Entomophagy for nutritional security in India: potential and promotion

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Entomophagy is practised on a large scale by the tribal communities in North East India compared to eastern and southern states. Termites, honey bees, grasshoppers, stink bugs, aquatic insects and silkworms are common and preferred insect species because they contain high amount of protein, fat, minerals and vitamins. Silkworms are successfully mass-reared on host plants or laboratory diets for commercial production. Generally, insects meant for food recipes are processed before consumption to improve taste, flavour, palatability and nutritional value which make them comparable with animal products. Thus, entomophagy supports nutritional security and family livelihood of tribal communities during difficult periods of the year.

This review discusses risks for human health due to consumption of insects and emphasizes conservation of at least major insect species collected from nature. Regular bioprospecting revealed a few new species but needs validation of their consumption through regulatory framework. This initiative would boost not only the sale in local markets but also may open new vista for export. Holistic approach and intensive efforts are needed to promote entomophagy in regions other than the North East.

Keywords: Constraints, edible insects, food products, human safety, nutritional security, tribal communities.

FOOD security in India is assured under the Food Security Act (2013) which clearly states that everyone should get nutritious food in sufficient quantity for the whole year. This is rather jeopardized by the ever-increasing human population which is causing imbalance between food production and nutrition[1]. It is estimated that the current population of 1.2 billion would reach 1.8 billion by 2050 (ref. 2). To feed the increasing population, there should be an increase in land, water and other natural resources. But it may not be possible because it is now evident from various reports that food production is fluctuating from year to year due to climate change, unusual seasonal distribution and often scanty rains. Despite this fact, India stands at the top of production of fruits, vegetables and milk, but per capita availability of these items is below the family need[3]. Consumption of meat is appreciated by economically stable people though the cost is often exorbitant and it affects natural balance. For example, rearing animals for meat and growing crops for food grains are responsible for ecological degradation as described by Gahukar[4] and van Huis and Oonincx[5]. Under such circumstances, proteinaceous food through alternative sources of food is being searched. In this perspective, edible insects such as mini livestock appear promising and a potential option because they are a rich source of protein, essential minerals and vitamins[6,7]. Therefore, insects form a major ingredient of daily diet and are consumed as emergency food whenever foodgrains are not available or during difficult times of the year (waiting for crop harvest, impossibility of loan, purchasing of farm inputs, failure of crops due to insufficient or unseasonal heavy rains, high cost of available food grains, difficult accessibility and payment of debt).

Limited data on entomophagy showed that it can support family livelihood to overcome food insecurity, at least for a short period of food penury. Insects also provide a reasonable source of income as fresh insects are sold in local unorganized markets[8]. Of course, marketing depends upon consumers' preference for certain edible insects. For example, *Nyishi* tribe in Arunachal Pradesh prefers stink bugs, *Nezara viridula* (L.) and white grub, *Anomala* sp. larvae. On the contrary, *Galo* tribe from the same area prefers wasp, *Vespa* sp. Both tribes consume a short-horned grasshopper, *Chondacris rosea* (De Geer) and ground cricket/mole cricket, *Brachytrupes orientalis* (Burmeister)[9]. To make it consumable, wings, antennae and legs of orthopterans and wings of odonata larvae are removed before consumption[9,10].

Entomophagy depends upon insect palatability, taste, availability and suitability, nutritional value, food taboo restrictions, local traditions and religious customs[9]. Generally, insect-based food is not socially supportive and acceptable in all regions though insects provide ecological services apart from assuring continuous supply of nutritious food to resource-poor families. As such, entomophagy is practised mainly by tribal communities in the states of Kerala[11], Odisha[12,13,] Jharkhand[12], Karnataka[12], Tamil Nadu[14], Chhatisgarh[12], Madhya Pradesh[15] and North East India[9,13,16,17]. The aim of this paper is to review current practices of entomophagy and their implications for nutritional security which is an important factor of human welfare. Moreover, since entomophagy is quite

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popular in North East region, we discuss the avenues to disseminate this practice in other states where entomophagy is absent or prevalent only among tribal populance on a small scale. Perspectives of insect-products/recipes have also been discussed as a food security measure.

Edible insect fauna of India

Over 2,000 insect species belonging to 18 orders are consumed worldwide[18]. In India, biodiversity had been existing since ancient times due to harmonious coexistence between tribal communities and natural resources. Despite this fact, systematic survey on edible insects has not been undertaken by any government agency. Chakravorty *et al.*[9] reported 298 edible insects belonging to coleoptera (34%), orthoptera (24%), hemiptera (17%), hymenoptera (10%), odonata (8%), lepidoptera (4%), isoptera (2%) and ephemeroptera (1%). Chakravorty[15] also stated insect diversity in Arunachal Pradesh (158 species), Manipur and Nagaland (41 species each), Assam (38 species), Meghalaya (16 species), Kerala (5 species) and Karnataka, Tamil Nadu, Odisha and Madhya Pradesh (1 species each).

Indigenous communities in the North East region prefer coleopteran insects for entomophagy as confirmed by two surveys. In one survey in Assam, Ronghang and Ahmed[19] sampled 30 insect species and reported 36.6% coleoptera followed by hymenoptera (23.3%) and the least was isoptera with 3.3%. In another survey, Chakravorty *et al.*[20] studied 81 insect species in Arunachal Pradesh. Maximum number of 24 insects (29.6%) was from coleoptera followed by orthoptera (20.9%) and hemiptera (19.7%), and minimum number of 9 species (11.1%) from odonata. In this study, Chakravorty *et al.*[20] did not include species from isoptera and lepidoptera, two important orders of edible insects. On the contrary, some unidentified insects were considered in the inventory. Furthermore, Chakravorty *et al.*[9] noted that the *Nyishi* tribe in Arunachal Pradesh consumed mostly coleoptera and hemiptera whereas the *Galo* tribe consumed insects from odonata and orthoptera. In Manipur state, a survey of edible insects conducted by Devi *et al.*[21] revealed 31 aquatic insects and a maximum of 14 species were from hemiptera. In Changlong district of Arunachal Pradesh, Chakravorty *et al*.[20] collected 51 insect species belonging to 9 orders which are consumed by local populations. In Arunachal Pradesh and Manipur, *Adi* and *Meitei* tribes consume insects belonging to hymenoptera, hemiptera, orthoptera, odonata and coleoptera[22]. In the same perspective, Ranjit Singh and Padmalatha[14] studied ethno-entomological practices in Tirunelveli district in Tamil Nadu and reported 11 edible insects. These surveys undertaken in limited areas showed a large variation in existing fauna which can be explored further to provide nutritious food to consumers.

Bioprospecting is generally intended for inventing new edible insects and for confirming current status of insects which are consumed[23]. There is urgent need of bioprospecting to know biodiversity of edible insects in states other than North East region. This is because it is possible that several insects are edible but are yet unknown or unidentified. These studies will help extend entomophagy to urban populations by convincing and motivating them to accept insects as food. This may not be possible in the near future because with degradation of natural resources, rapid civilization and shift to westernization from conventional systems, there is significant loss in traditional wisdom which has an important influence on entomophagy.

For edible insects, indigenous communities select the proper processing methods as they have experience for generations, and try to improve their daily food[24]. For example, after removing wings, grasshoppers are fried in oil and eaten after adding salt. Bamboo caterpillars are stuffed in bamboo pipe, smoked dry for 3–4 days, mixed with chilli/red pepper and salt and consumed with rice. Otherwise, dried material is crushed and mixed with chilli, salt and bamboo shoots to make a paste (‘chutney’). This highly appreciated preparation is commonly eaten in North East region. Most of the insects are degutted/defatted before processing as insects may contain toxic substances. The processed insects can then be preserved safely without microbial contamination. In an analysis of insects consumed in Assam and Arunachal Pradesh, it was ascertained that a majority of insects are consumed only after having processed them with various methods (Table 1). Insect eggs being a rare item are consumed in Assam after cooking and baking. Overall, larvae (nymphs) and adults are the most preferred life stages in both states.

Nutritional profiling

The content of essential nutrients is a baseline criterion while selecting insect species. In India, insect eggs, larvae/nymphs, pupae and adults are consumed probably because there is vast difference in the content of nutrients as per insect development period[24]. Consumption of crickets, termites, grasshoppers and caterpillars yields a high energy value. Content of protein is significantly higher than or equal to animal foods such as, chicken, pork, eggs, beef or lamb[4]. When five insects were compared for nutritive value, high protein content was found in dragon fly, *Crocothermis servilla* (Drury) larva (70.48%)[25], short-horned grasshopper, *Oxyahyla hyla* Serville adult (64.67%)[26], surface grasshopper, *Oedaleus abruptus* (Thunberg) adult (60.00%)[27] and eri silkworm, *Samiaricini* (Drury) pupa (71.9%)[28]. Contents of fat, fibre, sodium and potassium in stink bug, *Aspongopus nepalensis* Westwood, and calcium and magnesium in *C. servilla* larvae were comparatively high (Table 2). In case of

Table 1. Commonly explored major edible insect species documented from India

Method of processing	Insect species	Order: Family	Insect life stage(s)	State
Baked	*Apis cerana indica*	Hymenoptera: Apidae	Egg, larva, pupa	Assam[19]
	Antheraea assamensis	Lepidoptera: Saturnidae	Pupa	Assam[19]
	Oecophylla smaragdina	Hymenoptera: Formicidae	Egg, adult	Assam[19]
	Rhynchophorus phoenicis	Coleoptera: Curculionidae	Larva	Assam[19]
	Rhynchophorus ferrugineus	Coleoptera: Curculionidae	Larva	Assam[19]
Cooked	*Pentatomid* sp.	Hemiptera: Pentatomidae	Adult	Arunachal Pradesh[43]
	Locusta sp.	Orthoptera: Acrididae	Adult	Arunachal Pradesh[43]
Cooked + baked	*Polistes stigmata*	Hymenoptera: Vespidae	Egg, larva, pupa	Assam[19]
	Samia ricini	Lepidoptera: Saturnidae	Larva, pupa	Assam[19]
	Myrmica rubra	Hymenoptera: Formicidae	Larva, pupa	Assam[19]
Dry/deep fried	*Reticulitermes flavipes*	Isoptera: Rhinotermitidae	Adult	Assam[19]
	Dihammu scervinus	Coleoptera: Cerambycidae	Larva	Assam[19]
	Meligethes aeneus	Coleoptera: Nitidulidae	Larva	Assam[19]
	Batocera rufomaculata	Coleoptera: Cerambycidae	Larva	Assam[19]
	Okanagan sp.	Diptera: Asilidae	Adult	Assam[19]
Dry/deep fried + baked	*Megasoma elephas*	Coleoptera: Scarabaeidae	Larva	Assam[19]
	Apis dorsata	Hymenoptera: Apidae	Larva, pupa	Assam[19]
	Apis cerana indica	Hymenoptera: Apidae	Larva, pupa	Assam[19]
	Apis florea	Hymenoptera: Apidae	Larva, pupa	Assam[19]
Deep fried + roasted	*Mantis religiosa*	Orthoptera: Mantidae	Nymph, adult	Assam[19]
	Melanopus sp.	Orthoptera: Acrididae	Adult	Assam[19]
Raw/fresh	*Aeshna mixta*	Odonata: Aeshnidae	Nymph, adult	Assam[19]
	Neurothemis fluctuans	Odonata: Libellulidae	Nymph, adult	Assam[19]
	Apis dorsata	Hymenoptera: Apidae	Larva (hive)	Arunachal Pradesh[43]
	Apis cerana indica	Hymenoptera: Apidae	Larva (hive)	Arunachal Pradesh[43]
	Vespa mandarinia	Hymenoptera: Vespidae	Larva	Arunachal Pradesh[43]
Roasted	*Schizodactylus monstrosus*	Orthoptera: Gryllidae	Nymph, adult	Assam[19]
	Gryllus campestris	Orthoptera: Gryllidae	Nymph, adult	Assam[19]
	Gryllotalpa africana	Orthoptera: Gryllotalpidae	Nymph, adult	Assam[19]
	Odontolabis cuvera	Coleoptera: Lucanidae	Adult	Assam[19]
	Lucanus elsphus	Coleoptera: Lucanidae	Adult	Assam[19]
	Cyrtotrachelus buqueti	Coleoptera: Curculionidae	Larva	Arunachal Pradesh[43]
	Eurytrachelus titan	Coleoptera: Dynastidae	Adult	Assam[19]
	Libellula carolina	Odonata: Libellulidae	Adult	Assam[19]
	Schistocerca gregaria	Orthoptera: Acrididae	Nymph, adult	Assam[19]
	Belostoma indicus	Hemiptera: Belostomatidae	Adult	Arunachal Pradesh[43]
	Vespa tropica	Hymenoptera: Vespidae	Larva	Arunachal Pradesh[43]
	Vespa bicolor	Hymenoptera: Vespidae	Larva	Arunachal Pradesh[43]
	Polistes sp.	Hymenoptera: Vespidae	Larva	Arunachal Pradesh[43]

Table 2. Nutritional composition of commonly exploited edible insect species of India

Nutrient (%)	*Brachytrupes orientalis*[30]	*Oxyahyla hyla*[27]	*Oedaleus abruptus*[28]	*Aspongopus nepalensis*[10]	*Crocothermis sevilla*[25]
Carbohydrates	15.18	28.17	30.00	–	1.18
Crude protein	65.74	64.67	60.00	10.60	70.48
Fat	6.33	2.18	15.00	38.35	4.93
Crude fibre	8.75	9.23	–	33.47	9.62
Ash	–	–	5.00	2.10	1.34
Calcium	0.24	–	5.00*	0.12	86.5
Potassium	–	–	10.35	26.80	–
Sodium	–	–	1.02	14.10	–
Phosphorus	–	1.75	0.075	–	–
Magnesium	0.54	0.084	6.00*	–	37.00
Zinc	2.10	0.017	2.50*	9.30	–

*mg/kg.

termites, the sexual forms contained protein, carbohydrates and amino acids in the order of 87.3%, 2.7% and 6.7% respectively, whereas these contents in workers were 81.6%, 1.2% and 4.6% respectively[29]. Sexual forms are therefore preferred by tribal communities. Also, contents of essential amino acids, iron, zinc and copper satisfy the recommended daily allowance prescribed by FAO/WHO panel[30]. Thus, Chakravorty *et al.*[30] recommended edible insects as human food.

Chakravorty *et al.*[30] reported that *B. orientalis* adults contained palmitoleic acid 20–26%, linoleic acid 36–40%, stearic acid 9–32%, palmitic acid 50%, vitamin B12 and minerals (Fe, Zn, Cu). Mulberry silkworm (*Bombyx mori* L.) pupae contained protein 55.6%, fat 32.2% and high levels of essential amino acids such as valine, methionine and phenylalanine[31]. Eri silkworm pupae contained protein 16.0%, fat 8.0%, Ca 24 mg, P 175 mg, Mg 54 g, Zn 2.1 g, Fe 7 g, Mn 0.69 mg and Cu 0.45 ug/100 g (ref. 29). Further, high content of protein (75%) and total essential amino acids (44%) in defatted eri silkworm meal is ideal for preparing protein concentrates[32]. Therefore, eri silkworm pupae are very much accepted as nutritious food in the North East region[32]. Sangavi and Sarath[31] found low fat (2%), but high content of amino acids (57%) and protein (72%) in mulberry silkworm pupa powder, and unsaturated fatty acids (75%), essential linoleic acid (33%) and alpha-linoleic acid (35%) in oil extracted from pupae. These products are used in food industries.

Status of commercial insect farming

Currently, most of the edible insects are collected in nature and domesticated insects, particularly silkworms are considered for outdoor and indoor rearing on commercial scale. In North East region, silkworm larvae and pupae are consumed as food whereas in other places mulberry silkworms are destined for cocoon production. In this respect, some important points are elaborated below to perceive the current situation.

Indoor or house rearing

Indoor rearing of edible insects for commercial purpose has not gained momentum in India except for *B. mori* for which improved technology of insect breeding and cheap laboratory diets are available[33]. To further increase the efficiency of rearing, biofortification of diet (host plant foliage/laboratory media) with products containing protein, vitamins and essential nutrients has been recommended[33]. In future, the major constraint would be that cottage units and local enterprises may not adopt these measures unless there is market demand because indoor rearing is costlier than outdoor rearing.

Outdoor or semi-outdoor rearing

Rearing of domesticated silkworms on host plants in wired cages or wooden platforms has been successful with improved rearing techniques including infrastructure and use of disinfectants[33]. In central and southern states of India, mulberry silkworms are produced on commercial basis and cocoons are purchased by government agencies and the silk industries. From the sale, farmers can earn a net profit of Rs 110,600–114,400 by planting mulberry (*Morus alba*) crop on 0.4 ha (ref. 4). This system of insect production is gaining popularity at village level because structures from easily available and cheap indigenous material is used. For example, Sathe *et al.*[34] constructed rearing sheds in fields with mud wall and used nylon nets and bamboo poles for erecting rearing beds for mulberry silkworm. This simple structure helps to maintain ambient temperature and relative humidity.

Successful farming in nature has been reported from Assam by Ronghang and Ahmed[19] for the giant honey bee, *Apis dorsata* F., Indian honey bee *A. cerana indica*, spider wasp, *Pompilus atrax* Dahlbo and pollen beetle, *Meligethes aeneus* F. Similarly, commercial farming of eri silkworm and the muga silkworm, *Antheraea assmensis* Helfer is practised by local communities in North East region[33]. Collection of insects in the wild can be continued to the extent that there is minimum impact on the environment.

Marketing (local and export)

Several aspects of transforming insect biomass into consumer goods and delicious food dishes have been discussed in detail by Sun-Waterhouse *et al.*[35]. How to move from small production to big business is the current challenge. For bridging this gap, protocol and documentation in local language for commercial insect production units are not readily available. Cooperation and financial aid from government agencies through 'start-ups' is crucial particularly for small entrepreneurs. Additionally, the role of edible insects in the socio-economic development of rural communities needs appreciation of local communities[36]. Insect-based meat substitutes are potentially sustainable as mixing cricket powder in insect-based food products has been appreciated in Belgium, France, Netherlands, USA, Mexico and China[4]. Export potential can therefore be explored for Indian insect species which have high content of nutrients, are easy to rear and can be processed locally.

Key issues

Availability of local insect species

Although edible insects are present in different ecosystems, their population dynamics including seasonal abundance has not been studied. This information can help locals to identify areas and period of the year to collect insects from nature. Generally, insect collection is assured by regular and round-the-year availability from nearby forest areas. Tribal people know how and when to collect insects and preserve them after processing. These stocks are consumed whenever there is penury due to non-availability of foodgrains or animal products. Thus, food insecurity is prevented or reduced[6]. A greater number of insects are available in the warm season than in cold season[23]. Therefore, collection should possibly be made during this period. Once insects are collected in large quantity from diverse locations, locals exercise their preference. For example, a majority of persons (87.7%) in Assam consumed the pupae of eri silkworm followed by muga silkworm pupae (57.4% persons) and *B. mori* pupae (24.6% persons) irrespective of age and gender[37]. The reason for preference of eri silkworm pupae is the high content of protein and good taste.

Main source for terrestrial insects is the forest from where they are collected round the year. However, this natural source is being limited and insect populations are diminishing day by day because of certain circumstances, viz. (1) frequent forest fire and deforestation (logging, firewood) can destroy host plants of edible insects, (2) natural enemies can significantly reduce insect numbers. Other factors responsible for reduction include habitat changes and environmental contamination[5]. Limiting harvesting to certain periods on restricted area, protecting vulnerable insect species and afforestation can support existing populations. Therefore, forest management including survey of new host plants, and monitoring of insects and changes in ecosystems with local participation can facilitate conservation and augmentation of edible insects in natural niche/habitat which is crucial for maintaining steady supply of insects. These studies are however lacking in India.

For aquatic insects, degradation of water quality caused by pollution in the Loktak lake in Manipur resulted in extinction of few insects[38]. Among 31 species censored, the most preferred is the giant water bug, *Lethocerus indicus* Lepeletier & Serville which is popular as a regional delicacy. Earlier, it was generally available in abundance in paddy fields surrounding the lake and locals were selling it daily in local markets. With extensive use of synthetic fertilizers and pesticides in paddy cultivation, the bugs are slowly vanishing from their habitat and ultimately, people are losing their traditional food culture[38].

Edible insects considered as crop pests include grasshoppers, termites, ground crickets, palm weevils and white grubs. In Arunachal Pradesh, two stag beetles, *Dorcus* sp. and *Odontolabis gazella* (Fb.), termite, *Odontotermes* sp., bess beetle, *Odontotaenius* sp. and scarab beetle, *Polyphylla* sp. have been reported as regular crop pests[9]. These insects are destroyed by insecticide sprayings on crops and palm trees on which insects feed. Instead of spraying, these insects can be collected and consumed. Large scale collection can thus reduce pest populations in the field and can save money otherwise spent on chemicals.

Awareness and popularization

To appreciate insects as food, they should be tasty, nutritious and comparatively cheaper than animal or plant food[24]. There is need for an integrated food network to coordinate and exploit the huge potential of edible insects for human nutrition. In fact, demand for healthy foods or those classified as health-promoting items is increasing in the market[39]. Therefore, insect-based foods can be promoted by including them in the marketing chain. The awareness, knowledge and perception of rural and urban population can make the selling of edible insects as a commercial activity which would increase family income for betterment of indigenous populations. In due course of time, the population migration may also be prevented or at least lessened. Currently, the consumers' attitude and public perception need a significant change in favour of entomophagy as an innovative approach towards food security.

Regulatory legal frame work

Regulations are needed to safeguard human health because human safety is of prime importance while recommending edible insects. There are instances of allergy, and contamination of chemicals and biochemical compounds[40]. No intensive studies on these aspects have been undertaken in India. Antinutrients were found in five aquatic insects, and content of phenols and tannins ranged from 0.018% to 0.2685% and 0.301% to 0.528% (fresh weight) respectively[26]. Contents of tannin, oxalate, phytin phosphorus and phytin were 2.316%, 0.474%, 0.031% and 0.109% (dry weight) in a grasshopper, *O. hyla hyla*[26]. These contents being below the permissible level did not pose any risk to human health[27]. Other non-desirable effects of entomophagy reported by Chakravorty *et al.*[9] include biting of stink bug, *Tessaratoma quadrata* Distant causing fever, excessive consumption of another stink bug, *Aspongopus nepalensis* Westwood resulting in hallucination, plant bug, *Daladera cuticosta* Amyot & Serville producing burning sensation, and hair loss is possible after consuming long-horned beetle, *Oplatocera* sp.

For consumers, details on new foods with labelling and documentation would be needed to lessen taboos, boost consumers' knowledge and subsequently, encourage them for entomophagy. Generally, the Codex Alimetarius is applied for trading of farmed insects, legislation is however nearly absent in India. Establishing guidelines of regulatory reforms is a major difficulty probably because formal census system of consumption of edible insects is lacking. Likewise, processing and storage of farmed insects should follow the health and sanitation regulations for traditional food as well as for insects meant for export.

Legislation pertaining products containing insects which are allowed in the country is important to prevent immigration of undesirable species. For this, correct identification of insect species should be ascertained. The list of rules and regulations issued by the quarantine and food safety departments revised from time to time should be readily available to consumers and entrepreneurs. Based on hazards to human health, food defect action levels have been established in the USA[41] and Europe[42]. This information is not yet available in India. The permitted amount of insect or its parts will not harm human health if manufacturers adhere to guidelines outlined by the central government. Subsequently, with known levels of admixture of insect parts in food, it would be possible to take legal action or ban certain insect-containing food products under Food Safety and Standards Act, 2006. Currently, the Food Safety and Standards Authority of India (FSSAI) established under the Ministry of Health and Family Welfare is responsible for checking food items intended for marketing. Inclusion of insect-products in the list is needed to allow food industries to sell new products and popularize entomophagy by strengthening trans-border/inter-state trade. Obviously, this seems possible in states where non-vegetarian population consumes meat, eggs, chicken and other animal products.

Conclusion and future thrusts

With increasing awareness of nutritional security issues, it is important that consumption of animal products that are often prone to human diseases is reduced and entomophagy is popularized in India. Eventually, more research is needed to understand prevailing entomophagy in the North East region where indigenous communities enjoy nutritious food with insects as sustainable ingredient in main dish or as supplement. Constraints such as, content of antinutrients, and contamination of chemicals and biochemical compounds and other risks to human health (allergic reactions, disease infection, side effects) being minimum, consumption of silkworm larvae and pupae, water bugs, grasshoppers, field crickets, termites and dragon fly larvae would prove beneficial as a local source of protein, minerals and vitamins. In future, information on nutritional aspects can effectively be used for better utilization of insects to combat malnutrition and undernourishment with insect protein which is generally equal to or higher than what FAO/WHO recommended for human consumption. In this perspective, regulations established by FSSAI are to be rigorously respected in the production and processing of edible insects. For overall promotion, coordination between donor agencies or investors, entrepreneurs, marketing channels and voluntary organizations would probably be able to integrate entomophagy in future projects on human nutrition and family welfare not only in North East region but in other regions also.

Cultural services provided by edible insects and ecological benefits received by locals for not applying pesticides (since insects are collected from the fields) have been well accepted by local communities. To start commercial activity, the list of insects which can be reared successfully is yet to be made available to villagers. Further, identifying future research needs and establishing ongoing research themes should be done *a priori* by research institutes and government organizations. For small rearing units run by locals, choice to farm few selected species can be linked to local consumption and inter-state marketing. Research on augmenting nutritive value of insects, rearing trials in glasshouses, collection by wire nets or on host plants, business models and food chain network can encourage educated unemployed youth for establishing their own units. There is ample scope to implement recent findings (feeding of grasshoppers on brassica and other crops, replacing house cricket by field cricket, unit automation, etc.). Of course, coordination between entrepreneurs, experienced farmers, investors, NGOs, tribal development department and local community organizations is an essential forward step.

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