Exploring Entomophagy: Nutritional, Environmental, and Sociocultural Dimensions of Insect Consumption

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Abstract. In recent years, entomophagy, the consumption of insects as a sustainable food source, has garnered increasing attention due to its potential to address pressing global challenges related to nutrition, environment, and food security. This paper explores the practice of entomophagy, the consumption of insects as food, with a particular focus on its advantages, challenges, and acceptance among various populations. It begins by highlighting insects' nutritional richness compared to traditional meat sources and their potential to address food security and environmental concerns. The paper presents survey results indicating varying levels of receptiveness towards entomophagy, with barriers rooted in limited awareness, cultural perceptions, and concerns about safety and hygiene. Drawing from international case studies, it discusses strategies for promoting entomophagy, such as government endorsements, public education, and the integration of insects into animal feed. In conclusion, the study underscores the multifaceted benefits of entomophagy, including its potential to alleviate environmental pressures and contribute to sustainable economic growth. It also emphasizes the importance of addressing psychological barriers and increasing awareness to foster greater acceptance of insect-based nutrition. Overall, this paper provides valuable insights into the complex dynamics surrounding entomophagy and offers practical suggestions for its promotion and adoption as a sustainable dietary practice.

Keywords: Entomophagy, Bug-eating Diet, Protein Alternative.

1. Introduction

As the global population continues to increase, concerns about food security are becoming more prominent. According to the World Food Programme, the number of people experiencing food insecurity has doubled since 2020 [1]. Now, almost 10% of the population is suffering from hunger. In response to the escalating demand, large-scale corporations have resorted to the prolific production of food via unsustainable practices. These techniques, encompassing Concentrated Animal Feeding Operations (CAFOs) and synthetic fertilizers, which unleash pollutants, exacerbate biodiversity diminution, and instigate eutrophication and the formation of dead zones, among other adverse consequences. Recently, the emerging topic of entomophagy has gained the interest of scientists. This tradition of insect consumption, prevalent in numerous cultures and spanning myriad centuries, seems to have diminished or been undervalued in contemporary societies, notably in affluent nations. Entomophagy presents multifaceted advantages, including environmental benefits, dietary enhancements, and bolstering food security. Industrialized nations, frequently the principal agents of environmental quandaries, can significantly attenuate the extent of anthropogenic dilemmas they precipitate by incorporating insects into dietary habits and curtailing red meat intake.

Entomophagy could potentially be a crucial element in advancing our ecological objectives; however, the transition from a profound dependence on meat products to a nutritiously balanced diet poses considerable challenges. A segment of the populace exhibits reluctance towards embracing entomophagy, harboring psychological impediments and discomfort towards this practice. To solve the aforementioned obstacle, this paper conducted research with the goal of garnering insights into the perspectives and viewpoints individuals hold concerning entomophagy. This paper aims to offer an in-depth analysis of entomophagy, elucidating its numerous facets of advantages, coupled with a discussion on public sentiment regarding this practice.

2. An overview of Entomophagy

Insects are veritable repositories of nutrients, encompassing proteins, amino acids, a spectrum of minerals, and an assortment of vitamins such as B, C, D, E, and K. A comparative analysis with beef reveals a semblance in the iron content [2]. Indeed, a considerable number of insect species have the potential to furnish more substantial quantities of nutrients than the conventional flora and fauna that constitute our diet.

The prevalent overconsumption of meat is implicated in the augmented incidence of various ailments, notably carcinogenic conditions and cardiovascular diseases. As delineated in a publication by National Geographic News, "While hamburgers constitute approximately 18 percent protein and an equal percentage of fat, their cooked grasshopper counterparts boast up to 60 percent protein, complemented by a mere 6 percent fat content" [3]. Insects are not only a prodigious source of protein but also manifest diminished fat levels, affirming their health advantages over customary meat alternatives that we habitually ingest.

Furthermore, the existing meat production process delineates inefficiency, with an annual output of 58 million tons of meat being facilitated by the utilization of 77 million tons of plant resources [4]. The issue of food insecurity is exacerbated as the resultant meat is not equitably distributed, predominantly gravitating toward nations with substantial GDPs. Incorporating insect protein in diets could potentially ensure sustained access to food and vital nutrients, particularly in regions grappling with unstable food resources.

Despite the nutritional prowess of insects, the practice of consuming them is conspicuously absent in the dietary preferences of a substantial portion of the American populace. Historically, insects have been a staple in culinary practices, with entomophagy being embraced by civilizations such as the Romans and the Greeks, a tradition persisting in contemporary societies across Africa, Asia, and South America [3]. The conundrum then arises: why does the USA abstain from this dietary practice?

Predominantly, the American preference for protein sources leans heavily towards beef and poultry, as evidenced by a cartographic representation delineating the highest per capita meat consumption in the USA over a year [5]. This trend can be attributed to the relative affordability of meat products, coupled with a higher purchasing power prevalent among the populace [6]. Moreover, historical narratives have fostered an association between meat consumption and prosperity. An analysis of global patterns reveals that meat consumption, exceeding 60 kilograms annually per individual, is conspicuous in most Western nations, parts of East Asia, and regions of South America, a stark contrast to the modest figures noted in Africa, the Middle East, and Southern and Southeastern Asia. In the latter regions, the procurement of protein from insects is a common phenomenon. Supplementary data, presented in a separate map, illustrates the global distribution of edible insect species, with a substantial concentration noted in Asia, Africa, and the Americas, delineating a conspicuous correlation between the prevalence of edible insect species and patterns of meat consumption [7].

3. Advantages of Entomophagy

Individuals partake in the consumption of insects primarily for their nutritive content, although there exist other advantages to entomophagy that remain relatively unexplored by its practitioners. Beyond being nutrient-dense and satiating, insects also stand as an environmentally benign alternative to traditional meats.

Cattle, notorious for their significant methane emissions generated through digestive processes like flatulence and eructation, contrast starkly with the majority of insect species that are not associated with methane production throughout their lifespan. This attribute of insects signifies a potential paradigm shift in the agricultural sector, primarily as it implies a substantial reduction in the release of detrimental greenhouse gases into the ecosystem, notwithstanding their carbon dioxide emissions.

The cultivation of insects as a food source presents a considerably more efficient alternative to traditional livestock farming, particularly in the case of beef production. A stark contrast in resource utilization between insect and beef production can be highlighted through the conversion rate of feed to body mass; 100 pounds of feed facilitates the generation of 45 pounds of crickets, in comparison to the mere 10 pounds of beef produced with the same quantity of feed [3].

Companies like Ynsect, based in France, are pioneering advancements in insect farming by adopting vertical farming techniques, a notable shift from conventional farming practices. This innovative approach allows for optimal utilization of available space by enabling farming in a multi-story setup, a stark departure from the extensive land requirements associated with cattle rearing which necessitates expansive horizontal plots [8]. Such a methodology is not only space-efficient but also significantly curtails the carbon footprint associated with farming operations. As elucidated by data available on the Ynsect website, insect farming is responsible for a forty-fold reduction in carbon dioxide emissions, demands forty times less water, and occupies thirty times less land compared to cattle farming [8].

Furthermore, the traditional livestock farming sector, especially bovine farming, has been implicated in exacerbating biodiversity loss due to the substantial land areas allocated to monoculture corn cultivation to feed the livestock. This agricultural practice potentially heightens the susceptibility of ecosystems to diseases and other catastrophes, consequently undermining biodiversity. In contrast, the indoor environment of insect farming offers a promising solution to bypass the adverse implications of monocropping, thereby fostering a lesser impact on biodiversity loss. Hence, insect cultivation stands as a promising avenue, offering sustainable food production with minimized ecological repercussions.

4. Application Cases of Entomophagy

In East Africa, the agricultural sector is witnessing a burgeoning trend of utilizing insects, specifically the black soldier fly (BSF), as a potent resource. Numerous farms of varied scales have sprouted across the region, leveraging the notable benefits of insect farming. Notably, the largest nine insect farms in this locality are projected to collectively generate roughly 9780 metric tons of dried protein on an annual basis, which equates to the sustenance capacity of approximately 4.7 million chickens [9]. These establishments have successfully instituted efficient resource management protocols, whilst fostering a circular economic framework. Within this circular economy, these BSF farms have adeptly managed to recycle between 2 and 18 million tons of insect biowaste, transforming it into fertile compost [9]. Moreover, the waste derivatives of BSF are being converted into fuel briquettes, serving dual purposes: acting as a renewable energy source and reducing health hazards alongside resource wastage [9].

The insect enterprise arena in East Africa is experiencing robust growth, with nearly 1000 ventures operating in this sector, and continual expansion is being observed. As of 2018, the financial valuation of this industry stood at an impressive US$687.8 million, with forecasts from Mordor Intelligence indicating a steady annual growth rate of 12% [10]. The financial viability of this sector is attributed not only to the primary insect products but also to the profitable byproducts generated during the process. It has been documented that the market price for dried BSF larvae and the resultant frass fertilizer oscillates between US$ 1.1-1.4 kg^{-1} and US$ 0.3-0.35 kg^{-1}, respectively [9]. Consequently, BSF farming holds the potential to generate a substantial revenue stream amounting to US$2.6 billion from protein products and an additional US$19.4 billion from biofertilizer products annually [9]. This surge in the industry contributes significantly towards achieving the Sustainable Development Goal (SDG) 8 by promoting sustainable economic growth and fostering job creation.

In a recent development, Ynsect, a French company at the forefront of the insect farming industry, has entered into a collaborative venture with Lotte, a prominent Korean firm. This alliance aims to spearhead research and development initiatives focused on concocting insect-derived food products suitable for human consumption [11]. Given Lotte's extensive presence in numerous Asian markets,

this collaboration stands to significantly amplify the visibility and acceptance of insect-based nutritional alternatives, potentially heralding a shift in dietary preferences on a global scale.

5. Application cases of Entomophagy Survey Results and Discussion on People's Attitude on Entomophagy

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5.1. Survey results

In the contemporary context, the practice of entomophagy, or consuming insects as food, presents various advantages spanning economic, environmental, and nutritional aspects. However, it appears to encounter substantial resistance in finding acceptance within the American populace. In a bid to explore this reluctance more closely, particularly within the United States, the author conducted an empirical study involving a peer group.

The participant demographics were largely constituted of individuals aged between 13 and 18, representing 91.3% of the respondents, while the remainder fell within the 29-34 age bracket. The gender distribution was evenly split, and the majority of participants identified as Asian, followed by smaller representations from Caucasian and Latino/Hispanic groups. A significant proportion of the respondents were high school students (91.3%), and the remainder held either a bachelor's or a master's degree. The survey comprised six queries, seeking to gauge the participants' familiarity with and receptiveness towards entomophagy and elucidating the potential barriers to embracing this dietary practice.

The initial query revealed a limited familiarity with the term "entomophagy," with only 21.7% of respondents indicating prior awareness. Furthermore, the perception towards entomophagy varied; 26.1% exhibited a negative stance, 47.8% maintained a neutral position, while the remaining 26.1% expressed an eagerness to learn more about it. The subsequent inquiry explored their experiences and thoughts on consuming insects, indicating a mixed array of experiences and opinions ranging from distaste to finding insects surprisingly palatable.

Addressing the willingness to engage in entomophagy, 43.5% affirmed their readiness, motivated by potential gastronomic pleasure and recognized environmental and health benefits. Nevertheless, a notable 30.4% remained undecided, seeking further information on the advantages of entomophagy and expressing a preference for processed insect products as opposed to their natural form. A solid 26.1% declined outright, citing concerns regarding the insects' appearance and perceived uncleanliness. Notably, the willingness to try insect-based food increased when the prospect of consuming insects in processed forms was presented, reducing the rejection rate by 8.7%. The final question highlighted prevalent apprehensions concerning the safety and hygiene of consuming insects, accompanied by psychological deterrents emanating from the insects' appearance and common perceptions of them being revolting.

Upon analyzing the survey results, it was inferred that the primary hindrances to adopting entomophagy were largely rooted in limited awareness about the edibility of insects and prevailing associations with uncleanliness and disease. The survey highlighted a perceptible shift in acceptance

when insects were presented in processed forms, suggesting an avenue for increasing palatability and acceptance.

In a recent exploration of Polish perspectives towards the practice of entomophagy, individuals were presented with bread incorporating processed insects [12]. The study revealed that the reluctance in embracing this novel dietary practice is not necessarily grounded in a deficit of information, but rather hinges on pre-existing stereotypes surrounding the utilization of insects as nutrition. The study illuminated that the aversion could be significantly mitigated by integrating insects into food in a processed and thus "invisible" form, a transformation that seemingly increases their palatability and acceptance.

5.2. Discussion

Furthermore, an analysis aimed at deciphering the Turkish populace's attitudes towards entomophagy uncovered a series of complex concerns that constrained their willingness to adopt such dietary habits [13]. The apprehensions were multilayered, encompassing potential health and religious conflicts, the anticipated disagreeable taste, and a deep-rooted sense of revulsion towards insects. Additional factors influencing their hesitancy include societal and cultural pressures, along with a noticeable lack of accessibility to insect-based food products within the market sphere.

Moreover, a comparative study evaluating the receptiveness towards entomophagy within Chinese and German populations indicated an intriguing pattern of acceptance in both nations, albeit with varying degrees of enthusiasm [14]. The findings suggest that individuals in China demonstrated a heightened preference for insect-based foods compared to their German counterparts. This disparity propels one to speculate whether the observed higher acceptance within the Chinese demographic might be linked to a historical precedent of entomophagy in their culture. Simultaneously, it raises the question of whether the German population's openness to this dietary inclusion might be a product of enhanced educational awareness regarding the potential benefits of entomophagy or the result of a strategic presentation where insects were integrated into the test foods in an "invisible" manner, thereby reducing the psychological barriers associated with their consumption.

6. Promotion strategies and suggestions on Entomophagy

Insect cultivation is facilitated through relatively straightforward technology, devoid of any sophisticated complexities. Additionally, the administrative aspects of insect farms are quite uncomplicated, negating the need for extensive training [10]. Ethical production is a significant concern for numerous consumers, and fortunately, insect farming aligns perfectly with this priority. In stark contrast to conventional animal farming, which some perceive as unethical and potentially distressing due to the slaughter involved, insect farming operates on different ethical grounds. Typically, insects have brief life spans, approximately around two weeks depending on the species, which negates the necessity for premature termination. They naturally reach the end of their life cycle prior to the processing and distribution phase.

Despite having a plethora of other food options available due to its developed status, Germany exhibits a surprising acceptance towards entomophagy. This leads us to explore the various promotional strategies employed globally to encourage the integration of insect consumption into mainstream diets.

In the East African nations of Kenya and Uganda, governmental bodies have instated guidelines to "streamline the manufacturing, management, and refinement of edible insects for food and animal feed" [9]. These initiatives confer legitimacy upon burgeoning insect farming enterprises, fostering their growth through the establishment of safety protocols to protect consumers. Such government endorsements potentially act as a reassuring gesture, encouraging citizens to trust the safety and viability of insect-based food products.

In Pennsylvania, for instance, Lisa Sanchez, an ardent entomophagist, is committed to propagating knowledge and fostering a positive perception towards entomophagy. Through her initiatives of

preparing mealworm dishes in public spaces, she creates opportunities for residents to become acquainted with the practice [14]. Moreover, individuals who sample these dishes often depart with a newly acquired, favorable view of insect consumption. A study conducted in Italy in 2022 substantiates this phenomenon, illustrating that firsthand experience with insect-based food products effectively diminishes initial feelings of repulsion [14]. Consequently, repeated exposure seems to be a viable strategy to gradually dismantle pre-existing aversions.

While the thought of insect consumption might still be too daunting for some, it is heartening to note that direct human consumption is not the sole method to leverage the environmental benefits of insect farming. Insects also hold immense potential as a revolutionary component in animal feed, offering an ethical and environmentally friendly alternative to traditional feed constituents like corn. Companies like Ynsect have already begun capitalizing on this market, extending their product range to include plant fertilizers derived from insects.

Utilizing insects in various agricultural capacities can indeed mirror the benefits garnered through direct human consumption. By substituting a segment of traditional animal feed with insect-based products, it is plausible to mitigate the adverse impacts of monoculture farming and enhance biodiversity, while optimizing resource utilization efficiency. Overall, the multi-faceted applications of insect farming present a promising avenue to lessen environmental burdens while maximizing the benefits derived from insect utilization.

7. Conclusion

In conclusion, this comprehensive exploration of entomophagy has illuminated its multifaceted potential as a sustainable solution to address critical global challenges in nutrition, environmental sustainability, and food security. The nutritional richness of insects, including their protein content, vitamins, and minerals, presents a compelling alternative to traditional meat sources. Comparative analyses with beef underscore the health advantages of insect consumption, particularly their lower fat content, which can contribute to mitigating the escalating health issues associated with overconsumption of meat, such as carcinogenic conditions and cardiovascular diseases.

The inefficiencies inherent in traditional meat production, characterized by a substantial utilization of plant resources and an unequal distribution of resultant meat, further emphasize the need for alternative protein sources like insects. Insects' potential to ensure sustained access to food and vital nutrients, especially in regions with unstable food resources, cannot be understated. However, the paper also reveals the conspicuous absence of entomophagy in the dietary preferences of a significant portion of the American populace, despite historical and contemporary entomophagic practices in other parts of the world. The survey results highlight the barriers rooted in limited awareness, cultural perceptions, and concerns about the safety and hygiene of consuming insects. Nevertheless, the study offers optimism by showcasing successful promotional strategies and acceptance patterns in various global contexts. Government endorsements, public education, and initiatives involving direct exposure to insect-based foods have demonstrated their efficacy in increasing acceptance. Furthermore, the potential of insects as a component of animal feed opens up new avenues to leverage their benefits indirectly.

In a world grappling with the urgent need for sustainable food sources and reduced environmental impact, entomophagy emerges as a promising solution. This paper underscores the importance of continued efforts to dispel misconceptions, enhance education, and develop innovative strategies for the promotion of insect-based nutrition. By doing so, societies can harness the potential of entomophagy to not only nourish themselves more sustainably but also contribute to a healthier planet for future generations. As global awareness of the benefits of entomophagy continues to grow, the prospect of insects becoming a mainstream dietary choice becomes increasingly plausible, offering a path towards a more sustainable and nutritious future.

References

[1] World Food Program. A global food crisis. Retrieved from: https://www.wfp.org/global-hunger-crisis#:~:text=WFP%20estimates%20%E2%80%93%20from%2079%20of,%2DCOVID%2D19%20pandemic%20levels.

[2] Kim T K, Yong H I, Kim Y B, et al. Edible insects as a protein source: A review of public perception, processing technology, and research trends. Food science of animal resources, 2019, 39 (4): 521.

[3] Sharon Guynup, Nicolas Ruggia, For Most People, Eating Bugs Is Only Natural, July 15, 2004, Retrieved from: http: //sciencenglish.pbworks.com/w/file/fetch/49328539/Eating%20bugs%20National%20Geographic.pdf.

[4] van Huis A. Edible insects. Handbook of eating and drinking: Interdisciplinary perspectives, 2020: 965 - 980.

[5] UN food and agriculture organizations. Average total meat supply per person measured in kilograms per year. Retrieved from: https://vividmaps.com/wp-content/uploads/2021/09/meat-consumption-world-map.png.

[6] Dan Charles, The Making of Meat-Eating America, June 26, 2012, Retrieved from: https: //www.npr.org/sections/thesalt/2012/06/26/155720538/the-making-of-meat-eating-america.

[7] Fao Organization, Recorded number of edible insect species, Retrieved from: https://www.swissinfo.ch/resource/blob/47838462/71e0d5463d26de23353fdf8da300ecf0/edible_insects-eng-data.jpg.

[8] Ynsect, Impact, Retrieved from: https: //www.ynsect.com/impact/.

[9] Tanga C M, Egonyu J P, Beesigamukama D, et al. Edible insect farming as an emerging and profitable enterprise in East Africa. Current opinion in insect science, 2021, 48: 64 - 71.

[10] Madau F A, Arru B, Furesi R, et al. Insect farming for feed and food production from a circular business model perspective. Sustainability, 2020, 12 (13): 5418.

[11] Ynsect, Ÿnsect and the lotte R&D centre sign an mou, Retrieved from: https: //www.ynsect.com/2023/04/27/ynsect-and-the-lotte-rd-centre-sign-an-mou/.

[12] Orkusz A, Wolańska W, Harasym J, et al. Consumers' attitudes facing entomophagy: Polish case perspectives. International Journal of Environmental Research and Public Health, 2020, 17 (7): 2427.

[13] BAKKALOĞLU Z. Edible insect consumption and Turkish consumers' attitudes towards entomophagy. International Journal of Agriculture Environment and Food Sciences, 2022, 6 (1): 165 - 171.

[14] Beans C. How to convince people to eat insects. Proceedings of the National Academy of Sciences, 2022, 119 (46): e2217537119.