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Insects as a source of food for human hunger: A glimpse of hope for the future

Mohd Yaqub Khan[1*], Ping-Chun Hsu[1], Maryada Roy[1], Zainul Khan[2], Radheshyam Sharma[2], Harshit Srivastava[2]
[1] Biomedical Engineering Department, Chung Yuan Christian University, Taiwan
[2] Pharmacy Department, Azad Institute of Pharmacy & Research, Lucknow, Uttar Pradesh, India

Abstract
According to the World Organization World Meter, the current world population is 7.8 billion by March 2020, and if this rate continues, it will reach 9 billion by 2050. Expansion of the human population leads to hunger and malnutrition and puts more pressure on the agro-ecosystem. We must find alternative ways sources of food to feed our growing population because our traditional resources are inefficient to feed the population with all nutritional values. New resources should eco-friendly and full of nutrition. Edible insects can be one choice for feeding the growing population, and insects have always been a part of human history. We can find symbols and insects in many books, events, and ceremonies throughout the world. Researchers now focus on insects as our "food of the future", as our food resources become scarce and scarce in most parts of the world, especially in developing countries. Over 2 billion people worldwide have included over 1,900 species of insects in their diet plan because insects are good and cheap sources of proteins, vitamins, fats, minerals, all essential amino acids, antioxidants, and prebiotic fibers. But, though, there is the unpopularity of insects as food because of unawareness of its nutritional values and social and cultural fear. Report of the Department of Agriculture of the United States highlights one of the primary reasons for the non-acceptance of insects as our food and report say insects need to free from pathogens, poisons, hints of pesticides, allergens, microbes. Now researchers all over the world are looking up for a safe way to farm insects and use as novel food sources for the growing population and finding alternative ways to use insects' products in many other industries.

Keywords: agro-ecosystem, insects, human nutrition

Introduction

Have you heard the word "Entomophagy" before? *Entomophagy is a combination of Greek and Latin words, where "entomon", mean "insect", and "phagus", as "feeding on".* Although many of us never heard this word in their life before yet growing number of researchers and people propose that it will welcome a positive effect on war the globe is battling against food scarcity and malnutrition [1]. Edible insects can be an answer for hunger and malnutrition for some developed and under developing countries, for example, India, Indonesia, Pakistan, Bangladesh, and a lot more countries of Africa and Europe mainland. Eatable bugs can be showcased as *"Future Food"* [9]. As indicated by the *Food and Agriculture Organizations of the United Nations*, there are more than 1900 known types of edible insects that consistently eaten by more than 2 billion individuals over the world yet most of them are in tropical nations, for example, Asia, Africa, and Latin America. Most basic consumable insects are honey bees, ants, insects, cicadas, caterpillars, crickets, flies, dragonflies, true bugs, grasshoppers, wasps, beetles, leaf, termites, plant hoppers [10]. In the 2019 report distributed in *Knoema. World Data Atlas. 2019*., the present birth pace of the human populace is 18.2 per 1000 individuals [2] and 7.6 per 1000 individuals is the present demise rate [3]. This imbalance in birth rate and death rate is mainly due to advancement in medical science and social-economic life of a person and it result in boom in birth rate. *Wesley Rahn. 2019*. claims in 2050 human populace will reach up to 9.7 billion on earth [4] and expanding populace rate is a "Period Bomb", for us which when detonate it will prompt malnutrition and craving everywhere throughout the globe and it will crush our agro ecosystems. Right now, roughly 1.5 billion hectares (11 percent) of the land surface territory of the globe (13.4 billion hectares) is under crop production. Because of an expansion in populace more regions required for home, structures and which lead to an immediate effect on the pace of crop production. It is evaluated that in 2030 we will have 1.4 percent per annum development in crop creation when contrasted with 2.1 percent development in the current time frame [5]. In 2016, The *United Nations Food and Agriculture Organization (FAO)*, recommends around 815 million individuals over the globe (10.7 rate out of 7.6 billion individuals), were experiencing lack of malnutrition and hunger and circumstance in lower-centre salary nations are far away from creative mind [6]. Agriculture sectors share 6.4 percent of the world's all-out financial creation (The World Fact book. 2018), China is the biggest donor in the agribusiness divisions creation followed by India. Next comes the United States, Brazil, and Indonesia [7]. As our pace of populace proceeds at a similar rate and our assets, our farming area diminishes at a similar rate as we are confronting today then that day will before long show up when the entire world will be in the torment of hunger and malnutrition. It won't just influence the economic strength of any country yet in addition makes an irregularity in the public eye. Possibly the Third World War will be on "Nourishment". We need to locate a practical answer for the up and coming debacle for now and for our coming ages. Numerous researchers and analysts around the globe attempting to discover an answer for feed an expanding populace of the world with constrained assets. A few researchers and scientists proposed genetically modified crops, soil and water sensors, climate following, vertical

cultivating, and some more may be a solution to feed population. Yet at the same time, we need land to develop our harvest and with the expanding populace it is hard to get more land region for farming to give sustenance improve nourishment to everybody [8]. A beam of expectation can be found from a report distributed in the *Food and Agriculture Organization of the World Organization* in 2013, which is progressively centred around diminishing dietary benefit from our nourishment. Recommends us that "Consumable Insects" could turn into a wellspring of nourishment in our eating routine in the future and it also attests that edible insects may have on different occasions more protein source than a burger and more nutrient B12 than beef meat. Edible insects are likewise wealthy in different supplements, for example, fat, iron, calcium, omegas, amino acids, and zinc, which is basic sustenance for human body development and advancement [1].

Table 1: Diversity of Edible Insect species in the world [22]

Order	Species	Location
Lepidoptera	*Anaphe panda* (Boisduval)	DRC, Zambia, Cameroon, Cango, CA Republic, Nigeria, Tanzania, Zimbabwe.
	Cirina forda (Westwood)	South Africa, Botswana, Togo, Chad, Nigeria, Namibia.
	Dactyloceras lucina (Drury)	Togo, Chad, South Africa, DRC, Ghana, Mozambique.
	Gynanisa ata (Strand)	Zambia, DRC, Botswana, South Africa, Burkina Faso.
	Anaphe venata (Butler)	Ivory Coast, Sierra Leone, Liberia, Nigeria, Zambia.
Orthoptera	*Acanthacris ruficornis* (Fabricius)	DRC, Zambia, Ghana, Togo, Chad, CA Republic, South Africa, Namibia.
	Ruspolia differens (Serville)	Congo, CA Republic, Burkina Faso, Malawi, Mali, DRC, Zambia, South Africa.
	Zonocerus variegatus (Linnaeus)	Uganda, Malawi, Kenya, Cameroon, DRC, South Africa.
Coleoptera	*boas* (Fabricius)	Ivory Coast, Sao Tome', Guinea, Congo, DRC, Liberia.
	Rhynchophorus phoenicis (Fabricius)	Australia, Nigeria, Thailand, Congo, DRC, Liberia, Guinea.
Hymenoptera	*Apis mellifera* (Linnaeus)	Mexico, Cameroon, Niger, Angola, Congo, Nigeria, Guinea.
	Carebara vidua (Smith)	Sudan, Kenya, South Sudan, Zambia, DRC, Zimbabwe, Zambia.
	Carebara lignata (Westwood)	South Africa, DRC, Sudan, Namibia, South Sudan, Zambia.
Isoptera	*Macrotermes subhyalinus* (Rambur)	Angola, Kenya, Togo, Canada, the USA, Zambia, Angola.
	Macrotermes falciger (Gerstacker)	Benin, Australia, the Netherlands, Burkina Faso, Zambia, Zimbabwe.
	Macrotermes natalensis (Haviland)	Nigeria, Malawi, Congo, DRC, Malawi, South Africa, Burundi.

Dr Tilly Collins says (Lindsay Brown. 2019), "Edible insects have an outsized natural advantage, for example, insects radiate fewer greenhouse gases contrasted to others that affect ozonosphere of our blue planet, insects have a lower discharge of formulation like ammonia unlike as pigs, insects are often a solution for the natural conversion of organic waste streams into natural feed like protein for fish and poultry farm, insects required negligible amount of water and a little portion of land for his or her survival and raising, low capital and minimum technology required for harvesting insects in farms and this could be a good opportunity for urban and rural peoples for his or her livelihood [11]. *D. Dobermann, J.A. Quick., et al. 2017*, edible insects genetically vary from humans, hence they are fewer chances of transmitting diseases and viruses to a human when eaten [12].

Investigation in journal Trends in Ecology and Evolution (*Asa Berggren, Anna Jansson, et al. 2019*), Asa Berggren and her partners made an estimation in next five years edible insects' market are going to be a $710 million and edible insects are going to be available within the market in kind of snacks, flour, and different species [13]. This year in London (*Phil Coomes. 2018*), a sushi chain put a menu of roasted grasshoppers and declared as "crunchy" and "solid". In Ocado (Supermarket chain, UK), they sell a bundle of Eat Grub's BBQ smoky crunchy stewed crickets and they suggest the crickets as a trimming for soups, noodles, and servings of mixed greens [14]. In the United States, we can find another noteworthy activity of edible insects in cultivating. Farmers use the black soldiers flies as a characteristic converter of natural waste into the normal Feed which is exceptionally wealthy in protein hotspot for poultry and fish farming [15].

The Good- Nutritional Value of Insects

The nutritional value, taste, and texture of each insect vary from insect to insect. About 80% of the world's population ate insects in their diet. But, overall, insects are proteins, including vitamins, fats, minerals, all essential amino acids, antioxidants, and prebiotic fibers. According to the *USDA SR-25* report and the nutritional composition and safety aspects of edible insects, 2.5 billion people around the world have already eaten crickets for healthy, sustainable, delicious flavours. You can compare the nutritional value of the crickets with other common meat sources.

Table 2: Nutritional Value of Crickets with other common meat sources.

200 calories serving	Protein	Fat	Omega-3	Fiber
Crickets	31 g	8.1 g	1.8 g	7.2 g
90% Lean Beef	22.4 g	11.2 g	0.04 g	0 g
Farmed salmon	20.4 g	13.4 g	2.5 g	0 g

During this century, various insect powders such as cricket powder have become very popular. *Maxxam Analytics* analysed the nutritional value of cricket powder. The results of the analysis could be solutions to the growing demand for food and a better solution to provide more nutritional value to many people without significantly affecting the world's resources. This may suggest that our future generations are an option to reduce greenhouse gases and may be an important precautionary step that we take to save the planet [18].

Table 3: *Maxxam Analytics* analysed the nutritional value of 100 gram of cricket powder

Energy	1973 kJ (472 kCal)
Protein	58.76 g
Fat	24 g
Saturated Fat	8.48 g
Trans Fat	0.218 g
Cholesterol	0.228 g
Carbohydrates	8.4 g
Fiber (total dietary)	6.0 g
Sugars	0.5 g
Ash	6.5 g
Calcium	0.11 g
Iron	0.002 g
Potassium	1.1 g
Sodium	0.31 g
Omega-3	2.81 g
Omega-6	6.28 g
Saturated Fatty Acids	8.48 g
Cis-Monounsaturated	5.14 g
Cis-Polyunsaturated	9.09 g
B-12	24 µg

Byoung Deug Choi *et al. 2017*, Demonstrated Protein Extraction from Edible Insects by Sonication and Defatting method**.**

Materials

The author used n-Hexane and bovine serum albumin powder in the extraction process and purchased them from his respective vendors.

Edible insects

They microwave all pest samples and grind them to a fine powder using the conventional pest and mortar method. Stored at -40 °C until use.

Lipid removal by n-hexane defatting method

N-hexane solvent for lipid extraction from insect samples in a 1:20 ratio with a sample ratio. The filtration method removes the n-hexane after stirring for 12 hours with the samples and remixed the sample with n-hexane for total of 48 hours. The samples were poured onto aluminium foil and dried overnight under a fume hood. The Soxhlet extraction method calculates the total lipid content of insect samples.

Ultrasound method for protein extraction

Powdered insect samples (12.5 g) were mixed with distilled water (200 mL) with ascorbic acid (9.46 mM). The sample was sonicated for 20 min and aliquots were collected at 1, 2, 5, 10, 15, and 20-min intervals. Samples were able to sit between intervals and the whole process was performed on ice. The samples were passed through a 1 mm sized stainless-steel filter and the filtrates were collected and lyophilized for further use. The Sonics Vibra-Cell VCX750 ultrasonic unit was used for sonication. The Dumas method was used to calculate protein yield and protein content in insect samples using the NDA 701 Dumas Nitrogen Analyzer. They used Agilent 1100 HPLC with Eclipse AAA column for analysis of amino acid composition in insect samples [28].

Table 4: Ether extract of fats & crude protein (% of dry matter) in silk worm, cricket, and mealworm [21]

	Cricket	Meal worm	Silk worm
Fats	10-22	31-43	6-37
Crude protein	56-67	47-60	52-71

Table 5: Content of Amino Acid (g/16 g N) in insects produced as animal feed [21]

	Mormon cricket	House cricket	Black solider fly	Meal worm	FAO reference protein for 2-5 year-old child
Methionine	1.4	1.4	2.1	1.5	2.5 (Methionine+ Cyteine)
Cysteine	0.1	0.8	0.1	0.8	--
Lysine	5.9	5.4	6.6	5.4	5.8

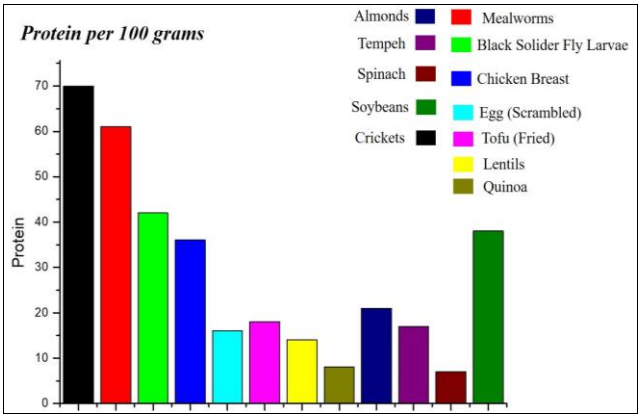

Fig 1: Comparison of Protein Composition of Crickets with other food sources [32]

"Building up a hunger for edible insects won't be simple in light of the fact that huge number of us have a fear of insects throughout our life", said Dr Lesnik. *Charlotte Payne* includes, it alarms individual to have a go at something which is new to them especially kids and youngsters [15]. With regards to the exploration paper *Simone Mancini, Giovanni Solari et al. 2019.*, some analysts are had some expertise in and leading different social investigations on volunteers through the *Theoretical model* that highlights two mainstays of research upheld nourishment neophobia and bug nourishment dismissal. The consequences of the *Theoretical model* may assist us with seeing progressively about nourishment neo phobia, socio demographic and other conduct develops upheld by a private and social level which will be an explanation behind the dismissal of edible insects as nourishment [16]. *Julie Lesnik*, an anthropologist and the creator of "*Consumable Insects and Human Evolution*", state Christopher called locals of America as brutal to his associates after coming back from America and bugs dietary pattern of local Americans became significant strides for Christopher to slave them [15]. Still insects are a significant piece of culture, tradition, and ritual around the world, for example, in Brazilian Amazon using *Pachycondyla commutate ants* during their ceremonies or in Southern California and Northern Mexico have a significance of *Pogonomyrmex californicus* insects in their rituals. We can discover the name of insects in different sections of blessed books like Qur'an, Ancient Egyptian, Shinto of Japan, and some more. Religious, social, custom, traditional values of insect and insidiousness look of insects can be an explanation among the populace for their neophobia of

eating insects [1]. There are some important points that can support the points and facts of edible insects which can lead to a bigger picture than the above discussion.

- **Health**
- Insects are health and nutritious.
- Rich source of Proteins (3 times), fats, high in iron, calcium, omegas, amino acid and Zinc.
- Thirty-times more vitamin B12 than beef.

- **Environment**
- Emit fewer Greenhouse Gases compared to others.
- Low emission of ammonia unlike as pigs.
- Can be solution for organic waste streams.
- Require minimal quantities of water.
- No requirement for land clearing for insect rearing.

- **Safe and sustainable**
- Low capital and technology required for insect harvesting and can be a good opportunity for urban and rural peoples for their livelihood.
- Genetically edible insects very from humans, hence they are less chance of transmitting diseases and viruses to human when eaten.

The Bad- Dark side of Insects Eating

All things considered, we have far to go regardless of whether the shopper gets settled with the edible insects' dietary pattern since we don't have a guideline to guarantee the quality and wellbeing of the insects made food items. The Department of Agriculture of the United States says they can't utilize bugs in our nourishment plan until they are free from pathogens, poisons, hints of pesticides, allergens, microbes. In 2016 North American Coalition for Insect Agriculture appeared to work with controllers and advance more bugs into our eating regimens [17]. Google has a website called *Bugsfeed*, which displays information about stores and restaurants that offer edible insects, and has 204 restaurants and stores on it. There is an option to select "By Type", "By Country", "By Insect", or "By Product", giving customers the confidence to choose their stores or restaurants. Below are some of the restaurants and stores [19].

- Santa Clara, CA, United States. 99 Chicken....
- Austin, TX, United States. Aketta by Aspire....
- Alameda, CA, United States. Alameda Natural Grocery....
- Athens, GA, United States. All Things Bugs LLC....
- Nice, France. Aphrodite....
- London, United Kingdom. Archipelago Restaurant....
- West Monroe, LA, United States. Armstrong's Cricket Farm....

Fig 2: One of the restaurants in D.C., serve dead bugs to eat under the PR stunt for Ehrlich Pest Control [20]

Still, there is very little information available on the Internet that pests and their toxicity can affect our body's system. One study has suggested that insects can trigger allergic reactions, as crustaceans do. You should stay away from roasted grasshoppers or cricket dough. In 1950s, reported an intestinal "fluke" (or an infestation of harmful bacteria) that infects many people in Malaysia. They are derived from eating dragonflies. Insect "chitin" or "exoskeleton" can affect our body's ability to absorb insect proteins, but now researchers have discovered many health benefits of chitin. Chitin boosts immunity, helps fight cancer, and helps with inflammation. One study reported low level of harmful chemicals or pesticides in the raising of insects, we cannot ignore the use of pesticides in producing edible insects when its production is unregulated. Insects that are food sources pose minimal risk to our health. Some insects are delicious and healthy food source, but it is imperative that experts know about them because some insects carry venom or toxins inside them to protect themselves from predators, and if someone ingests them with their venom or toxin, they can die or suffer other metabolic disorders [23]. However, finding a place to buy edible insects is still a problem, as some key issues and myths have made it impossible for the public to include pests in their diet. However, these restaurants and shops bring the light of hope and various government and non-government organizations are conducting awareness campaigns in different countries around the world.

Market growth of Edible Insects and their products

The value of current growth is limited as the production of insects as a food source is not yet regulated. However, based on data available from Google and Meticulous Research, research shows that the food pest market is expected to reach USD 7.96 billion by 2030, depending on the type of product (whole insects, insect food, powder insects, feed, drinks, proteins). And in volume by 2030, it will reach 732,684.1 tons [24]. Another report published by *Kunal Ahuja* and others in Global Market Insights suggests that the edible insect market exceeds $ 112 million in 2019. The demand for low-fat, high protein and lean foods has grown significantly, and is estimated to be between 2019 and 2026 will grow at more than 47 percent of the average annual growth. The Canadian Food Inspection Agency (CFIA) has designated insects as "fresh produce" and allows twenty-five dead mites and four insect fragments for every 225 grams of cheese products. The CFIA sets standards, policies, and provides nutrition and food safety information. These regulations help stimulate the growth of the edible insect market and the global market [25]. They are few companies all over the world which are a major player in the insects' market such as Hao Cheng Mealworm Inc. (China), Kreca (Netherlands), Proti-Farm (Netherlands), Chapul Inc. (U.S.), Eat Grub (UK), Bitty Foods (U.S.), Edible Inc. (Korea), Thailand Unique (Thailand). Beetles are one of the best options for the population, but cricket's market share has increased significantly. The global edible insect market has reached significant level in the Asia-Pacific region and we except its growth to reach Europe, North America and Latin America.

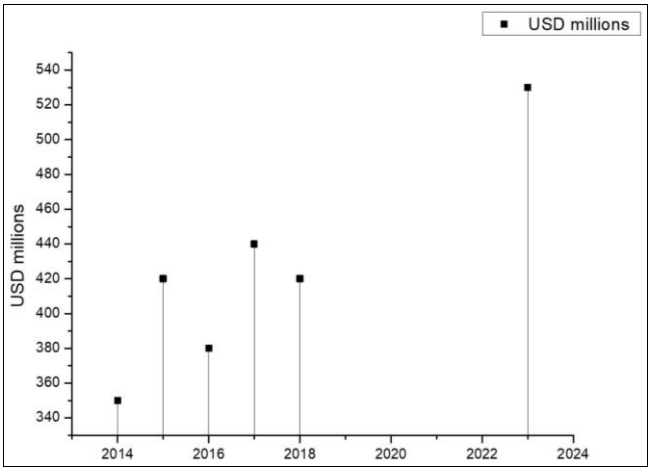

Fig 3: Revenues of Edible Insects Market in USD millions in Asia-Pacific, 2014 to 2023 [33]

Conclusion

We need certain implication in your current food production systems in a global perspective. In current system of food production is somewhat putting a burden on your resources in the terms of clearing land for agriculture use, global warming, loss of natural habitats, use of excessive pesticides, having on negative impact on health and welfare issues in animal production systems which indirectly decreases the quality of nutritional value from our food and increase the cost of producing them. Due to improper balance in nutrition in our food can lead to formation of physiological stress on our young mind and they are not able to live their social life [26]. Edible insects and its other products can be a modern solution to our current food productions problems because edible insects are highly rich in protein and various amino acids, especially in essential amino acid which is essential for human health. They are also having good nutritional value of unsaturated fatty acids, carbohydrates, vitamins, and minerals. Unlike the common meat production from other animals' edible insects don't need for large area of land for their farming and it is very cheap source of protein as compared to another source.

An enormous variety of insect species has pharmaceutical and commercial value and a source of food. Bees and silkworms are a noble example and anywhere, bees and silkworms can produce huge tones of honey and silk respectively, and can be an inexpensive source for local farmers and a boon to the country. Scaly insects of the order Hemiptera produces a red dye, and we called it carmine, which is used in the textile, food, pharmaceutical, and other industries. A medicinal protein produced by insects, resilin, is currently used as medicine to repair arteries and whereas the venom of insects is medicinally used in the treatment of infected wounds and burns [22]. We use many other products of insects such as wax, biodegradable polymers in pharmaceutical and as well in the biomedical engineering field as biomaterials for dental mold, electrospinning, imaging techniques, drug-delivery technology, implants and many others [27]. Insect biotechnology or yellow biotechnology is one of the new areas of research today. Insects have developed a vast arsenal of active substances; which insects have been used for protection from predators and disease or to explore natural sources of food. The main role of insect biotechnology is to provide people with these natural substances more economically and safely. Recently, scientists have succeeded in developing techniques that allow the genomes of many species to be sequenced. These techniques allow scientist to extract individual genes and study the function of individual genes in insects [29]. There really are many opportunities and the future for insect proteins to function as nutrient recyclers, manufacturers of chemicals such as biodegradable plastics made from chitin derivatives, green solvents made from fats, nutrient media for cell culture, and mini-bio-factories for biology and therapeutics [30]. Technology can play an important role in adaptation of insects' food to humans. Using technology, we can hydrolyse insect protein products using a mixture of protease enzymes, which can be a good source of protein, and with the help of flavour, sweetener, and colour agent, we can make product more acceptable [31]. This new approach to entomophagy could be interdisciplinary linked to agriculture, forestry, medicine, food and animal husbandry to address the current state of world hunger.

Notes

The authors declare no competing financial interest.

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