Feeding the Future: Insects as a Sustainable Solution to Protein Deficiency

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ABSTRACT

The global population has been increasing continuously. Proteins are vital for the existence of living organisms, including humans. They serve as bodybuilding components. Human beings are mostly dependent on plant-based and animal-based food materials for protein sources. Plant-based and animal-based protein sources are more costly, labour-intensive, and require more time for production. Globally, due to the lack of availability or the increased cost of protein sources, many humans are facing protein deficiency disorders. Hence, in search for other protein sources, insects are identified as the best alternatives to plant and animal-based protein sources. In many countries, humans are raising insects and consuming them as a protein-rich food. Choosing insects as a protein source is a comparatively cheap and efficient way of providing protein sources to low-income countries.

INTRODUCTION

The human population is increasing steadily. As of now, approximately 8.2 billion people are on the globe (Worldometer, 2025). In 2024, around 673 million people, about 8.2% of the current global population, faced hunger due to insufficient food or lack of food availability. It is estimated that by 2030, 512 million people around the globe will be undernourished, and many people across the world will be suffering from protein deficiency (FAO, IFAD, UNICEF, WFP, and WHO, 2025). Children are more vulnerable to protein deficiency, known as protein-energy malnutrition. According to a recent estimate, 25% of children across the world are suffering from

protein-energy malnutrition (Care Health Insurance). As per 2024 statistics, globally, around 6.6% of children, approximately 42.8 million children under 5 years of age, suffer from wasting, also known as low weight for height, and 23.2% or 150.2 million children suffer from stunting, also known as low height for age (UNICEF, World Health Organization, and World Bank, 2025).

As of now, India is the world's most populous country, having recently surpassed China. India's population is approximately 1.4 billion (Worldometer). It is estimated that around 13.7% of Indians, or about 194.6 million people, are undernourished, 35.5% children under age 5 are stunted, and 18.7% of children under age 5 are wasted (Concern Worldwide and Welthungerhilfe, 2023). A 2017 IMRB survey revealed that approximately 73% of Indian diets are deficient in protein, and only 10% of Indians are consuming adequate protein.

Proteins

Proteins are commonly known as the building blocks of life. They are made up of individual units known as amino acids. As of now, 20 genetically coded amino acids exist in nature. These amino acids are linked to each other through peptide bonds, leading to the formation of proteins. Differences in the sequence of amino acids result in the formation of various proteins. In a living system, proteins perform several functions. For example, collagen provides strength and elasticity to bones and skin, keratin protects by forming nails, hair, and other layers of skin, elastin helps in providing flexibility to various tissues, enzymes like amylase, lipases, and pepsin digest carbohydrates, fats, and proteins, hemoglobin helps in carrying oxygen in the blood, various hormones like insulin regulate blood sugar levels, antibodies fight against various pathogens, muscle contractions are possible through actin and myosin, and histone helps in packing DNA into a compact structure within the cell nucleus, all these are proteins. Living systems cannot function without proteins.

Living organisms have two sources for amino acids. Some amino acids are synthesized in the body itself, and these amino acids are known as non-essential amino acids. There are 11 non-essential amino acids, such as Alanine (Ala, A), Arginine (Arg, R), Asparagine (Asn, N), Aspartic Acid (Asp, D), Cysteine (Cys, C), Glutamic Acid (Glu, E), Glutamine (Gln, Q), Glycine (Gly, G), Proline (Pro, P), Serine (Ser, S), and Tyrosine (Tyr, Y). Some amino acids are not synthesized and must be obtained through the diet, and these amino acids are known as essential amino acids. There are 9 essential amino acids, such as Histidine (His, H), Isoleucine (Ile, I), Leucine (Leu, L), Lysine (Lys, K), Methionine (Met, M), Phenylalanine (Phe, F), Threonine (Thr, T), Tryptophan (Trp, W), and Valine (Val, V). Deficiency in the intake of essential amino acids in the diet results in several disorders and diseases.

Protein Deficiency

Protein deficiency is more common in children and is represented by kwashiorkor disease. This disease has symptoms such as oedema in the legs, feet, hands, and face; fatty liver; hair and skin abnormalities; muscle loss; and increased susceptibility to infection. Marasmus is another disease caused by a deficiency in both proteins and calories. It is characterized by fatigue, weakness, diarrhoea, a weakened immune system, wrinkled skin, stunted growth, and muscle and weight loss. In adults, protein deficiency causes muscle mass loss, also known as sarcopenia or muscle wasting; a weakened immune system due to a lack of production of protein antibodies; oedema or swelling in the ankles, abdomen, and feet; hair problems like hair loss, thinning, brittleness, and color change; skin problems like lesions,

rashes, flakiness, dryness, and hyperpigmentation; nail-associated problems like brittle nails, white bands, and ridges; a higher chance of bone fractures; liver diseases; mood changes and cognitive impairments; and slow wound healing. Hence, a diet rich in essential amino acids should be taken daily. According to the Indian Council of Medical Research (ICMR), 0.8 to 1.0 g of protein per kilogram of body weight is recommended daily.

Protein sources

Plant-based food materials and animal-based food materials are the primary sources of protein for human beings. Plant-based food materials containing all 9 essential amino acids include quinoa, buckwheat, soy (tofu, tempeh, edamame, soy milk), amaranth, chia seeds, hemp seeds, spirulina, and teff etc. Apart from these, there are several other plants and their products that provide amino acids, but they are excessive in some amino acids and deficient in others. For producing these plant-based proteins, we need land, labour, water, seeds, fertilizers, weedicides, and pesticides, etc. Additionally, we need to put in a lot of effort, time, and money to achieve a good quantity and quality of yield. In some cases, due to the adoption of intensified agricultural practices—such as using higher amounts and repeated application of fertilizers and pesticides, several environmental problems like climate change have arisen.

Similarly, for producing animal-based food material for protein, we need to raise fodder crops, which require almost similar efforts as mentioned earlier. Additionally, animals require land for housing, labour for care, and skilled persons for the management of diseases, etc. Furthermore, we need to wait for the growing animal to reach the proper size for obtaining meat. It was statistically determined that to produce 1 kg of plant-based protein, we need to spend approximately €116.32/kg of protein (₹11,625.04 INR). In the case of animal-based protein, especially beef and lamb, the cost is €131.76/kg of protein (₹13,163.50 INR), and for obtaining protein from seafood, the cost is approximately €179.97/kg of protein (₹17,980.20 INR) (ESCI-UPF News, 2024). Hence, among plant, animal, and seafood sources, a greater amount of cost is spent on animals for obtaining protein. To overcome this, a search for another source that yields protein at a lower cost is necessary.

Insects

Insects are the most abundant small-sized living creatures on Earth. In many cases, most people generally consider insects only as pests causing damage to crops. But, apart from acting as pests, insects also help mankind in many ways, such as providing food by performing pollination, and producing silk, lac, etc. Additionally, insects directly serve mankind by acting as food materials. They are also animals, and similar to other higher animals that provide food to humans, these insects are also a good source of calories, proteins, and fats. The nutritional value of insects depends on several factors, such as the type of insect used (species), stage of insects (larva, pupa, adult), type of food material consumed by insects, and method of preparation (drying, boiling, frying). According to Van Huis et al. (2013), on a dry weight basis, the crude protein content of Hemiptera adults and larvae is 42–74%, Odonata adults and naiads is 46–65%, Homoptera adults, larvae, and eggs is 45–57%, Hymenoptera adults, pupae, larvae, and eggs is 13–77%, Lepidoptera larvae and pupae is 14–68%, Coleoptera larvae and adults is 23–66%, and Orthoptera nymphs and adults is 23–65%.

Furthermore, per 100 g fresh weight, the larval and adult stages of *Locusta migratoria*, *Acridium melanorhodon*, and *Ruspolia differens* contain 14–18 g and 13–28 g of

protein; the adult stage of *Sphenarium purpurascens* contains 35–48 g of protein; the larval stage of *Bombyx mori* contains 10–17 g of protein; the larval stages of *Rhynchophorus palmarum*, *R. phoenicis*, and *Callipogon barbatus* have 7–36 g of protein; larvae of *Tenebrio molitor* have 14–25 g of protein; and adult crickets and termites have 8–25 g and 13–28 g of protein, respectively (Van Huis et al. 2013). This reveals that insects are a good source of dietary proteins.

Insects as Food

Eating insects is known as entomophagy. Approximately 1,900 insect species are eaten by humans globally. The most commonly used insects in the human diet include the Mopane worm (*Gonimbrasia belina*), African palm weevil (*Rhynchophorus phoenicis*), yellow mealworm (*Tenebrio molitor*), house cricket (*Acheta domesticus*), migratory locust (*Locusta migratoria*), chapulines (grasshopper) (*Sphenarium purpurascens*), silkworm larvae (*Bombyx mori*), weaver ant (*Oecophylla smaragdina*), giant water bug (*Lethocerus indicus*), bamboo borer (*Omphisa fuscidentalis*), red palm weevil (*Rhynchophorus ferrugineus*), black soldier fly larvae (*Hermetia illucens*), termite (*Macrotermes bellicosus*), cicada (*Magicicada septendecim*), and honeybee larvae and pupae (*Apis mellifera*).

Among all the edible insects, the Coleoptera order is the most consumed, accounting for 31%, followed by Lepidoptera (18%), Hymenoptera (14%), Orthoptera (13%), Hemiptera (10%), Isoptera and Odonata (3% each), Diptera (2%), and other orders (5%). Several countries across the world consume insects. African countries such as the Democratic Republic of the Congo, the Central African Republic, Cameroon, Nigeria, South Africa, Zambia, and Zimbabwe; Asian countries like Thailand, Laos, Vietnam, China, Japan, South Korea, Indonesia, Malaysia, and India; and Latin American countries including Mexico, Colombia, Brazil, Peru, Venezuela, and Ecuador all have populations that consume insects as food (Van Huis et al. 2013).

Insects as Chips

Some products made from insects are readily available in markets as edible chips. The house cricket (*Acheta domesticus*) is one example. House crickets are raised on farms. After attaining the proper size, they are collected and roasted, followed by grinding to obtain flour. House cricket flour is mixed with salt and other ingredients like corn flour, wheat flour, or rice flour, and made into sheets of desirable sizes and shapes by adding water and mixing the flours. Later, the sheets are dried and deep-fried in oil or baked. Afterwards, the fried or baked sheets are flavoured with various substances and preservatives. These chips are then packed and sold in markets. Cricket chips are sold under various brand names across the world, such as Chirps Chips (USA), Jimini's (France), Bugsolutely Cricket Pasta & Chips (Thailand & Italy), Small Giants (UK), and Cricketa (India), etc.

Advantages

Due to the lack of availability of quality food materials, many children and adults suffer from protein deficiency disorders. Eating insects rich in protein can help alleviate protein deficiency-related disorders. Additionally, in comparison to plant-based and animal-based proteins, the production of insect-based proteins is much cheaper and requires less labour, time, effort, inputs, and equipment. Insects are small creatures, so insect farming requires less space and feeding material. Additionally, insects have efficient feed conversion efficiency; for producing 1 kg of body mass, insects, for example, crickets, use only 2 kg of feed, whereas cattle require 8 kg of feed. In comparison to plants and animals, insects complete their life cycle in a

very short time, which means their availability is greater.

CONCLUSION

Plant-based and animal-based protein production cause several environmental pollution problems, such as climate change, but insect farming creates very little environmental pollution. Furthermore, establishing a new industry related to insect farming will generate employment for many people. In some instances, diseases are spread from rearing birds to humans, such as bird flu, but in insect farming, the chances of spreading diseases from insects to humans are very low. In India, due to the lack of awareness among the people or due to customs, most people treat insects as pests and harmful organisms. Creating awareness about the insects as a protein source will help in overcoming protein deficiency.

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