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Entomophagy: A Future Feed Security System

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ABSTRACT

From the point of view of the current environmental situation which leads to non-availability of agricultural land, water resource, emission of greenhouse gases ultimately causing global warming, Entomophagy i.e. practice of eating edible insects comes as a rescue to the future feed security system. Edible insects, considered as an inexhaustible natural resource have larger food value with high content of fat, protein, crude fiber, vitamins and minerals making it nutritionally comparable with other protein sources. Some edible insects also have increased levels of omega-6 & 3 fatty acids. Studies have calculated that livestock rearing leads to about 18% greenhouse gas emission whereas barring a few insects like cockroaches, termites which produce small amount of CH4, others have practically no such harmful environmental impact. Socio- economic picture of edible insect trade comes clearly from South-East Asia with its well-established farms and trade routes. The market value for insects often exceeds from that of its other protein counterparts, as a result of which, insect farming can prove to be a rich source of income for farmers. Insect rearing requires very little technical knowledge and principal investment, so it can be taken on by anyone. In future, as prices of conventional protein rises, insects may well prove to be a cheaper source. Here in this review paper, Insect's contribution to food security, solution to the problem of protein shortages, recent growth in demand for edible insects, consumer awareness and acceptance of insects as food has been discussed.

KEYWORDS: *Entomophagy, edible insects, protein counterpart, insect rearing, natural resource.*

INTRODUCTION

In many 3rd world countries like India children aresusceptibletomalnutritionduetohighdemandofprotein- based food leading to its non-availability and hike in price. Day by day scarcity of food resources is increasing and importing of foods is becoming more expensive. Children are being exposed to poor nutritional levels when both macro & micro nutrients are insufficient to maintain growth and development. To effectively respond to this situation researchers have turned their attention to insects not only because of their abundance and enormous biomass but also because of insects being a source of good quality protein with high digestibility. Thus, wider adoption of entomophagy, practice of eating edible insects could help alleviate growing pressure on food production and also reduce malnutrition. Natural resources like land, water and energy are declining, so these resources need to be conserved and managed to produce more food. Livestock farming is becoming costly progressively. Insect culture, on the other hand, requires little areas, little water and hence is nick named as "mini-livestock". Insects also play an important role in improving soil fertility, breaking down waste products until it is fit to be consumed by bacteria and fungi. Thus, insects are of valuable importance medically, commercially, and ecologically. In a world where providing adequate nutrition to people is a huge problem, edible insects should be taken into consideration. The local "conventional" practices of consuming insects are not new (McGrew, 2014). The recent global interest on entomophagy has annexed a new dimension to the concept. 73 out of 98 known companies to proffer insects as animal feed or human food were founded during 2013-2015(Dossey et al., in press). So, definitely a global edible insect 'movement' is coming forth. The benefits of insects as food do not just rely on technical and economic feasibility, but also on political and social context. With the growing world population, there are now more than 3.7 billion people suffering from malnutrition, mainly due to lack of protein and energy from food(Olaf M et al.,2005). Also, new agricultural land is very little to produce food for human beings, and as such a greater proportion of people are eating resource-intensive animal protein than ever before. This narrative review thus aims to showcase some of the positive & negative aspects of entomophagy thereby presenting it as a future feed security system. The paper will scrutinize the nutritional benefits, environmental issues, socio economic aspect, disadvantages, food safety & preservation and future prospects ofentomophagy.

II. NUTRITIONAL BENEFITS

Insects are a good source of protein, fat, minerals, vitamins & energy (Rumpold & Schlüter 2013a) with comparable energy content with other fresh meat sources which vary across insect species & within species depending on what they have fed on, their stage of development, sex and environmental factors (Bukkens 1997; Ramos-E lorduy *et al.* 2002; Finke & Oonincx 2014).

2.1. Macro Nutrients

Protein comprises of about 30% to 65% total dry matter, thereby being one of the most important component of edible insects. Amino acid composition and digestibility of protein expressed as a percentage of that of an "ideal" protein is used to check the protein quality (Belluco *et al.* 2013). Edible insects offer alimited amount of tryptophan & lysine. Whether insect protein is suitable for human sustenance is yet to be assessed, but studies with juvenile rats have put forward that crickets have superior source of protein when compared to a plant based protein source like soy protein. Insects contain unsaturated fatty acid similar to that of poultry and white fish but more polyunsaturated fatty acid (PUFAs) than poultry or red meat. The main PUFAs which are present in insects are Omega-3 fatty acids, Docosahexanoic acid & Eicosapentanoic acid andtheyareresponsiblefornormalcellularfunctio ninthehuman body.

2.2. Micro Nutrients

Insects have varied level ofmicronutrients which differs from one species to the other, although some have consistently higher values of some specific micronutrients. In some insect species iron is found in the range of 18 to 1562 mg/100gm dry matter with low levels in ants, mid-levels in termites and the highest levels in cricket (Christensen 2006). Zinc, calcium and vitamin A are also found in insects. In crickets zinc content is in the range of 8- 25 mg/100gm dry matter (Christensen 2006) whereas ants, termites and crickets have calcium in the range of 33-341 mg/100gm dry matter. Vitamin A is present across different species of insects in the range of 3-273 µg/100gm dry matter (Christensen2006).

	Protein (% dry matter)	Fat (% dry matter)	Energy (kcal/100 g)
Coleoptera (adult beetles, larvae)	40.69	33.4	490.3
Rhynchophorus phoenicis (palm weevil larvae)	32.86	36.86	478.87
Tenebrio molitor (mealworm larvae)	48.35	38.51	557.12
Diptera (flies)	49.48	22.75	409.78
Hemiptera (true bugs)	48.33	30.26	478.99
Hymenoptera (ants, bees)	46.47	25.09	484.45
Oecophylla smaragdina (weaver ant)	53.46	13.46	
Isoptera (termites)	35.34	32.74	
Lepidoptera (butterflies, moths)	45.38	27.66	508.89
Bombyx mori (silkworm larvae)	61.8	8.81	389.6
Cirina forda (shea caterpillar)	47.48	11.5	359
Galleria mellonella (waxworm larvae)	38.01	56.65	650.13
Samia cynthia ricini (ailanthus silkworm pupae)	54.7	25.6	463.63
Odonata (dragonflies, damselflies)	55.23	19.83	431.33
Orthoptera (crickets, grasshoppers, locusts)	61.23	13.41	426.25
Acheta domesticus (house cricket adult)	65.04	22.96	455.19
Schistocerca sp.	61.05	17	427
Sphenarium purpuracens (chapulin adult)	61.33	11.7	404.22
Ruspolia differens (brown longhorn grasshopper)	44.3	46.2	

Table1:*Protein,fatandenergycontentofsomeinsects. Data from Rumpold & Schlüter2013a.*

Species	Calcium	Iron	Vitamin A
Rhynchophorus phoenicis (African palm weevil larvae)	131.05	22.75	11.25
Tenebrio molitor (mealworm larvae)	45.77	5.46	
Oecophylla smaragdina (weaver ant)	63.85	65.4	
Agro (termites)	132	161	
Bombyx mori (silkworm larvae)	102.31	9.54	273.99
Cirina forda Westwood (shea caterpillar)	17.48	23.93	2.99
Galleria mellonella (waxworm larvae)	59.28	6.57	4.5
Samia ricinii (silkworm pupae)	72.2	23.7	
Acheta domesticus (house cricket adult)	171.07	8.75	24.33
Sphenarium purpuracens (chapulin adult)	112	18	
Ruspolia differens (brown longhorn grasshopper)	24.5	13	280

Table 2: *Mineral and Vitamin A content in popularly consumed species. All minerals in mg/100 gm dry matter except Vitamin A (µg/100gm dry matter). Data from Rumpold & Schlüter (2013a).*

III. ENVIRONMENTAL CONSIDERATIONS

Production of food has wider impact on environment which is being brought to the forefront particularly regarding the emissionofgreenhousegaseslikeCO_2.Itispredicted thatby 2025,atleast1.8millionpeoplewillbelivinginregions with inadequatefreshwatersuppliesandafurthertwo-thirdsofthe global population will be in areas under pressure from dwindling water resources (FAO 2012). Freshwater is a limited resource, out of which an approximate 70% isused by agriculture and livestock industries (Doreau *et al.* 2012). Incaseofagriculture,waterisbeingusedinitsdirectfrom& ultimately to cultivate fodder for the production of livestock. Raiseindemandformeatamplifiesthestrainonproducersto farmextralivestock,whichagainrequiresfurtherland.Since insects rely on their environment to control metabolic processes, they are significantly more efficient than other livestock in terms of feed conversion (van Huis 2013). The agricultural sector contributes most of the greenhouse gas emissions, with livestock accounting for an overall 18% of CO_2 equivalents (van Huis 2013; Sachs 2015). Studies have proven that insects produce much fewer greenhouse gases than standard large livestock and are approximately on par with chickens on a per kilogrambasis.

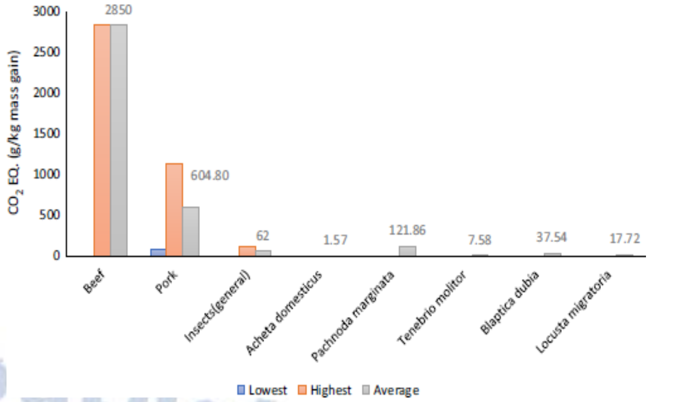

Figure 1: *Carbon dioxide (CO_2) production equivalents (EQ.) duringrearingoflivestockandinsects.DatafromOonincxet al. (2010).*

IV. SOCIO ECONOMIC ASPECT

Farming insects can offer unique employment and income earning opportunities in both developed & developing countries. Insect cultivation can serve as a livelihood diversification strategy that provides multiple income generating means. The market strategies include insects as exoticfood,westernapproachestoday:insectasnoveltyfood and lastly insect as pet food. The benefits of creating such organizations include reduction in the costs of buying farm inputs,production,processingandmarketing.Theacceptance towards entomophagy comes from increase in price of fresh meat sources, staples & consumerawareness.

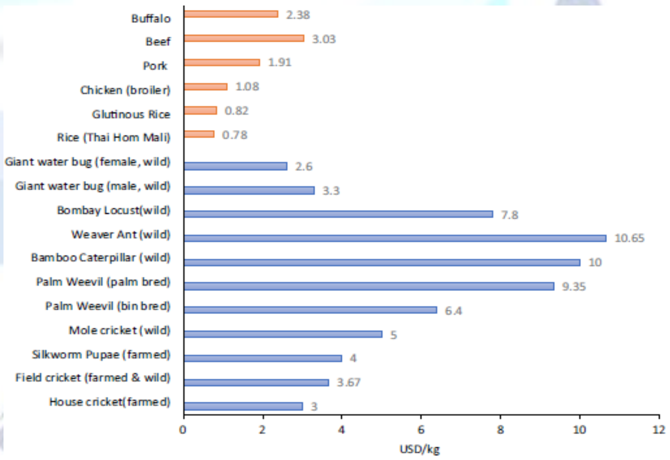

Figure 2: *Market Value of insects and staples in Thailand. Insect data from Hanboonsong et al. (2013), rice pricesfromThaiExportersAssociationon2March2016and meat prices from Thai Office of Agricultural Economics, values for the week of 22 February 2016.*

V. THE HURDLES NEEDED TO FACE TOUSE INSECTS AS FEED ORFOOD

Aswealreadyknow,amultitudeofnewopportunitieslies for allowingtheinsectstobeusedasfoodandfeed,therearealso many hurdles that one has to face to do so, and that is owing to the fact that there are scope for numerous innovative ideas that can employed on entomophagy and also the fact that there has been not enough research done on the subject, thus allowing it to be sceptical for many. The most important of the issues will have to be the distrust over using insects as food as many believe they may contain "anti-nutrient" properties, the apprehensions around food safety associated to storage space and allergic reactions, acceptance by the consumers and vague or unrealparameters.

5.1. Anti-nutrient properties: Chitin is a structural nitrogen- based carbohydrate which is found in the exoskeleton of insects. They may contain "anti-nutrient" properties which can be due to adverse effects on protein digestibility. One studyofseveninsectspeciesfound2.7–49.8mgchitin perkg fresh weight and 11.6–137.2 mg/kg in dry matter (Finke 2007). And there was also a study which compared dried honeybeesand honeybeeproteinanditendeditsconclusion on the note that chitin exclusion considerably enhanced the quality of the insect protein as considered through protein digestibility, amino acid content, protein efficiency ratio and net protein utilization (Ozimek et al. 1985). Even though chitin is typically considered to be indigestible by humans (Bukkens1997),thechitinolyticenzymes,formedbybacteria from the human gastrointestinal tracts, have lately been established, signifying that chitin and chitosan may be digested(Paoletti et al. 2007; Duskova et al. 2011; Rumpold &Schlüter2013a).Theprobabletoxicityofsomecompounds in insects is concerning. Now, there are two categories of toxic insects: phanerotoxics and crypto toxics. Crypto toxics include toxic substances from whichever direct synthesis or by build-up from their diet whereas Phanerotoxics have precise organs that produce toxins (Belluco 2013). Generally consumed insect species are not in this categories, or studies of the levels of oxalate, hydro cyanide, phytate, tannins and phenols in edibles insect species have seen that values fall very well below levels of toxicity for consumption of human (Ekop et al. 2010; Shantibala & Lokeshwari2014).

5.2. Microbial risks: Spore-forming bacteria and enterobacteriaceae have been reported to be found in mealwormsandcrickets,withelevatedlevelsfoundin insects that had already been crushed – possiblydue to the discharge of bacteria from the gut (Klunder 2012). While detrimental bacteria such as Salmonella have been found in insects that were closely in contact with livestock (Belluco 2013), research suggests that gut micro biota of the insects provide for bulk contamination (Rumpold 2014). Some danger of mycotoxins has been recognized, but this has been studied only in the two emperor moth species (Imbrasia belinaand Bucnaea alcinoe), with strains acknowledged chiefly in the intestinal tract or from exterior contamination (Simpanya & Allotey 2000; Braide & Oranusi 2011). Very little is known when it comes to the question that howto safely store insects to decrease microbialmenace.

5.3. Allergens: Many arthropods, which include arachnids, myriapods,crustaceansandinsects,areknowntobringabout allergic reactions in predisposed individuals, which are caused by the presence of arginine kinase, tropomyosin, haemocyanin and glyceraldehyde 3-phosphate dehydrogenase (Belluco 2013; Srinroch 2015). Cross- reactive allergies have been identified in cockroaches, dust mites andcrustaceans.

5.4. Massproduction: Forinsectstobeconsideredfeasiblemicro livestock, it has to be possible to produce them on a hefty scale in a safe, sustainable and efficient way. Noteworthy advances have been made with controlled conditions and artificial rearing diets for mass rearing. The idyllic insect species would have high egg hatch, high egg production, optimum synchronization of pupation, a short larval stage, a highproductivity(i.e.highconversionrateandhighpotential ofbiomassincreaseperday),highweightsoflarvaeor pupae, low vulnerability to diseases, low feed costs, a high-quality protein content and capability to live in high densities (Rumpold & Schlüter2013b).

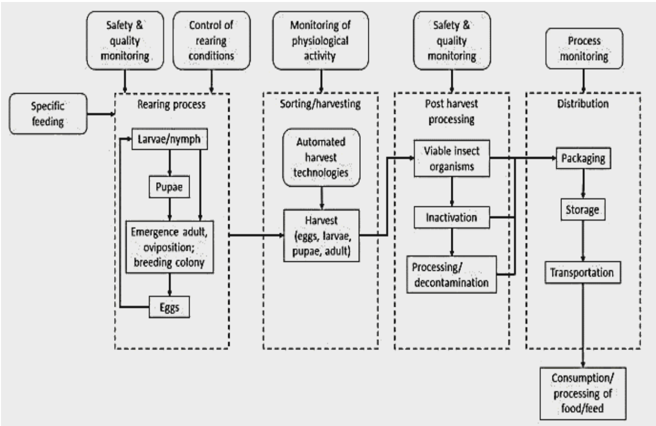

Figure 3: *Model insect production system, reproduced from Rumpold & Schlüter(2013b).*

5.5. Consumer acceptability: In countries where entomophagy isthestandard,insectsareseenasanesteemedproteinsource and knowledge on which species are edible is considered to be local wisdom which has been passed down through generations. On the contrary, insects can bring into play primeval harmful reactions: 'deeply embedded in the psyche isaviewofinsectsasdirty,disgustinganddangerous'(Looy et al. 2014). Moderately, the chief significant factors seem to be familiarity, convenience, attachment to meat (Verbeke 2015; Gere 2017) and interest in the environment. Conceivably the first step to escalating consumer acceptability of entomophagy is through improved use in animal feed.

VI. FOOD SAFETY ANDPRESERVATION

Food safety, preservation and processing are intimately linked. Insects, akin to several meat products, are loaded in moistureandnutrients,providinganencouragingatmosphere for microbial survival and augmentation (Klunder et al., 2012).TheHazardAnalysisCriticalControlPoints(HACCP) system, a science-based and methodical tool, finds out accurate hazards and makes control systems to guarantee the safety of food (FAO/WHO,2001a).

Insects can be conserved and traded after (sun-) drying – a classic method used in processing the mopane caterpillar (Allotey and Mpuchane, 2003). Other effortless preservation methodssuchasacidifyingtheinsectswithvinegarhavebeen triumphant. A different example is the use of insects for protein fortification in fermented food products. A horde of other modern-day preservation methods should be explored, such as the purpose of ultraviolet light and high-pressure technologies, as well as ample packagingmethods.

VII. FUTURE PROSPECTS ANDCONCLUSION

Future research should deal with questions allied to the levelling up of insect production to industrial levels, such as: how can the environmental trail of insects linger diminutive when levelled up commercially?; how can insect dietetic profiles be enhanced in an organized and reliable conduct?; are there any detrimental effects to human or animal populations from the using up of huge quantities of insects?; howcaninsectsbefedonamercantiledegreeinasustainable means?; what do the rules around insect farming, processing and storage space necessitate to envelop?; how can the economic assessment of reputable insect supply chains be secluded so as not to injure livelihoods? And what do insect supplyandvaluechainslooklikeaccordingtotheprecise end exercises? Finally, only if insects are capable to contribute with established Western livestock, predominantly chickens, or livestock feed within the supply-value string, will they be deemed a workablesubstitute?

Research points out that insect could play a vital part in managing the looming protein supply predicament. By and large, insects include adequate levels of fats, protein and micronutrients to have a say to advances in universal health and food precautions, mutually by means of straight use and meandering apply in feeds. In accumulation, research has verified that insects can have a trifling environmental trace and a superior monetary significance than other livestock protein sources; they are not likely to cause considerable microbial risks; they have been shown to reason allergic reactions in persons with acknowledged arthropod allergies.

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