Edible Insects

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Edible insects have been considered as either nutritious food items per se, or as wholesome ingredients to various dishes and components of traditional subsistence. Protein, fat, mineral and vitamin contents in insects generally satisfy the requirements of healthy food, although there is considerable variation associated with insect species, collection site, processing method, insect life stage, rearing technology and insect feed. A comparison of available data(based on dry weight) showed that processing can improve the nutrient content, taste, flavour, appearance and palatability of insects, but that there are additional factors, which can impact the content and composition of insect species that have been recommended for consumption by humans.

entomophagy insect edibility insect farming insect diversity acceptability

1. Introduction

In contrast to insectivory, which refers to a diet exclusively consisting of insects, entomophagy means that the consumption of insects represents one component of a much wider food spctrum. Entomophagy (the habit of eating insects) has been practiced since time immemorial by humans [1][2][3] and their primate relatives [4][5]. Although entomophagy was not new to science, it was a paper by Meyer-Rochow [6], which for the first time suggested that edible insect species ought not to be neglected in the quest to safeguard future global food security.

2. Regions where Insects are consumed

At present edible insects are still recognized as a sustainable food item by many residents of sub-Saharan Africa, South and Central America (including Mexico), South-East Asia and the Australia Papua New Guinea region. The consumption of insect species depends upon availability/access, suitability, preference, nutritional value, religious beliefs and social customs [7][8][9][10][11][12]. In North-East India, some highly appreciated species of edible insects are available (mostly seasonally) for sale at the local markets, but their cost is often higher than that of conventional animal meats or food of vertebrate origin [13][14]. This holds true also for Laos [15], Cameroon and many other African countries [16][17]. Nonetheless, the local people prefer the insects because of their taste and for traditional aspects [13][14][18]. However, insect consumption is declining, with one of the reasons being a shortage of the product due to a lack of facilities to efficiently and systematically rear suitable species and another reason in developing countries being an increasing “westernization” in terms of food choices [19]. As a result, sellers experience disruptions and delays in obtaining supplies and potential buyers are frustrated by the fluctuations of the product’s condition and availability.

3. Nutritional Properties

As several scientific reports have demonstrated to date, the nutritional value of edible insects is no longer in doubt; they appear to possess features like comparable protein and mineral contents to the conventional foods of animal origin and, if not superior, a fat content with a higher share of unsaturation, which broadens their utlization as an alternative food resource [18][20][21][22][23][24][25][26][27][28][29][30][31][32][33]. Insects contain easily digestible quality protein with all the essential amino acids readily identifiable (except for methionine and tryptophan, which are present in low levels). The absence of tryptophan and fractional recovery of methionine and cysteine are attributed to methods of analysis and not necessarily because they are actually absent. For example, based on the data of 5 insects, viz. yellow mealworm *Tenebrio molitor* L., house cricket *Acheta domesticus* L., superworm *Zophobas morio* Fabricius, lesser mealworm *Alphitobius diaperinus* Panzer and the roach *Blaptica dubia* Serville, Yi et al. [34] observed that the amount of essential amino acids (EAA) was high and that the content of protein was similar to that of conventional meat products. In China, the pupal powder of the silkworm *Antheraea pernyi* Guerin-Meneville is appreciated, because of its substantial amount of protein (71.9%), EAA, fat (20.0%) and ash (4.0%) [35].

4. Factors Influencing the Nutritional Properties of Edible Insects

With established techniques such as HPLC (high-performance liquid chromatography) for extraction and quantification of nutrients and bioprospecting of new species of edible insects, studies on the nutritional value of insects are being intensified with an aim to search economic and efficient ways to supply processed insects [36]. Currently, nutritional contents are not yet known for the majority of the surveyed/collected insect species of the various geographical locations and eco-zones that they occur in. Furthermore, knowledge and perception of factors that are encountered during the rearing of domesticated insects or those collected in the wild is limited and available only for a certain number of species. More studies on the chemical compositions of edible insects in relation to factors like geography, climate, processing and preparation methods would facilitate the identification of species most suitable for mass rearing and a potential to ameliorate the state of health in humans in certain parts of the globe [37].

5. Sustainability

The overall value of edible insects is not restricted to health and nutritional issues alone, but to a very large degree related related to environmental issues [38][39]. High efficiency of food conversion, less requirement of land and water, negligible methane emissions of insects in comparison to conventioanl foods of animal origin are extra advantages satisfying sustainability and environmental concerns [40][41]. Keeping the nutritional potential and ecological benefits of edible insects in mind, small scale industrialization could be advoctaed to reduce the environmental pressure that accompanies the production of animal protein.

6. Suggestions for Future Research

Insects are being considered as an alternative to conventional protein sources for both developing as well as developed countries. Edible insects have received attention from researchers in recent years because, firstly, the consumption of insects has spread to urban areas and the current concept is oriented towards health-related as well as ecological issues, and secondly, because conventional livestock rearing and certain systems of crop cultivation have proved environmentally disastrous [36][42][43][44]. Bioprospecting is currently limited to a few eco-zones in countries where insects have commonly been consumed. Intensive surveys may yet reveal more species that could be considered for consumption and farming. The shelf life of processed insects could possibly be improved if more research were devoted to this aspect. Factors responsible for nutrient content and quality of edible insects have not been explored sufficiently and to know how the chemical composition, handling and storage methods, contamination with micro-organisms, the insects' diet, feeding schedules, host plants and the plant's own nutrient content as well as the seasons affect food insect marketability would be of considerable benefit in selecting the most suitable species [45]. There is a need to develop rearing facility designs to be made available to small mass production units, which can help create a socially acceptable climate for the expansion of entomophagy [46]. Mass collections of aquatic insects by using nets woven by fishermen may be a remunerative venture, but encouraging locals and creating marketing channels as well as obtaining permits to fish for aquatic insects could be major hurdles. Recently, Oppert et al. [47] suggested sequencinggene transcripts from embryos, one-day hatchlings, nymphs and male and female adults of *A. domesticus* to use genetically modified crickets for improved insect production. Regulations and legislation along with proper farming procedures, storage and hygiene would benefit consumers by way of healthier insects. Frameworks shared by different countries exist in Europe [48] but are lacking for most developing countries [49]. Proper processing and decontamination methods against micro-organisms during collection and storage, and preference of species should be included in surveys to ensure food safety [23]. Also, information on anti-nutrient contents of edible insects is still inadequate and therfore screening of possible anti-nutrients remains a task for the future. A compilation of all this information may be used to select a few insect species for mass rearing or augmenting their survival rate in natural habitats and a linkage through regional or international networks among countries/regions where entomophagy is practiced would be a first step. The network could facilitate exchanges and dissemination of information on insects and insect related recipes. It is essential to conserve wild edible insect populations and to improve the survival of the most popular species [17]. This can be achieved by studying the population dynamics of these insects, identifying their host plants, and controlling their enemies.

Other actions can include restrictions on over-harvesting, revoking the decreasing diversity of host plants, boosting the insects' resilience to adverse weather phenomena and seasonal effects and monitoring insect diseases. A regulatory legal framework is required to guarantee that manufacturing practices, quality management, hazard analysis and other issues related to content and quality of edible insects are meeting acceptable standards [49]. Furthermore, proper labelling and documentation of the insect product would help to boost the consumers' knowledge and interest in entomophagy as would some cheeky and witty slogans to promote insect-containing food items [39]. The scientific guidelines explained by the European Food Security Authority [48] are worth studying to prepare a manual for insects consumed in developing countries, either on a regional or national basis to assure food and nutritional security. In certain regions the people's diet may lack zinc, but in others there may be a shortage of iron, or calcium. To improve situations such as these, some species of insects could be promoted that are particularly rich in the minerals that are needed. Likewise, there may be reasons to boost certain fatty acids in the diet, acids that could be supplied by specific species of insects. To be able to select the most appropriate species, it is of course essential to know precisely the chemical composition of the insect species, which demonstrates how important it is to have a detailed catalogue of the contents of as many species of insects as possible. If one extends this to animal feed, fish culturists may desire in particular protein-rich species, but pigs should perhaps be fed fatty insects and poultry farmers may wish to obtain insects with a high calcium content.

7. Conclusion

To promote insect-based functional foods as a platform for certain health-related properties is a promising option and is to some extent already taking place, e.g., larvae of the pallid emperor moth *Cirina forda* for protein solubility, oil absorption capacity and foaming stability [50], *T. molitor* larvae for their oil, foaming and emulsion capacity [51], black soldier fly for peptides with antimicrobial activity against the stomach ulcer bacterium *Helicobacter pylori* [52] and male silkworm pupal extract with its Viagra-like effect for erectile dysfunction [53].In fact, Meyer-Rochow [54] reviews hundreds of species that can be used therapeutically, but in many cases also serve as food for humans. This is an aspect certainly worth exploring further.

References

1. Bequaert, J. Insects as food: How they have augmented the food supply of mankind in early and recent years. Nat. Hist. J. 1921, 21, 191–200.
2. Bergier, E. Peuples Entomophages et Insectes Comestibles: Étude Sur les Moeurs de L'Homme et de L'Insecte; Imprimérie Rullière Frères: Avignon, France, 1941.
3. Bodenheimer, F.S. Insects as human food. In Insects as Human Food: A Chapter of the Ecology of Man; Bodenheimer, F.S., Ed.; W. Junk: Hague, The Netherlands, 1951; pp. 7–38.
4. Bogart, S.L.; Pruetz, J.D. Insectivory of savanna chimpanzees (Pan troglodytes verus) at Fongoli, Senegal. Am. J. Phys. Anthropol. 2011, 145, 11–20.
5. McGrew, W.C. The 'other faunivory' revisited: Insectivory in human and non-human primates and the evolution of human diet. J. Human Evol. 2014, 71, 4–11.
6. Meyer-Rochow, V.B. Can insects help to ease the problem of world food shortage? Search 1975, 6, 261–262.
7. Gahukar, R.T. Entomophagy and human food security. Int. J. Trop. Insect Sci. 2011, 31, 129–144.
8. Lensvelt, E.J.S.; Steenbekkers, L.P.A. Exploring consumer acceptance of entomophagy: A survey and experiment in Australia and the Netherlands. Ecol. Food Nutr. 2014, 53, 543–561.

9. Shouteten, J.J.; De Steur, H.; De Pelsmaeker, S.; Lagast, S.; Juvinal, J.G.; De Bourdeaudhuij, L.; Verbeke, W.; Gellynck, X. Functional and sensory profiling of insect-, plant- and meat-based burgers under blind, expected and informed conditions. Food Qual. Prefer. 2016, 52, 27–31.
10. Menozzi, D.; Sogari, G.; Veneziani, M.; Simoni, E.; Mora, C. Eating novel foods: An application of the theory of planned behaviour to predict the consumption of an insect-based product. Food Qual. Prefer. 2017, 59, 27–34.
11. Tan, H.S.G.; House, J. Consumer acceptance of insects as food: Integrating psychological and socio-cultural perspectives. In Edible Insects in Sustainable Food Systems; Halloran, A., Flore, R., Vantomme, P., Roos, N., Eds.; Springer: Berlin, Germany, 2018; pp. 375–386.
12. Ghosh, S.; Jung, C.; Meyer-Rochow, V.B. What governs selection and acceptance of edible insect species? In Edible Insects in Sustainable Food Systems; Halloran, A., Flore, R., Vantomme, P., Roos, N., Eds.; Springer: Berlin, Germany, 2018; pp. 331–351.
13. Chakravorty, J.; Ghosh, S.; Meyer-Rochow, V.B. Practices of entomophagy and entomotherapy by members of the Nyishi and Galo tribes, two ethnic groups of the state of Arunachal Pradesh (North East India). J. Ethnobiol. Ethnomed. 2011, 7, 5.
14. Chakravorty, J.; Ghosh, S.; Meyer-Rochow, V.B. Comparative survey of entomophagy and entomotherapeutic practices in six tribes of Eastern Arunachal Pradesh (India). J. Ethnobiol. Ethnomed. 2013, 9, 50.
15. Meyer-Rochow, V.B.; Nonaka, K.; Boulidam, S. More feared than revered: Insects and their impact on human societies with some specific data on the importance of entomophagy in a Laotian setting. Entomol. Heute 2008, 20, 25.
16. Muafor, F.J.; Genetegha, A.A.; le Gall, P.; Levang, P. Exploitation, Trade and Farming of Palm Weevil Grubs in Cameroon; Center for International Forestry Research Content: Bogor, Indonesia, 2015.
17. Gahukar, R.T. Edible insects collected from forests for family livelihood and wellness of rural communities: A review. Glob. Food Secur. 2020, 25, 100348.
18. Chakravorty, J.; Ghosh, S.; Meyer-Rochow, V.B. Chemical composition of Aspongopus nepalensis Westwood 1837 (Hemiptera; Pentatomidae), a common food insect of tribal people in Arunachal Pradesh (India). Int. J. Vitam Nutr. Res. 2011, 81, 49–56.
19. Mueller, A. Insects as food in Laos and Thailand—A case of “Westernization”? Asian J. Soc. Sci. 2019, 47, 204–223.
20. Ramos-Elorduy de Conconi, J.; Pino-Moreno, J.M.; Marquez-Mayaudon, C.; Valdez, F.R.; Perez, M.A.; Prado, E.E.; Bourges-Rodriguez, H. Protein content of some edible insects in Mexico. J. Ethnobiol. 1984, 4, 61-72.

21. Bukkens, S.G.F. The nutritional value of edible insects. Ecol. Food Nutr. 1997, 36, 287-319.
22. Bukkens, S.G.F.Insects in the human diet: nutritional aspects. In: Ecologcical implications of minilivestock; Paoletti, M.G., Ed.; Sci. Publ., Enfield, USA, 2005; pp. 545-578.
23. Rumpold, B.A.; Schlüter, O.K. Nutritional composition and safety aspects of edible insects. Mol. Nutr. Food Res. 2013, 57, 802–823.
24. Chakravorty, J.; Ghosh,; Jung, C.; Meyer-Rochow, V.B. Nutritional composition of Chondacris rosea and Brachytrupes orientalis: two common insects used as food by tribes of Arunachal Pradesh. J. Asia Pac. Entomol. 2014, 17, 407-415.
25. Chakravorty, J.; Ghosh, S.; Megu, K.; Jung, C.; Meyer-Rochow, V.B. Nutritional and anti-nutritional composition of Oecophylla smaragdina (Hymenoptera: Formicidae) and Odontotermes (Isoptera: Termitidae): two preferred edible insects of Arunachal Pradesh. J. Asia Pac. Entomol. 2016, 19, 711-720.
26. Ghosh, S.; Jung, C.; Meyer-Rochow, V.B. Nutritional value and chemical composition of worker larvae, pupae and adults of the honey bee, Apis mellifera ligustica as a sustainable food source. J. Asia Pac. Entomol. 2016, 19, 487-495.
27. Ghosh, S.;Lee, S-M.; Jung, C.; Meyer-Rochow, V.B. Nutritional composition of five commercial edible insects in South Korea. J. Asia-Pac. Entomol. 2017, 20, 686-694.
28. Ghosh, S.; Chuttong, B.; Burgett, M.; Meyer-Rochow, V.B.; Jung, C. Nutritional value of brood and adult workers of the Asia honeybee species Apis cerana and Apis dorsata. In: African Edible Insects as Alternative Source of Food, Oil, Protein and Bioactive Components; Mariod, A.A., Ed.; Springer Nature, Switzerland, 2020; pp. 265-273.
29. Ghosh, S.;Sohn, H-Y.; Pyo, S-J.; Jensen, A.B.; Meyer-Rochow, V.B.; Jung, C. Nutritional composition of Apis mellifera drones from Korea and Denmark as a potential sustainable alternative food source: comparison between developmental stages. Foods 2020, 9, 389.
30. Ghosh, S.;Namin, S.M.; Myer-Rochow, V.B.; Jung, C. Chemical composition and nutritional value of different species of Vespa Foods 2021, 10, 418.
31. Nowak, V.; Persijn, D.; Rittenschober, D.; Charrondiere, U.R. Review of food composition data for edible insects. Food Chem. 2016, 193, 39–46.
32. Paul, A.; Frederich, M.; Uyttenbroeck, R.; Hatt, S.; Malik, P.; Lebecque, S.; Hamaidia, M.; Miazek, K.; Goffin, D.; Willems, L.; et al. Grasshopper as a food resource? A review. Biotechnol. Agron. Soc. Environ. 2016, 20, 337–352.
33. Fogang Mba, A.R.; Kansci, G.; Viau, M.; Hafnaoui, N.; Meynier, A.; Demmano, G.; Genot, C. Lipid and amino acid profiles support the potential of Rhynchophorus phoenicis larvae for human food. J. Food Compos. Anal. 2017, 60, 64–73.

34. Yi, L.; Lakemond, C.M.M.; Sagis, L.M.G.; Eisner-Schadler, V.; van Huis, A.; van Boekel, M.J.S. Extraction and characterization of protein fractions from five insect species. Food Chem. 2013, 141, 3341–3348.
35. Zhou, J.; Han, D. Proximate, amino acid and mineral composition of pupae of the silkworm, Antheraea pernyl in China. J. Food Compos. Anal. 2006, 19, 850–853.
36. Gahukar, R.T. Edible insects farming: Efficiency and impact on family livelihood, food security and environment compared to livestock and crops. In Insects as Sustainable Food Ingredients: Production, Processing and Food Application; Dossey, A.T., Morales-Ramos, J.A., Rojas, M.G., Eds.; Elsevier Inc.: New York, NY, USA, 2016; pp. 85–111.
37. Sun-Waterhouse, D.; Waterhouse, G.I.N.; You, L.; Zhang, J.; Liu, J.; Liu, Y.; Ma, L.; Gao, J.; Dong, Y. Transforming insect biomass into consumer wellness foods: A review. Food Res. Int. 2016, 89, 129–151.
38. Payne, C.L.R.; Scarborough, P.; Rayner, P.; Nonaka, K. Are edible insects more or less ‘healthy’ than commonly consumed insects? A comparison using two nutrient profiling models developed to combat over- and under-nutrition. Eur. J. Clin. Nutr. 2016, 70, 285–291.
39. Meyer-Rochow, V.B.; Jung, C. Insects used as food and feed: isn’t that what we all need? Foods 2020, 9, 1003.
40. Van Huis, A.; van Itterbeeck, J.; Klunder, H.; Mertens, E.; Halloran, A.; Muir, G.; Vantomme, P. Edible Insects: Future Prospects for Food and Feed Security; FAO: Rome, Italy, 2013.
41. Oonincx, D.G.A.B.; Van Itterbeeck, J.; Heetkamp, M.J.W.; Van den Brand, H.; Van Loon, J.J.A.; Van Huis, A. An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. PLoS ONE 2015, 5, e14445.
42. Hedenus, F.; Wirsenius, S.; Johansson, D.J.A. The importance of reduced meat and dairy consumption for meeting stringent climate change targets. Clim. Chang. 2014, 124, 79–91.
43. Gahukar, R.T. Insects as human food: Are they really tasty and nutritious? J. Agric. Food Inf. 2013, 14, 264–267.
44. Rojas-Downing, M.M.; Nejadhashemi, A.P.; Harrigan, T.; Woznicki, S.A. Climate change and livestock: Impacts, adaptation and mitigation. Clim. Risk Manag. 2017, 16, 145–163.
45. Belluco, S.; Losasso, C.; Maggioletti, M.; Alonzi, C.C.; Paoletti, M.G.; Ricci, A. Edible insects in a food safety and nutritional perspective: A critical review. Compr. Rev. Food Sci. Food Saf. 2013, 12, 296–313.
46. Berggren, A.; Jansson, A.; Low, M. Using current systems to inform rearing facility design in the insects as food industry. J. Insects Food Feed 2018, 4, 167–170.

47. Oppert, B.; Perkin, L.C.; Lorenzen, M.; Dossey, A.T. Transcriptome analysis of life stages of the house cricket, Acheta domesticus, to improve insect crop production. Sci. Rep. 2020, 10, 3471.
48. EFSA (European Food Safety Authority). Risk profile related to production and consumption of insects as food and feed. EFSA J. 2015, 13, 4257.
49. Grabowski, N.T.; Tchibozo, S.; Abdulmawjood, A.; Acheuk, F.; Guerfali, M.M.; Sayed, W.A.A.; Plötz, M. Edible insects in Africa in terms of food, wildlife resource, and pest management legislation. Foods 2020, 9, 502.
50. Omotoso, O.T. Nutritional quality, functional properties and antinutrient composition of the larva of Cirina forda (Westwod) (Lepidoptera: Saturniidae). J. Zhejiang Univ. Sci. B 2006, 7, 51–55.
51. Zielińska, E.; Karaś, M.; Baranaik, R. Comparison of functional properties of edible insects and preparation thereof. LWT Food Sci. Technol. 2018, 91, 168–174.
52. Alvarez, D.; Wilkinson, K.A.; Treilhou, M.T.; Tene, M.; Castillo, D.; Sauvain, M. Prospecting peptide isolated from black soldier fly (Diptera: Stratiomycidae) with antimicrobial activity against Helicobacter pylori (Campylobacteriales: Helibactericeae). J. Insect Sci. 2019, 19, 17.
53. Oh, H.G.; Lee, H.Y.; Kim, J.H.; Kang, Y.R.; Moon, D.I.; Seo, M.Y.; Back, H.I.; Kim, S.Y.; Oh, M.R.; Park, S.H.; et al. Effects of male silkworm pupa powder on the erectile dysfunction by chronic ethanol consumption in rats. Lab. Anim. Res. 2012, 28, 83–90.
54. Meyer-Rochow, V.B. Therapeutic arthropods and other, largely terrestrial, folk medicinally important invertebrates: A comparative survey and review. J. Ethnobiol. Ethnomed. 2017, 13, 9.