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The potential of entomophagy against malnutrition and ensuring food sustainability

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Abstract

Ecological aspects, economical aspects, and biological aspects of insects are attractive to researchers for several reasons. The consumption of insects called entomophagy is a matter of discussion since the last few decades because the published literature views entomophagy as a potential measure in combating human malnutrition and in achieving food security sustainably. Some insects are potential source of nutrients with their contents of protein, fat, micronutrients. Some insects provide therapeutic benefit to human population. Insects as a protein source have many advantages namely nutritional value, less greenhouse gases and ammonia emission, less land area requirement, low feed conversion efficiency. In addition, insects being able to convert low-value organic side streams into high-value protein products. Thus, it is safe to recommend that emphasis will be given on collection of insect species (harvesting), preservation, preparation, and marketing. As a significant portion of human population suffers from malnutrition, the entomophagy, a traditional practice of insect consumption is now becoming more important to humanity. The present communication deals with the nutritional value of edible insects, economical aspects and ecological aspects of entomophagy to evaluate the benefits of this traditional food culture.

Keywords: *Food insecurity, Food value, Insect farming, Cultural aspect*

1. Introduction

The insect constitutes 90% of metazoan, many of which are pests and some play beneficial ecological roles (Mandal, 2018). Some insects are potential source of nutrients for people. Developed countries now consider the edible insects to provide the nutritional support to the malnourished peoples (Tang *et al*., 2019). Some 3071 ethnic groups in 130 countries traditionally practice insect eating (vide Tang *et al*., 2019). FAO listed insects as an alternative source of human nutrition (FAO, 2010). African, Asian, and Latin American people consume vast amounts of insects (vide Tang *et al*., 2019). Worldwide about 150 million children including 52% South Asian and 21% Sub-Saharan African children are malnourished (Tang *et al*., 2019). As the 'food of the future' insects, have valuable prospects. People of developing countries could consume energy rich edible insects

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(DeFoliart, 1992) to combat malnutrition. However, insect farming for food is still at an early stage (vide Tang *et al*., 2019). Nutritional values of insects are potential substitutes for the humans and animals feed products (Ramos-Elorduy, 2005). The EAT-Lancet Commission called for "planetary health diets`` for improving human health and environmental sustainability (Willett *et al*., 2019). Such diets contain chiefly the plant-sourced- and low animal sourced - food, depends on the people's cultural context and socioeconomic condition (Samaddar *et al*., 2020), and called for the major shifts in dietary habits and diets. Protein, fat, vitamins, and minerals in addition to dietary fiber and iron content of edible insects are comparable to commonly consumed livestock (Tao and Li, 2018).

2. Cultural aspects of entomophagy

The term "entomophagy" in a historical context has been mainly used by people who do not eat insects, denoting a peculiar eating habit from other cultures. The eating of insects is very common in the tropics but not in Western countries. Foraging for termites as food was practiced by early hominids for nearly a million years in South Africa. Ethnographic, ethnohistoric, and archeological data show that insects may have been the major components of meals in the Great Basin in the USA. Prehistoric human coprolites with chitinous exoskeletons of insects have been recorded in other places of the USA. The quantity present in coprolites suggests that they were eaten as food. Silk was produced in China around the fourth or the fifth century BC. In the Shanxi province in China, cocoons of the wild silkworm, *Theophila religiosae* (Lepidoptera), were found about 2000 to 2500 years ago with large holes in them suggesting their human consumption. Anthropologists seem unaware of the role of insects in food history. The reasons perhaps are the Western bias against insects, and the low "visibility" of insects in archeology (vide Van Huis, 2018).More than 2000 arthropod species belonging to Coleoptera (31%), Lepidoptera (17%), Hymenoptera (15%), Orthoptera (14%), Hemiptera (11%), Isoptera (3%), Odonata (dragonflies), Dipteran (flies), and others (9%) were listed. Eating insects is mostly limited in tropical countries because of availability of edible insects throughout the year and in tropical zones, insects are larger as they respire through the tracheal system. Tropical insect species are often aggregated to facilitate harvesting. In fact, it is easier to harvest insects from nature in warmer regions, and it was probably an important part of the diet (Vide van Huis, 2018).

2.1. Totems and taboos

The Kaingang in the Amazon treat ants with spirits of their ancestors and do not kill them. For the Kalanga people (Zaka district) in Masvingo, Zimbabwe, a rain-making ceremony holds to bring vital water for the production of the edible stink bug, *Encosternum delegorguei* (Hemiptera), edible caterpillars, and wild fruits. After a harvesting ceremony, the community collect the edible insects which ensures that mature insects are harvested only to safeguard from overharvesting and extinction of the insects. A particular clan is left to oversee the harvesting of the insects, to avoid overexploitation. The grasshopper *Ruspola differens* (Orthoptera), is found in large numbers in Uganda at a time of the year. Many indigenous societies have totem groups which regard an object, often an animal, as their ancestor. Therefore, the eating of the totem animal is forbidden to members of the totem clan or only to a very moderate consumption is allowed. Children of inward State of Nigeria are discouraged to eat the larvae. The larvae of the silkworm *Anaphe infracta* (Lepidoptera) feed on several trees in Africa. They are not so much appreciated as food. Both larvae and pupae are eaten in Zambia. Certain ethnic groups believe that pregnant women will not be able to deliver the child if they eat the insect.

3. Food value of edible insects

Eating *Tessaratoma papillosa* (longan stink bugs) is remarkable in southern China. Once the people of Thailand ate this insect, which was promoted to warm areas. Consuming cicadas is very popular in rural China. As the cicadas feed on trees, to rear them is difficult in large scale. The larvae of *Clanis bilineata* called Doudan is a traditional food and a commercial item in Jiangsu province. Temperature controls Doudan production. The product becomes expensive in winter. A large-scaled farming of termites, palm weevils, and caterpillars has attained success in the tropical areas. Over two billion people eat insects habitually, which significantly fulfill the animal protein demand of people in some regions. Data from 34 African countries shows that people in Africa consume 524 edible insect species (Van Huis *et al*., 2017). Diversity of edible insect species include 60 species in India, 96 species in the Central African Republic, 250 species in sub-Saharan Africa, 348 species in Mexico, 187 species in China (Vide Tang *et al*., 2019), 83 species in Ecuador (Ramos-Elorduy, 2005), 40 species in Nigeria (Onore ,1997), 55 species in Japan (Chen *et al*., 2009), 50 species in Thailand (Roulon-Doko, 1998) and Borneo . Ants, bees, beetles, wasps, and caterpillars are commonly consumed (vide Tang *et al*., 2019). Others include leafhoppers, sand bugs, dragonflies, termites, crickets, cicadas, and grasshoppers, (Johnson, 2010). In India, 158 insect species are found in Arunachal Pradesh, whereas this number is 38 for Assam, 41 for Nagaland, 16 for Meghalaya, 5 for Kerala and 1each for Odisha, Madhya Pradesh, Karnataka, and Tamil Nadu (Gahukar, 2018). People also consume insect eggs, pupae, larvae, and nymphs. Edible insects occupy planned diets throughout the year in some regions (Banjo *et al*., 2006). A group of people in South Africa called Pedis value insect meals derived from caterpillars, even more than beef (Womeni *et al*., 2009). Palm weevils, a traditional African diet are prepared especially by frying *Rhynchophorus phoenicis* larvae (Banjo *et al*., 2006; and Payne and Van Itterbeeck, 2017). In Mexico, few people accept maize flour tortillas fortified with ground yellow mealworm larvae (*Tenebrio molitor*) (Aguilar-Miranda *et al*., 2002). *Lethocerus indicus* (giant water bug), is popular in Vietnam, Laos, and Cambodia (Kiatbenjakul *et al*., 2015). Consumer accepts its odour, which provides a flavor. Common edible insect species are *Acheta domesticus; Apis mellifera, Bombyx mori, Imbrasia belina, Rhynchoporus phoenicis,* and *Tenebrio molitor* which are in commercial use. People generally eat only larvae of *R. phoenicis, T. molitor,* and *I. belina* (Tao and Li, 2018; and Tang *et al*., 2019). *T. molitor* grows quickly with use of dry low-nutritional waste as feed and its production has been industrialized owing to its vitality (Tang *et al*., 2019). Orthopterans like cricket are easy to harvest from swarming, and only adults are used as food. Silkworm pupae are a food source (Tomotake *et al*., 2010) in China, Japan, Thailand, and Vietnam.

Generally, insects are healthy food because they provide carbohydrates, proteins, fats, vitamins and minerals, with energy value (Capinera, 2004; and Johnson, 2010). Nutritional value varies species wise in different insects. Even within the same group, the nutritional values differ according to the origin, its diet and on the life cycle stage (Finke and Oonincx, 2014; and vide Tang *et al*., 2019). The process of transforming (frying, cooking, drying) insects into food also influences their nutritional values (vide Tang *et al*., 2019).

3.1. Energy value

Caloric contributions of edible insects vary between 290 and 750 kcal / 100g (Tang *et al*., 2019). These insects also provide crucial macronutrients and could be an exceptional source for energy and macronutrients. Madagascar, or Zambia exhibit more severe rates of chronic malnutrition with 22 to 33 edible insect species (vide Tao and Li, 2018; and Tang *et al*., 2019) which are remarkable for their levels of energy and nutrients. A study in Thailand showed that 100 g of insects (fresh weight) had comparable calories than equal weights of commonly consumed livestock, excluding pork (Payne and Van Itterbeeck, 2017; and Tang *et al*., 2019). The caloric values of 78 insect species found in Mexico ranged from 293-762 kJ per 100 g of dry matter (Tao and Li, 2018; and vide Tang *et al*., 2019). *Locusta migratoria* now plaguing Madagascar have calories between 598 and 816 kJ per 100 g of fresh weight in the Netherlands (Oonincx and van der Poel, 2011; and vide Tang *et al*., 2019). Larvae or pupae are energy rich in comparison to adults. Insect species with high protein content have low energy content (Bednarova *et al*., 2013).

3.2. Fat content

The fat content in immature stages of insects varies between 8 and 70% based on dry weight and emits an attractive flavor. Triacylglycerols constitute about 80% of fat. Generally, the phospholipids content is less than 20% in fat, but varies depending on the insect life stage. A relatively high content of C18 fatty acids including linolenic acid and oleic acid occur in the fat (Tzompasosa *et al*., 2014; and Tang *et al*., 2019). Palmitic acid content is high. In Lepidopteran and Heteropteran larvae, the fat content is quite higher. The fat content in adults (mainly triacylglycerol) is less than 20%. MUFAs, SFAs usually constitute more than 80% of all fats. Stearic- and palmitic acid are the main components of SFAs. The SFAs content in adults is generally higher than MUFAs. MUFAs and PUFAs are present in rich quantities in insects. Six insects from Cameroon of Sub-Saharan Africa are excellent sources of fat, ranging between 9.12% and 67.25% (dry weight basis) (Womeni *et al*., 2009; and Tao and Li, 2018). They are also rich in PUFAs and MUFAs with more nutritional benefits and potential to replace the intake of saturated fatty acids (Enos *et al*., 2014; and Tao and Li, 2018). The PUFAs include essential fatty acids, like linoleic (omega-6) and linolenic (omega- 3) acids (Womeni *et al*., 2009). Comparable findings in Thailand varied between 0.34% and 23.98% of total fat content (Tao and Li, 2018). The energy value of insects depends on fat content.

3.2.1. Therapeutic benefits of fat

The MUFAs in insects reduce blood pressure, cure immune and inflammatory diseases in humans (Tang *et al*., 2019). The mature insects are the best source of PUFAs. Linoleic acid has the acne reductive, and skin lightening property. Orthopterans are also the best source of linoleic acid. Lepidoptera with high quantities of PUFAs is rich in α-Linolenic acid with a nutraceutical potential to protect the brain. Both linolenic acid precursors are vital for the synthesis of prostaglandin, thromb and a-Linolenic acid in humans. Inadequate intake of linolenic and α-Linolenic acids may be the cause of growth retardation, skin damage, reproductive disorders, and diseases of kidney, liver, neurological and eye of human. Extracting these ingredients from insects has the great potential in the healthcare system (Tang *et al*., 2019).

3.3. Protein content

The protein content is notably higher or equivalent to other animal foods like pork, and chicken (Gahukar, 2018). Insects are a substantial source of protein partly because of their caloric value. Insect protein digestibility varies between 76 and 96 % (Vide Tang *et al*., 2019). On average, these values are only a little smaller than values for egg protein (95%) or beef (98%) and sometimes higher than many plant proteins. In China, some insects contain higher amounts of protein than most plants and commercial meat, fowl, and eggs (Xiaoming *et al*., 2010; and Vide Tang *et al*., 2019). In a study, 11 orders of insects showed protein contents ranging from 13% to 77% (dry weight basis). Other researchers reported a range of 37%-54% protein content in eight insects found in Thailand (vide Tang *et al*., 2019; Ghosh and Ansar, 2019; and Tao and Li, 2018). Based on dry weight basis the proportion of crude protein varies between 40 and 75 % (Tang *et al*., 2019) in edible insects of which76 to 96% essential amino acids are generally digestible (Bukkens, 1997; and Tang *et al*., 2019). Insects in general meet the WHO criteria for amino acids like lysine, histidine, arginine, phenylalanine, isoleucine, leucine, threonine, valine, and tyrosine although some contain low amounts of methionine, cysteine, and tryptophan.

3.4. Micronutrient content

Micronutrients are essential for healthy life (Tang *et al*., 2019). Edible insects contain micronutrients like iron, magnesium, manganese, phosphorus, potassium, selenium, sodium, and zinc. A major concern for developing countries is iron deficiency (WHO., 2014; Tao and Li., 2018; and Tang *et al*., 2019). Many of the insects are safe for consumption and contain levels of iron that often exceed other generally eaten animals. Edible insects such as the popular palm weevils (*Rhynchophorus phoenicis*) or mopane caterpillars (*Imbrasia belina*) can provide 12 and 31 mg of iron per 100 g of weight, respectively (Banjo *et al*., 2006). Chicken and beef provide only 1.2 and 3 mg of iron respectively (Payne and Van Itterbeeck, 2017). Analogous to shellfish or prawns, habitat and diet of insects can change their flavor and even their nutritive values (Tao and Li, 2018). Most insects contain a low amount of Calcium (less than 100 mg/g based on dry matter). Macronutrient is deficient in daily diets in developing countries. Insects are great sources of vitamins and micronutrients and can provide vitamins A, B1-12, C, D, E, K, required for normal health. B1, B2, and B6 are sufficient in caterpillars. In bee brood vitamins D and A are sufficient (vide Tang *et al*., 2019). Red palm weevil is rich in vitamin E (Tang *et al*., 2019). However, housefly larvae and adults of melon bugs are abundant with it. Pupae of *Polybia occidentalis* contain 54 mg of potassium per 100 g.

4. Entomophagy and food security

Food insecurity remains a serious issue for much of the world. At least 50% of the population is moderately or severely malnourished (WFP and UNICEF, 2011). The Asia and Sub-Saharan Africa have the highest rates of hunger. About two- thirds of the total hungry population resides in Asia (Tao and Li, 2018). About 805 million people suffered from insufficient food (WFP, 2015; and Tao and Li, 2018). Madagascar is one of the 10 countries with the highest chronic malnutrition (WFP and UNICEF, 2011; and Tao and Li, 2018). In 2013, 4 million people affected with hunger in Madagascar and about one-third of its population suffered from food insecurity (WFP and UNICEF, 2011).

Rice is the major commodity for consumption (FAO, 2014). People intake proteins from both vegetable and animal sources one and two times per week (WFP and UNICEF, 2011; and Tao and Li, 2018). Fat is a major energy source is low in Malagasy diets (FAO, 2010). The chief staple meal for African people commonly mainly the carbohydrates like sorghum, millet, rice, maize, and fonio (Filli *et al*., 2014). Scarce availability of animal protein makes the Malagasy people macronutrients deficient (Wu Leung, 1968). About 20% or less of the children had access to foods rich in minerals, and vitamins from plant source, fruits, legumes, and dairy products. Thus, 84% of households suffered from inadequate food per year (WFP and UNICEF, 2011). Malnourishment in early childhood results in life-threatening consequences. Chronic malnutrition leads to irreversible stunting and is the important risk factor for illness and death (Muller and Krawinkell., 2005; WFP, 2015; and Tao and Li, 2018).

5. Economic and environmental impacts of insect consumption

The prediction suggests that global population will reach 9 billion by 2050 (FAO, 2009). The demand for food and feed will be increased requiring food production increase by 70% (FAO, 2009). There is a call to conserve natural resources considering the present state of our environment. Rearing insects requires less land than farming other livestock. Edible insects also have the potential to be farmed requiring no additional land clearing to advance production (Tao and Li, 2018; and vide Tang *et al*., 2019). Insects such as crickets (*Acheta domesticus*) and mealworms (*T. molitor*) produce low amounts of Greenhouse gases. The FAO (2013) predicts that by 2025, two-thirds of the world will be under stress of water shortages. When considered against the quantity required to produce 1 kg of grain protein, 100 times more water is required to produce the same weight of animal protein, especially as water is necessary for forage and feed production (Chapagain and Hoekstra, 2003; and Tao and Li, 2018). Although the quantity of water required for farming insects is now unavailable, the results are likely in favorable directions, in parallel with greenhouse gas, and ammonia emissions. Farming livestock also requires feed, which necessitates further land clearing. In case of poultry to produce 1 kg of livestock, at least 2.5 kg of feed is required, 5 kg for pork, and 10 kg for beef (Smil, 2002; and Tao and Li, 2018). In case of crickets (*A. domesticus*), this is 1.7 kg to produce the same weight (Collavo *et al*., 2005; and Tao and Li, 2018). Only a percentage of this livestock weight is edible, consequently reducing the actual production and availability of meat protein and other nutrients. While chicken and pork provide 55% of edible weight, beef only provides 40% (Van Huis and Oonincx, 2017). Crickets (*A. domesticus*) conversely offer 80% of its live weight for eating. Insects in general reproduce more rapidly. The cricket can lay 1200-1500 eggs within 30 days (Patton, 1978; and Tao and Li, 2018). Insects reach their adult stages quicker than their livestock counterparts do. Insects play an important role in plant reproduction (Van Huis and Oonincx, 2017), in waste biodegradation, in recycling organic waste and providing nutrients for farm animals (Bernard and Womeni, 2017).

6. Risks of practicing entomophagy

Regulations for governing insects eating are deficient globally. Some insects might contain carcinogen. African silkworm larvae cause the seasonal ataxia syndrome through its thiaminase content. Toluene, a depressant toxic is found in some insect products. Silkworms, cicadas, crickets, wasps, grasshoppers, and stink- bugs cause allergies. The fourth allergenic offenders in China since 1980 were the insects (Tang *et al*., 2019). Composition of commercial insects would help in understanding their consumption risk. Reliable diagnostic tools for detections for the risks of consumption that are harvested from nature should be emphasized (Van Huis and Oonincx, 2017). Insects provide a suitable environment for microorganisms to live and breed. Enterobacteriaceae and sporulating bacteria use insects. Only boiling cannot prevent the danger of bacterial infection (vide Tang *et al*., 2019). Preventive measures must be adopted during the production and storage. Edible insect population in stable help maintains the ecosystem function. Human interference in insect population disrupts the ecosystem regulation process (Payne and Van Itterbeeck, 2017). Insect exploitation beyond the regeneration potential makes ecosystems chaotic. Insect collection should ideally be made before the mating season to ensure the equilibrium of next generation. Mayflies and caddisflies have always been at a low level. Indiscriminate pesticide use has declined in some insect groups in some areas or regions. African Goliath beetle was endangered due to loss of its host trees. People are now not concerned about the potential threat the beetle faces and enjoy the delicacy freely (vide Tang *et al*., 2019). Climate change also influences the insect population (Toms and Thagwana, 2005).

7. Conclusion

The information available of edible insects all over the world is rather limited. DeFoliart (1999) and Yen (2009a) feel that acculturation to Western lifestyles tends to cause a reduction in the use of insects as food. We now realize that the eating of insects as a protein source has many advantages which can be divided into: nutritional value; less greenhouse gases and ammonia emissions; less land area requirement; low feed conversion efficiency and insects being able to convert low-value organic side streams into high-value protein products. Thus, it is safe to recommend that emphasis will be given on collection of insect species (harvesting), preservation, preparation, and marketing. All these works should be done before the loss of information. The challenge is now to collect and evaluate traditional practices (Van Huis, 2018).

Some insects improve soil fertility. Insects efficiently bio-transform abundant, low- cost organic wastes into animal biomass (Bernard and Womeni, 2017). Black soldier fly, housefly, and yellow mealworm convert the organic waste biologically. The low-nutritive waste becomes high- nutritive matters at the time of growth. Larvae and pupae are the source feed for cattle, poultry, and fish (Tang *et al*., 2019). Edible insects, with their high feed conversion efficiency and fecundity, and their minimal space for rearing, offers an advantageous solution for present and future food insecurity. In sustainably meeting global food demands through food security the use of insects as food and feed has a significant role to play. Insects as a source of food is economically, ecologically, culturally sound at least to a part of the global human population, and maintaining it definitely ensures the implementation of the concept of sustainable development (Mandal and Nandi, 2013). As ended by the 2019 Nobel Prize Laureates, culture, context, socioeconomic status, and food environment shape the dietary patterns. The High-Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security proposed a conceptual framework for food systems (Samaddar *et al*., 2020). From the information given above on various aspects of entomophagy, the authors strongly argues to promote the traditional practice of entomophagy to ensure food security for the malnourished people, which in turn will help to achieve the sustainable development goals.

Conflicts of Interest

None

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