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ENTOMOPHAGY AS A NUTRITIONAL SUPPLEMENT: A FORESIGHT TOWARDS FUTURE SUSTAINABLE FOOD AND FOOD SECURITY

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Abstract

In recent years, the global food system has faced numerous challenges, including the need to meet the nutritional demands of a growing population, ensuring food security, and mitigating the environmental impact of food production. Traditional livestock farming, which heavily relies on land, water, and feed resources, has been recognized as a major contributor to deforestation, greenhouse gas emissions, and water pollution. As a result, there is a pressing need to explore alternative and sustainable food sources. One such alternative gaining attention is the consumption of insects, known as entomophagy. Insects have been consumed as food by various cultures throughout history and across different regions of the world. They are rich in protein, essential amino acids, vitamins, and minerals, making them a potentially valuable source of nutrition. The background of the research on entomophagy as a food supplement addresses the global challenges associated with traditional livestock production. It highlights the limitations of current food systems in meeting the growing demand for protein-rich foods and emphasizes the need for innovative and sustainable solutions and mitigate food security. By diversifying protein sources and exploring alternative food sources, such as insects, it is possible to address the issues of food security, environmental sustainability, and resource efficiency.

Keywords

Food Security, Entomophagy, Global Challenges, Sustainability, Resource Efficiency, Sustainable Food Systems, Solutions.

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Introduction

Global Challenges of Traditional Livestock Production

Traditional livestock production practices face several significant challenges on a global scale. These challenges highlight the need for alternative food sources, such as insects, to ensure food security and address sustainability concerns. The key challenges associated with traditional livestock production include:

- **Environmental Impact-** Traditional livestock farming, particularly intensive systems, contributes to significant environmental degradation. It is a major source of greenhouse gas emissions, including methane and nitrous oxide, which contribute to climate change. Livestock farming also leads to deforestation for pastureland and feed production, biodiversity loss, water pollution through runoff of animal waste and excessive use of antibiotics and hormones, and soil degradation.
- **Resource Intensiveness-** Traditional livestock production requires substantial land, water and feed resources. It puts pressure on agricultural land, as large areas are dedicated to grazing and feeding production. Moreover, livestock farming consumes vast quantities of freshwater for animal drinking, sanitation, and irrigation purposes. The production of feed crops, such as soybeans and corn, further exacerbates the strain on water resources and contributes to deforestation and land degradation.
- **Feed Conversion Efficiency-** Livestock animals have a lower feed conversion efficiency compared to insects. It takes a significant amount of plant-based feed to produce a relatively small amount of meat, resulting in inefficient resource utilization. Insects, on the other hand, are highly efficient in converting feed into usable protein, requiring considerably less land, water, and feed resources per unit of edible protein.
- **Land Use Pressure-** The expansion of traditional livestock farming contributes to the conversion of natural ecosystems, including forests and grasslands, into agricultural land. This conversion leads to habitat loss for wildlife, reduces biodiversity, and

contributes to the destruction of fragile ecosystems. In contrast, insect farming has a smaller ecological footprint and can be carried out using vertical farming techniques, requiring less land compared to traditional livestock production.

- Antibiotic Resistance- The routine use of antibiotics in livestock farming, particularly in intensive systems, has led to the emergence of antibiotic-resistant bacteria and pest. This poses a significant public health concern, as antibiotic resistance compromises the effectiveness of antibiotics in treating infections in both animals and humans. Insect farming, by nature, does not require the use of antibiotics, reducing the risk of antibiotic resistance development.

Need for Alternative Food Sources

The need for alternative food sources has become increasingly apparent due to various challenges faced by the global food system. These challenges highlight the importance of exploring new approaches to meet the nutritional demands of a growing population, ensure food security, and address environmental sustainability concerns. Several factors contribute to the need for alternative food sources:

- Population Growth- The world's population is continuously increasing, projected to reach nearly 10 billion by 2050. This rapid population growth poses significant challenges in terms of producing enough food to meet the nutritional needs of all individuals. Traditional food production systems, including livestock farming, may struggle to keep pace with the escalating demand for protein-rich foods.
- Resource Constraints- Conventional food production, particularly livestock farming, places substantial strain on land, water, and other natural resources. As the global demand for food rises, the competition for limited resources intensifies. Alternative food sources that are more resource-efficient, such as insects, can help alleviate this strain by requiring less land, water, and feed per unit of protein produced.
- Environmental Impact- Traditional food production systems, particularly intensive livestock farming, have a significant environmental footprint. They contribute to deforestation, greenhouse gas emissions, water pollution, and biodiversity loss. Alternative food sources that have a lower environmental impact, such as insects, can play a crucial role in mitigating these adverse effects and promoting more sustainable food production practices.
- Climate Change- The agriculture sector is a major contributor to greenhouse gas emissions, which drive climate change. Livestock farming, especially the production of ruminant animals, generates significant methane emissions. Shifting towards alternative food sources, including insects, can help reduce the carbon footprint associated with food production and mitigate the impacts of climate change.
- Food Security- Ensuring food security is a critical global concern. Traditional food systems, particularly in regions with limited agricultural resources, may struggle to provide sufficient protein-rich foods to meet the nutritional needs of the population. Alternative food sources, such as insects, offer an opportunity to diversify protein sources, increase food availability, and enhance food security.
- Innovation and Novelty- Embracing alternative food sources encourages innovation and culinary diversity. Exploring new food sources stimulates creativity in food production, product development, and culinary traditions. Alternative food sources

like insects present an opportunity to introduce novel and sustainable food options that can expand dietary choices and cater to evolving consumer preferences.

Literature Review

This literature survey provides an overview of the existing research and scholarly work on the Entomophagy as a food supplement for sustainable food and food security.

- It explores various dimensions of this topic, including nutritional value, environmental sustainability, consumer acceptance, market trends, and regulatory considerations. By examining a range of studies, this overview aims to highlight the potential of insects as a sustainable and nutritious alternative to conventional protein sources.
- In a study conducted by Van Huis et al. (2013), an extensive review was conducted on edible insects as a sustainable food source. The review highlighted the nutritional composition of insects, including their high protein content, essential amino acid profiles, and micronutrient content. It also discussed the environmental benefits of insect farming, such as low greenhouse gas emission and reduced land and water requirements compared to traditional livestock.
- Another study by Oonincx et al. (2010) focused on the environmental impact of insect farming through a life cycle assessment (LCA) approach. The findings showed that insects had a significantly lower environmental footprint compared to conventional livestock in terms of greenhouse gas emissions, land use, and water consumption. The study emphasized the potential of insect farming as a sustainable and resource-efficient food production system.
- Consumer acceptance and perception of insects as food were explored in a systematic review by Halloran et al. (2017). The review analysed studies on consumer attitudes, sensory perception, and factors influencing the acceptance of insect-based foods. It highlighted the importance of factors such as taste, product familiarity, and effective communication in shaping consumer acceptance.
- Another study emphasized the need for innovative processing techniques and product development to enhance consumer appeal. In terms of regulatory considerations, Rumpold and Schlüter (2013) examined the legislative frameworks related to insects as food and feed in the European Union. The study identified challenges and gaps in the existing regulations and emphasized the need for supportive policies to facilitate the growth of the insect industry. It highlighted the importance of safety regulations, labelling requirements, and harmonized standards to ensure consumer confidence and market integration.
- Chen et al. (2019) conducted a review specifically focusing on the potential of insects as food in Sub-Saharan Africa. The study highlighted the nutritional value of insects, cultural acceptance in African communities, and their potential role in addressing food security and poverty alleviation. It emphasized the need for further research, capacity building, and supportive policies to promote insect farming and consumption in the region.
- Tan et al. (2020) examined consumer acceptance and potential factors influencing the consumption of insects in Western countries. The review analysed studies on consumer attitudes, sensory perception, food safety concerns, and cultural barriers. It identified sensory appeal, information transparency, and familiarity as important

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factors influencing consumer acceptance. The study emphasized the need for targeted marketing strategies, education campaigns, and product development to enhance consumer perception and promote insect-based foods.

Methodology

The paper employs a mixed methodology combining the qualitative and quantitative approach based on analysis of published articles and research papers and a number of case studies. From the studies, which have been conducted in developed as well as developing countries to assess the parameters leading to protein rich food sustainability? Case studies are referred to show that entomophagy is a current reality in developed countries and an alternative food source in the unprecedented global challenges.

Research Objectives

- To examine the entomophagy as a food supplement for a sustainable food source and understand their potential role in addressing food security and environmental challenges.
- Outlines secondary objectives that support the primary objective, such as exploring the nutritional value of insects, assessing their availability and production feasibility, and evaluating the potential socioeconomic impacts of insect-based food systems.

Research Questions

- What is the nutritional composition of various insect species and how do they compare to traditional protein sources?
- What are the environmental impacts of insect farming and how do they differ from traditional livestock production?
- How can insect farming be scaled up to meet the growing demand for alternative protein sources?
- What are the cultural and societal factors that influence consumer acceptance and attitudes towards insect consumption?
- What are the potential barriers and challenges in integrating insects into mainstream food systems and how can they be overcome?

Discussion and Results

Introduction to Entomophagy

Entomophagy, the practice of consuming insects as food, has a long history and cultural significance in various parts of the world. Although it may seem unconventional to some, entomophagy offers a sustainable and potentially transformative solution to the challenges faced by the global food system. This section provides an introduction to the practice of entomophagy, exploring its historical and cultural context.

- Historical Context- Insects have been consumed as a food source by humans for thousands of years. Archaeological evidence suggests that insects were a significant part of the diet of our early ancestors. In many cultures, including those in Africa, Asia, Latin America, and Oceania, entomophagy has been a traditional practice,

passed down through generations. Insects were not only consumed for their nutritional value but also as a response to food scarcity and cultural traditions.

- **Cultural Significance-** Entomophagy plays a significant role in the cultural heritage of many communities. Insects are incorporated into traditional recipes, rituals, and celebrations, reflecting the cultural diversity and richness of different societies. For example, fried crickets are a popular street food in Thailand, roasted mealworms are enjoyed in African countries, and ant larvae are used in Mexican cuisine. Understanding the cultural context of entomophagy is essential in promoting wider acceptance and appreciation of insects as a food source.
- **Nutritional Value-** Insects offer a valuable source of nutrition. They are rich in protein, healthy fats, vitamins, minerals, and dietary fiber. Some insects, such as mealworms and crickets, have protein contents comparable to or even higher than traditional livestock, making them a nutritious alternative protein source. In addition, insects can be raised with less feed, water, and land compared to traditional livestock, making them a resource efficient and sustainable option.
- **Environmental Sustainability-** Insects are remarkably efficient at converting feed into usable protein. They have a smaller ecological footprint compared to traditional livestock, requiring fewer resources and emitting fewer greenhouse gases. Insect farming has the potential to reduce deforestation, land degradation, and water pollution associated with conventional agriculture. By promoting entomophagy, we can contribute to more sustainable and environmentally friendly food systems.
- **Overcoming Barriers-** Despite the historical and cultural acceptance of entomophagy in certain regions, it may face cultural and psychological barriers in others. The perception of insects as pests or the unfamiliarity of consuming insects can create resistance to their inclusion in mainstream diets. However, efforts are underway to overcome these barriers by raising awareness about the nutritional benefits of insects, promoting culinary innovation, and addressing cultural biases.

Acceptability and Consumer Attitudes

The acceptability and consumer attitudes towards insect consumption vary across different regions and cultures. While insect consumption has a long history in certain societies, it may face cultural and psychological barriers in others. Here are some key factors influencing acceptability and consumer attitudes towards insect consumption:

- **Cultural and Traditional Factors-** Cultural norms and traditions play a significant role in determining the acceptability of insect consumption. In regions where insects have been traditionally consumed for generations, such as parts of Africa, Asia, and Latin America, they are considered a normal part of the diet and cultural heritage. In these societies, insects are often incorporated into traditional recipes, rituals, and celebrations, making their consumption more widely accepted.
- **Perception of Insects-** Consumer attitudes towards insects are influenced by the perception of insects as food. In many Western societies, insects are primarily associated with pests or uncleanliness, which can create a psychological barrier to their acceptance as a food source. Overcoming the perception of insects as pests and promoting their nutritional value and sustainability benefits are essential in changing consumer attitudes.

- Nutritional Awareness- Increasing awareness about the nutritional value of insects can positively impact consumer attitudes. Insects are rich in protein, healthy fats, vitamins, and minerals, making them a valuable and sustainable source of nutrition. Educating consumers about the nutritional benefits and potential health advantages of insect consumption can help shift attitudes and promote their acceptability.
- Culinary Innovation- Culinary innovation plays a crucial role in making insects more appealing to consumers. By incorporating insects into familiar and appetizing dishes, chefs and food entrepreneurs can make them more approachable for consumers. Creative cooking techniques, flavour profiles, and presentation can help overcome the initial aversion and generate curiosity and interest among consumers.
- Food Safety and Regulations- Consumer concerns about food safety and regulations can affect the acceptability of insects as food. Ensuring proper processing, quality control, and adherence to food safety standards is essential to build consumer trust. Establishing clear regulations and standards for insect farming, processing, and labelling can contribute to the acceptability and consumer confidence in insect-based products.
- Environmental and Sustainability Considerations- Growing concerns about environmental sustainability and the impact of traditional livestock farming have led to an increased interest in alternative protein sources, including insects. Highlighting the sustainability benefits of insect consumption, such as their low environmental footprint and resource efficiency, can influence consumer attitudes. Emphasizing the role of insects in addressing global food security and mitigating climate change can resonate with environmentally conscious consumers.
- Marketing and Communication- Effective marketing and communication strategies are essential in promoting insect consumption. Engaging campaigns, informative labelling, and transparent sourcing can help build trust and familiarity among consumers. Highlighting the cultural history, nutritional benefits, and culinary versatility of insects can generate interest and curiosity, encouraging consumers to overcome any initial reservations.

Environmental and Social Impacts

The environmental and social impacts of insect consumption are important considerations when assessing the prospects of insects as a food source. Here, we delve into the environmental and social aspects related to insect consumption:

- Environmental Impacts:
 - i. Land Use Efficiency- Insects are highly efficient in converting feed into protein. They require significantly less land compared to traditional livestock, making them a more sustainable protein source. Insect farming can help alleviate the pressure on land resources and reduce deforestation caused by the expansion of agricultural land.
 - ii. Water Use Efficiency- Insect farming generally requires less water compared to traditional livestock farming. Insects have a lower water footprint, reducing the strain on freshwater resources. This can be particularly significant in areas prone to water scarcity or facing water resource challenges.
 - iii. Reduced Greenhouse Gas Emissions- Insect farming generates fewer greenhouse gas emissions compared to traditional livestock farming. Insects have a lower carbon footprint due to their efficient feed conversion and digestion processes. Shifting

towards insect consumption can contribute to mitigating climate change and reducing the environmental impact of food production.

- iv. Resource Efficiency- Insects can be reared on organic waste materials, such as food scraps and agricultural by-products, reducing waste and promoting circular economy principles. By utilizing these resources, insect farming contributes to resource efficiency and waste reduction.
 - Social Impacts:
 - i. Livelihood Opportunities- Insect farming can provide income and livelihood opportunities, particularly in rural areas where traditional agricultural practices may face challenges. Small-scale insect farming can be relatively low-cost and accessible, offering economic empowerment and diversification for local communities.
 - ii. Food Security- Insects can play a role in improving food security, especially in regions prone to food scarcity. Insect consumption provides an additional source of nutrition and protein, contributing to a more balanced and sustainable diet.
 - iii. Cultural Preservation- Embracing insect consumption can help preserve cultural traditions and heritage. In many cultures, insects have been a part of traditional diet for generations. By promoting insect consumption, cultural practices and knowledge related to insect preparation and cooking can be preserved and celebrated.
 - iv. Social Acceptability and Awareness- Introducing insects as a food source may require raising awareness and promoting social acceptability. Educating the public about the nutritional benefits, sustainability advantages, and safety of consuming insects is crucial in overcoming any cultural or psychological barriers.
 - v. Ethical Considerations- Some consumers may find insect consumption more ethically acceptable compared to traditional livestock farming practices. Insects are often considered to have a lower capacity for suffering and a smaller ecological footprint, leading to ethical considerations favouring their consumption.

Food Security and Sustainability

Food security and sustainability are critical aspects to consider when discussing the prospects of insects as a food source.

- Food Security:
 - i. Nutritional Value- Insects are highly nutritious and rich in protein, healthy fats, vitamins, and minerals. Incorporating insects into diets can help address nutritional deficiencies and provide essential nutrients, especially in regions where access to high quality protein sources is limited.
 - ii. Resource Efficiency- Insect farming requires fewer resources compared to traditional livestock production. They have higher feed conversion efficiency, meaning they can produce more protein using less feed. This efficiency makes insects a sustainable option for meeting the protein needs of a growing population, contributing to food security.
 - iii. Climate Resilience- Insects have the potential to thrive in diverse environments, including harsh or marginal conditions. Their adaptability to different climates and ability to reproduce quickly can enhance resilience in food production systems, especially in areas susceptible to climate change impacts or natural disasters.

- iv. Reduced Pressure on Land and Water- Insects require significantly less land and water compared to traditional livestock farming. By utilizing vertical farming systems or rearing insects on organic waste, the pressure on agricultural land and freshwater resources can be reduced, leaving more land available for other agricultural purposes.
 - Sustainability:
 - i. Environmental Footprint- Insect farming has a lower environmental footprint compared to traditional livestock production. They produce fewer greenhouse gas emissions, require less land, and have lower water and feed requirements. Incorporating insects into the food system can contribute to mitigating climate change and reducing overall environmental impact.
 - ii. Biodiversity Conservation- Insects are abundant and diverse in nature, and their cultivation for food can help alleviate pressure on wild species. By promoting insect consumption, it is possible to reduce the demand for protein derived from traditional livestock and protect biodiversity by minimizing habitat destruction and wildlife exploitation.
 - iii. Circular Economy- Insect farming can be integrated into circular economy principles by utilizing organic waste streams as feed sources. Insects have the ability to convert various types of organic waste, such as food scraps or agricultural by products, into valuable protein sources. This can contribute to waste reduction, resource efficiency, and the development of sustainable food systems.
 - iv. Sustainable Protein Alternative- As the global demand for protein increases, finding sustainable alternatives becomes crucial. Insects have the potential to serve as a sustainable protein source, reducing the reliance on conventional livestock production, which is associated with land degradation, deforestation, and water pollution.

Conclusion

The research on the entomophagy as a food supplement for sustainable food and food security is expected to yield several key outcomes:

- Consumer Acceptance- The study aims to provide insights into consumer acceptance of insects as a food source. It is anticipated that the research will reveal the level of consumer willingness to incorporate insects into their diets, factors influencing their acceptance, and potential barriers that need to be addressed for widespread adoption.
- Market Trends and Opportunities- By examining market trends, the study aims to identify potential opportunities for the growth and development of the insect food industry. It is expected to provide insights into market demand, product preferences, and potential niches for insect-based foods.
- Sustainability Considerations- It will shed light on the sustainability aspects of insect production and consumption. It is anticipated to highlight the environmental benefits of insect farming, such as reduced land and water use, lower greenhouse gas emissions, and efficient resource utilization.
- Regulatory Frameworks- The study aims to identify and analyse existing regulatory frameworks surrounding the production and marketing of insect-based foods. It is expected to provide recommendations for the development of appropriate

regulations that ensure food safety, quality, and consumer protection while promoting innovation and market growth.

- Nutritional Value- By evaluating the nutritional composition of insects, the study aims to provide valuable information on their potential as a sustainable and nutrient-rich food source. It is anticipated to contribute to the understanding of the nutritional benefits and challenges associated with incorporating insects into the human diet.

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