars are especially rich in Vit B1, B2 and B6 Riboflavin is represented in edible insects in amounts from 0.11 to 8.9 mg to 100 g. Vitamin B12 is found in abundance in larvae of the yellow mealworm beetle *T. molitor* (0.47 µg per 100 g) and the house cricket *Acheta domesticus* (5.4 µg per 100 g in adults, 8.7 µg per 100 g in nymphs). However, many other species that have been analysed contain only negligible amounts of this vitamin[26].

Sensory quality of edible insect

In India insects are consumed alive immediately after being caught. In the case of further processing, the best method for their humane killing is scalding by hot water after starvation for 1–3 days. Other subsequent culinary processing may be roasting, cooking, baking, frying or drying. Larvae of the yellow meal worm, smaller larvae of mealworms and migratory locusts belong to the three most common types of insects offered in special stores where edible insects are bred and processed for human consumption[27].

Table 4: Common edible insects in India and its processed form

Scientific name	Common name	Order	Edible form
Cybister confuses	Diving beetle	Coleoptera	Roasted fried and curry
Hydrophilus olivaceus Fab.	Water scavenger	Coleoptera	RoastForms of larva and adult
Anoplophora glabripennis Mot.	Asian long horned beetle	Odonata	Roasted and fried forms
Acisoma panorpoides Ram.	Dragonflies	Odonata	Roasted or fried body
Belostoma indica	Giant water bug	Hemiptera	With edible herbs and spices
Oecophylla smaragdina	Red Ant	Hymenoptera	Chatni
Laccotrephes maculatus Fabr.	Nepa	Hemiptera	Fried body
Oxya hyla hyla	Grasshopper	Orthoptera	fried and edible with herbs
Odentotermies sp.	Termite	Isoptera	Consumed live

Sensory properties are important criteria for the consumption of edible insects. Taste and flavour of insects are very diverse (Table 5). Flavour is mainly affected by pheromones occurring at the surface of the insect organism[18]. It also depends on the environment where insects live and the feed that they eat. Selection of feed can also be adapted depending on how we wish insects to taste. If insects are scalded, they are practically tasteless, because pheromones are washed off by rinsing. During cooking process food ingredients like spices and condiments and other seasonings imparts desired flavors to the insects.

The exoskeleton of insects decides the texture of final product. Insects are crunchy, crispy and sounds accompanying their eating resemble the sounds of crackers or pretzels[18]. Pupae, larvae (caterpillars) and nymphs are the most consumed stages of edible insects as they contain a minimal amount of chitin. Therefore, they are not so crispy during their consumption and are more digestible for the human body. The vast majority of insects are almost odour-free due to the exoskeleton. A pleasing colour does not always indicate that an insect is delicious. During cooking, the insect's colour usually changes from the original shades of grey, blue or green to red due to the oxidation of coloring pigment. Insects containing a considerable amount of oxidized fat, or improperly dried insects, may be black. Properly dried insects are golden or brown and can be easily crushed by the fingers.

Table 5: Taste and flavour of selected edible insect species

Edible insect	Taste and flavour
Ants, termites	Sweet, almost nutty
Larvae of darkling beetles	Whole meal bread
Larvae of wood-destroying beetles	Fatty brisket with skin
Dragonfly larvae and other aquatic insects	Fish
Cockroaches	Mushrooms
Striped shield bugs	Apples
Wasps	Pine seeds
Caterpillars of smoky wainscots	Raw corn
Mealybug	Fried potatoes
Eggs of water boatman	Caviar
Caterpillars of erebid moths	Herring

Risks of insects eating

A large collection of insects in the wild could pose serious interference to the landscape ecosystem and on agriculture production. Therefore, it is recommended to consume insects reared at farms in controlled and defined conditions. The subsequent health safety of edible insects is thus ensured by the choice of appropriate and safe feed. The results of analyses carried out in the years 2003–2010 has shown possible risks of eating insects fed by bran containing a higher concentration of heavy metals[2]. It is not recommended to consume insects fed by an inappropriate diet, for example by organic wastes. Other possible risks of consuming edible insects are eating inappropriate developmental stages of insects, poor handling and culinary treatment. According Lenka Kouřimská and Anna Adámkováto,[14] consumption of grasshoppers and locusts without removing their feet can lead to intestinal blockage, which could have fatal consequences. Eating insects can also cause allergies. Some insects have a rigid external covering for the body formed of chitin, which is difficult to digest for humans. Today, due to the lack of food containing chitin there is a deficiency of the enzyme chitinase which cleaves chitin. Some individuals have such a small amount of this enzyme that the eating of insects can cause an allergic reaction to them. People most at risk are those who are allergic to seafood, such as shrimp.

Conclusions and future recommendations

It can generally be concluded that insects are a potential source for food and alternate source for protein rich food since they have a well-balanced nutrient profile, meet amino acid requirements for humans and high in polyunsaturated fatty acids and also rich in micronutrients and vitamins. Insects may be included among the common diet of consumers in India and other developing countries where malnutrition is a common problem. They could also be used as a nutritional supplement for formulating special diets for sports persons, vulnerable groups of protein energy malnutrition. Appropriate species selection based on suitability for mass production and characteristics such as robustness and protein/biomass supply and on intended use is also mandatory. In comparison to livestock, rearing insects seems to be more environmentally friendly with regards to greenhouse gas production, water consumption and land requirement.

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