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From Bugs to Bucks: Insect Farming's Role in Sustainable Agriculture and Economic Growth

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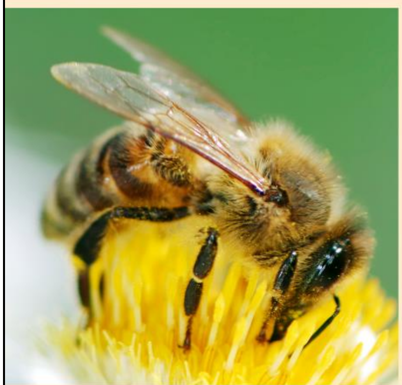
Gundreddy Raja Reddy, B. Thirupam Reddy,

Shashikala M, B V Jayanth



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PREFACE

In the face of an ever-growing global population and the escalating challenges of climate change, sustainable agriculture has emerged as a critical area of focus. Traditional farming practices, while foundational, are increasingly under pressure to meet the food security needs of billions without further degrading our planet's resources. It is within this context that we explore the transformative potential of insect farming—a practice that has been part of traditional diets and agricultural systems in many cultures, yet remains vastly underutilized in modern food and feed production.

"From Bugs to Bucks: Insect Farming's Role in Sustainable Agriculture and Economic Growth" delves into the multifaceted benefits and opportunities presented by insect farming. This book is not just a technical guide but a comprehensive analysis of how insect farming can serve as a catalyst for both ecological sustainability and economic prosperity.

India, with its diverse agro-climatic conditions and rich tradition of entomophagy (the practice of eating insects), stands at a unique vantage point to leverage insect farming. The country's rapid economic development and dynamic agricultural sector offer fertile soil for integrating innovative farming practices that can address pressing issues such as malnutrition, environmental degradation, and rural unemployment. Insect farming presents several compelling advantages. Nutritionally, insects are rich in protein, vitamins, and minerals, making them an excellent supplement or alternative to conventional livestock. Environmentally, insect farming requires significantly less land, water, and feed compared to traditional livestock farming, and it produces fewer greenhouse gases. Economically, the relatively low investment and operational costs associated with insect farming provide a viable livelihood option for smallholder farmers and entrepreneurs, potentially driving rural development and poverty alleviation.

This book aims to illuminate the path forward for stakeholders across the spectrum—farmers, policymakers, entrepreneurs, researchers, and consumers. Through a combination of case studies, scientific research, and practical insights, we illustrate how insect farming can be seamlessly integrated into India's agricultural landscape. We also address potential challenges, including regulatory hurdles, consumer acceptance, and the need for research and development to optimize farming practices and ensure food safety.

The journey from bugs to bucks is not just a technical transition but a paradigm shifts in how we perceive food, agriculture, and economic growth. It requires an openness to innovation and a commitment to sustainability. As we navigate this journey, it is our hope that "From Bugs to Bucks" will serve as both a roadmap and a source of inspiration for building a more resilient and prosperous agricultural future in India.

Editors

ACKNOWLEDGEMENTS

The creation of "From Bugs to Bucks: Insect Farming's Role in Sustainable Agriculture and Economic Growth " has been a collaborative journey, made possible by the contributions and support of numerous individuals and organizations. First and foremost, we extend our deepest gratitude to the farmers and entrepreneurs who have embraced the potential of insect farming and shared their invaluable experiences and insights. Your pioneering spirit and dedication to sustainable practices are the true inspiration behind this book.

We profoundly thank the research community, whose rigorous scientific studies and innovative approaches have laid the foundation for understanding the vast potential of insect farming. Special thanks to the policymakers and governmental agencies in India, particularly the Ministry of Agriculture & Farmers Welfare and the Ministry of Environment, Forest, and Climate Change, for their forward-thinking policies and support in promoting sustainable agricultural practices. Your vision and commitment are crucial for fostering an environment where insect farming can thrive.

We are grateful to Bhumi Publishing House for believing in this project and providing the necessary resources and support to bring it to realization. Our editorial team, especially Bommireddy Thirupam Reddy, has been exceptional in guiding this work from concept to completion. A heartfelt thanks to my colleagues and students at ICAR- Indian Agricultural Research Institute, New Delhi, whose intellectual curiosity, and enthusiasm for sustainable agriculture have been a constant source of motivation. The collaborative spirit and diverse perspectives within our academic community have enriched this book in countless ways.

We also wish to acknowledge the invaluable feedback and support from industry experts and practitioners. Your practical insights and experiences have added depth and relevance to this work. Finally, we are deeply indebted to our family and friends for their unwavering support and encouragement throughout the writing process. Your patience, understanding, and belief in the importance of this work have been my anchor.

This book is dedicated to all those who strive for a more sustainable and prosperous future through innovative agricultural practices. May our collective efforts help realize the full potential of insect farming in India and beyond.

TABLE OF CONTENT

INTRODUCTION

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Abstract:

The global population is projected to reach 9.7 billion by 2050, placing immense strain on traditional food and resource production systems. Insect farming presents a compelling and sustainable solution, offering a protein-rich, environmentally friendly alternative to conventional livestock. This paper explores the re-emergence of entomology in commercial applications, analyzing its potential to revolutionize food security, waste management, and resource utilization. We discuss the scope of insect farming, its advantages over traditional livestock, and the diverse applications of insects in various industries. We delve into the current state of the industry, exploring established and emerging insect species for farming, production techniques, and processing methods. The abstract delves into current trends, challenges, and future prospects of commercial entomology, highlighting its potential to revolutionize industries and foster a greener future. We emphasize the need for research and development, consumer education, and policy support to unlock the full potential of this transformative industry.

Keywords: Insect farming, Entomology, Sustainable Agriculture, Food Security, Protein Source, Waste Management, Bioconversion.

Scope:

The scope of this abstract encompasses the diverse applications of entomology in commercial sectors, including agriculture, food and nutrition, waste management, and medicine. It explores the role of entomology in addressing key challenges such as pest management, food security, waste reduction, and disease control. Additionally, the abstract discusses emerging trends, technological advancements, and regulatory considerations shaping the field of commercial entomology. By examining the intersections between entomology and various industries.

This paper focuses on the commercial application of insect farming as a sustainable solution for food and resource production. We will explore the following aspects:

- Species: We will discuss the most promising insect species for farming, their nutritional value, and suitability for different applications.

- Production Systems: Different insect farming techniques, including vertical farming and controlled environments, will be analyzed.
- Processing and Applications: Processing methods for converting insects into food ingredients, animal feed, and biomaterials will be covered.
- Sustainability Benefits: The environmental advantages of insect farming compared to traditional livestock will be explored.
- Challenges and Opportunities: We will discuss the existing hurdles and identify areas for future research and development.

Introduction:

For centuries, insects have been a staple food source for many cultures across the globe. However, in Western societies, the consumption of insects has been largely absent due to cultural norms and lack of awareness. This trend is shifting as the world grapples with the challenges of food security, climate change, and resource depletion. Insect farming is emerging as a game-changer, offering a sustainable and efficient approach to food production.

Entomology, the scientific study of insects, has traditionally been synonymous with fields like taxonomy, ecology, and pest management. However, in recent years, the scope of entomology has expanded beyond academia to encompass diverse commercial applications. This shift is driven by a growing recognition of insects' untapped potential to address pressing challenges in agriculture, food production, waste management, and healthcare. Commercial entomology, therefore, emerges as a dynamic and interdisciplinary field at the intersection of science, industry, and sustainability.

The urgent need for sustainable practices in various sectors has spurred interest in harnessing the unique characteristics of insects for innovative solutions. In agriculture, where pest management is paramount, biocontrol methods utilizing natural enemies of pests offer environmentally friendly alternatives to chemical pesticides. In the realm of food and nutrition, entomophagy—the consumption of insects—has gained traction as a sustainable protein source, offering a viable solution to global food insecurity. Additionally, insects' remarkable ability to decompose organic waste presents opportunities for efficient waste management strategies, reducing landfill waste and greenhouse gas emissions.

Moreover, insects hold promise in medicine and pharmaceuticals, with their compounds offering potential therapeutic benefits and bio-remediation capabilities. From antimicrobial peptides to venom toxins, insect-derived substances are being explored for drug development and disease treatment. As commercial entomology continues to evolve, it promises to drive sustainability and innovation across industries, fostering resilience and ecological integrity in a rapidly changing world.

Commercial Entomology: Agricultural Beneficial Applications

In agriculture, entomology plays a pivotal role in addressing pest management challenges while promoting sustainable practices. Through various beneficial applications, insects contribute to enhancing crop yields, reducing reliance on chemical pesticides, and preserving ecological balance. This section explores key agricultural beneficial applications of commercial entomology, highlighting their significance in promoting sustainable agriculture.

Biocontrol Agents:

Beneficial insects, such as parasitoids, predators, and microbial agents, serve as natural enemies of agricultural pests, helping to maintain pest populations at manageable levels. For example, parasitic wasps like *Trichogramma* spp. and predatory insects like lady beetles (Coccinellidae) and lacewings (Chrysopidae) prey on pest species such as aphids, caterpillars, and mites. These biocontrol agents offer effective, environmentally friendly alternatives to chemical pesticides, reducing the ecological impact on beneficial organisms and minimizing pesticide residues in crops (Bale *et al.*, 2008).

Insect Pollination:

Many agricultural crops, including fruits, vegetables, and nuts, depend on insect pollinators for successful reproduction and yield. Bees, in particular, are highly effective pollinators and play a crucial role in enhancing crop productivity. Commercial beekeeping and pollination services contribute significantly to agricultural production by ensuring adequate pollination of crops such as almonds, apples, and blueberries. Additionally, wild pollinators such as bumblebees and solitary bees contribute to crop pollination, highlighting the importance of conserving natural habitats and biodiversity in agricultural landscapes (Klein *et al.*, 2007).

Biological Pest Control Products:

In recent years, the development and commercialization of biological pest control products have gained momentum as sustainable alternatives to chemical pesticides. These products often contain microbial agents, such as entomopathogenic fungi (e.g., Beauveria bassiana, Metarhizium spp.) or bacteria (e.g., Bacillus thuringiensis), which target specific pest species while minimizing harm to non-target organisms and the environment. Biological insecticides offer effective control of pests such as caterpillars, beetles, and mosquitoes, with reduced risks of pesticide resistance and environmental contamination (Lacey *et al.*, 2015).

Advantages of Insect Farming:

- Efficiency: Insects require significantly less land and water compared to traditional livestock. They convert feed into protein at a much faster rate, making them highly efficient meat producers.
- Sustainability: Insect farming produces lower greenhouse gas emissions and ammonia compared to conventional animal agriculture. It also requires less land, reducing deforestation and habitat loss.

- Nutrient Richness: Insects are a rich source of protein, healthy fats, vitamins, and minerals. They can be processed into various food ingredients, providing a nutritious alternative to conventional animal products.
- Waste Management: Insects can be used to convert organic waste streams like food scraps and manure into valuable resources. This bioconversion process reduces landfill waste and creates nutrient-rich fertilizer for crops.
- Diverse Applications: Insects can be used for various purposes beyond human food. They can be processed into animal feed, creating a more sustainable alternative to fishmeal and soy. Insect chitin can be used in bioplastics and pharmaceuticals, further expanding their applications.

Established and Emerging Insect Species:

Several insect species have shown promise for commercial farming, each with unique advantages:

- Mealworms (*Tenebrio molitor*): These highly adaptable insects are a rich protein source and can thrive on various organic waste streams.
- Black Soldier Flies (*Hermetia illucens*): Black soldier fly larvae are efficient waste decomposers and can be processed into animal feed or biofuel.
- Crickets (Gryllidae): Crickets are a popular edible insect with a high protein content and mild flavor. They can be easily integrated into various food products.
- Locusts (Locustinae): Locusts offer a highly nutritious and readily available food source, particularly in areas where they are traditionally consumed.

Production Techniques

The commercial rearing of insects involves creating controlled environments that optimize growth and reproduction. Common production techniques include:

- Vertical Farming: Stacked containers or vertically arranged trays allow for efficient space utilization in insect farms.
- Modular Systems: Modular units allow for scalability and customization of the production process.
- Controlled Environments: Temperature, humidity, and light are carefully regulated to maximize insect health and productivity.

Processing Methods:

Insects can be processed into various products depending on their intended application:

- Whole or Ground Insects: Insects can be dried, roasted, or frozen for direct consumption or incorporation into food products.
- Insect Flour and Powder: Grinding insects into a fine powder creates a versatile ingredient for baking, protein bars, and other food applications.

- Insect Oil: Extracted insect oil is rich in healthy fats and can be used as a functional food ingredient or in industrial

Insect product: Honey, wax (from Apis mellifera), silk (from Bombyx mori), shellac (from Laccifer lacca) and cochineal dyes, i.e. red dye widely used in cosmetics, medicinal and food product (derived from scale insects, *Dactylopius coccus*).

Nutrient recycling: Insects feed on dead and decaying plants, animals and animal excreta and help in recycling the nutrients. Some insects burrow into soils and improve the soil structure and texture. Examples are dung feeders and termites.

Source of food: Over 500 species of insects are used as food by humans-usually crickets, grasshoppers, beetles, wasps, butterfly larvae, bugs etc.

Scientific study: Insects are very important materials for research and study, like genetic study in *Dorsophila melanogaster*.

Miscellaneous: Some insects are used for medicinal purpose, decoration, hobby, and pets.

B. Beneficial insects

a) Productive insects

i) Silk worm: The silk worm filament secreted from the salivary gland of the larva helps us in producing silk.

ii) Honey bee: Provides us with honey and many other byproducts like bees wax and royal jelly.

iii) Lac insects: The secretion from the body of these scale insects is called lac. Useful in making vanishes and polishes.

iv) Insects useful as drugs, food, ornaments etc,

(a) As medicine eg. Sting of honey bees- remedy for rhenmatism and arthritis

Eanthoridin - extracted from blister beetle –useful as hair tonic.

(b) As food - for animals and human being.

For animals- aquatic insects used as fish food. Grass hoppers, termites, pupac of moths.

They have been used as food by human beings in different parts of the world.

(c) Ornaments, entertainers

- -Artists and designers copy colour of butterflies.
- Beetles worm as necklace.
- Insect collection is an hobby

(d) Scientific research

Drosophila and mosquitoes are useful in genetic and toxicological studies respectively.

(II) Helpful insects

(i) Parasites: These are small insects which feed and live on harmful insects by completing their life cycle in a host and kill the host insect. Eg egg, larval and pupal parasitoids

(ii) Predators: These are large insects which capture and devour harmful insects.

Eg Coccimellids, Preying matritids.

(iii)Pollinators: Many cross-pollinated plants depend on insects for pollination and fruit set.
Eg Honey bees, aid in pollination of sunflower crop.
(iv) Weed killers: Insects which feed on weeds, kill them thereby killers. Eg Parthenium beetle eats on parthenium. Cochneal insect feeds in Opuntia dillenii.
(v) Soil builders: soil insects such as ants, beetles, larval of cutworms, cri kets, collumbola, make tunrels in soil and facilitate aeration in soil. They become good manure after death and enrish soil.
(vi) Scavengers: Insects which feed on dead and decaying matter are called scavengers. They important for maintaining hygine in the surroundings.
Eg. Carrion bettles, Rove beetles feed on deade animals and plants.

Overall, the beneficial applications of commercial entomology in agriculture underscore the importance of integrating ecological principles and biological control strategies into modern farming practices. By harnessing the power of beneficial insects and promoting sustainable pest management approaches, agricultural stakeholders can enhance crop productivity, conserve natural resources, and contribute to a more resilient and sustainable food system.

Prospects:

Technological Advancements:

Continued advancements in biotechnology and genetic engineering will unlock new opportunities for leveraging insect biology in commercial applications, leading to more targeted and effective solutions.

Policy and Regulation:

Collaborative efforts between policymakers, industry stakeholders, and research institutions are essential to establish regulatory frameworks that facilitate the responsible development and commercialization of insect-based products.

Public Awareness and Acceptance:

Education and outreach initiatives are critical to fostering public acceptance of insect-based solutions and dispelling misconceptions surrounding entomophagy and insect-derived products.

Global Collaboration:

International collaboration and knowledge-sharing platforms will accelerate innovation and adoption of commercial entomology practices, driving positive societal and environmental impact on a global scale.

Conclusion:

Commercial entomology presents a paradigm shift towards sustainable practices and innovation across industries. By harnessing the diverse capabilities of insects, we can address pressing challenges while promoting environmental stewardship and economic prosperity. From agriculture to medicine, entomology offers versatile solutions that prioritize efficiency, resilience, and ecological integrity. As we continue to explore the vast potential of insects, commercial entomology holds the key to a more sustainable and resilient future for generations to come.

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BEEECONOMY: EMPOWERING FARMERS FOR SUSTAINABLE INCOME

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Abstract:

A natural heritage shared by all, bees and the products they make deserve development. Because honey and other bee products have high nutritional value and therapeutic qualities, they are highly sought after, and their consumption is increasing steadily. The characteristics and distinct chemical makeup of bee products serve as the foundation for their use in human nutrition. The rise in interest and demand for this kind of food among different social groups is influenced by consumer awareness of the beneficial effects that food can have on health and well-being. Adding bee products to one's diet on a regular basis may help the body function better. New technologies have hit the market aimed at streamlining the bee product acquisition process. Because of their consumption and promotion of their medicinal properties, bee products are not only widely used in many industries but also play a crucial role in helping people form healthy eating habits.

Introduction:

The honey bee is considered a master chemist. Apiculture is the study of growing and managing honeybees for the purpose of extracting honey (Basu, 1993). This practice entails raising honeybees for human benefit and has the potential to strengthen any country. Bees provided pollination services that not only sustained but also increased crop production, in addition to producing honey and other byproducts. Hippocrates (460–370 BCE) was most intrigued in the health-promoting qualities and nutritional worth of bee products. In addition to having an extensive past in India, honey was the first sweet food that our ancestors who lived in rock shelters and forests tasted. (Khanra and Mukherjee, 2018). They hunted bee hives for this gift of God. Honey and bee products were found in several industries such as pharmaceuticals, bees wax industries, bee venom, royal jelly, bee nurseries, bee equipment and hives etc (Kritsky, 2015). These organic materials can be used as food, construction materials, lubricants, sealants, medicines, and more for both human beings and bees. Nowadays, bees are considered a kind of miraculous insect (Lozo *et al.*, 2015). Bees themselves synthesise products like royal jelly and bee venom. This enables them to become a perennial species that can be used in any habitat on the planet. To boost the diet and be fit modern consumers are seeking natural food product which contains bioactive product from natural source. They have antibacterial, inflammatory and antioxidant qualities, a scientific study claims that they have numerous health benefits. In an effort to create new atoms and receive electrons from other atoms, they are trying to pair with other atoms along with single electrons. (Ononye and Akunne, 2015). This leads to the generation of ROS and free radicals, which modify the DNA of numerous organisms through molecular transformation. Consequently, chronic diseases like rheumatoid arthritis and cancer emerged. Bees use an oily secreted solution designated bee wax to construct their honeycomb. The combination of different pollens to produce honey is known as bee pollen. Beeswax and other oils and resins are combined to create propolis, which is then used by the bees to build their hives and preserve perishables like honey. We describe all the bee products in this article, along with their properties, uses, and importance.

Goal of 'Sweet Revolution' Aatmanirbhar Bharat Abhiyaan

Given the significance of beekeeping in the nation's Integrated Farming System, the government approved a three-year (2020–2022) funding allocation of Rs. 500 crores for the National Beekeeping & Honey Mission (NBHM). The Aatmanirbhar Bharat programme included the announcement of the mission. In order to accomplish the "Sweet Revolution," which is being carried out by the National Bee Board (NBB), NBHM seeks to advance scientific beekeeping nationwide. The main goals of NBHM are to enhance agriculture and horticulture production, create jobs and income for both farm and non-farm households, develop the beekeeping industry holistically, and empower women through beekeeping by setting up Integrated Beekeeping Development Centers (IBDCs), honey testing labs, bee disease diagnostic labs, custom hiring centers, apitherapy centers, nucleus stock, bee breeders, etc. In addition, Mini Mission-II of the program seeks to raise awareness of scientific beekeeping; Mini Mission-III focuses on research and technology generation in beekeeping; and Mini Mission-II addresses post-harvest management of beekeeping and beehive products, including collection, processing, storage, marketing, and value addition. For 2020–21, NBHM has been granted a sum of Rs. 150.00 crore.

Status

According to current estimates, the nation harvests approximately 1,33,200 MT of honey from the 19.34 lakhs honey bee colonies, 2.50 lakh beekeepers, and wild honey collectors. This amounts to a value of Rs. 2704.31 crore, when one considers that modern beekeeping was introduced to India just thirty years ago with the establishment of the Khadi and Village Industries Commission (KVIC). India is a significant global honey exporter; in 2022–2023, the country shipped 79,929.17 MT of natural honey to other nations for a total value of Rs. 1,622.77 crore. India exports more than half of its honey production to other nations. Honey is exported by

India to over 83 nations. The USA, Saudi Arabia, the United Arab Emirates, Bangladesh, Canada, and other countries are the main markets for Indian honey.

Scope

The Asia-Pacific region is expected to be the leading producer of apiculture, with a 4.3% annual growth rate predicted for the market between 2020 and 25. The Indian apiculture industry is anticipated to grow at a compound annual growth rate (CAGR) of around 12% and reach a valuation of Rs. 33,128 million by 2024, according to a report by IMARC. The sixth-largest exporter of natural honey is India. A total of 59,536.75 MT of natural honey were exported in 2019–20, valued at Rs. 633.82 crore. The United States, Saudi Arabia, Canada, and Qatar were the main export markets. It may be possible to use the global market's need for organic honey to advance organic beekeeping standards. The landscape for beekeeping and the species might be increased on a commercial basis by expanding the industry. This offers the beekeeping businesses profitable options. A well-structured and technologically advanced beekeeping industry is a great way to create job opportunities and support skill development initiatives. Additionally, it will contribute to the achievement of Sustainable Development Goals 15 (Biodiversity and Vibrant Ecosystem), 2 (Zero Hunger), 3 (Good Health and Well-Being), and 1 (No Poverty). Beekeeping can be a profitable endeavor in areas with suitable floral pasturage. India has enormous potential for the growth of beekeeping because to its varied environment and plenty of floral resources derived from both naturally occurring plants and farmed crops. According to available statistics, more than 50 million hectares of land are farmed for crops that are useful to bees and benefit from pollination by bees, such as oilseeds, pulses, and orchards. Additionally, it is predicted that 60 million hectares of woods have beekeeping potential.

This vast area of farmland and forest could easily support one crore bee colonies or more. Beekeeping can be profitable for all types of people: landless people, underemployed people, farmers, women, children, and landowners. Bee hives can be found in backyards or on a house's roof. A subsistence farmer can make more money from beekeeping than from other pastimes. If beekeepers have the required time and interest, they can convert their pastime into a profitable company by selling the extra honey and wax from their hives. A hamlet or group of villages may decide to establish a cooperative, which would generate income and jobs by selling beekeeping essentials like honey and beeswax, as well as hives, frames, smokers, extractors, and containers.

Opportunities

Food and drink, agriculture, military medicine, cosmetics, paints and chemicals, and other end users are among the many end users evaluated. There are several uses for propolis, which is made up of various plant resins that the bees gather and utilize to plug holes in the hive. It is currently recognized to possess a wide variety of pharmacological qualities, such as antioxidant, anti-inflammatory, anti-bacterial, anti-fungal, anti-tumor, and mildly antiviral effects. There is evidence that Royal Jelly may have some cholesterol-lowering, anti-inflammatory, wound-healing, and antibacterial properties, and it is commonly used as a nutritional supplement.

Market Trends

In 2020, the Indian apiculture market reached a valuation of around Rs. 18,836.2 million. Over the projection period of 2021–2026, the industry is anticipated to develop at a CAGR of 12.4%, reaching a value of INR 37,235.9 million by 2026. According to a Fact MR analysis, during the projected period (2019–2029), the honey market is expected to develop at a rate Cargo 5.1%. Honey's demand for use in healthful culinary applications is still rising worldwide. Because honey and its byproducts have been linked to health advantages, the Asia-Pacific area is seeing an increase in the consumption of apiculture products like honey. In 2020, the Indian honey market was estimated to be worth INR 17.29 billion. From 2021 to 2026, the market is anticipated to expand at a compound annual growth rate (CAGR) of almost 10%, reaching a valuation of almost INR 30.6 billion.

Competitive Landscape

Leading companies are taking calculated risks to build their businesses, including Dabur India Limited, Bartnik, Baidyanath, Patanjali Ayurveda, Khadi, Himalaya, Arnold Honeybee, Miller's Honey Company, and Beehive Botanicals Inc.

Honey bees produce a wide range of goods, such as honey, beeswax, pollen, royal jelly, propolis, and bee venom (Kishan Tej *et al.*, 2017). Below is a description of honey bee items that are useful.

1. Honey

Bees gather nectar from plants, regurgitate it, and store it in their comb cells to produce honey, a sticky, sweet liquid (Singh *et al.*, 2012). Honey was a symbol of strength, grandeur, or wealth. Honey was reserved for the Pharaoh and his officials in ancient Egypt. The therapeutic qualities of honey were valued not only in Egypt but also in ancient Greece, where it was offered as a sacrifice to the gods because the Greeks believed that honey was a source of wisdom as well as strength (Qamar and Rehman, 2020). Honey quality varies with floral nectarines and species like While honey from wild bees (*A. dorsata*) is extracted by squeezing the combs, which contain pollen and larvae, honey from domesticated bees (*A. mellifera* and *A. cerana indica*) is extracted using a centrifugal force and is impurity-free.

Properties: Honey is a great source of minerals, vitamins, proteins, acids, and carbohydrates, which are mostly made up of glucose and fructose. Bees produce nectar at the start of June, which has higher levels of phenolic acids and flavonoids. However, honey made from nectar collected in May, July, or August has a lower concentration of these compounds. The location, kind of nectar, and time of year all affect how much of these compounds end up in the final product. Long-term survival is facilitated by the high sugar and low water content, acidic nature, and antimicrobial enzymes that bees produce (Cheepa *et al.*, 2022 and Dumitru *et al.*, 2022).

Honey is frequently applied topically to heal wounds and treat burns, skin infections and coughs. Peptic ulcers, gastritis, and gastroenteritis can all be prevented and treated with honey. The polyphenolic compounds (e.g., phenolic acids: chlorogenic, caffeic, ellagic, ferulic, gallic, p-coumaric), primarily flavonoids (e.g., catechin, chrysin, kaempferol, luteolin, naringenin, pinocembrin, rutin, and quercetin), are also largely responsible for the therapeutic properties of honey (Tanleque-Alberto *et al.*, 2020). Because of its antimicrobial qualities, honey can help relieve aches. Antioxidant qualities in honey make it useful for anti-aging treatments. Flavonoids and phenolic acids are capable of scavenging harmful free radicals. They protect cells from oxidative damage, which is the main contributor to heart problems, cancer, ageing, and metabolic issues (Almasaudi, 2021; Ferreira Da Cruz *et al.*, 2019). The small amounts of naturally occurring microorganisms (yeasts and moulds) in honey that are derived from pollen, the digestive tract of bees, dust, air, and flowers do not pose a health risk to humans. A higher concentration of potentially harmful microorganisms in honey, such as Saccharomyces, *Escherichia coli*, coliform bacteria, and Penicillium, may be a sign of secondary contamination during human processing. A dose of 0.6% honey is effective in raising feed efficiency, body weight gain, daily growth rate, feed conversion ratio, and feed consumption of freshwater pomfret in flooded peat fish ponds. (Silalahi *et al.*, 2021).

With increasing of population, rising awareness of the health benefits of honey and the ensuing rise in sweet diets, healthcare spending, and the acceptance of preventive medical treatments, Asia-Pacific is the largest and fastest-growing region, with a compound annual growth rate of 5.2%. Punjab produces 35 kg of honey on average per colony annually, with a maximum of 80,000 bees. (Vasukidevi *et al.*, 2021). India continues to have very low per capita consumption of honey (50 g/year), while worldwide consumption is 250–300 g and in Germany, it is 2 kg/year. (Marar, 2019).

M ead, also called as honey wine, was the first alcoholic beverage that men brewed before wine or beer. The flavours of mead have grown to include malt, spices and herbs, and fruits like blueberries and cherries. This evolution could increase the price of honey and increase beekeepers' profits.

2. Propolis

Beeswax and resins extracted from leaves and twigs using the mandibles to moisten them with salivary gland enzymes and beeswax combine to form propolis, likewise referred to as bee glue. Propolis is Greek in origin and means "entering a city." (Anjum *et al.*, 2019). When the bees start to seal the nest before winter, in late summer and early autumn, this raw material is at its most plentiful in the hive. Among the Apis species, only *A. mellifera* is main. To ensure seal the hive and create containers for storing honey and pollen, the tropical stingless bees do collect a resinous material like propolis. Propolis relied in spaces, seal openings, and construct beehives because it is firm and breakable in cold weather but supple, elastic, and adhesive when heated. Propolis acts as a sealant, keeping mould, spores, and microorganisms out of the hive (Fearnley, 2005 and Przybylek and Karpinski, 2019).

Properties: Resins (40–50%), waxes (20–30%), pollen (5%), polyphenols (14–16%), terpenes (8–12.5%), and essential and aromatic oils (10%) constitute the bulk of the substances found in propolis. Microelements, including iron, copper, phosphorus, manganese, zinc, calcium, cobalt, magnesium, and selenium, vitamins B1, B2, B6, C, and E, have been found in <1% of the bee putty. (Mohdaly *et al.,* 2015; Pobiega *et al.,* 2017; Szeleszczuk and Zielinska-Pisklak, 2013).

Humans have applied propolis topically to heal wounds, ulcers, and rashes. They have also taken propolis orally to treat diabetes, obesity, cancer, and other ailments. It is effective as a fungicide and disinfectant. It has antifungal, antibacterial, and anti-yeast qualities. Based on research in cell culture and animal models of diseases like diabetes, obesity, and cancer, propolis is said to have anti-inflammatory, antioxidant, antidiabetic, and even antineoplastic properties. (Aspay, 1977 and Olivieri *et al.*, 1981). Dentifrices, lozenges, mouthwashes, creams, gels, and cough syrups all contain propolis. Because propolis contains resin that contains flavonoids, caffeic acid, and esters of aromatic acids for preservative in both processed and unprocessed meat in the food industry. These substances most likely function by preventing the virus from infecting additional cells and by eliminating its outer shell. Evidence has shown that antiviral qualities can combat the herpes simplex virus HSV-1 and HSV-2. (Pobiega *et al.*, 2019 and Demir *et al.,* 2020). The flavonoids phenolic acids, galangin, and pinocembrin have the power to eliminate radicals and shield cells from ageing. (Kurek-Górecka *et al.*, 2020; Rojczyk *et al.*, 2020). Allergic reactions *viz.*, angioedema and anaphylaxis from commercial sources of propolis have been reported. The allergic reactions are likely due to plant flavonoid aglycones (Anjum *et al.*, 2019). In India, India Mart is selling propolis (Forever Bee Propolis) at the cost of Rs 1,800/bottle containing 60 tablets.

3. Bee Wax

The worker bee's wax glands begin to produce wax when it is 14–18 days old. The bee makes this on its own during the warmest time of day. Wax is used to build the comb cells that bees use to rear their young. Pollen and honey are also stored in the cells. A bee must eat eight to fifteen kilogrammes of honey to produce one kilogramme of wax; the colour of the wax may change based on the pollen source. Usually, damaged combs are utilised to produce wax.

Properties: The specific gravity of beeswax is 0.95, and its melting point is 65 °C. Beeswax is made up of saturated hydrocarbons (12.5% and 15.0%), long chain fatty acid (13.5–15.0%), and complex esters of monoatomic alcohols and fatty acids (70.4% and 74.7%). (Mishra, 1995 and

Phadke and Phadke, 1977). Approximately 30–40%, global beeswax trade is utilised by the pharmaceutical and cosmetics (cold creams, rouges, and lipsticks) industries. The global price per kilogramme is typically between $4 and $10. The production of candles uses about 20% of the beeswax traded worldwide. In the arts and industry, about twenty percent are used as models and castings. In addition, create jewellery, decorations, and figures that are then moulded and cast in bronze, gold, or silver. Beeswax can be purchased in India for between Rs. 250 and Rs. 1500 per kilogramme. Although edible, it applied as a coating. or in combination with other materials to preserve and prevent the growth of mould on cheese.

4. Bee Pollen

Bee Pollen is known as the most natural and complete food. They extract pollen pellets from the pollen baskets (Corbucular) located on the foraging bees' hind legs. When there are no flowers to produce pollen, beekeepers can gather pollen from beehives and store it for the bees to eat.

Properties: Pollen granules contain over 250 different substances, mainly carbohydrates, proteins (40%), fatty acids- palmitic acid, arachidic acid, and stearic acid belong to saturated fatty acids, mono- and polyunsaturated fatty acids (omega 3 and 6), phospholipids, and phytosterols, lipids (0.3% to 20%), vitamins A, B, C, D, E, K, and Vitamin B6 (Methionine), minerals, and polyphenols, 35% of is sugar (fructose and glucose). The highest per cent of proteins (40%), depends plants and season (Rzepecka-Stojko *et al.,* 2015), amino acids (glycine, aspartic acid, glutamic acid, alanine, leucine, valine, lysine, serine, and isoleucine) (Taha *et al.*, 2019). Enzymes *viz*., alpha-amylase, beta-amylase, invertase, lipase, and alkaline phytase, derived from plants and bee saliva. Alpha-amylase and beta-amylase break down starch and glycogen. Invertase breaks down sucrose. Lipases break down lipids and phospholipids by the alkaline phytase that breaks down phytic acid, thanks to which it is possible to increase the bioavailability of nutrients contained in pollen (Barrientos *et al.,* 1994; Kurek-Gorecka *et al.*, 2017).

Adolescents and children require polyunsaturated fatty acids for healthy growth and development. Because of unsaturated fatty acids, phospholipids, and phytosterols, pollen has hypoglycemic properties, they prevent the accumulation of fat and cholesterol in the liver. Menopausal women should incorporate this ingredient into their daily diet. Athletes and the elderly are also recommended to add pollen to their diets because it has a positive effect on metabolism and aids in cell regeneration in cases of malnutrition (Ramkumar *et al.,* 2023). Pollen is already widely used in Chinese clinical practice and the German Federal Office of Health has officially recognized pollen as a medicine. Pollen extract has a cytotoxic effect on leukemia cells and prostate cancer cells (Shahraki *et al.*, 2019). It also helps in reducing the side effects of chemotherapy and radiotherapy. Pollen supplementation has a positive effect on both human and animal organisms. (Ramkumar *et al.*, 2023). In India, Bee Pollen Caps @ 500 mg (250 Capsules) are available at the cost of Rs. 2,100.00/-(approx.). Bee pollen has been reported to cause allergic reactions in patients with asthma, atopic dermatitis and with allergies to pollen.

5. Bee Bread

One final product, fed to honeybees after fermentation is called "bee bread." It’s made up of a combination of nectar, saliva, and pollen. Pollen and bee bread are not as nutritious as bee bread, even though they come from the same plant.

Properties: It is a source of protein (20%), lipids (3%), (24%–35%) carbohydrates, and about 3% minerals, vitamins (C, B, E, and K) and macro- and micronutrients, polyphenols (phenolic acid and flavonoids), sterols, carotenoids, and enzymes (phosphatases). In addition, bee bread contains over 25 different micro- and macro elements such as calcium, iron, potassium, copper, zinc, selenium, and magnesium ((Didaras *et al.*, 2020 and 2021 and Margaoan *et al.*, 2019). Bee digestive systems contain lactic acid bacteria called Fructobacillus and Lactobacillus, which contribute to the higher bioavailability of nutrients in bee bread (Ispirli and Dertli, 2021). Bee bread have a high moisture content (6 to 9/100 g). The water content of fresh bee bread provides a favorable environment for the development of beneficial bacteria (Kieliszek *et al.*, 2018; Mohammad *et al.*, 2021), as well as pathogenic bacteria, fungi, and molds. This raises concerns about the risk of adverse microorganisms like those discovered in pollen (Clostridium, Bacillus) (Lozo *et al.*, 2015). Because lactic acid fermentation by bacteria and yeasts is present, bee bread has a higher acidity (pH 3.2 to 5.9). Following the fermentation process, the total amount of phenols and flavonoids in the pollen increased from 1.24 to 2.40 times. Honeybee health and fertility depend on fatty acids (Brutscher *et al.*, 2019). Unsaturated fatty acids are also good for the human body; they have anti-inflammatory and anticoagulant qualities (Simopoulos, 2004) and lower blood levels of cholesterol and triglycerides (Von Schacky and Harris, 2007). The pollen used to make bee bread contains proteins and protein compounds, as well as polyphenols, fatty acids, and phytosterols that contribute significantly to the bread's antimicrobial activity (Didaras *et al.*, 2020, 2021), Methionine and arginine, two amino acids with numerous vital roles in human metabolism, can be found in bee products.

6. Royal Jelly

Royal jelly is a milky white liquid. Nurse bees produce royal jelly between the ages of 6 and 12 days of worker bees from the pharyngeal and mandible glands.

Properties: The primary components of royal jelly are acidity (pH 4.1–4.8) and water (between 50% and 60%). It has a sour, tart, and mildly bitter flavour (Sidor *et al.*, 2021). Large groups of chemical compounds make up proteins, which are primarily composed of glucose, fructose, and sucrose (17%), carbohydrates (15%), mainly glucose, fructose, and sucrose (Xue *et al.*, 2017), and lipids (about 3%–4%), which include fatty acids (3-hydroxydodecanoic, 11-oxododecanoic, and 11-S-hydroxydodecanoic; Isidorov *et al.*, 2012), mineral compounds (about 1.5%), vitamins (A, E, C, and B complex), nucleotides, peptides, and polyphenols (Collazo *et al.*, 2021), and the highest concentration of phenolic acids, followed by flavones and flavonols (Persuric and Pavelic, 2021), Proteins like albumin and globulin, enzymes, hormones, and neurohormones—such as acetylcholine, which controls the function of endocrine glands by releasing hormones into the bloodstream—as well as gamma globulin, which modulates immune responses and increases an organism's capacity to fight infections (Kamyab *et al.*, 2019). Enzyme activity is enhanced by the acidic environment found in milk (Ramadan and Al-Ghamdi, 2012).

There are medicinal and dietary applications for royal jelly (Strant *et al.*, 2019). Due to the abundance of nutrients and biostimulants (10-hydroxy-2-decenoic acid, for example), it serves to supplement daily diet deficiencies. Furthermore, according to Bąk and Wilde (2002), royal jelly can also be found in honey jellies, sugar syrups, jam, and pectins. Nucleotides are known for their ability to stimulate the immune system, boost both physical and mental immunity, improve lipid and liver metabolism, support healthy intestinal tissue renewal, and more (Kędzia *et al.*, 2019). Studies have proven that royal jelly has antimicrobial qualities (Fratini *et al.*, 2016). Gram-positive (Bacillus subtilis, Staphylococcus aureus) and gram-negative (Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae) bacteria are inhibited in their growth by royal jelly. Additionally, it works against yeast (Candida albicans) and mould (Aspergillus fumigatus and A. niger). The two regions that consume the most royal jelly, after Japan, are Europe and North America. Some European countries add royal jelly to yoghurts (Kavas, 2022), while Asian countries use it in a variety of drinks (Moriyama *et al.*, 2017).

7. Bee venom:

Bee venom is naturally adopted by bees, use this as a preventative measure to safeguard their domain. The principal elements are proteins and peptides. A traditional treatment for joint pain, apitherapy is practiced in India and a few other countries. In order to treat bee stings, patients are instructed to hold the bee by its wings with their thumb and index finger on the affected areas. One possible application would be an ointment made by mixing apitoxin, Vaseline, and salicylic acid (1: 10: 1). Salicylic acid makes skin softer and makes penetration easier. Arthritis and other chronic pains are treated with bee venom. Recently, bee venom and other bee products have been utilised in the cosmetics industry. Prices for bee venom also vary, ranging from $30.00 US (occasionally even much lower) to $300.00 US per gram (Dumitru *et al.*, 2022).

8. Bee Pollination

Bees are the most important pollinators of domestic plants because they primarily rely on the nectar and pollen of flowers. Honeybees, specifically *Apis mellifera* L., are the most economically valuable pollinators of crop monocultures worldwide because they can be concentrated in large numbers whenever and wherever needed, and they pollinate a broad range of crops throughout the growing season (Rai *et al.*, 2020).

Indian scenario:

In India, the utilization of honey has been gradually increasing in the previous few decades. Honey is heavily used by medical processing companies in India (Mattu, 2017). The majorly, beeswax, the other main commodity produced by bee colonies, are in the pharmaceutical, cosmetic, and soap industries. The demand of honey has increased dramatically as a result of dedicated programmes like the Honey Project in India. India's beekeeping industry is driven by growing consumer demand for wholesome, natural foods. Increasing consumer knowledge of honey's health benefits benefits the Indian beekeeping industry. The increasing number of Ayurvedic practitioners is driving up the marketplace for honey, a more natural substitute with a host of therapeutic benefits (Mishra *et al.,* 2020). The market would grow even more due to the growing demand for natural, organic, and cruelty-free cosmetics. There were 9091 beekeepers, beekeeping businesses, and honey societies as of January 2019. Its growth in the last 12 years has been 200%. Additionally, the industry's top regional sector is South India (Crane, 1980 and Sivaram, 2004).

Scope of Honey Bee Byproducts in India

Scope of Commercial Production of Honey Bee Byproducts in India. The scope of commercial production of honey bee byproducts in India is vast and offers numerous opportunities for beekeepers and entrepreneurs. Beyond honey, honey bee byproducts include a variety of valuable materials with an abundance of uses in different industries. This is a summary of the extent:

1. Beeswax: Beeswax is a versatile natural product used in cosmetics, pharmaceuticals, candle making, and polishes. India has a growing demand for beeswax in industries such as cosmetics, *viz.,* lip balms, creams, and lotions. Additionally, beeswax candles are gaining popularity as eco-friendly alternatives to paraffin candles, creating opportunities for beekeepers to capitalize on this market

2. Royal Jelly: Royal jelly, produced by worker bees, is sought after for its potential health benefits. In India, there is a growing market for royal jelly-based health supplements and skincare products. Day to day demand is expected to increase as consumers become more health-conscious and seek natural remedies.

3.Propolis: Bees gather propolis, a resinous material, from the buds of plants, has antimicrobial and antioxidant properties. In India, propolis used as a traditional medicine. With having health benefits of propolis, there is potential for its commercial production and incorporation into dietary supplements, herbal remedies, and skincare products.

4. Bee Pollen: Bee pollen is a nutrient-rich product collected by bees from flowering plants. It is valued for its high protein content and potential health benefits. In India, bee pollen is marketed as a dietary supplement and functional food ingredient. As consumers prioritize health and wellness, the demand for bee pollen products is expected to grow, presenting opportunities for beekeepers to expand their product offerings.

5. Bee Venom: Bee venom therapy, or apitherapy, involvesthe therapeutic use of bee venom for various health conditions. In India, niche market for bee venom-based products and treatments. With ongoing research into the medicinal values of bee venom, there is potential for the commercialization of bee venom extracts and formulations for pharmaceutical and healthcare applications.

6. Bee Bread: Bee bread, a fermented mixture of pollen and honey, serves as a nutritious food source for honey bee colonies. Because of its high nutritional content, bee bread can be marketed as a high-end health food item in India. There is opportunity for beekeepers to produce and market bee bread to health-conscious consumers due to the growing interest in natural and organic foods.

The prospects of commercial production of honey bee byproducts in India are promising, offering significant opportunities for beekeepers, entrepreneurs, and the economy as a whole. Here are several key prospects:

Diversification of Revenue Streams:

Beekeepers can expand their sources of income beyond honey production by engaging in the commercial production of honey bee byproducts. Through the extraction and processing of byproducts like royal jelly, propolis, bee pollen, bee venom, and bee bread, beekeepers can increase the profitability of their operations and make extra money.

Value Addition and Higher Returns:

Value-added honey bee byproducts command higher prices in domestic and international markets compared to raw honey. By means of procedures that add value such as purification, refining, and packaging, beekeepers can create premium-quality byproducts that cater to niche markets and discerning consumers, resulting in higher returns on investment.

Expanding Market Opportunities:

India's market for byproducts is growing quickly due to rising awareness among the people regarding medicinal and health advantages. The health food, nutraceutical, and cosmetic industries present a sizable market opportunity for byproducts like royal jelly, propolis, and bee pollen due to the growing demand for natural and organic products.

Health and Wellness Trends:

Honey bee byproducts have become more and more popular among consumers who are concerned about their health because of their nutritional value and possible medical benefits.

India is witnessing a surge in the demand for bee-derived products due to growing consciousness about the health advantages of natural remedies and functional foods. By offering premium, organic byproducts, beekeepers can profit from this trend by tapping into the wellness market.

Research and Innovation:

Continued research and development in the field of apiculture and bee product processing technologies can further enhance the prospects of commercial production of bee byproducts in India. Research and development expenditures have the potential to increase market opportunities and propel industry growth by revealing new formulations, uses, and applications of byproducts.

Export Potential:

India could export a substantial amount of honey bee byproducts to other nations. With a wealth of biodiversity, a range of ecosystems for beekeeping, and a long history of apiculture expertise, India is well-positioned to meet the global demand for high-quality bee products. Honey bee byproducts can be exported to boost foreign exchange profits and elevate India's profile in the global apiculture market.

Conclusion:

Interest in biologically active natural products, which have been connected to their pro-health and healing properties, is influenced by growing awareness of environmental issues as well as the trend towards healthier living. Good quality, especially natural products, is a priority demand factor in the rapidly expanding food product market. Honey, bee venom, royal jelly, propolis, beeswax, and pollen collected by bees are other products produced by modern beekeeping enhancing the beekeeping industry's vibrancy is essential for support the Green Business Revolution's national goals of reducing poverty, enhancing community livelihoods, and preserving sustainable natural resources.

India is one of the largest producers and consumers of honey in the world, with an estimated annual production of 1.2 lakh metric tonnes. India has a rich tradition and culture of beekeeping dating back to ancient times. At present, about 12,699 beekeepers estimate 9 34 lakh honeybee colonies are registered with the National Bee Board, and India is producing about 1,33,200 metric tonnes of honey (2021-22 estimate). In November 2022, a new species of endemic honeybee, the Indian black honeybee (Apis karinjodian), was discovered in the Western Ghats after a gap of more than 200 years.

Beekeeping has the potential to generate income and employment opportunities for rural households by producing honey and other bee products such as wax, propolis, etc. Honey is a high-value product that has huge demand in domestic and international markets. It is also a source of nutrition and health for consumers. It can also help empower women and youth by involving them in beekeeping activities as entrepreneurs or in self-help groups. It not only presents economic opportunities but also plays a pivotal role in preserving the delicate balance of our environment. By fostering sustainable practices, embracing innovation, and nurturing knowledge-sharing platforms, we pave the way for a thriving future for beekeeping entrepreneurs.

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WEAVING WEALTH: SERICULTURE PRODUCTS BOOSTING FARMER INCOME

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Abstract:

The products of sericulture are the fabric, along with cocoon and raw silk. It involves a wide range of tasks, from growing the host plants to gathering leaves for the silkworms to feed them, and from raising the silkworms from their eggs to harvesting their cocoons and reeling them to make raw silk, which is then processed to render the finished item. Numerous by-products, also known as wastes, are produced in each activity. These include: wasted leaves; dead, sick, and diseased larvae; pupa; damaged cocoons; silk waste; and portions of host plants, such as mulberry fruits and stems, castor seeds, and tapioca tubers. When these waste products are used effectively, the sericulture industry becomes more lucrative and appealing and can double the farmer's income.

Keywords: By products, Moriculture, Properties, Sericulture, Uses

Introduction:

Sericulture entails a wide range of tasks, starting with the cultivation of host plants for silkworm feeding, followed by the rearing of silkworms to produce cocoons, the reeling of cocoons to produce raw silk and the processing of raw silk. Numerous wastes, also known as byproducts, are produced in each of the activities (Jadhav *et al.*, 2011). Anything created during the production or processing of another product is a by-product. Prior to shifting its market to supply valuable supplements and raw materials for medicine, the global silk industry solely concentrated on producing silk. From that time on, it has been manufacturing goods like mulberry tea, a decoction made from mulberry leaves that is believed to enhance kidney and liver function as well as sharpen hearing and shine eyes (Ameet Singh *et al.*, 2017). Because dried fruit powder has anti-mutagen properties, medication may hinder normal, healthy cells from changing into cancerous ones. Mulberry fruit juice can be used to cleanse the body of impurities and treat heart issues. Silkworms, or "bio-plants," produce very safe products. Eggs from silkworms are processed into a proteic extract with hepatoproteanic properties, and pupal oil has properties similar to those of an anti-inflammatory and anti-tumefying agent. Nothing is truly wasted in the sericulture. We can reduce waste at every level by creating some useful products (Sharma *et al.,* 2022). More jobs will be created and the sericulture sector will become more sustainable, stable, and profitable with the efficient use of waste. Here we emphasised the potential for several medicinal qualities of mulberry leaves, fruits, bark, roots, silkworms, pupa, moths, etc. while keeping various aspects of sericulture in mind.

What is a By-Product?

A byproduct is usually anything that is wasted. Nonetheless, mulberry farming and silkworm rearing or reeling yield a variety of by-products that reduce the net cost of production and boost farmers' profits. It also generates a variety of interesting products for consumers.

By-Products of Moriculture- Properties and Uses

Mulberry Leaves: It is a chief food for silkworms. High in vitamins B, C, and K as well as calcium, phosphorus, and magnesium. They have antioxidants and are an adequate supply of ascorbic acid. Mulberry leaf has been known to have diuretic, blood sugar- and blood pressure-lowering properties. It also aids in decrease in weight and anticancer properties. Thus, leaves are utilised in the preparation of various medications, herbal supplements, etc. Mulberry leaf can protect against serious illnesses like hyperlipidemia, atherosclerosis, and Alzheimer's disease (Chandrashekara *et al.,* 2009). left over leaves of mulberry used as cattle feed or used to feed rabbits and poultry Lyengar in 2007

Mulberry Shoots: Dried mulberry shoots are a common fuel and firewood source. For composting, dry twigs can be utilised. In terms of high degree of elastic, flexibility strength, hardness, shock resistance, etc., it is comparable to teak. The wood is ideal for building homes as well as for making furniture, sporting goods and agricultural tools, leftover waste to make papers. Shafts, poles, and spokes are made from the wood of mulberry and non-mulberry silkworm food plants. It has 0.32% tannin, which is useful in the colouring industry (Naveena *et al.,* 2017).

Mulberry Fruits; Fruit powder from mulberries helps the body produce good cholesterol and regulates how quickly carbohydrates are absorbed. It is thought to guard against cancer, heart disease, and a host of other dangerous illnesses. It functions as an anti-mutagen, preventing malignant cells from mutating from healthy, normal cells. (Hou, 2003). To make mulberry wine, ripe, tart mulberry fruits are utilised. (Ehow, 2009). Made from pure, fresh mulberry fruits, the anti-obesity mulberry drink is a super fruit drink loaded with antioxidants. It is a rich source of resveratrol, which has been associated with advantages for heart health. They are also used to treat urinary issues, constipation, fever, tinnitus, dizziness, and sore throats. Fruits are also used to treat intestinal parasites like tapeworms, loss of appetite, and flatulence (Kim *et al.,* 1998). Fruit wine is a very popular beverage among women in Europe. Anthocyanins found in mulberry fruits include cyaniding-3-glucoside and cyaniding-3-rutinoside, which are used as regulators of diet (Wrolstad, 2001).

Mulberry Stem: The stem of mulberries is also utilised in medicine. Stems have hypotensive, diuretic, and antirheumatic properties. Mulberry stem bark possesses vermifuge and purgative qualities. Toothache is alleviated by using a bark tincture (Singh and Ghosh1992).

Mulberry Root: Mulberry roots are utilised in medications with therapeutic and anthelmentic qualities, and they are one of the main ingredients of the medication "Glucosidase," which is used to treat high blood pressure. The black mulberry (*Morus nigra*) has root bark, affluent in calcium malate, tannins, sugar, phytosterol, phytobaphenes, fatty acids, and phosphoric acid. They lower blood sugar levels in diabetic patients and Deoxyjirimycin (DNJ), an alkaloid found in bark extract, is thought to be effective against the AIDS virus. Root bark of *M. alba* is used in traditional Chinese medicine named as "Sang bai Pi, which is used to cure cough, asthma and many other diseases. The ethanolic extract of "Sang Bai Pi" have been reported to contain flavnoids viz; Morusin, Mulberrofuran D, G, K and Kwanon G, H., of which Morusin and Kwanon H showed positive activity against HIV (Shi-De *et al.,* 1995).

Mulberry Bark: Artificial leather can be produced by processing mulberry bark, which is also used to make ropes, nets, and other products.

By-Products of Sericulture

Silkworm Rearing

Raising silkworms produces a sufficient amount of waste, which includes excess harvested leaves (10–20%), unfed leaves (20–30%), larval litter (60% of ingested food), and exuvia from moulted larvae. In addition, rejected worms, dead larvae, and weak or unhealthy worms are also considered wastes.

Litter: There are numerous applications for it that are detailed below.

Compost: Litter from silkworm larvae makes a great organic fertiliser. Nitrogen, phosphoric acid, and potash are present in the litter. It is more cost-effective to use litter for animal feeding than to apply it directly as manure. Comparison with cow dung compost, the manurial value of bio-digested cowdung plus litter slurry is higher. Rearing a hundred disease-free Silkworm laying needs 1 tonne of mulberry leaves, which yields about three hundred kilogrammes of litter and five hundred kilogrammes of leftover mulberry waste, which includes dried leaves, leaf veins, leaf stalks, and other materials. (Mala and Chandrashekhar, 2020 and Lochynska and Frankowski, 2018).

Animal Feed: Separated leftover leaf from silkworm litter is fed to cattle, sheep, pigs, buffaloes, and chickens. Because they contain more protein, chicks fed on them lay larger and more frequent eggs

Biogas Plant: In addition to cowdung, silkworm litter makes up an excellent raw material for biogas plants.

Pharmaceutical Industry: It is possible to extract and use the secondary chemicals found in mulberry leaves in litter for the pharmaceutical industry.

Chlorophyll and Related Compounds: In China and Japan, products containing chlorophyll used in cosmetics and medicine. Chlorophyll is utilised as a colouring agent in toothpaste, food waxes, and soaps. It is additionally utilised as a deodorant, a wound-healing agent, and a medication to stop gum and tooth bleeding. Carotene and phytol are extracted from silkworm litter and have practical uses in the medical field. Medication derived from the excrement of silkworms that treats leukaemia and hepatitis. Litter can also be used to make premium paints, pencil covers, and activated carbon.

Carbohydrate Compounds: Chinese scientists developed techniques to reduce the fructose, pectin, and polymers present in silkworm waste. In order to dissolve poorly soluble medications, the Sri Ram Institute of India has developed methods for extracting chitin and chitosan from the exuvia of silkworms.

Suturing Material: Surgical sutures can be made from silk gut of of mature larvae. The dead larvae can be used as a source for surgical guts (Suryakant Mishra, C and Madhab Palvi, 1992; Sharma *et al.*, 2017).

Grainage Operation

The leftover items generated in grainage include cut-open, punctured cocoons, dead and unused moths, and abandoned eggs.

Use of Pupae:

The pupa is the stage where the most nutrients and energy are stored. Without lowering the fat content, the pupae could be used in conjunction with poultry feed to increase the ability to lay eggs. Pupae protein is superior to fish or soybean protein by a wide margin. Pupal cakes to animal feed for pigs, rabbits, poultry and dog treats. Pupae have an oil content of 4.8% and 9.0% in males and females, respectively. A pupa can yield up to 25–30% of its dry weight in oil, used to prepare cosmetics, glycerin, paints, varnishes, pharmaceuticals and home-made soaps in addition to lighting lamps. Pupa oil and linseed oil combined in a 25:75 ratio in jute industry to soften jute fibres (Suresh *et al.*, 2012).

Cut-open Cocoons

The empty cut-open cocoons are processed into spun silk in grainages, where sex separation is done by hand by severing the cocoons. Cut open cocoon shells used in homes, in along with spun silks, to create crafts like greeting cards, bouquets, wall hangings, and garlands.

Pierced Cocoons

Pierced cocoons are the result of the moths emerging. in India uzi pierced cocoons are raw materials for hand-spinning industry to create silks like ghicha and katia, which are then used to make fabrics for tablecloths, caps, lady scarves, gent's chaddar, and curtains. These are raw materials to make "mautka yarn," a coarse hand-spun yarn that is extensively utilised in the handloom weaving sector. Additionally, pierced cocoons are used to make crafts such as bouquets, garlands, wall hangings, greeting cards, and flowers (Naveena *et al.*, 2017 and Ameet Singh *et al.*, 2017

Discarded/ Defective Cocoons

Some of the defective cocoons that cannot be reeled in and are sorted out before marketing/reeling include flimsy, urinated, malformed, melted, double, flossy, uzi infected, loose-knit cocoons, which make up approximately 0.5 to 1 % of the cocoon production. Value addition is anticipated to produce returns in post-cocoon sectors is 10 to 25 percent overall. Numerous items, such as garlands, flower vases, wreaths, pen stands, dolls, jewellery, wall hangings, wall plates, clocks, bouquets, and greeting cards, are made from waste silk cocoons. (Vathsala, 1997).

Waste Moths

In China, silk moths that are discarded after mating or being excluded are now utilised to prepare wines. The most well-known is a wine made by Shaanxi Sericultural Technology Station from male silkworm moths. It is purported to be used to treat impotence, irregular menstruation, and menopausal symptoms (Ameet Singh *et al.*, 2017).

By-Products of Reeling

The two main byproducts of silk industry are the dead pupae and silk waste obtained at different stages of processing the cocoon into raw silk. Silk waste (25 and 30%) produced during reeling is found in filatures, roughly 40% in charkha, and 30 to 40% in cottage basins. Cooker's waste (35%) and reelers' waste (20–25%) from cocoon processing process and account for about 25% of the production of raw silk. 0.5 to 1 percent of these are subpar cocoons, like ones that are discoloured or distorted. About 15% of the production of good silk waste is accounted for by the cocoon's unreelable parchment or pelade layer. The spun silk industry uses all of this silk waste that is thus produced during reeling as its primary raw material. Basin Refuse-2-3% (When sorting and boiling, unreelable cocoons are mixed with regular cocoons). Basin Residue unreelable portion of the cocoon left behind in the reeling basin). At various points in the manufacturing process of silk thread, during the knotting and cleaning procedures (reeling, winding, rewinding, throwing, etc.), thread waste (strazza) is created. The dead pupae, which account for around 80% of the weight of the cocoon, are another significant by-product obtained during reeling. Because it contains 23 percent fat, used to prepare non-edible oil and as a raw material for detergents and cosmetics. Pupae that have not been processed are also fed to fish, poultry, and cattle.

Spun Silk: Spun silk is a type of less expensive silk thread that is twisted together to create yarn from short lengths that are either broken off during processing or recovered from wastes and damaged cocoons (Rekhmoni *et al.*, 2020). Various types of yarn produced from wastes and defective cocoon are.

Dupion Silk: It’s from double cocoon.

Noil Yarn: Noil Yarn is short staple residue obtained from silk waste.

Matka Yarn: Made from the pierced cocoon and cut cocoon. Matka yarn is good for making jacket, suit etc.

Ghicha Yarn: Originating from a cocoon that isn't utilised in the typical reeling operation. Typically, this yarn is used as a blend material with fabrics made of pure cotton, katia silk, or silk.

Balkal Yarn: Balkal is a thick, coarsee yarn made from tasar peduncle.

Katia Yarn: Katia yarn is made from tasar silk waste left after reeling including floss.

Silkworm Pupa Compost: The dried pupae have 8% nitrogen. Pupal waste can be bio converted to enriched compost and used as a source of nutrients because high amount of protein and nitrogen in addition to micronutrients like zinc, copper, magnesium, and manganese (Mahesh *et al.,* 2020).

Silkworm - Source of Medicine:

All the stages of silkworm, *Bombyx mori*, its products, by-products and waste products used as potential medicinal sources (Singh *et al.,* 2012)

Larvae: Apart from their nutritional value, they are useful in treating bronchial asthma, primary trigeminal neuralgia, polyps, vocal nodules, heart disease, diabetes, and pain and facial palsy. Adipokinetic hormone (AKH), chymotrypsin inhibitors, ß-N -acetylglucosaminidase, the sex pheromone bombykol, amino acids, and other from larvae (Sharma *et al.,* 2022).

Silkworm Feaces: Chlorophyll, pectin, phytol, carotene, triacontanol, solanesol, and other paste-like substances are extracted from the faeces of silkworms and are used to treat a wide range of illnesses such as acute pancreatitis, chronic nephritis, stomach and gastric disorders, leukocytopenia, blood cholesterol, and hepatitis. Phytol is used to make vitamin A's carotene as well as vitamins E and K. Additionally, some diabetics use faeces as a medication or dietary supplement (Park *et al.,* 2011)

Pupae: Pupae used in antibacterial and antihistaminic preparations. Pupa comprises crude protein (50–60%), fat (25–35%), free amino acid (5–8%), sugar (8–10%), vitamins E, B1 and B2, calcium and phosphorus. 100g of dried silkworm pupae can provide a person with 75% of their daily protein requirement (Singh and Suryanarayana, 2003). The pupae become more nutritive due to the presence of minerals like calcium, selenium, and phosphorus, as well as vitamins like pyridoxal, riboflavin, thiamine, ascorbic acid, folic acid, and nicotonic acid (Koundeniya and Thanagaleu, 2005). It is possible to extract lysine, chitin, and chitosan from pupae. Pupal oil also contains 1-Deoxynojirimycin (DNJ), which is a potent alpha glucosidase inhibitor used to treat diabetes (Kotake-Nara *et al.,* 2002). Masala cookies can be made with 7 percent silkworm pupal residue powder, which has 16.6 grammes of protein, 79.3 grammes of carbohydrates, 51.3 grammes of fat, 854 kcal of energy, 114.5 mg of calcium, and 6.6 mg of iron (Vishaka *et al.,* 2020)

Reeled Cocoons: It provides edible pelade, which is easily digested and a useful food ingredient. It lowers Glucose levels in the blood and cholesterol. Pelade contain palmitic, stearic, oleic, and linoleic acids used as food additives and in pharmaceutical preparations. Fibroin is a treatment option for Type 2 diabetes, a condition marked by signs of insulin resistance such as hyperglycemia and hyperinsulinemia. Fibroin accelerates glucose metabolism and glycogen turnover independently of insulin action (Sharma *et al.*, 2022).

Silk Powder: Silk powder is also prepared from left over silk waste, used in cosmetics and medicine for reducing cholesterol and blood pressure. The rearer themselves also uses the waste to make crude silk for domestic use (Rekhmoni *et al.,* 2020).

Tasar silk

Utilising different secondary data sources, such as pierced tasar cocoons, lower-quality cocoons and their wastes, and some of the intermediate items as follows, one can create value-added non-textile products out of tasar silk cocoons.

1) Reeled Tasar / Tasar Raw Silk: It is reeled from Tasar cocoons using different appliance. Reeled Tasar is finer in nature.
2) Tasar Gicha: Hand-drawn yarn extracted from Tasar cocoons without twisting.
3) Tasar Katia: Yarn spun from Tasar waste following cleaning and opening.
4) TasarJhuri: Yarn was spun from unclean Tasar waste without having to be opened and cleaned.
5) Balkal yarn: Yarn boiled in an alkaline solution and then opened up, spinning out of the peduncles of tasar cocoons.
6) Tasar Spun Silk: Yarn spun in the mill out of tasar silk waste (Muniswamy Reddy and Sarvesh Kumar, 2014).

Eri Silk:

The ericulture is a village craft and the rearing, spinning and weaving activities are handed over from one generation to the other as the erisilk fabric, unique in appearance and aesthetic in appeal and national dress of the Assamese in North East India. Pupae of silkworms have rich biochemical compositions and can be used as a basic food source. More significant as a delicacy than its silk which has high nutritional values of include total lipids (26%), free amino acids (5-8%), crude protein (55–60%), and 100 gm of dried eri silkworm pupae can meet a person's daily protein needs by 75%. (Singh and Suryanarayana, 2003). Pupae are smoked and dried in ash and hot coal in the Assamese regions of Meghalaya, Karbi Anglong, and other places. In other places, the pupae are boiled and semi-dried and resemble peanut shells or blackened pea or cashew nuts. The tasty food items, known as "endi" (fry, pakori/chop, cake, etc.), can be made from pupae and used as a source of protein in soups and sauces when powdered (Choudhury and Satyendra, 2003).

Muga Silk:

Muga silk cloth is very largely used by the Assamese women as mekhela, riha-sador sarees. It has 97 percent protein, 3% fat, and wax, and contains 18 amino acids that are beneficial to your skin. Muga silk is the most allergen-free fabric available. It repels dust mites and is resistant to dust, fungus, mold, and a few other pollutants. The golden muga silk is the gift of nature and the “Pride of Assam” and the extreme monopoly of North east India. The most distinctive quality of muga silk is that it can absorbed 85.08% of harmful UV ray of the Sun exposure of which may lead to the skin cancer (Minti *et al.,* 2017 and Krishiworld, 2003).

Cocoon Art and Handcraft:

The Indian economy places a high priority on the handicraft sector. One of the fascinating uses for by-products is the visually appealing cocoon craft, which offers opportunities for skill development and self-employment while also generating income. Post-coon industries are believed to require less capital and high-income value added by products that contribute between 10% and 25% of total returns to value addition. The leftover silk cocoons are being used to create a variety of items, including garlands, flower vases, wreaths, pen stands, dolls, jewellery, wall hangings, wall plates, clocks, bouquets, and greeting cards.

Indian Scenario:

In India, sericulture is a long-standing agriculture-based sector that dates back more than 500 years. All commercially recognised silk varieties, including Mulberry, Tasar, Muga, and Eri, are produced in the nation. Nonetheless, micro and small-scale businesses dominate the highly dispersed and disorganised silk industry. There are 8.51 million workers in this industry, most of them come from impoverished and indigenous communities. Women make up 54% of the workforce, which is more than half. The sericulture sector is currently worth Rs 15000 crores.

Conclusion:

The agro-based industry of silk worm production is well-suited for farmers, entrepreneurs, and artisans in rural areas. Because of its quick return on investment, quick gestation period, low investment requirements, and high employment potential, it has emerged as a promising rural activity in India. With improvement, sericulture byproducts can be transformed into useful goods like compost, human medication, cosmetics, handicrafts, and more. With sericulture and the right use of silk waste, the silk industry's value can rise by as much as 40%. One possible way to address the issue of the decline in silk production is through the development of sericulture in this direction, which involves introducing the by-products of sericulture into the market and effectively utilising the human capacity, research, and production facilities currently available for sericulture.

Prospects

Sericulture, the art and science of producing silk, has enormous commercial potential in India, both for the silk itself and byproducts produced in the course of the sericulture process.

These are India's prospects for producing sericulture and non-mulberry byproducts commercially:

Diversification of Silk Byproducts: India has a rich heritage of sericulture, primarily focused on mulberry silk production. However, there is significant scope for diversification into non-mulberry silk varieties such as Eri, Muga, Tasar, and wild silk. Commercial production of these silk varieties and their associated byproducts can open up new markets, both domestically and internationally, catering to diverse consumer preferences and increasing revenue streams for sericulturists.

Value Addition and Market Expansion: Byproducts derived from sericulture, including silk waste, pupae, sericin, and chrysalis oil, offer opportunities for value addition and market expansion. These byproducts can be processed into various value-added products such as cosmetics, pharmaceuticals, dietary supplements, and functional foods. Commercializing these byproducts not only enhances the profitability of sericulture but also promotes entrepreneurship 6 and innovation in downstream industries.

Sustainable Development and Rural Livelihoods: Sericulture and the production of silk byproducts contribute to sustainable development and rural livelihoods in India. Sericulture provides employment opportunities for millions of farmers and artisans, particularly in rural and semi-urban areas. By promoting sericulture and byproduct utilization, India can empower rural communities, alleviate poverty, and foster inclusive growth across regions.

Promotion of Traditional Crafts and Cultural Heritage: Eri, Muga, and Tasar are examples of non-mulberry silk varieties that are essential to India's traditional craftsmanship and cultural legacy. Handloom weaving, embroidery, and dyeing techniques are examples of traditional crafts that can be revitalised and promoted through the commercial production of these silk varieties and the byproducts they produce. This improves the marketability of indigenous products in both domestic and foreign markets while also protecting cultural heritage.

Research and Innovation: Continued research and innovation in sericulture and byproduct utilization are essential for unlocking the full potential of the sector. Investments in research and development can lead to the discovery of new applications for sericulture byproducts, improved processing techniques, and enhanced product quality. Collaborations between academia, industry, and government agencies can accelerate innovation and drive the growth of the sericulture sector.

In conclusion, there are plenty of opportunities for value addition, market expansion, sustainable development, cultural promotion, and research-driven innovation in the commercial production of sericulture and non-mulberry byproducts in India. India can maintain its position as the world leader in silk production and advance the socioeconomic development of the nation by fully utilising the potential of sericulture and its byproducts.

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LAC CULTURE- PRODUCTS, APPLICATIONS AND INHERENT PROPERTIES

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Abstract:

Lac is a commercially important cash crop that provides a vital source of income for millions of resource-poor people living in the country's tribal-dominated forests and sub-forests. Lac cultivation is the breeding of lac insects for the production of lac. Lac is a natural resin that is secreted by the lac bug *Kerrica lacca*, which belongs to the Tachardidae family. Lac retains its monopoly as a non-toxic, biodegradable, natural, and safe resin used in pharmaceuticals, cosmetics, and surface coatings for a wide range of industrial applications. India is the world's largest producer, processor, and exporter of lac, with an average production of 20,000 tons over the last five years. Following the discovery of lac's global commercial potential, organized study on the crop was initiated in India. Authentic knowledge has been generated through research and documentation on every facet of lac production, processing, product development, and usage diversification. Lac can be processed to produce a number of economically significant by-products. Resin makes up the majority of lac (65%), with two significant by-products, lac colour (1%), and lac wax (5.6–6%) following. Depending on the requirements of the many industrial applications, the lac resin is processed into a variety of value-added forms. In a same vein, wax and dye are used in a variety of industries, including textile and pharmaceutical.

Introduction:

In India, lac is a naturally occurring resinous material of significant commercial value. It is the only resin derived from animals that may be used for a variety of purposes, such as thin film, adhesives, and plastics, where it can be used as a decorative and protective covering. Although the lac contributes slightly but significantly to the nation's foreign exchange earnings, its cultivation provides a supplementary source of income for about 3–4 million tribal people, who represent the socioeconomically weakest segment of the Indian population. This is the lac's most significant economic role. More over half of the lac produced worldwide in India, making it the world's leading producer. It produced around 90% of the world's total output during the First World War, thus giving it a monopoly in the lac trade. Currently, the nation produces 20–22 thousand tons of stick lac, or raw lac, annually on average. Waste land and homestead land in India provide the majority of the lac generated there. In certain places, trees on government land are taken on a lease or rental basis, while host trees that are standing on rayyati properties are typically employed for lac cultivation (Chattopadhyay, 2011).

A sticky substance called lac is secreted by female scale insects. Lac insects are plant sap feeders (Sharma *et al.*, 2006; Singh *et al.*, 2009; Shanker *et al.*, 2023) therefore grow vigorously only on certain plant species known as lac hosts. India has been using it since the Vedic era. It is mentioned for the first time in the Atherva Veda. The bug is referred to as "Laksha" and its behavior and habits are explained there. The renowned Indian epic "Mahabharata" also describes a "Laksha Griha," an ignitable mansion of lac that the "Kauravas" deftly built through their architect "Purocha" with the intention of burning their formidable foe "Pandavas" alive (Chattopadhyay, 2011). The Hindi word lakh, which is derived from the Sanskrit word Laksh, which means a lakh or hundred thousand, is synonymous with the English word lac (Ogle, 2006). Lac insect cultivation has a long history in Asia, with some claiming that it dates back 4000 years in China, where it accompanied the rise of the silk industry. Lac is Nature's gift to mankind and the only commercial resin of animal origin known to man. It is the hardened resin made by small lac insects, who are members of the bug family. Around 300,000 insects are killed to make 1 kg of lac resin. Lac insects produce resin, lac colour, and lac wax. The applications of these items have evolved throughout time. Lac resin, dye, and other substances are still widely used in the Ayurvedic and Siddha medical systems. Due to its eco-friendliness, biodegradability, and self-sufficiency, lac has gained particular relevance in the modern era due to growing environmental consciousness worldwide. Promoting lac and its culture can aid in the development of eco-systems and provide reasonably high economic returns because lac insects are raised on host trees that are mainly found in wasteland areas. The impoverished and tribal people who live in forest and sub forest regions rely on it for their livelihood (Singh, 2007).

Composition and Their Properties

The approximate concentration of different lac ingredients is as follows: water 2–3%, mineral substances 3–7%, resin 68–90%, colour 2–10%, wax 5–6%, and albuminous compounds 5–10%. Lac is known as a versatile resin since it has so many advantageous qualities.

Important Properties of Lac

i) It is soluble in alcohol.
ii) It has an adhesive property.
iii) Water resistance.
iv) Have a high scratch hardness.
v) It has the ability to form a uniform, long-lasting film.
vi) It allows for rapid sandpaper rubbing without gumming or slicking

Importance of lac culture

- An excellent means of subsistence for underprivileged farmers.
- Guaranteed revenue stream in years of drought.
- Need little inputs, like as water and pesticides.

- Grown best on marginal and damaged terrain.
- No rivalry with other agricultural or horticultural crops for farmland and operations.
- In no way damage other plants or animals or the health of the host tree.
- Prevents rural-to-urban population movement.
- Gives women more options for better careers and earnings

Lac Products and Their Use:

1) Lac Dye

Lac dye is an Anthro quinoid derivative combination. Laccaic acid is the principal colour imparting component of lac dye (Sharma *et al.,* 2020). It has traditionally been used to dye wool and silk. Its colour can range from purple red to brown to orange, depending on the mordant employed. It is used for colouring in the food and beverage industries (Mansion *et al.,* 2022). Lac colouring has recently been replaced by synthetic dye. However, with increased focus and knowledge on the usage of eco-friendly and safe materials, particularly those involved with human contact and ingestion, there is a resurgence of high demand for lac dye as a colouring ingredient (Singh, 2007).

2) Lac Wax

Lac wax is a compound composed of higher alcohols, acids, and their esters. It is a constituent of natural resin lac. It is found to the extent of nearly 4-5% in seedlac, 3-5% in shellac and slightly higher percentage in stick-lac (5-6%) (Sharma *et al.,* 2020). It is used in polishes for shoes, floors, and vehicles (Mansion *et al.,* 2022), food and confectionery, as well as medication tablet finishing, lipsticks, tailor's chalk and crayons. Shellac wax has also been utilized in manufacture of radio condensers because of its high melting point. Used for making of finishing waxes for boot soles because of its hard and lustrous nature (Sharma *et al.*, 2020).
Recently, it has been reported that, the long chain fatty alcohols like triacontonol, dotriacontonol, octacosanol and hexacosanol are known for plant growth regulatory activity whereas triacontanol is a natural plant growth regulator and used commercially also. It is found in epicuticular waxes and responsible for plant growth promotion activities (Sharma *et al.,* 2020).

3) Shellac

Shellac is a natural gum resin that was given to humans by nature and is employed in over 100 industries. It is a natural, non-toxic, medically innocuous, edible resin. Shellac is a hard, stiff, amorphous, and brittle resin that contains a little amount of wax and a component that gives it its distinctive pleasant odor. Lac resin is an intimate mixing of numerous chemical compounds rather than a single chemical substance. Shellac weighs slightly more than water. Its natural colour ranges from deep crimson to pale yellow. It softens at 65-70^{0}C and melts at 84-90^{0}C when slowly heated. insoluble in water, glycerol, hydrocarbon solvents, and esters and easily dissolves in alcohols and organic acids. Methylated spirit is the most often used solvent for dissolving shellac. Aqueous solutions can also be prepared using gentler alkalis such as ammonia, borax, and sodium carbonate. Shellac has an acidic flavour. The acidity level is 70. It is a kind of ester. The saponification value is 230. It contains hydroxyl number 260 and five free hydroxyl groups. The iodine value of 18 indicates that it is unsaturated. The carboxyl value of 18 indicates the presence of a free aldehydic group. It has a molecular weight of 1000 on average. Shellac has a 5% wax component that is insoluble in alcohol. It can be dissolved in n-hexane, pure terpentine, and other hydrocarbon oils. It is hard and has a melting point of 840 degrees Celsius (Singh, 2007).

It has the following extra ordinary properties:

i) It is thermoplastic.

ii) It has been approved for a variety of uses in the food business.

iii) It is also UV-resistant.

iv) It has outstanding dielectric qualities, such as dielectric strength, low dielectric consent, and strong tracking resistance, among other things.

v) It has good film forming characteristics. Its film adheres well to a wide range of surfaces and has a high gloss, hardness, and strength.

vi) Shellac is a strong bonding agent with a low thermal conductivity and coefficient of expansion. It is notable for its thermal flexibility and ability to absorb huge amounts of fillers.

vii) Under tropical storage conditions, shellac may soften and solidify without affecting its characteristics. Long-term storage under poor conditions, on the other hand, may result in property deterioration.

viii) When shellac is heated over its melting point for an extended period of time, it loses its fluidity and transitions from a rubbery to a hard, horn-like, and infusible state.

Use:

- It is utilized in fruit coatings viz., citrus and apple fruits, as well as separating and glazing agents for sweets, marzipan, and chocolate. Binder for foodstuff stamp inks, such as cheese and eggs.
- It is utilized as a mascara binder, nail polish additive, conditioning shampoo, hair spray film forming agent, and scent micro-encapsulation (Mansion *et al.,* 2022).
- It is utilized in enteric (i.e. digestive juice-resistant) tablet coatings and as an odor barrier in dragées.
- It is used to make photographic material, lithographic ink, and to stiffen felt and hat material.
- It is used in the production of phonograph recordings.
- Lac is used by jewellers and goldsmiths to fill hollows in ornaments.

- It is also used to make toys, buttons, pottery, and artificial leather.
- It is also used commonly as sealing wax.

With rising consumer environmental consciousness, this natural and renewable raw material is increasingly being exploited in the development of innovative goods outside of the traditional user industries. Here are a few examples:

Leather: Seasoning and Products for Caring

Among these are printing inks for use as a binder in flexographic printing inks for non-toxic food packaging printing; wood treatment such as primers, polishes, and matt finishes; textiles used as stiffeners; electrical applications such as capping, lamination, and insulation; abrasives used as a binder for grinding wheels; and other uses such as micro-encapsulation for dyes and inks.

4) Bleached Shellac

Bleached shellac is non-toxic and physiologically innocuous (edible), and it is widely used in the food, packaging, and associated sectors. Apart from the foregoing, bleached shellac is utilized for its properties such as binding, adhesive, hardness, gloss, odorlessness, fast drying, and prolonging shelf life (in the absence of refrigeration), among others. Bleached shellac can be used to make clear, transparent, or very light-coloured alcoholic or water-alkali solutions (Singh, 2007).

Use:

Bleached shellac is widely used in the following industry:

- Paints (primer for plastic parts and plastic film)
- Aluminium industry (primer for Aluminium and Aluminium foils)
- Flexographic printing inks
- Pharmaceuticals (for coating of pills, tables and gel caps and coating for controlled release preparation)
- Confectionery (in coating of confections, chewing gums, marzipan chocolates, nutties, jelly- and coffee-beans etc) (Mansion *et al.*, 2022).
- Binder for food marking and stamping inks and Binder for egg coating
- Barrier coating for processed food, vegetables, fruits and dry flowers
- Textiles (used as textile auxiliaries and felt hat stiffening agents)
- Cosmetics (used in hair spray, hair and lacquers, hair shampoos, and binder for mascara)
- Finishing wood (as a binder for wood coatings and dyes, as well as a filler/sealer for porous surfaces and fissures)
- Antique picture frames and wood polish (French polish)

- Fireworks & pyrotechnics (used as a binder for fireworks, matches, and in magnesia coating)
- Electric (as a lamp cement binder)
- Electronics (it is a binder for insulating materials and a molding compound component). Print-plate mass coating and glue for si-cells.)
- Grinding wheels (it is a binder for grinding wheel additives).
- It is a primer for plastic parts and films.
- Rubber (it is a natural rubber ingredient)
- Leather (in leather auxiliary products)

5) Dewaxed Bleached Shellac

Dewaxed white shellac is applied in the same manner as other grades of shellac. The main distinction between this shellac and others is that it is a little harder, shines a little brighter, and is completely free of wax. Bleached lac offers excellent properties and characteristics such as sticky, binding, hardening, gloss, and odorlessness. It has great adherence to many substrates, including human hair, and good film forming properties. It is non-toxic and has no physiological effects. In ethanol and lesser alcohols, a good solution can be formed. It can also be dissolved in water by mixing it with an alkali such as ammonia. Many additional resins, raw materials, and additives used in cosmetics, medicines, and food formulations are compatible with it (Singh, 2007).

Use:

- Fruit and vegetable coating
- Tablet and capsule coating
- Confectionery coating
- Aluminium foil and paper coating
- Coating used in the cosmetics sector
- It is utilized in hair sprays (pump sprays or aerosol sprays, hair setting lotio*+9ns, hair shampoos, mascara, eyeliners, nail polishes, lipsticks, and micro encapsulation of aromas and perfume oils.
- It is utilized in confections, chewing gum, candles, cakes, eggs, citrus fruits, and apples, as well as printing inks for eggs and cheese.

6) Aleuritic Acid (Shellac Aleuritic Powder)

Aleuritic acid (9, 10, 16-trihydroxypalmitic acid), produced via saponification from shellac, is a unique acid with three hydroxyl groups, two of which are of adjacent carbon atoms. Aleuritic acid comes in the form of a white powder or granule. It is moderately soluble in hot water or lesser alcohols (methyl alcohol, ethyl alcohol, and isopropyl alcohol) and crystallizes when the solution is cooled. It dissolves in lesser alcohols such as methyl, ethyl, and isopropyl. Technical grade Aleuritic Acid (99% purity) is a slightly yellow, odorless substance (Singh, 2007).

Use:

Aleuritic acid is in high demand in the perfumery and pharmaceutical industries because it is an ideal starting material for the synthesis of civetone, ambrettolide, isoambrettolide, and other compounds with a musk-like odor. Shellac Aleuritic Acid is used to make civetone. It is widely employed in the production of perfumes and is in high demand among perfume manufacturers in France, Italy, Germany, and the United States, among others.

The following are some more suggested uses for aleuritic acid:

- In medicine, glucose monoaleuritate (a non-toxic, non-hemolytic water-soluble molecule) is synthesized as an isocaloric replacement for dietary tripalmitin.
- Condensation of aleuritic acid with pithalic andydride and glycerin, rosin, and other ingredients to produce plastics with good adhesive qualities.
- Aleuritic acid esters are utilized in the manufacture of lacquers, polymers, and fibers.

Potential of India in Lac Production

Nowadays, there is a greater emphasis on the use of environmentally friendly and safe materials, particularly those involved with human touch and ingestion. Lac is a non-toxic, natural, renewable, biodegradable resin. As a result, a significant increase in global demand for lac is expected. The intended goal of increasing lac output is relevant and significant. It is a source of income for tribal and underprivileged people who live in forest and sub-forest areas. India is the world's leading lac producer, producing roughly 18,000 metric tons of unprocessed raw lac per year. Approximately 85% of the country's output is exported to foreign countries. The United States, Germany, and Egypt are among the world's top lac importers. India exports lac in the following forms: seed lac, dewaxed lac, bleached lac, shellac/button lac, and aleuritic acid (Singh, 2007). After India, lac is produced more in Thailand. Along with these, lac is also produced in Indonesia, parts of China, Myanmar, the Philippines, Vietnam, and Cambodia etc. In India, lac production is mainly restricted to the Chhota Nagpur region of Jharkhand state, Chhattisgarh state, Madhya Pradesh, West Bengal, Orissa, Uttar Pradesh and Maharashtra. Among the lac growing states, Jharkhand state ranks 1st followed by Chhattisgarh, Madhya Pradesh, Maharashtra and Odisha and the Contribution of these five states in national lac production is about 53%, 17%, 12%, 8% and 3%, respectively. These major lacs producing five states contribute around 93% of the national lac production (Yogi, 2015; Mishra).

India has great potential for lac culture. The areas for lac cultivation can be broadly classified into three categories :(a) Regular lac cultivation areas – at present, only 20-25% of the total available trees are being utilized, (b) Moderate lac cultivation areas – around 10-15%

available trees are being utilized, and (c) Lac host trees are available but due to lack of knowledge and awareness, none of the trees are utilized for lac cultivation. Thus, on an average, only 15% of the available lac host trees owned by farmers are being utilized for lac cultivation presently. There are vast untapped areas, which are ecologically favourable for lac production in the country. These places have prospective lac host plants that, if properly explored in a scientific and methodical manner, have the potential to increase lac production. Enhancing the utilization of idle or underutilized lac host plants in lac growing areas can also increase lac production.

The Indian Lac Research Institute (ICAR), Namkum, Ranchi, established in 1924, is actively engaged in addressing the goal of increasing lac productivity and production through technology transfer and adoption by integrating research, development, and extension. The Institute has created a number of technologies and cultivation packages. Lac output can be increased in the future by implementing and adopting scientific cultivation methods, efficient host plant management, integrated pest management, boosting exploitation of unexploited host plants, and cultivation under the 'Joint Forest Management' initiative (Singh, 2007).

To meet national and international demand, equal focus must be placed on improving manufacturing quality. Lac quality declines as a result of the following factors: late harvesting, insufficient storage, primary processing shortly after harvesting, and a lack of proper processing devices for quality and recovery. These issues can be addressed by implementing the Institute's recommended technologies.

Conclusion:

Lac insect farming provides a vast tapestry of products with diverse applications and distinctive inherent features. Lac-derived products, such as shellac and lac dye, have showed extraordinary adaptability and significance in a variety of disciplines. This journey through the cultivation, extraction, and application of lac-based materials has shown not just the historical roots of this technique, but also its lasting relevance in modern circumstances. The numerous applications of lac products, which include cosmetics, food, and traditional crafts, demonstrate the important role lac plays in our daily life. Lac's natural, renewable, and sustainable features make it a precious resource in an era where environmental awareness is crucial. It is clear from considering the many facets of lac farming that this traditional method is still changing to meet contemporary needs and adhere to sustainable practices. There are significant economic ramifications for lac farming communities, underscoring the possibility of a good socioeconomic effect and community empowerment.

Future Scope:

- Exploring innovative extraction methods, such as green and eco-friendly processes, could further elevate the environmental credentials of lac-derived products.

- comprehensive studies on the potential medical and pharmaceutical applications of lac insect-derived compounds. Understanding the therapeutic properties and biomedical applications of these compounds could open new avenues for research and development.

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INSECT-DERIVED NATURAL DYES: FROM COCHINEAL TO LAC AND THEIR IMPACT ON FARMERS' INCOME

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Abstract:

The majority of natural dyes of animal origin derived from insects were red in colour. The insect species *Dactylopius coccus* produces cochineal, a significant animal origin dye that is still used to colour textilesFor centuries some scale insect species have been used for the production of dye (*Porphyrophora polonica*, *P. hameli*, *Kermes vermilio*, *Kerria lacca*), wax (*Ceroplastes ceriferus*, *C. irregularis*, *Ericerus pela*), lac and shellac (*K. lacca*); these hemipterons are also the source of honeydew. Three groups of insect dyes are described: three cochineal dyes, the kermes dye and the lac dye. The major color components are carminic acid, kermesic acid and laccaic acids, respectively. These dyes are red anthraquinone derivatives. Nowadays, some of them (*Dactylopius coccus*) deliver natural pigment which is used for yoghurt, sweets and soft drinks production. The female insects that reside on cacti (*Opuntia species*) and produce dye are harvested from their bodies. Another red dye with an animal origin, Kermes comes from the bug *Kermes licis*. Although it has been used to colour animal fibres since antiquity, this dye lacked cochineal's fastness qualities. In the past, lac was also well-known for colouring animal fibres. It is made from the bug *Kerria lacca's* stick-like secretions (stick lac), which are found on twigs. It is produced as a by-product when stick lac is processed to make shellac.

Keywords: Insects, Cochineal Dye, Kermes Scale, *Kerria lacca*, Carminic Acid

Introduction:

The demand for natural dye is constantly increasing with an increase in awareness of the public on the ecological and environmental problems associated with synthetic dyes (Subramanian, 2005). The effort of cultivating natural dye from insects has been suggested by Prasad (Prasad, 2007) with a view to exploit it from India. The coccid, *Dactylopius coccus* (Hemiptera: Dactylopiidae) is the most important species due to its being used for the extraction of carmine acid, a natural red dye used in food, pharmaceutical, and cosmetic industries (Vigueras, 2001). Modernization in dyes and chemicals gave birth to synthetic dyes. Until then, natural dyes from animal and plant extracts were used to colour garments. The process of extraction was tedious and hence the garments were expensive. Thus, these dyes were used in making attires for the rich, kingly, and the wealthy. The use of insects for obtaining a certain colour for the purpose of dyeing has been dated back to the 15^{th} century. Names of colored components Chemists have been unimaginative in naming the color components of the insect dyes. The first to be named was the major color component of the cochineals, carminic acid, possibly by De la Rue (1845). Later, the dye from kermes was named kermesic acid and the several components of the lac dye were termed laccaic acids.

The coccid is an insect living on cladodes of prickly pears (*Opuntia ficus indica*). Dried females are a source of red dyes widely utilized in food, textile, and pharmaceutical industries (Mendez, 2004). D. opuntiae is another wild species found in Mexico and has a shorter lifespan and reproduction cycles with a larger number of generations per year (Mann, 1969). All the cochineal species have a high content of proteins and minerals. The residuals from coloring extraction can be used to enrich food for avian species or to prepare fertilizers (Quijano, 2007). Cochineal is used to produce scarlet, orange, and other red tints. The production and exploitation method of the dye was also studied by many workers in this field (Flores–Flores and A. Tekelenburg, 1995; Aldama-Aguilera, 2005). The insects are killed by immersion in hot water or by exposure to sunlight, steam, or the heat of an oven. Each method produces a different colour which results in the varied appearance of commercial cochineal. It takes about 155,000 insects to make one kilogram of cochineal (VKRTEX, 2009). Likewise, oak galls were gathered and used commercially as a source of tannic acid. It was a principal ingredient in wool dyes and black hair colourants used during the Greek empire as early as the 5th century BC. It is still used commercially in the leather industry for tanning and dying and in manufacturing of some inks. Tannic acid was obtained from the Aleppo gall found on oak trees (*Quercus infectoria Olivier*) in Asia and Persia. The trees produce gall tissues in response to the chemical substance secreted by the larvae of tiny wasps (*Cynips gallae tinctoriae* Olivier; Hymenoptera: Cynipidae) that infest the trees. 50%– 75% of gall's dry weight is composed of tannic acid (Grieve, 2009). The aspect of exploring as well as utilizing natural dyeproducing insects is quite virgin in the India. North-eastern region being a main region of oak cultivated area, there is an absolute scope in this field and thus enthusiastic approach is required in near future.

In India, agriculture is the primary source of livelihood for a significant portion of the population, particularly in rural areas. However, farmers often face challenges such as unpredictable weather patterns, pests and diseases, fluctuating market prices, and dependency on a single crop, which can impact their income stability. During agricultural off-seasons or periods of low crop yields, farmers may experience reduced income or even financial distress.

In this context, the cultivation and production of insect-derived dyes offer an alternative source of income for farmers, especially those with access to suitable climatic conditions and resources for dye cultivation. Here's how insect-derived dyes can contribute to income diversification and risk mitigation for farmers in India:

Supplementary Income: Insect-derived dyes such as lac, cochineal, and kermes provide farmers with an additional source of revenue beyond traditional crop cultivation. Farmers can cultivate dye-producing insects or plants during agricultural off-seasons or on marginal lands where traditional crops may not thrive, thereby utilizing resources effectively to generate income year-round.

Market Opportunities: The demand for natural and eco-friendly dyes is increasing globally, driven by consumer preferences for sustainable and ethically produced textiles. Insect-derived dyes, known for their vibrant colors and eco-friendly properties, are sought after by textile manufacturers, designers, and consumers looking for alternatives to synthetic dyes. Farmers can tap into these market opportunities by supplying insect-derived dyes to textile industries and artisanal crafts markets.

Reduced Dependency on Monocropping: Mono-cropping, or the practice of growing a single crop repeatedly on the same land, can expose farmers to risks such as pest infestations, soil depletion, and market price fluctuations. By diversifying into insect-derived dye cultivation alongside traditional crops, farmers can spread their risk and buffer against losses associated with mono-cropping. This diversification strategy enhances the resilience of farming households to economic shocks and environmental stresses.

Value Addition: Insect-derived natural dyes add value to locally produced textiles, enhancing their marketability and commanding premium prices in domestic and international markets. By adding value through dye cultivation and processing, farmers can capture a larger share of the value chain and increase their income per unit of output. Value addition also creates opportunities for rural entrepreneurship and small-scale agribusiness development.

Sustainable Agriculture Practices: Insect-derived dye cultivation often involves sustainable farming practices that promote biodiversity conservation, soil health, and water conservation. By adopting eco-friendly farming methods, farmers can contribute to environmental sustainability while earning a livelihood from insect-derived dye production. This aligns with India's goals of promoting sustainable agriculture and reducing the ecological footprint of farming activities.

In summary, insect-derived dyes offer farmers in India a viable pathway to income diversification, risk mitigation, and sustainable agriculture. By leveraging the market demand for natural dyes and tapping into the value-added opportunities in the textile sector, farmers can enhance their livelihoods and build resilience against the uncertainties of traditional crop farming.

1. **Cochineal dye** which is isolated from:

a) Porphyrophora hameli - From antiquity through the 20th century, Azerbaijan employed this particular variety of cochineal. Evidence the use of the Asian Armenian cochineal, Porphyrophora hamelii, dates to the 8th century BCE (Ferreira *et al.*, 2004). The oldest known pile rug, the Pazyryk rug, was found in 1949 in the grave of a Scythian nobleman in the Pazyryk Valley of the Altai Mountains in Siberia and now resides in the Hermitage Museum in Saint Petersburg. The rug likely contains Armenian cochineal dyed wool created 2245 ± 35 years ago (Hajdas *et al.*, 2004). The insects live on the roots of two species of grasses, Aeluropus littoralis and Phragmites australis; consequently, harvesting the insects is labor intensive.

b) Margarodes polonicus and Porphyrophora polonica - It is referred to as Polish Cochineal. Readers of oriental ornamental art literature are least likely to be familiar with the Polish Cochineal coccid dye bug and its dye than other insect dyes. The insects live on the roots of a wide variety of small plants including perennial knawel in Poland. These insects were found as far as east of Poland as Kazakhstan. An analysis of 15 cochineal dyed textiles dated between the 15th and 19th centuries from Italy, Turkey, India and Iran were dyed frequently with Polish cochineal even after American cochineal became available during the 16th century (Serrano *et al.*, 2011). However, for many centuries, this coccid dye manufacturer dominated the textile dye trade and the commercial history of eastern Europe and the Near East. Even while there isn't much concrete proof that Polish Cochineal dye was used in any particular form of Oriental rug, its availability on the market at the time some rug types were created would make it more difficult to draw generalisations regarding the usage of insect dyes.

***c) Dactylopius coccus or Coccus Cacti*-** American cochineal is derived mainly from the insect, *Dactylopius coccus*, which lives on cactus and was used by the Aztec, Incan and Mayan peoples. Over the centuries, the natives of Mexico and Peru improved the yield of the dye by selective breeding of both the cactus and the insects, which resulted in a product that was significantly superior to the Old-World cochineals (Greenfield, 2005). The Spanish took over the trade in cochineal soon after they invaded Central and South America during the 15th and 16th centuries (Dapson, 2007). During the 19th century, Peru and Mexico were major sources, but currently Peru claims 85% of the world market. A cactus-feeding bug from Spanish America or other Spanish areas is the source of the cochineal colour, which was utilised in some Caucasian, Persian, and Turkish rugs and fabrics.

The bug makes carminic acid, which keeps other insects from consuming it. To manufacture carmine colour, often known as cochineal, carminic acid, which makes up generally 17–24% of the weight of dried insects, can be removed from the body and eggs and combined with aluminium or calcium salts.

Modern Use

Cochineal is still used as a food colouring, a cosmetic dye, and a fabric dye. As a preliminary stain for the evaluation of tissues and polysaccharides, it is also utilised in histology.

2. Kermes - The kermes insect, *Kermes vermilio,* lives on the kermes oak, *Quercus coccifera*. This oak is not a grand stately tree; rather it is a weedy little bush with shiny dark green spiky leaves, like holly (Cooksey, 1995) Kermes (formerly krmz, qrmz) derives from the term "kirmizi," which in all Turkic languages denotes "red." The Kermes scale insect, primarily *Kermes ilicis* (previously *Coccus ilicis*) or *Kermes vermilio*, which is distantly related to the cochineal insect and is found on species of oak (especially Kermes oak) in Mediterranean countries as well as in some regions of Iran, produces a dye that is extracted from the dried bodies of the females.

Kermes was an expensive dye that required an alum mordant and the Pope controlled the alum mines in Italy (Cooksey, 2013). It was, however, a short-lived triumph for kermes, because 30 years after Columbus travelled to America, the Spanish would import the superior American cochineal that slowly replaced the native European red dyes (Cardon, 2007). Suggestions that kermes was the only rich red dye known in Europe and the Middle East before the discovery of the New World (Dapson, 2007) are wide of the mark: "(k)ermes was by no means the only insect red dye used in the ancient Middle East" (Taylor, 1987)

3. Lac dye - *Kerria lacca* insects have been cultivated in India for thousands of years. These insects yield two different products, lac dye and a shellac or lacquer resin. The earliest mention of lac dye is found in verse number 5 of the 5th volume of Atharva-Veda, a sacred text of Hinduism, dated about 1,500 BCE, where its medical use for open wounds or oral administration is described (Shamim *et al.,* 2014). Accounts have been found of the cultivation of lac insects for both the dye and the shellac in China dating as early as the 3rd century CE (Tsai 1982). The use of lac as a pigment on a wine jug found in Puglia, Italy dated from the 3rd century BCE has been reported recently (Dyer *et al.,* 2018).

The lac insects live on branches of trees of many different species. In the decade following 1866, the amount of lac dye exported from India and British Burma varied from 8,385 to 20,864 cwt (1 cwt = 50.8 kg)/year (O'Conor 1876). By 1995, the probable annual international trade in lac dye was estimated to be 10 tons (1 ton = 1016.0 kg). Lac dye use in India is small and the bulk of the aqueous dye extract, obtained from the first step of processing lac, is discarded (Green 1995).

The lac dye was used in rugs and textiles in India and in places near trade routes where lac was accessible. It was created by an insect (*Kerria lacca*) that produces both dye and shellac. Silk was typically dyed with lac, which produced a spectrum of hues from rose to purple.

4. Oak Gall

This medieval ink starts with a wasp. In spring, it punctures the soft young buds of the oak tree and lays its eggs. The tree forms little nut-like growths around the wasp holes – and it is these protective oak galls which, when crushed and fermented, created the basis of the deep black drawing ink of the Middle Ages.

Name	**Source**	**Host plant**	**Colour**
American cochineal	*Dactylopius coccus cacti*	Opuntia	Blue /red carminic acid Medicine, Food production, Cosmetics and Fabric Dyeing
Cochineal of azerbaijan	*Porphyrophora hamelii*	feeds on the bottom stems and roots of several grasses found within Aeluropus.	Packaging labels in food and cosmetics, Hand-woven oriental rugs and royal outfits, food colorant, Painting works
Polish cochineal	*Porphyrophora polonica L.*	It breeds and feeds primarily on the roots of the host plant, Scleranthus perennis, and is a soil dweller and root feeder. (Perennial knawel)	Red /various
Kermes	*Kermococcus vermilis*	The larval, immature female of the Kermes oak tree is fastened to its branches. (*Quercus coccifera*)	Kermesic acid Dye Industry
lac	*Kerria lacca*	The host plants of lac insects are *Palas (Butea monosperma), Kusum (Schleichera oleosa) and Ber (Zizyphus mauritiana*)	Varnishes, paints, Sealing wax, Coating of pills, Glossiness of fruits and vegetables, Confectionary food products. Vinyl records and Coloring military uniforms

Figure 1: Cochineal dye

Figure 2: Kermes dye

Uses

- ✓ Cochineal is one of the few water-soluble colours that doesn't degrade over time. It is one of the most heat-, light-, and oxidation-resistant natural organic colourants, and it is even more stable than several synthetic food dyes.
- ✓ The water-soluble form of calcium carmine is used in alcoholic beverages; the insoluble form is used in a variety of products.
- ✓ They can also be found in a variety of dairy products, sauces, and sweets, as well as in meat, processed poultry products, sausages, alcoholic beverages, and bakery products like toppings, cookies, desserts, and pie fillings.
- ✓ Carmine is thought to be safe enough to use topically near the eyes.
- ✓ Among the cosmetics that make use of a substantial portion of the produced insoluble carmine pigment are lipsticks, face powders, rouges, and blushes.
- ✓ In the pharmaceutical industry, cochineal is used to colour pills and lotions.
- ✓ Cochineal-dyed wool and cotton are essential elements of Mexican folk art and crafts. In some communities in the Mexican state of Oaxaca, cochineal is still produced and used to make handcrafted textiles.

Risks

A tiny percentage of persons have been discovered to suffer occupational asthma, food allergies, and cosmetic allergies despite the ubiquitous usage of carmine-based colours in food and cosmetic items.

Certainly! In India, the utilization of insect-derived natural dyes has a long history deeply intertwined with traditional practices and cultural heritage. Here are some additional insights on how these dyes impact farmers' income in India:

Historical Significance: Insect-derived dyes like cochineal, kermes, and lac have been utilized in India for centuries, contributing to the rich tapestry of textile traditions. These dyes were prized for their vibrant hues and were often used in the production of luxury textiles, including silk and wool garments.

Cultural Heritage: Insect-derived natural dyes are deeply rooted in India's cultural heritage, with indigenous communities and artisanal craftspeople preserving and passing down the knowledge of dye extraction and application from generation to generation. This heritage plays a crucial role in sustaining rural livelihoods and preserving traditional craftsmanship.

Economic Impact: The cultivation and processing of insect-derived dyes create economic opportunities for farmers and rural communities across India. Farmers involved in sericulture, lac cultivation, and other related activities benefit from the sale of dyestuff to textile manufacturers, dyers, and artisans.

Diversification of Income: For many farmers, insect-derived dyes offer a valuable source of supplementary income, especially during agricultural off-seasons or periods of low crop yields. By diversifying their income streams, farmers can mitigate the risks associated with mono-cropping and seasonal fluctuations in agricultural markets.

Value Addition: Insect-derived natural dyes add value to locally produced textiles, enhancing their marketability and commanding premium prices both domestically and internationally. This value addition benefits not only farmers but also artisanal communities involved in textile production and handloom weaving.

Sustainable Practices: Insect-derived dyes are often harvested from renewable sources such as lac insects and cochineal bugs, making them environmentally sustainable alternatives to synthetic dyes. By promoting sustainable farming practices and biodiversity conservation, the cultivation of insect-derived dyes contributes to India's goals of environmental stewardship and sustainable development.

Government Initiatives: The Government of India, recognizing the socio-economic importance of traditional dyeing practices and artisanal crafts, supports various initiatives aimed at promoting the sustainable production and marketing of insect-derived natural dyes. These initiatives include training programs, financial incentives, and market linkages for farmers and artisanal communities engaged in dye cultivation and textile production.

Overall, the utilization of insect-derived natural dyes in India represents not only a cultural legacy but also a pathway to economic empowerment for farmers and rural communities, fostering sustainable livelihoods and preserving traditional knowledge for future generations.

Conclusion:

Numerous publications discussing natural dyes have been published during the past few years. The goal of this review is to draw attention to the harmful effects that synthetic dyes have on both the environment and human health. But as of right now, there is no cost-effective way to get rid of both the colour and the toxicity of the synthetic dyes released into the environment. Natural dyes, which are supposedly inexpensive, non-toxic, renewable resources with little influence on the environment, have caught the interest of the scientific community for use in a number of conventional and recently discovered application fields.

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CULTIVATING WEALTH FROM THE EARTH: EXPLORING THE COMMERCIAL POTENTIAL OF VERMICULTURE AND VERMICOMPOSTING

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Abstract:

Vermiculture is the cultivation of annelid worms such as earthworms or bloodworms for use as bait or in composting. The method of producing vermicompost that contains various water-soluble nutrients, a great natural nutrient-rich organic fertilizer, and a soil conditioner is known as vermicomposting. Batch reactors (containers on legs or the ground), stacked bins or containers, windrow systems on concrete or the ground, and continuous flow reactors are all designed for large-scale vermiculture and vermicompost production. Vermiculture and vermicomposting produce commercial items like vermicompost and its products, plastic degradation, bioturbation, worms for bait or feed, and medications.

Introduction:

Vermicomposts are byproduct of earthworms and microorganisms decomposing organic waste rapidly. Earthworms ingest organic waste and break it down into smaller fragments by passing it through a grinding gizzard, then feed on the bacteria that thrive on organic materials. The process speeds up the microbiological degradation of organic matter, increases microbial populations, and alters the material's physical and chemical properties, culminating in rapid humification, in which unstable organic matter becomes completely oxidized and stabilized. Vermicomposts are fragmented peat-like materials with good water-holding capacity and aeration, high porosity and drainage (Kiyasudeen *et al.*, 2016).

Physical Properties

Vermicomposts have a mull-like soil odor and are dark and homogenous. They have significantly enlarged surface areas, resulting in additional microsites for microbial decomposition organisms and robust nutrient adsorption and retention. Albanell *et al.*, (1988) found that vermicomposts have pH values close to neutrality, which could be attributed to the production of CO_2 and organic acids during microbial digestion. Elvira *et al.* (1995) discovered that the earthworm *Eisenia andrei* (Bouché) dramatically increased humification rates in paper-pulp mill waste. The transformation of ingested organic matter into humic chemicals during passage through the earthworm gut indicated that the rate of humification increased throughout gut transit. The organic-matter concentration of final vermicompost should be greater than 20-25% (but less than 50%). The ash content is just the compost's nonvolatile solids minus inert particle components including glass, metal, plastic, gravel, and big clay aggregates. Contamination with inert materials in high-quality vermicomposts should be very low, less than 0.5-1.0% by weight.

Bulk density is an essential physical attribute of vermicomposts that determines other plant development variables including porosity, aeration, and moisture-holding capacity, among others. Pore space should account for 70-80% of total volume of the organic materials acceptable for potting soil. High bulk density has the disadvantage of raising container medium transport costs and limiting porosity and air capacity, which should be avoided as much as possible in commercial culture media. However, extremely low bulk density might result in excessive aeration of the substrate and, as a result, a decrease in accessible water. De Boodt and Verdonck (1972) stated that an ideal substrate for the plant growth have a minimum of 85% overall porosity, container capacity between 55% and 75%, and air space between 20% and 30%. Sum of the airfilled macropores and water-filled micropores in a saturated substrate is a percentage total porosity. Vermicomposts of high grade should have a reasonably fine maximum particle size (less than 0.2 mm (0.007 in) diameter). The moisture percentage of vermicomposts should be between 75% and 90% throughout processing, but moisture content in finished vermicomposts can vary greatly. A vermicompost's moisture content can be altered by adding water or drying. Vermicomposts have good physicochemical and biological qualities, making them ideal for the use as supplements to greenhouse container growth media, organic fertilizers, or soil amendments for a variety of horticultural crops.

Chemical Properties

The chemical composition of vermicomposts is controlled in part by the level of earthworm activity and the conditions under which they have been grown, but mostly by the parent wastes used. Vermicomposts, particularly those derived from animal waste manures, usually had more mineral elements compared to commercial plant growth medium, and several components of these, such nitrates, P, and soluble K, Mg, and Ca, were more easily absorbed by the plants (Arancon *et al.*, 2004a, b). The pH range of suitable potting medium or soils for plant growth is 5.5 to 8.0, with 6.0 to 7.0 preferred. The pH of vermicomposts varies depending on a parent organic material of which they were created; for example, vermicomposts made of sheep dung had a pH of 8.6, vermicomposts made from cattle manure had a pH of 6.0-6.7, and vermicomposts made from sewage sludge had a pH of 7.2. Specification of the $CaCO_3$ (lime) content in alkaline vermicomposts may also be appropriate. The cation-exchange capacity of vermicomposts should be in the 50-100 meq/L range. The overall concentration of salts (mineral anions and cations) in vermicomposts can reach levels that hinder plant growth or are harmful to plants, especially if the vermicompost is made from animal dung feedstocks. In saturated extracts of high-quality plant development media, soluble salt concentrations (measured as electrical conductivity) should not exceed 1-2 dS/m (100-200 mS/m) for sensitive plants and seedlings and 2-3 dS/m (200-300 mS/m) for established plants. Because earthworm activity is restricted at concentrations above 0.5%, vermicomposts typically have low salt contents (Edwards and Arancon, 2004). The electrical conductivity of pig dung vermicompost was 322 mS/m.

A vermicompost's overall carbon concentration is closely correlated with its organic matter composition. Thus, the degree of stabilisation attained throughout the vermicomposting process may be evaluated using changes in the total carbon content. The total nitrogen concentration of vermicomposts can vary greatly (from 0.1% to 2-4% or higher). Total N in pig dung vermicomposts was 0.43% (Atiyeh *et al.*, 2002). It is a key factor for determining the total nutritional value of vermicomposts. One of the most often used and possibly valuable markers of the stability of organic materials such as composts and vermicomposts is the C:N ratio. Microorganisms have a C:N ratio of 15 to 25, whereas humus has a C:N ratio of 11 to 12. C:N ratios in adequately stabilized material are usually less than 20-22. Much greater C:N ratios may indicate the presence of the bioavailable carbon and, so, material that is not fully stabilized. While nitrogen-rich products may not always be fully stabilized despite having low C:N ratios, changes in the ratio from the raw material feedstock to the final product may be just as significant as the absolute final value. Coffee pulp vermicomposting enhanced the availability of nutrients such as P, C, and Mg. Vermicomposts have higher mineral nutrient contents compared to commercial plant growth medium. Elvira *et al.* (1995) suggests that the rapid mineralization of the organic waste, enhanced microbial activity, breakdown of polysaccharides, and higher rates of humification attained during vermicomposting can account for the quantity and quality of nutrients found in vermicomposts. During the bioconversion of solid paper-pulp mill sludge by earthworms, the total extractable C, non-humified fraction, and humification rates increased while the overall carbohydrate content declined toward the conclusion of the trial (Kiyasudeen *et al.,* 2016).

Biological Properties

The prevailing understanding is that composts and vermicomposts benefit from higher overall populations of microorganisms. In comparison to thermophilic composts, vermicomposts exhibit significantly more microbial activity and food webs. They are rich in actinomycetes, fungi, and bacteria that degrade cellulose (Kiyasudeen *et al.,* 2016). Furthermore, Tomati *et al.*, (1983) showed that earthworm castings recovered after sludge digestion contained a considerable number of microorganisms, particularly bacteria. Vermicomposts had significantly higher populations of bacteria (5.7×10^7), fungus (22.7×10^4), and actinomycetes (17.7×10^8) than traditional thermophilic composts (Kiyasudeen *et al.,* 2016). Extracts from paper-sludge vermicomposts were shown to be dominated by actinobacteria, which have the ability to control fungal infections in plants (Yasir *et al.,* 2009).

Various Applications of Vermicomposts

1. Vermicompost and Soil Fertility

Vermicompost's micro and macro components, enzymes, vitamins, and hormones can all have a considerable impact on plant development and productivity (Sinha *et al.,* 2009). Vermicomposts include plant-available nutrients such as nitrates, exchangeable phosphorus, calcium, soluble potassium, and magnesium (Kiyasudeen *et al.*, 2016). Furthermore, the large specific surface area provides various microsites for microbial activity and excellent nutrient retention. When fertilizer and vermicompost were applied combined, the rice plant (*Oryza sativa*) absorbed the greatest nitrogen (N), phosphorus (P), magnesium (Mg), and potassium (K) (Jadhav *et al.*, 1997). The incorporation of vermicompost increases soil pH, microbial population, and enzyme activity. It also lowers the amount of water-soluble chemicals that may contaminate the environment (Kiyasudeen *et al.*, 2016). According to Sreenivas *et al.* (2000), ridge gourds (*Luffa acutangula*) absorbed nitrogen more readily when 50% of the fertilizer mix consisted of vermicompost. Expelled via the earthworm's digestive tract, mucus promotes rivalry and antagonism among various microbial populations, which leads to the synthesis of few antibiotics and hormone-like biochemicals that accelerate plant development. Furthermore, mucus promotes and quickens breakdown of the organic matter, which is composed of stable humic compounds that contain high concentrations of plant-available nutrients and water-soluble phytohormonal components (Edwards and Arancon, 2004)

Vermicasting improves soil fertility, structure, and plant growth. They help minimize illnesses caused by soil-borne plant infections, hence increasing agricultural productivity (Singh *et al.*, 2008). Organic carbon 9.15–17.98%, total nitrogen 0.5–1.5%, available phosphorus 0.1–0.3%, available potassium 0.15 %, calcium and magnesium 22.70–70 mg/100 g, copper 2–9.3 (ppm), zinc 5.7–11.5 (ppm), and available sulfur 128–548 (ppm) were the nutrient status of the vermicomposts according to Kale (1995). Vermicomposts are utilized as substitute potting media because of their affordability, superior nutrient status, and unique physiochemical properties. Garden tomatoes grew up to 15% more quickly when vermicomposted pig manure was added to potting media at 20, 30, and 40% by volume. The mixture with 20% of vermicompost produced the highest marketable yield of fruit. Treatments with 100% vermicompost resulted in smaller growth and fewer leaves than other treatments because of high moisture content and potential phytotoxicity (McClintock, 2004).

Vermicompost has the advantageous competence to act as a buffer, reducing the harm that might be caused by an overabundance of nutrients that could otherwise result in phytotoxicity. Vermicompost functions as a slow-release fertilizer and soil conditioner as a result, heavy metals are less available to plants during vermicomposting because they mix with humic acids and other polymerized organic components. When compared with soil fertilized with mineral fertilizers, soil amended with vermicompost produced higher-quality fruits and vegetables with lower levels of nitrate and heavy metal.

2. The Function of Vermicompost Bacteria in Biomedical Waste Management

It is impossible to overestimate the significance of managing biomedical waste, biosolids, and sewage sludge making use of simple, safe methods. All of these pollutants are infectious and must be sterilized before they may be disposed of in the environment. Pathogenic bacteria can also be found in biosolids. Waste biocomposting causes biological change and stability of the organic matter, thus reducing pathogen threats. Vermicomposting lacks a thermophilic phase, which may increase the risk of using this technology for infectious waste management; however, vermicomposting significantly reduced pathogen indicators such as fecal coliform, Salmonella sp., enteric virus, and helminth ova in biosolids (Sidhu *et al.,* 2001). Biosolids vermicomposting decreased faecal coliforms and Salmonella sp. levels from 39,000 MPN/g to 0 MPN/g and <3 MPN to <1 MPN/g, respectively (Dominguez and Edwards, 2004).

Municipal sewage sludge vermicomposting using *Lampito mauritii* eliminated Salmonella and Escherichia coli. Earthworm activity on sludge reduced pathogen levels and putrefaction odors, accelerating sludge stabilization (Kiyasudeen *et al.,* 2016). The diminution or eradication of these enteric bacterial communities at the end of the vermicomposting phase is consistent with the discovery that earthworms eat germs and can selectively digest them. Earthworms are used to remediate sewage water as well as to manage solid waste.

Earthworms work as aerators, crushers, grinders, chemical degraders, and biological stimulants in wastewater, promoting the growth of 'beneficial decomposer bacteria'. Earthworms also granulate clay particles, increasing hydraulic conductivity and natural aeration, as well as mill silt and sand particles, increasing total specific surface area and thereby improving organic and inorganic matter adsorption in wastewater. Furthermore, the earthworm's body acts as a 'biofilter,' removing 90%, 80-90%, 90-92%, and 90-95% of the biological oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), and total suspended solids (TSS) from wastewater through 'ingestion' and biodegradation of organic wastes, heavy metals, and solids from wastewater and 'absorption' through body walls (Sinha *et al.,* 2008).

Vermicomposting is essential for the safe discarding of solid waste from wastewater treatment facilities and biomedical wastes, along with the bioconversion of these waste materials into beneficial composts free of enteric bacterial populations. Depending on the type of earthworm utilised, vermicomposting has been demonstrated to reduce the occurrence of several pathogens in different waste types, such as *Salmonella enteriditis*, *Escherichia coli*, total and faecal coliforms, helminth ova, and human viruses. Improving aerobic conditions may lead to indirect ways of eradication of diseases by minimising the coliform load. Digestive enzymes and mechanical grinding may provide direct pathogen reduction during intestinal passage (Aira *et al.*, 2011).

3. The role of vermicompost in promoting plant growth

Vermicomposts have recently gained popularity as biofertilizers due to their superior nutritional value and higher microbial and antagonistic activity. When used as a media supplement, vermicompost derived from diverse parent materials, such as food waste, bovine dung, pig dung, and so on, increased seedling growth and development while increasing agricultural productivity. Chamani *et al.* (2008) found that adding vermicompost to soil-less bedding plant media boosted germination, development, flowering, and fruiting in a variety of greenhouse vegetables and ornamentals, including marigolds, pepper, strawberries, and petunias. Several studies have shown detectable quantities of plant growth regulators in vermicompost, including auxins, gibberellins, cytokinins generated from microbes, and humic acids. *Bacillus* and *Arthrobacter species* produce cytokinins in soil, which increase seedling vigor (Atiyeh *et al.*, 2002). Microorganisms create gibberellins, which affect plant growth and development, whereas *Azospirillum brasilense* produces auxins, which regulate plant growth in the paoceae family (Arshad and Frankenberger, 1993). Furthermore, humic chemicals can promote plant development. Humic compounds, according to Valdrighi *et al.* (1996), boosted the dry matter yields of maize and oat seedlings, the number and length of tobacco roots, the dry weights of the roots, shoots, and nodules of groundnut, soybean, and clover plants, and the vegetative growth of chicory. They also stimulated the growth of roots and shoots in plant tissue cultures.

Vermicomposts made from animal manure, food wastes, sewage, and paper mill sludges have been found to have high quantities of humus (Arancon *et al.*, 2003a, b). In addition to helping plants overcome stress and promote growth, the humus's fulvic and humic acids breakdown insoluble minerals in organic matter and make them easily available to plants. Carrots (*Daucus carota*) have been shown to exhibit auxin-like cell proliferation and nitrate metabolism in response to humic compounds taken from vermicomposts (Muscolo *et al.*, 1996).

When earthworm castings are used to propagate plants, root initiation, biomass, and population are all boosted. The existence of microbial metabolites was thought to be the cause of the hormone-like effect that earthworms have on plant metabolism, growth, and development, which results in dwarfing, rooting stimulation, internode elongation, and premature flowering (Edwards, 1998). Vermicompost's aqueous extracts induced growth in Petunia, Begonia, and Coleus that was comparable to the application of hormones like auxins, gibberellins, and cytokinins. This substantial evidence implies that vermicompost has a high concentration of compounds that influence plant growth (Tomati *et al.*, 1988). In cucumber, dwarf maize, and coleus bioassays, vermicompost contained considerable amounts of cytokinins, auxins, and gibberellins (Edwards *et al.*, 2004). The plumule length of maize seedlings dipped in vermicompost water differed significantly from that of regular water, indicating that vermicompost contains plant growth stimulants. Studies evaluating the effects of vermiwash and urea solution on seed germination, root and shoot length in *Cyamopsis tertagonoloba* found that vermiwash included hormone-like substances. Significant quantities of Indole-acetic-acid (IAA), gibberellins, and cytokinins were discovered in aqueous extracts of cattle dung produced vermicompost using high performance liquid chromatography (HPLC) and gas chromatography mass spectrometry (GC-MS) (Edwards *et al.*, 2004).

Earthworm-associated gut microorganisms produce extremely water-soluble and light-sensitive plant growth hormones, which improve vermicomposting. These hormones are absorbed by the humic acid compounds in vermicompost, increasing their stability and extending their duration in the soil, eventually suppressing plant growth. In addition to its high nutritional content and readily available nutrients, vermicompost is a biofertilizer that promotes germination, development, flowering, and fruiting in a variety of crops thanks to its humic acid content and other plant growth-regulating chemicals.

Singh *et al.* (2008) found that applying vermicompost increased plant spread (10.7%), leaf area (23.1%), dry matter (20.7%), and overall strawberry fruit yield (32.7%). By replacing strawberry fields with vermicompost, the incidence of physiological abnormalities such as albinism (16.1-4.5%), fruit deformity (11.5-4.0%), and grey mold (10.4-2.1%) was much lower. This implies that vermicompost has an important role in lowering nutrient-related diseases and Botrytis rot, resulting in a greater marketable fruit yield of 58.6% and better-quality criteria. The fruit obtained from the plant receiving vermicompost was larger, more visually appealing, and contained more ascorbic acid and total soluble solids (TSS). Singh *et al.*, (2008) found that the best results were obtained at 7.5 t ha -1. All metrics appeared to be dosage dependant. When vermicompost was treated, mung bean (*Vigna radiata*) germination increased to 93%, and the plant expanded and produced more than the control (Karmegam *et al.*, 1999). Similarly, soil treated with vermicompost generated higher fresh and dry matter yields of cowpea (*Vigna unguiculata*) than soil modified with bio-digested slurry. *Abelmoschus esculentus*, okra, hyacinth bean, *Lablab purpureas*, tomato, eggplant, sunflower (*Helianthus annuus*), tomato (*Lycopersicon esculentum*), grapes, and cherry were among the plants that benefited from vermicompost treatment (Kiyasudeen *et al.*, 2016). The presence of beneficial bacteria that stimulate plant growth and antagonistic bacteria that suppress disease, as well as improved physicochemical properties and readily available nutrients from processed waste, may be responsible for increased plant growth.

4. Vermicompost's use in Pathogen Control and Plant Disease Management

The abundance of beneficial microorganisms in vermicompost enables biological control of harmful fungus. Bio-control, sometimes known as "general suppression," involves the activities and interactions of soil microbes that strive with diseases for 39 resources or create antibiotic compounds (McClintock, 2004). In general, pathogen spores in compost-amended soils are more thickly covered by beneficial fungal and bacterial propagules, reducing their infectivity. These helpful populations frequently parasitize the hyphae of harmful fungi. Beneficial bacteria may limit the resources required by pathogenic fungal spores for germination by consuming the amino acids, sugars, volatile ethanols and aldehydes released from root and seed tissue, as well as decaying plant debris. While antibiosis and competition for resources by beneficial microbial populations can reduce pathogenic fungus, an increase in the plant growth promoting rhizobacteria (PGPR) can also improve induced systemic resistance (ISR) in plants. ISR is a disease-suppression strategy that involves boosting physiological barriers against pathogenic fungi, bacteria, and viruses. The presence of PGPR (primarily *Bacillus spp*. and *Pseudomonas spp*.) causes an increase in chitinases, beta-1 and 3-glucanases, peroxidases, and other pathogenesis-related proteins, as well as the accumulation of anti-microbial low-molecular weight substances and the formation of protective biopolymers (lignin, callose, glycoproteins) (Chen *et al.,* 1987; McClintock, 2004). Conventional thermophilic composts support a limited range of microorganisms, whereas non-thermophilic vermicomposts are abundant in microbial diversity and activity. They also contain a diverse range of antagonistic bacteria, making them useful bio-control agents that help suppress diseases brought on by phytopathogenic fungi that are carried by the soil (Kiyasudeen *et al.,* 2016).

Earthworm feeding reduces the survival of plant diseases including *Fusarium sp*. and *Verticillium dahlia* while increasing the populations of hostile fluorescent pseudomonads and filamentous actinomycetes (Elmer, 2009). Bacilli and *Trichoderma spp*. populations remain stable. Earthworm activities help to reduce Rhizoctonia-related root diseases in cereals. Earthworms have been shown to reduce the occurrence of field diseases of clover, cereals, and grapes caused by Rhizoctonia and *Gaeumannomyces spp*. (Clapperton *et al.,* 2001). The earthworms *Aporrectodea trapezoides* and *Aporrectodea rosea* act as vectors for Pseudomonas corrugate 214OR, a biocontrol agent for wheat take-all caused by *G. graminis* var. tritd (Doube *et al.,* 1994). *Fusarium oxysporum* f. sp. asparagi and *F. proliferatum* on susceptible asparagus cultivars (*Asparagus officinalis*), *Verticillium dahliae* on eggplant (*Solanum melongena*), and *F. oxysporum* f. sp. Lycopersici race 1 on tomato were found to cause significantly less disease in greenhouse investigations on the augmentation of pathogen-infested soils with *L. terrestris*. Plant weights increased by 60–80% and disease severity decreased by 50–70% when earthworms were added to the soil. The incidence of 'Powdery Mildew', 'Color Rot', and 'Yellow Vein Mosaic' in

Lady's finger (*Abelmoschus esculentus*) was greatly reduced by vermicompost application (Agarwal *et al.*, 2010). *R. solani, P. drechsleri*, and *F. oxysporum* fungal infections in gerbera were lessened when vermicompost was added to the growth media. Under greenhouse conditions, vermicompost fed at low rates (10–30%) to horticulture bedding media greatly decreased Rhizoctonia and Pythium (Edwards *et al.*, 2004). The *P. brassicae*-induced club-rot of cabbage was inhibited by immersing the roots in a clay and vermicompost mixture. When potato plants were treated with vermicompost instead of inorganic fertilizers, their sensitivity to *P. infestans* was decreased (Kostecka *et al.*, 1996).

5. Vermicompost's use in Arthropod Pest Control

Organic amendments serve to reduce a wide range of insect pests, including European corn borer, other corn insect pests, aphids and scale insects, and brinjal shoot and fruit borer. Vermicompost addition also decreased the incidence of jassids (*Empoasca kerri*), aphids (*Aphis craccivora*), *Spodoptera litura*, *Helicoverpa armigera*, leaf miner (*Apoaerema modicella*), and spider mites on groundnuts, in addition to psyllids (*Heteropsylla cubana*) on a tropical leguminous tree (*Leucaena leucocephala*) (Kiyasudeen *et al.*, 2016). Vermicompost, added at a rate of less than 50% to the soilless plant growth medium MetroMix 360 (MM360), reduced the damage caused by infestations of Pseudococcus spp. on tomato seedlings, *M. persicae* on cabbage seedlings, *M. persicae* on pepper seedlings, and caterpillars (*Pieris brassicae* L.) on cabbage seedlings. Aqueous vermicompost extracts reduced the establishment rates of *M. persicae*, citrus mealybug, two-spotted spider mite, striped cucumber beetles (*Acalymna vittatum*) on cucumbers, and tobacco hornworms (*Manduca sexta*) on tomatoes. Higher dosages of vermicompost teas also resulted in pest mortality (Edwards *et al.*, 2010). Solid vermicompost was added to greenhouse and field tests to lessen damage from A. vittatum, spotted cucumber beetles *(Diabotrica undecimpunctata*), and larval hornworms *(Manduca quinquemaculata*) on cucumbers and tomatoes. The incidence of "Thrips" *(Scirtothrips dorsalis*) and "Mites" (*Polyphagotarsonemus latus*) on chillies (*Capiscum annum*) was dramatically decreased by using vermicompost and vermiwash spray (Saumaya *et al.*, 2007).

6. Vermicompost's Function in Nematode Management

In the field, vermicompost treatments dramatically lower the number of plant parasitic nematodes. Vermicomposts decreased the number of galls and egg masses of *Meloidogyne javanica* as well as the assault of *Meloidogyne incognita* on tobacco, pepper, strawberry, and tomato (Edwards *et al.*, 2007). The application of vermicompost reduces plant parasitic nematodes by a number of conceivable processes that involve both biotic and abiotic elements. The population of nematode antagonists (e.g., *Pasteuria penetrans*, *Pseudomonas spp*. and chitinolytic bacteria, *Trichoderma spp*.) and other common nematode predators, such as nematophagous mites like *Hypoaspis calcuttaensis*, collembola, and other arthropods that selectively feed on plant parasitic nematodes, is stimulated when organic matter is added to the soil (Kiyasudeen *et al.*, 2016). The addition of vermicompost increased the number of rhizobacteria that promote plant growth and create enzymes that are toxic to plant parasitic nematodes. These fungi also produced enzymes that could capture and destroy nematodes and cysts. Moreover, low C/N ratios in the compost and nematicidal compounds released during vermicomposting, such as hydrogen sulfide, ammonia, nitrates, and organic acids, have direct negative effects on plant parasitic nematodes, while alterations in the physiochemical properties of the soil, such as bulk density, porosity, water holding capacity, pH, EC, CEC, and nutrition, have indirect negative effects.

Derivatives of Vermicompost

i. Vermiwash

Vermiwash is a liquid that is collected after water has passed through a column of worm action and is extremely beneficial as a foliar spray. It is a collection of earthworm excretory products and mucus secretions, as well as micronutrients derived from soil organic molecules. These are carried to the leaves, shoots, and other sections of plants in the natural ecosystem (Ansari and Ismail, 2012). Vermiwash appears to have the intrinsic property of working both as a fertilizer and as a moderate biocide. Vermiwash is also 'productive' and 'protective' to agricultural crops. This liquid, which contains some growth hormones known as "auxins" and "cytokinins," is rich in nutrients, vitamins, amino acids, potassium, magnesium, zinc, iron, and copper. It is also partially derived from the bodies of earthworms. It also has a lot of bacteria in it that fix phosphate and nitrogen. Vermiwash has outstanding "pest-killing" and "growth-promoting" qualities. Using vermiwash and vermicast extracts improved paddy growth and yield, according to Thangavel *et al.*, (2003). The application of 0.5 t/ha of vermicompost and 6 dilutions of vermiwash led to a significant reduction in thrips and mite assaults in chili plants, as well as the highest yield (2.98 quintal/ha). Suthar (2010) discovered substances in vermiwash that resembled hormones.

ii. Vermicompost Tea

Vermicompost tea is made by extracting water from solid vermicomposts to transform microorganisms, soluble nutrients, and plant-beneficial compounds into liquid form. It can be applied through a number of routes to promote plant development and the management of pests and diseases in horticultural and agricultural systems. On plant foliage, it can be applied immediately. It has also been shown to be beneficial in small doses when used as a soil drench. More precisely, the organic substrates—vermicomposts—from which the healthful components are derived set vermicompost teas apart. Vermicompost tea's chemical and biological characteristics can change based on inputs and other process variables. One variable that may be controlled when making vermicompost tea is the ratio of vermicompost to water. Ratios of solid vermicompost to water ranging from 5% (1:20) to 20% (1:5) were found to be effective in laboratory and greenhouse tests. No matter what ratio of vermicompost to water was used during manufacture, the finished extract may need to be further diluted for certain applications. Vermicompost tea is shaken, stirred, and allowed to aerate during the extraction process. This encourages the growth of aerobic microorganisms in the tea or aqueous solution while preventing the growth of anaerobes, which could result in metabolic wastes. To boost microbial activity, supplements or additives can be added to the aerated tea solution. Additives and supplements have included molasses, humic acids, kelp, rock powders, fish emulsions, and a host of other compounds. Vermicompost tea production takes anywhere from a few hours to several days. A generally used and convenient brewing time is 24 hours, with constant aeration and agitation, though this varies greatly depending on the type and size of equipment, among other considerations. Temperature influences the types of organisms that grow and their rates of growth. Vermicompost teas are now available and used in large-scale agriculture, viticulture, orchards, horticulture, nurseries, grass greens, commercial landscaping, and home gardens. The farming system, problems with pests and diseases, and the state of the environment all influence the rates, frequency, and application methods. Vermicompost tea is well recognized for introducing millions of bacteria, fungi, actinomycetes, and protozoa, together with the metabolic waste of these organisms, to increase soil microbiological activity. Vermicompost tea contains microorganisms, water-soluble fulvic acids (building blocks for humic acids) and particulate humates, plant-growth hormones produced by microbes, and compounds that promote micronutrient availability (chelating effect). The soluble nutrients in vermicompost tea support plants directly while also feeding existing soil microbes. Like vermicompost, it boosts soil biological activity and delivers useful organic chemicals. Unlike vermicompost, it can be applied both to plant foliage and to soil. Direct foliar application of vermicompost tea provides nutrients that the plant can directly absorb while also introducing a diverse array of microorganisms that colonize leaf surfaces (Kiyasudeen *et al.*, 2016).

iii. Vermicomposting Leachate

Water is given or sprayed on a regular basis during the vermicomposting process to maintain moisture in the reactor. Furthermore, leachate is produced during vermicomposting because microorganisms leak water as they degrade organic material. The extra water that leaches out is commonly referred to as vermicomposting or worm bed leachate. Because of its high concentration of plant nutrients and the presence of humic and fulvic acids, vermicomposting leachate can be used as liquid fertilizer after collection (Gutiérrez-Miceli *et al.*, 2008). The majority of animal wastes cannot be used as is. Direct dumping may cause environmental contamination, particularly in big quantities. As a result, it has become an environmental issue. Over the last two decades, vermicomposting has gained acceptance as a method of recycling organic waste. The utilization of animal waste, such cow dung, in the vermicomposting process thus addresses the issue of disposing of animal waste while simultaneously yielding valuable goods like vermicompost and vermicomposting leachate. Vermicomposting leachate contains humic acids, which regulate a number of processes related to plant growth, including macro- and micronutrient adsorption, therefore despite its high nutrient content, it may be beneficial to plant development (Arancon *et al.*, 2005). The fresh and dried shoot weight as well as the height of the maize plants were significantly impacted by the application of vermicomposting leachate. The study conducted by Tejada *et al.*, (2008) found that plants treated with vermicomposting leachate (cow dung) and green forage as foliar fertilizer exhibited greater chlorophyll content, increased plant height, leaf macronutrient content, yield, and an average number of fruits per tomato plant compared to those treated with Hewitt solution. The incidence of albinism, fruit malformation, and gray mould was reduced in the vermicomposting leachate of cow dung waste, vegetable waste, and a combination of vegetable and cow dung waste when applied as foliar fertilizer to straw berry plants than in the control treatment (Singh *et al.*, 2010).

Conclusion:

Vermiculture, the process of composting organic waste with earthworms, has shown to be an environmentally sound and sustainable way to improve soil and manage waste. The products derived from vermiculture, such as vermicompost and vermicompost tea, have demonstrated significant benefits in agriculture, horticulture, and ecological restoration. Additionally, the inherent properties of vermicompost, such as improved soil structure, enhanced nutrient content, and microbial activity, contribute to overall soil health and plant growth. The applications of vermiculture extend beyond traditional agriculture, finding use in urban gardening, landscaping, and even wastewater treatment. The versatility of vermicompost and its by-products makes it a valuable resource in promoting sustainable practices and reducing the reliance on chemical fertilizers.

Future Scope:

- Exploring the potential of earthworms in bioremediation processes, such as the removal of pollutants and heavy metals from contaminated soils.
- Investigating novel applications for vermicompost and its derivatives, such as biopesticides, soil conditioners, and specialty fertilizers, can diversify the market and create new revenue streams.
- Research on earthworms' ability to sequester carbon and how it can help mitigate climate change is a developing topic that needs more attention.

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BRIDGING NATURE AND MEDICINE: EXPLORING THE THERAPEUTIC POTENTIAL OF INSECTS IN ENTOMO-ETHNOMEDICINE AND COMMERCIAL OPPORTUNITIES

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Abstract:

The fascinating connection between insects and traditional medicine, explored in the field of entomo-ethnomedicine, represents a captivating blend of ancient knowledge and modern scientific exploration. With a staggering diversity of over 110,000 described species, insects stand as integral contributors to global biodiversity, yet their potential therapeutic benefits remain largely unexplored. Notably, bee and ant venoms emerge as reservoirs of substantial therapeutic potential, housing a myriad of bioactive compounds. Despite challenges like cytotoxicity, innovative strategies such as nanoparticle-based delivery systems and genetic modifications hold promise for optimizing the efficacy of these natural products. Delving into the medicinal applications of various insect orders, including Coleoptera, Mantodea, Isoptera, Hemiptera, and Homoptera, reveals a rich tapestry of traditional practices spanning diverse cultures. From targeted ailment treatments to the discovery of potential antimicrobial and anticancer compounds, insects offer a trove of possibilities for drug development. Maggot therapy, deeply rooted in ancient practices and validated by modern biomedical research, emerges as a particularly effective strategy for wound healing. As global antibiotic resistance looms, the importance of insect-derived antimicrobial peptides becomes increasingly apparent, presenting a crucial source for future chemotherapeutic agents. The integration of traditional knowledge with scientific advancements emerges as the key to unlocking the expansive therapeutic potential of these fascinating creatures, offering cost-effective healthcare alternatives, particularly in regions with limited access to conventional treatments. Insects, armed with their diverse chemical defenses, signify a promising frontier for innovative drug development, bridging the gap between nature and healing in the pursuit of global well-being. Future endeavors should prioritize interdisciplinary collaboration, technological innovation, and conservation efforts to harness the full therapeutic potential of insect-derived substances responsibly.

Keywords: Entomo-Ethnomedicine, Insect-Derived Compounds, Antimicrobial Peptides, Maggot Therapy.

Introduction:

Insects, constituting one of the most diverse classes in the animal kingdom with over 110,000 described species, represent a crucial but understudied facet of traditional medicine (Hellmann and Sanders, 2007). Indigenous communities, often the custodians of medicinal plant and animal knowledge, face biodiversity loss integral to their practices (Scheffler *et al.*, 2009). While botanical ethnomedicine has received attention, ethnozoology, particularly ethnoentomology, remains underexplored (May, 2000). Insect-based traditional knowledge, known as entomo-ethnomedicine, has only recently gained scientific recognition. Insects and arthropods, forming 80–90% of global biodiversity, have been integral to traditional medicine in parts of East Asia, Africa, and South America (Butenandt *et al.*, 1961). Despite the potential therapeutic benefits of these arthropods, their study is nascent, presenting an opportunity for scientific exploration and technological discoveries (Morgan, 2004). In an economically challenged world, insects, with their vast diversity and potential medicinal substances, may offer cost-effective alternatives, particularly in regions with limited access to conventional healthcare. Entomotherapy, focusing on the medicinal use of insects, encompasses diverse cultural practices globally, providing a rich yet untapped source for novel chemistry and potential applications in medicine and beyond.

Historical Roots of Entomotherapy:

Table 1: Historical Evolution of Entomotherapy: A Cross-Cultural Perspective

Country	Examples of Insect Use	References
Brazil	Mud wasps, grasshoppers, and bloodsucker bugs for various treatments	(Costa-Neto, 2003; Ramos-Elorduy, 2001)
Mexico	Stinkbugs, and grasshoppers for iodine-rich remedies targeting goiters and anemia	(Azmi and Ali 1998)
Africa	Mole cricket gut contents for treating infected feet in Nigeria, termite mandibles for suturing wounds in Somalia	(Zimian *et al.*, 1997)
China	Silkworms, scorpions extensively studied for pharmacological compounds	(Costa-Neto, 2002)
South Korea	Centipedes, silk moth larvae for treating ailments like arthritis and stroke	(Zimian *et al.*, 1997)
India	Honey, pollen, propolis, and venom from bees for tonics, wound treatments, and remedies for various conditions	(Valli, 1998)
Japan	Historical records of entomotherapy, contributing to the global tradition	(Namba *et al.*, 1988)

The intricate history of traditional medicine includes a captivating chapter on the therapeutic use of insects across diverse cultures and continents. Dating back to ancient times, entomotherapy has left its mark on various regions, from Egypt in the 16th century B.C. to contemporary practices in Brazil, Mexico, Africa, China, India, and South Korea. Insects such as silkworms, grasshoppers, and beetles have played a crucial role in traditional healing, addressing ailments from wound healing to goiters and anemia. Recent research underscores the pharmacological potential of insects in combating diseases caused by microorganisms. For an in-depth exploration of historical aspects, refer to the table below, offering insights into global folk traditional uses of insects.

1. Hymenoptera Therapeutics: Exploring Medicinal Marvels from Bees, Wasps, and Ants

The order Hymenoptera encompasses a diverse group of insects, including bees, wasps, hornets, ants, sawflies, horntails, and ichneumonflies, constituting over 115,000 species globally. This order is characterized by a unique chemical defense mechanism, injecting venom directly into their victims. Bee-derived products, such as honey, venom, and royal jelly, have been integral to traditional medicine for centuries, with various therapeutic applications.

A. Honey: Nature's Healing Elixir

Honey, a substance produced by *Apis mellifera* (honeybee), has been a staple in folk medicine, utilized for treating wounds, inflammation, infections, and a myriad of other conditions. Its therapeutic effects are attributed to its diverse composition, including antimicrobial phenolic compounds (p-hydroxybenzoic acid, naringenin, pinocembrin, and chrysin) and antimutagenic carbohydrates. Honey's osmotic properties aid wound healing by moisturizing the wound bed, reducing maceration risk, and inhibiting fibrin that hinders tissue repair.

Wound Healing and Burns:

Numerous studies highlight honey's efficacy in wound healing, with comparable results to conventional dressings. It has been successfully employed in treating infected wounds, post-surgical infections, and burns. In burn treatment, honey has demonstrated faster healing times compared to conventional dressings, showcasing its potential in managing superficial and partial-thickness burns.

Miscellaneous Uses:

Honey's versatility extends to treating infectious diseases, skin conditions, gastrointestinal disorders, and allergic rhinitis. Studies suggest its efficacy in conditions like seborrheic dermatitis, hydatid disease, and gastrointestinal infections in children. However, caution is advised in using honey for children under one year due to the risk of botulism.

B. Honey and Beeswax Combinations:

The combination of honey and beeswax, enriched with olive oil, exhibits antibacterial properties. Clinical trials involving psoriasis and atopic dermatitis patients reveal promising results, with fewer lesions and improved symptoms. Additionally, honey and beeswax mixtures have shown effectiveness in treating diaper rash and experimentally induced inflammatory bowel disease in rats.

C. Royal Jelly: Nature's Elixir of Life

Royal jelly, a secretion from worker bee pharyngeal glands, has been historically used for various health conditions. Studies demonstrate its estrogenic properties, stimulating osteoblasts, collagen production, and wound healing. Royal jelly exhibits immunomodulatory effects, suppressing auto-antibody production and promoting antibody production in mice.

D. Bee Venom: Medicinal Arsenal from Stings

Bee venom therapy has a rich history in folk medicine, dating back thousands of years, where it was employed to treat various ailments ranging from arthritis and rheumatism to cancer and infections. While bee venom, specifically from honey bees, has been used in crude formulations like Apiven in France, its widespread acceptance in conventional medicine is yet to be achieved (Hoffman, 2010). The multifaceted composition of honey bee venom includes active peptides (melittin, apamine, mast cell degranulating peptide, adolapin), enzymes (phospholipase A2, hyaluronidase), and active amines (histamine, serotonin, catecholamine) (Hoffman, 2010).

Melittin, comprising 40–60% of the dry weight of venom, has been a focal point of research due to its potential anticancer properties. Despite its cytotoxic nature, melittin inhibits various cancer cell types, such as melanoma, osteosarcoma, and hepatic cells (Hoffman, 2010). Strategies to mitigate melittin's cytolytic effects include dilution for selective targeting of cancer cells and genetic modifications (Zhao *et al.,* 2006). Additionally, synthetic melittin peptides coupled with delivery vehicles, such as Hecate-CGb, show promise in specific cancer targeting (Hoffman, 2010).

Nanoparticle-based delivery of melittin emerges as a promising strategy to enhance its therapeutic potential. Utilizing nanoparticles with avb3 integrin-binding ligands significantly reduced tumor load in experimental mice (Huang *et al.*, 2013). Other components in bee venom, such as phospholipase A2 and apamine, exhibit anticancer activities by inhibiting tumor cell growth and inducing apoptosis (Hoffman, 2010). Bee venom's antimicrobial properties against a spectrum of microbes, including *Escherichia coli* and *Candida albicans*, further extend its potential applications (Norman Ratcliffe *et al.,* 2014).

Table 2: Overview of Medicinal Functions of Different Honey Products and Associated Specific Factors

Honey Product	Activity	Specific Factors	References
Honey and Royal Jelly	Wound healing by increasing TNF-a, IL-1b, TGF-b, and MMP-9 cytokines from keratinocytes and re-epithelialization of skin wounds	Not determined	Majtan *et al.*, 2010
Honey and Royal Jelly	Wound healing by release of cytokine TNF-a from murine macrophages	Apalbumin 1(¼ major royal jelly protein-1)	Majtan *et al.*, 2006
Honey	Wound healing by release of cytokine TNF-a from murine and human monocytes/macrophages via TLR4	5.8 kDa honey fraction	Tonks *et al.*, 2007
Honey	Killing antibiotic-resistant bacteria including MRSA	Synergistic action of sugar, hydrogen peroxide, methylglyoxal, and defensin-1	Kwakman *et al.*, 2010
Royal Jelly	Blocking the PA-IIL lectin of P. aeruginosa	Apalbumin 1	Lerrer *et al.*, 2007
Royal Jelly	Anti-angiogenesis	10-hydroxy-2-decenoic acid	Izuta *et al.*, 2009
Royal Jelly	Neurite growth stimulation	Adenosine monophosphate N1 oxide	Hattori *et al.*, 2010
Royal Jelly	Anti-allergic response	Apalbumin 3 (¼ major royal jelly protein 3)	Okamoto *et al.*, 2003
Propolis	Killing human pancreatic cancer PANC-1 cells	Cycloartane-type triterpenes C30H44O3	Li *et al.*, 2009

E. Ants in Traditional Medicine:

Compounds derived from ants, like decahydroquinoline derivatives, have been isolated from poison dart frogs, emphasizing the interconnectedness of ecosystems. Various ant species, including *Polyrachisla mellidens*, *Pogonomymex sp*., and *Dasymutilla occidentalis*, have been employed in treating ailments like rheumatic diseases and chickenpox (Norman Ratcliffe *et al.*, 2014). *Polyrhachis vicina* Roger, used historically in Chinese medicine, serves as a tonic drink to boost the immune system and alleviate rheumatoid arthritis (Chen, 2009). The alleged medicinal properties of ants, attributed to substances like citral, ATP, histamine, growth hormone, and superoxide dismutase, showcase the diversity of bioactive compounds within ant venom (Norman Ratcliffe *et al.*, 2014). In addition to direct venom applications, ants play a role in symbolic systems and traditional rituals in Amazonia (Cesard *et al.*, 2003). The bite of the black ant is believed to stimulate newborns to walk early among the Arawak Indians of Guiana (Lauck, 2002). Ant medicine is considered beneficial for liver-related conditions, sexual performance, and increasing appetite in cancer patients (Chen, 2009).

F. Wasp Products in Traditional Medicine:

Wasps, belonging to the Vespidae family, offer diverse therapeutic potential. The clay nests of mud daubing wasps are consumed by pregnant women in Zaire to provide lime to the fetus (Adriaeus, 1951). Vespid wasp venom, containing mastoparan, exhibits pharmacological activities such as mast cell degranulation, activation of G-protein-mediated mechanisms, and anti-cancer effects. The use of wasp nests in treating conditions like child fright disease, arthritis, and toothache reflects the varied applications of wasp products in traditional medicine (Pemberton, 1999). Studies on wasp venom components, such as mastoparan and NVP-(1), have demonstrated anti-cancer effects and inhibition of proliferation in hepatoma cells (Wang *et al.*, 2008).

2. Diverse Therapeutic Potential of Coleoptera Beetles in Traditional Medicine

Coleoptera, comprising a vast array of beetles, stands as the largest order in the animal kingdom with over 350,000 identified species, surpassing the count of insects in any other order. This immense diversity includes well-known species like ladybugs, fireflies, junebugs, stag beetles, weevils, burying beetles, rove beetles, click beetles, and rose chafers, among others.

A. Diving Beetle (Dytiscidae)

The predatory water beetle, *Cybister tripunctatus* Greshew, traditionally used in a Korean water beetle game, demonstrates medicinal significance. Known to aid in conditions like polyuria (in the elderly), enuresis in children (nocturnal urination), and various blood stasis issues, these beetles find application in traditional remedies (Pemberton, 1999).

B. Scarab Beetle (Scarabaeidae)

Scarab beetle larvae are employed in the treatment of liver cirrhosis (Pemberton, 1999). In Alagoas, Brazil, folk remedies involve using palm beetles for earaches, showcasing the diverse applications of these insects in traditional medicine. Additionally, the sacred scarab

(*Scarabaeus sacer*) in ancient Egypt held cultural significance and was utilized in religious rites and as amulets (Cherry, 1985).

C. Ladybird Beetle (Coccinellidae)

The harlequin ladybird presents potential in medicine through the production of harmonine, a compound with broad-spectrum antimicrobial activity. This suggests the possibility of harnessing the insect's properties for pharmaceutical purposes.

D. Meal worm (Tenebrionidae)

The tenebrionid beetle *Palembus dermestoides*, introduced in Brazil, is utilized in traditional medicine for conditions such as asthma, arthritis, tuberculosis, and sexual impotence (Costa-Neto, 1999).

E. Jewel Beetle (Buprestidae)

Thrincopyge Alacris Le Conte and *Chrysobothris basalis*, have been used in Mexico as aphrodisiacs, akin to the well-known Spanish fly. The larvae are prepared by roasting or crushing and are consumed to treat urogenital disorders and as a stimulant (Costa-Neto, 1999).

F. Click beetle (Elateridae)

Larvae of *Copris* species in the Elateridae family, known as *Tlalomitl*, are consumed to alleviate impotence in men. Additionally, *Straiegus julianus*, a Scarabeidae species, is used to prepare a drink believed to enhance sexual performance (Costa-Neto, 1999).

G. Weevil (Curculionidae)

Studies analyzing the integument of the red palm weevil, *Rhynchophorus ferrugineus*, have identified compounds with potential medicinal applications. Kopsinyl alcohol, detected in the female insect sternum, shows chemical relations to an indole alkaloid with anticancer properties (Al-Dawsary, 2014).

H. Blister beetle (Meloidae)

Lytta vesicatoria, contains cantharidin, a compound with effects on the urogenital system. Despite its historical use as an aphrodisiac, cantharidin's extreme toxicity raises concerns, but research indicates its potential in cancer therapy (Berenbaum, 1995).

Table 3: Recent Studies on the Utilization of Cantharidin:

Cells Treated	Results	References
Human Colorectal Cancer Cells	Reduced CDK1 kinase activity, apoptosis induction through mitochondrial and death receptor pathways, and activation of caspases 8, 9, and 3	Huang *et al.*, 2011
Human Bladder Carcinoma Cells	Blocked activities of matrix metalloproteinase-2 (MMP-2) and/or MMP-9 resulting in an antimetastatic effect	Huang *et al.*, 2013

Human Breast Cancer Cells	Reduced adhesion and migration by repressed cell adhesion to platelets by downregulation of $\alpha 2$ integrin adhesion molecule	Shou *et al.*, 2013
Yeast CRG1 (Cantharidin Resistance Gene 1)	Details of transcriptional regulation of the CRG1 gene for methyltransferase, during cantharidin stress	Lissina *et al.*, 2011
Hepatocellular Carcinoma Cells	A new gene therapy approach to kill hepatocellular carcinoma cells by inhibiting PP2A with the α-fetoprotein promoter enhancer linked to the pgk promoter	Li *et al.*, 2012
Normal Rats	Design of cantharidin solid lipid nanoparticles as drug carriers which can be given orally	Dang and Zhu, 2013

3. Maggot Therapy: A Historical Perspective and Modern Applications

Maggot therapy, also known as larval therapy, has a rich historical background and has evolved into a medically recognized practice for wound healing. The therapeutic use of fly larvae, particularly those of the *Lucilia sericata* species, has been documented across diverse cultures, including Asia, South America, and Australia (Cherniack, 2010). Traditionally, maggots have been employed to treat wounds by various communities, with records dating back to the Middle Ages.

Biomedical Applications of Dipteran Species:

Dipteran species, including Muscidae, Tabanidae, and Calliphoridae, have demonstrated biomedical significance in wound healing and infection control. Horse fly adults from the Tabanidae family have been employed in traditional Korean medicine to address issues such as Amenorrhea, abdominal blood stasis, and indigestion (Pemberton, 1999). Notably, maggots of the blowfly *Lucilia sericata*, a member of the Calliphoridae family, have been extensively used in Maggot Therapy, a practice recognized for its efficacy in debridement, wound healing, and disinfection (Ratcliffe *et al.*, 2014).

Maggot Therapy Mechanisms:

Maggot therapy involves three essential processes: debridement of wounds, wound healing, and disinfection of wounds. Debridement occurs through the extracorporeal production of enzymes by maggots, including chymotrypsin- and trypsin-like serine proteases, DNase, and glycosidases (Chambers *et al.*, 2003; Brown *et al.*, 2012; Telford *et al.*, 2012). These enzymes facilitate the breakdown of necrotic tissue, biofilms, and debris in the wound, promoting granulation and healing. Maggot secretions also play a crucial role in wound healing by activating fibroblasts, angiogenesis, and immunomodulation (van der Plas *et al.*, 2007; Bexfield *et al.*, 2010). Furthermore, maggot therapy exhibits disinfecting properties through antibacterial substances such as lucifensin, alloferons, and seraticin, effectively combating bacterial infections, including antibiotic-resistant strains (Andersen *et al.,* 2010; Bexfield *et al.,* 2004).

Clinical Applications and Contemporary Studies:

Commercially grown maggots, typically derived from sterile conditions, are applied in wound healing procedures. Clinical studies have shown promising outcomes, with maggot therapy proving effective in the treatment of chronic leg wounds, arterial or venous stasis ulcers, diabetic ulcers, and pressure ulcers (Cherniack, 2010). Controlled trials have demonstrated that maggot-treated wounds undergo faster debridement, although some patients may experience higher pain levels compared to conventional treatments (Cherniack, 2010).

4. Lepidoptera in Medicine: Harnessing the Therapeutic Potential of Butterflies and Moths

Lepidoptera, the order encompassing butterflies and moths, comprises an array of species, with approximately 150,000 recognized worldwide. This diverse group has garnered medicinal significance, with various families offering unique therapeutic benefits.

A. Hepialidae: Cordyceps Sinensis Utilization

Hepialidae, a family within Lepidoptera, is notably associated with the medicinal application of *Cordyceps sinensis*. The larvae of Hepialid moths, such as *Hepialis oblifurcus*, when infected with this fungus, are employed for treating lung diseases and enhancing stamina (Pemberton, 1999). In regions like Oaxaca, Veracruz, and Chiapas, *Phasus* spp. larvae are consumed for their aphrodisiac properties, aiding against gastrointestinal issues (Conconi, 1982).

B. Megathymidae: Meocuilin as Aphrodisiac

The Megathymidae family contributes to medicinal practices with *Aegiale hesperiaris*, known as "Meocuilin." Eaten alive, these white agave worms are believed to possess aphrodisiac properties, addressing both stomach disorders and rheumatic diseases (Pemberton, 1999).

C. Saturniidae: Samia Cynthia Ricini and Women's Health

Samia Cynthia ricini, from the Saturniidae family, is integrated into Chinese traditional medicine for its potential in women's health. Ethanol extraction from female moths exhibits positive effects on aged mice, promoting vaginal health, hormonal balance, and bone mineral content (State Administration of Traditional Chinese Medicine of People's Republic of China, 1999).

D. Gelechidae: Jatropha Leaf Miner for Medicinal Purposes

Infestation of Jatropha Leaf Miner (*Stomphosistis thraustica*) presents an opportunity for traditional healers. The green larva is utilized as a galactagogue, promoting milk flow in lactating women. Additionally, it is employed in treating common fever when prepared as a decoction.

E. Cecropidae Caterpillar Venom: Cecropins in Cancer Therapy

Cecropins, isolated from Lepidoptera, particularly *Hyalophora cecropia*, exhibit antimicrobial and anticancer activities. These peptides show promise in treating various cancers, including bladder cancer, without significant cytotoxic effects on benign cells (Andreu *et al.*, 1985; Chen *et al.*, 1997).

F. Bombycidae A Multifaceted Medicinal Resource

Silkworms, belonging to the Bombycidae family, offer diverse medicinal applications. Adult males are used for conditions like impotence and premature ejaculation, while larvae dung finds use in diabetes and arthritis treatment (Pemberton, 1999). The silk itself, produced by Bombyx mori, has been explored extensively for its biomedical applications.

Silk's attractiveness in medicine arises from its slow biodegradation, biocompatibility, and self-assembly properties. Additionally, it boasts high tensile strength, manipulatable structure, and composition (Norman Ratcliffe *et al.*, 2014).

Nanoparticles and copolymer blocks derived from silk find use in targeted drug delivery to cancer cells (Numata and Kaplan, 2010). Silk-based materials have shown promise in repairing cartilage, bones, ligaments, and tendons, while silk-heparin supports contribute to vascular tissue growth (Zhang *et al.*, 2010; Seib *et al.*, 2014). Silk hydrogels have potential applications in breast cancer treatment, and antibiotic-loaded silk hydrogels can prevent and treat infections (Seib *et al.*, 2013; Pritchard *et al.*, 2012).

5. Orthoptera in Traditional Medicine: Exploring Therapeutic Applications

The order Orthoptera encompasses a diverse group of insects, including grasshoppers, plague locusts, katydids, crickets, and pygmy grasshoppers, with over 20,000 recognized species globally. Beyond their ecological roles, certain Orthoptera species hold medicinal significance in traditional practices.

A. Crickets and Mole Crickets: Remedies for Urinary Ailments

In Mayan communities, *Gryllus assimilis*, the black cricket, is employed in treating urinary system ailments, particularly addressing a condition known as kalwiix, characterized by urine retention (Ruiz and Castro, 2000). Additionally, crickets, katydids, and specific grasshoppers find application in treating throat and ear illnesses (Berenbaum, 1995). Gryllotalpidae, specifically *Gryllotalpa africana*, commonly known as mole cricket, holds medicinal value in Nigeria. The mole cricket is utilized for various conditions, including retention of urine, urolithiasis (bladder stones), edema, lymphangitis, furuncles (Pemberton, 1999). In Nigeria, the gut contents of mole crickets are used for treating infected feet, and in some regions, barren women incorporate burned mole crickets into special soups to enhance fertility (Fasoranti, 1997).

B. Grasshoppers: Versatile Remedies in Folk Medicine

Acrididae, specifically *Oxya* species, commonly known as rice field grasshoppers, find medicinal use in Asia. They are recommended for treating child fright disease, tetanus, whooping cough, general coughs, and weakness (Pemberton, 1999). In South Africa, the Venda people use fried bapu grasshoppers (*Lamarckiana spp*.) to treat bedwetting in children and alleviate nightmares (van der Waal, 1999). Grasshoppers are also suggested for throat and ear illnesses (Berenbaum, 1995). Various grasshopper species, such as *Sphenarium spp*., *Taenipoda sp*., and *Melanoplus sp*., are employed as powerful diuretics in kidney disease treatments (De Asis, 1982).

C. Locusts: Dietary Supplements and Blood Fortification

Locusts, specifically *Schistocerca spp*., are pulverized and consumed as a dietary supplement, addressing nutritional deficiencies, and fortifying the blood (FAO, 1973). In traditional medicine, locusts are reported to alleviate post-childbirth anemia and assist in lung diseases like asthma and chronic cough.

6. Phasmida in Medicinal Context: Chemical Defenses and Potential Therapeutic Insights

Phasmida, encompassing stick insects and leaf insects, beyond their ecological role as masters of camouflage, certain species of Phasmida have garnered attention for their medicinal importance, particularly in the realm of chemical defense.

Camouflage and Chemical Deterrence

Phasmids, notably stick insects, are renowned for their non-chemical defense mechanism—camouflage. However, the emphasis lies in their deployment of irritating chemical substances against attackers. These substances serve as potent deterrents and are released from specialized glands when the insects are disturbed (Dossey, 2010)

Compound Diversity in Phasmids

Despite their relatively low species count compared to other insect orders, Phasmida exhibits a high level of compound diversity in their defense secretions. These compounds, originating from specialized glands, present an untapped resource for potential pharmaceutical exploration. Phasmids, including *Anisomorpha buprestoides* and *Parectatosoma mocquerysi*, produce a variety of compounds, such as anisomorphal, dolichodial, peruphasmal, iridodial, and parectadial (Dossey, 2010).

Potential Therapeutic Applications

Recent discoveries, such as parectadial in *Parectatosoma mocquerysi*, highlight the intriguing pharmacological potential of Phasmida. Parectadial's effects on human skin suggest possible cytotoxic or cytostatic properties, opening avenues for investigation as an anticancer agent. Furthermore, the presence of glucose in their defensive spray raises questions about its role in biosynthesis and transport, presenting an opportunity for biosynthesis studies (Dossey, 2010). In Malaysian Chinese culture, walking sticks (Phasmida) are raised for their excreta, which, when dried and combined with herbs, form a traditional treatment for conditions such as asthma, upset stomach, and muscle pain (Boyle, 1992).

7. Blattaria: Cockroaches in Medicine and Folk Tradition

Blattaria, comprising around 4,400 species of cockroaches, holds medicinal significance in various cultures. Ground or cooked cockroaches were historically used for earaches, epilepsy, and even as lactation stimulants in China. In South China, boiled *Periplaneta spp.* (cockroaches) were administered to children for minor ailments, acting as a deterrent for feigned illnesses. *Blatta orientalis*, an Indian species, was considered a remedy for asthma. Traditional practices in the Amazon region involved using powdered *Periplaneta americana* for urinary retention, renal colic, and asthma attacks. Historical records detail the diverse ailments treated by cockroaches until the 1950s (Curto and Piermarocchi, 1990).

8. Mantodea: Mantises in Korean Folk Medicine

Mantodea, housing praying mantises, has approximately 1,500 recognized species. In Korean folk medicine, praying mantis egg cases are employed to enhance male sexual stamina, reflecting cultural beliefs (Wilsanand *et al.*, 2007).

9. Isoptera: Termites as Therapeutic Agents

Isoptera, the termite order with at least 1,900 species, showcases remarkable medicinal importance. In Somalia, the mandibles of *Termes bellicosus* are used for suturing wounds. Certain termite species are utilized to treat heart pains and child malnutrition in Africa. Termites, such as *Odontotermes formosanus* in India, are used for ulcer treatment. Recent findings suggest termite species possess antimicrobial properties, with novel peptides like termicin showing therapeutic potential (Wilsanand *et al.*, 2007).

10. Heteroptera: Bugs in Traditional Healing Practices

Hemiptera, with over 50,000 species worldwide, includes bugs with significant medicinal roles. Bugs from the Pentatomidae family are used externally for treating various diseases, including scrofula. Triatoma bugs, when brewed into tea, are believed to treat heart diseases. Bugs are applied as analgesics, anesthetics, and even for unblocking noses. Leaf-footed bugs, such as *Pachilis gigas*, are roasted and powdered for treating whooping cough (De Asis, 1982; Meza, 1979).

11. Homoptera: Cicadas and Mealybugs in Traditional Medicine

Homoptera encompasses cicadas, mealybugs, and others, with over 46,000 recognized species. Cicada nymphal skins are used for hearing problems, coughs, and other ailments in traditional practices. Mealybugs, like *Coccus axin*, are utilized for various medicinal purposes, including skin treatments, pain relief, and managing fluid imbalances (Pemberton, 1999; Wilsanand *et al.,* 2007).

Antimicrobial Peptides: A Comprehensive Overview

Antimicrobial peptides (AMPs) gained prominence in 1980 with the isolation of cecropin from the cecropia moth, marking a pivotal moment in the exploration of insect innate immunity (Boman *et al.,* 1976). These short proteins exhibit potent activity against bacteria, viruses, fungi, and parasites, making them potential alternatives to conventional antibiotics amid the escalating antimicrobial resistance crisis. In insects, AMPs are crucial components of innate immunity, secreted by cells like haemocytes, fat body, and gut tissues (Brogden, 2005). The induction of AMPs mediates a robust humoral immune response, offering sustained protection against persistent infections (Lemaitre and Hoffmann, 2007). The repertoire of AMPs extends beyond pathogen defense, influencing endosymbiont control (Wiesner and Vilcinskas, 2010). Over 2786 AMPs, with 277 from insects, have been identified, showcasing their ubiquity across various organisms (Antimicrobial Peptide Database). Most AMPs share characteristics such as amphipathicity, cationicity, and 5-100 amino acid residues, aiding their interaction with microbial membranes (Otvos, 2002).

Classification of Insect Antimicrobial Peptides

Insects exhibit a diverse array of AMPs, with species-specific repertoires influenced by environmental threats. The classification of insect AMPs encompasses their structural and functional attributes, revealing a remarkable evolutionary plasticity (Vilcinskas *et al.,* 2013). Structural classes include linear α-helical peptides, cysteine-stabilized peptides (defensins), and proline/glycine-rich peptides, each with distinct antimicrobial properties (Mylonakis *et al.,* 2016).

1. Linear α-helical AMPs

The archetype, cecropin, exemplifies this class, demonstrating activity against various pathogens (Kokoza *et al.,* 2010). Cecropins, abundant in dipterans and lepidopterans, offer promise in anti-cancer applications and vector control (Hoskin and Ramamoorthy, 2008).

2. Cysteine-stabilized AMPs

Defensins, characterized by intramolecular disulfide bridges, exhibit a diverse range of antimicrobial activities, including antiparasitic effects in vector insects (Boulanger *et al.,* 2006). Despite challenges with physiological saline solutions, synthetic defensins show potential as antibiotics and anti-cancer agents (Iwasaki *et al.,* 2009).

3. Linear proline/glycine-rich AMPs

Proline-rich AMPs, found in various insect orders, display antimicrobial specificity influenced by lipopolysaccharide binding and membrane penetration (Taniguchi M *et al.,* 2017). Glycine-rich AMPs, with diverse targets, hold promise as anti-mycotics (Thevissen *et al.,* 2007).

Modes of action of insect antimicrobial peptides

Insect antimicrobial peptides (AMPs) primarily exert their action through interactions with bacterial cell membranes. With a net positive charge and significant hydrophobic residues, AMPs are attracted to the negatively charged and lipophilic membranes of bacterial cells, creating pores or causing lysis by thinning the outer membrane leaflet. To access bacterial membranes, AMPs may employ the self-promoted uptake model, displacing polyanionic cations in the bacterial cell wall. Three models describe how AMPs destabilize cell membranes: barrel stave, carpet, and toroidal pore models. While most AMPs increase membrane porosity, proline-rich AMPs, like bumblebee abaecin, target intracellular bacterial components. Some AMPs inhibit protein synthesis or cell wall synthesis, while others neutralize virulence-associated microbial metalloproteases. Co-occurring AMPs may enhance each other's activity, and synergistic effects have been observed. Notably, certain AMP combinations, such as LSer-Def4 and LSer-Cec6, display greater antibacterial activity than individual peptides. Beyond antibacterial effects, some AMPs exhibit anti-inflammatory properties by inhibiting cytokine production, while others show antitumor activity by interacting with negatively charged tumor cell membranes. Derivatives of mellitin and synthetic alloferon demonstrate potential for cancer treatment (Mylonakis *et al.,* 2016; Marxer *et al.,* 2016; Wachinger *et al.,* 1998).

Activity Screening and Medical Applications of Insect Antimicrobial Peptides

The rising threat of drug-resistant infections, particularly from 'ESKAPE' bacteria, highlights the urgent need for innovative antimicrobial agents (Laxminarayan *et al.,* 2013). The Centers for Disease Control and Prevention (CDC) reports a substantial public health impact, with two million annual infections in the USA caused by antibiotic-resistant bacteria, leading to 23,000 deaths and significant economic losses (www.cdc.gov/). Europe faces an annual cost of approximately €1.5 billion due to antibiotic resistance (ecdc.europa.eu/). In response to this crisis, initiatives like the UK's Five-Year Antimicrobial Resistance Strategy emphasize the critical importance of prioritizing antibiotic drug discovery (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/244058/20130902_UK_5 year_AMR_strategy.pdf) (Roberts *et al.,* 2009).

High-Throughput Screening Using *C. elegans*

The identification of potential antimicrobials involves high-throughput screening methods, and the nematode Caenorhabditis elegans serves as an alternative host for this purpose. With its fully sequenced genome, C. elegans enables efficient screening of antimicrobial peptides (AMPs) (Moy *et al.,* 2009). This model organism's suitability stems from its well-characterized innate immune responses, including p38 mitogen-activated protein kinase (MAPK) pathways (Dierking *et al.,* 2016). High-throughput experiments, facilitated by automated robotic systems, leverage the C. elegans–microbe liquid assay to identify agents with direct antimicrobial, immunomodulatory, or antivirulence effects (Breger *et al.*, 2007). Recent screens of synthetic insect-derived AMPs revealed promising results, indicating the potential synergistic activity of insect AMPs with conventional antibiotics against multidrug-resistant pathogens (Mylonakis *et al.*, 2016).

AMPs: Standalone Agents and Transgenics in Medicine and Agriculture

Antimicrobial peptides (AMPs) exhibit diverse applications in medicine and agriculture. Acting as standalone agents, insect-derived AMPs show efficacy against antibiotic-resistant strains, as seen with the defensin from the beetle Allomyrina dichotoma and cecropin analogue D2A21 (Yamada *et al.*, 2005). Moreover, insect AMPs demonstrate antiviral properties, inhibiting viruses like Herpes simplex and HIV-1 (Kruse *et al.*, 2008). These peptides are also explored in transgenics, with AMP-expressing plants conferring resistance to bacterial and fungal pathogens.

Controlling Disease Vectors and Drug Delivery Systems

In combating vector-borne diseases, the focus shifts to altering the immune response of insect vectors. Transgenic approaches aim to enhance insect defenses against pathogens, potentially reducing vector competence (Boulanger *et al.*, 2001). Additionally, antimicrobial peptides, like cecropin, expressed in transgenic insect vectors, exhibit promise in preventing the development of diseases such as malaria (Hull *et al.*, 2012). Furthermore, AMPs, including the hemipteran peptide pyrrhocoricin, show potential as drug delivery systems due to their ability to penetrate target cells with low toxicity, offering a unique avenue for therapeutic applications (Otvos *et al.*, 2002).

Obstacles to Therapeutic Use of Antimicrobial Peptides (AMPs)

Antimicrobial peptides (AMPs) hold great potential for combating bacterial infections, but their therapeutic use faces various obstacles. These challenges encompass high cost, difficulties in mass production, loss of activity under physiological conditions, potential toxicity, peptide aggregation, stability issues, and the prevalence of effective conventional antibiotics. Additionally, limited FDA approvals for AMPs have led to pharmaceutical companies abandoning their development, despite the escalating antibiotic resistance crisis (Gordon *et al.*, 2005).

Conclusion:

The intricate relationship between insects and traditional medicine, known as entomo-ethnomedicine, presents a captivating intersection of ancient wisdom and modern scientific exploration. With over 110,000 described species, insects contribute significantly to global biodiversity, and their potential therapeutic benefits remain largely untapped. Bee and ant venoms, for instance, exhibit substantial therapeutic potential, driven by a myriad of bioactive compounds. While challenges like cytotoxicity exist, innovative approaches, including nanoparticle-based delivery systems and genetic modifications, hold promise for enhancing the efficacy of these natural products. Exploration into the medicinal uses of various insect orders, such as Coleoptera, Mantodea, Isoptera, Hemiptera, and Homoptera, reveals a rich tapestry of traditional practices across diverse cultures. From treating specific ailments to serving as potential sources for antimicrobial and anticancer compounds, insects offer novel avenues in drug development. Maggot therapy, rooted in ancient practices, stands out as an effective approach to wound healing, validated by modern biomedical research. As antibiotic resistance looms as a global threat, the value of insect-derived antimicrobial peptides becomes increasingly apparent. These peptides, with their ability to act synergistically with conventional antibiotics and prevent resistance development, emerge as a crucial source of future chemotherapeutic agents. Integrating traditional knowledge with scientific advancements holds the key to unlocking the vast therapeutic potential of these fascinating creatures, offering cost-effective alternatives in regions with limited access to conventional healthcare. Insects, with their diverse chemical defenses, present a promising frontier for the development of innovative medicines, bridging the gap between nature and healing in the pursuit of global well-being.

Future thrust:

1. Interdisciplinary Collaboration: Future efforts should prioritize interdisciplinary collaboration, merging entomo-ethnomedicine with fields like pharmacology and nanotechnology. This collaborative approach will unravel the therapeutic potential of insect-derived substances, fostering a synergy between traditional wisdom and modern scientific advancements.

2. Technological Innovation: The focus on innovative technologies, such as nanoparticle-based delivery systems and synthetic peptides, remains crucial. Refining these approaches will address challenges like cytotoxicity and enhance the effectiveness of insect-derived compounds, making them practical and accessible for diverse healthcare applications.

3. Conservation and Sustainability: A pivotal thrust is the promotion of conservation and sustainable practices. With biodiversity loss impacting indigenous communities, there's a need to preserve insect populations and habitats. Emphasizing ethical considerations and environmental sustainability ensures responsible harnessing of the therapeutic benefits of insects, benefiting ecosystems and human well-being.

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COMMERCIALIZING EDIBLE INSECTS: A SUSTAINABLE SOLUTION FOR FUTURE FOOD SYSTEMS

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Abstract:

The rising need for food on a global scale, propelled by the swift expansion of the population, requires a significant increase in food production by 2050. Livestock production, occupying 70% of agricultural land, is look ahead to double by 2050, posing challenges to sustainability. Insects emerge as a viable alternative protein source, rich in nutrients and culturally accepted in many regions, particularly in North East India where entomophagy is ingrained in traditions. Over 255 edible insect species are recorded in India, predominantly in the North East, with practices extending to Tamil Nadu, Karnataka, Kerala, Odisha, Madhya Pradesh, and the Andaman Islands. Insects offer a sustainable and nutritious food source, often requiring less land, water, and food compared to traditional livestock. The interest of insect consumption includes biodiversity, economic viability, food security, and innovation in the food industry. Insects contribute to culinary diversity, with their economic advantages evident in quick reproduction, increased feed conversion rates, and the capacity to thrive on organic waste. Despite these advantages, the affirmation of insects as a mainstream food source varies globally, with cultural stigma still present in some areas. The exploration of insects as components in processed foods demonstrates their potential in the food industry. However, taste, odour, visual appearance, and textural aspects play crucial roles in consumer acceptance, highlighting the value of sensory characteristics. In conclusion, consumable insects present a potential solution to the world-wide food demand, offering a well-balanced nutrient profile and environmental sustainability compared to traditional livestock farming. Entomophagy, an ancient cultural practice, offers not just nutritional advantages but also resonates with the increasing emphasis on sustainable food choices. With their diverse nutrient profiles, palatable insects emerge as an appealing alternative protein source in the changing landscape of future food systems.

Introduction:

The escalating demand for food, driven by a rapidly growing global population, poses a significant challenge for future food production. (FAO) estimates that by 2050, the globe must augment its food production to meet the needs of a projected 9 billion people. Notably, approximately 70% of all agricultural land is allocated to livestock production, and the demand for livestock products is expected to double by 2050, primarily due to the effects of urbanization. This necessitates a quest for alternative protein sources. Insects, were eaten as food in various places worldwide and considered delicacies, emerge as a noteworthy alternative. Beyond their cultural significance, insects offer substantial nutritional value, being rich in proteins and essential minerals, thereby holding great potential in contributing to food security. In North East India, entomophagy is a prevalent practice embedded in the culture of many communities. in the festival "Bohag Bihu" in Assam, the red tree ant (*Oecophylla smargdina*) is a significant food item, believed to contribute to health by preventing infections of diseases such as scabies, malaria, toothaches, stomach disorders, and blood pressure India, recording 255 species of consumable insects, predominantly practices entomophagy in the North Eastern states. Nevertheless, indigenous communities in Tamil Nadu, Karnataka, Kerala, Odisha, Madhya Pradesh, and the Indian Andaman Islands integrate termites, grasshoppers, ants, and honeybees into their culinary traditions. Internationally, excluding European and North American regions, insects are generally included in diets and esteemed as delicacies, with a historical practice dating back centuries (11). The term for the human utilization of insects, entomophagy, derives from the Greek words "entomon," meaning "insect," and "phagein," meaning "to eat." As per the Food and Agriculture Organization (FAO) in 2013, more than 1,900 species of insects are presently ingested by at least 2 billion individuals globally. The primary insect orders consumed include Coleoptera (31%), Lepidoptera (18%), Hymenoptera (14%), Orthoptera (13%), Hemiptera (10%), with smaller proportions for Isoptera, Odonata, and Diptera. Predominantly observed in Asia, Africa, Australia, and Latin America, entomophagy offers a sustainable and deeply rooted cultural solution to address the growing food demand.

Why Insects are Eaten?

Insects are used as food in numerous cultures globally for their copious amount of protein, vitamins, minerals, and essential fatty acids. Including insects into diets offers a acceptable and nutritious food source, especially in regions where alternative protein options are limited (Bodenheimer *et al.,* 1951). In contrast to regular livestock like cattle, pigs, or chickens, insects are often viewed as a more environmentally rational food source. They typically require less land, water, and feed to produce the same amount of protein, making them a potentially eco-friendlier option. Insects are integral to traditional diets in cultures, particularly in parts of Africa, Asia, and Latin America, for centuries (Barennes *et al.*, 2015). Certain insects are regarded as delicacies and are incorporated into various culinary dishes. The vast heterogeneity of palatable insect species offers a wide range of flavors and textures, adding variety to diets and culinary experiences. Insect farming can be economically advantageous in specific regions compared to traditional livestock farming. With their rapid reproduction rate, high feed efficiency, and ability to thrive on organic waste, insects present a potentially cost-effective food source (Nyberg *et al.,* 2021). Insects contribute to food security, especially in regions prone to food shortages, as they can be harvested locally, providing a readily available source of nutrition. The innovative use of insects as ingredients in processed foods, such as protein bars, snacks, and flours, allows for the integration of insect protein into various food products. Despite these advantages, the acceptance of insects as a mainstream food source varies across cultures. While some societies still hold a stigma against consuming insects, others view them as a sustainable and nutritious alternative to conventional protein sources. The increasing interest in sustainable food practices and the exploration of alternative protein sources have heightened attention on insect consumption in recent years.

Edible Insects in India

In India, insects have historically been incorporated into specific regional cuisines. Commonly consumed insects include red ants, which are prevalent in northeastern states and used in traditional dishes. Additionally, certain caterpillars and moth larvae are consumed within tribal communities. Grasshoppers and Locusts: In some regions these are consumed, often fried or roasted. (Belluco *et al.*, 2013) Silkworm Pupae: In some parts of India, the northeastern states, silkworm pupae are consumed. It's important to emphasize that the safety and hygiene of the insects are paramount. If you are interested in trying edible insects, it's recommended to source them from reputable suppliers and to corroborate that they are properly cooked or processed to eliminate any potential health risks. Additionally, local regulations and cultural considerations should be taken into account.

The Delicious Appeal of Consumable Insects

The perception if these insects are enjoyable to eat is highly subjective and can vary greatly among individuals. Taste fondness is shaped by cultural backgrounds, personal experiences, and attitudes toward different foods. In cultures where insect consumption is traditional, people often consider insects to be delicious and incorporate them into various culinary dishes. These insects offer a diverse range of flavors, ranging from nutty and earthy to savory and slightly sweet, based on the species and preparation methods. Their taste and texture can be likened to other protein sources, with some insects being described as having a crunchy or chewy texture. However, in regions where insects are not traditionally consumed, the idea of eating them may be met with hesitation or aversion due to cultural factors and social norms (Weru *et al.,* 2021).

Nevertheless, due to growing interest in these type of insects in recent years, particularly within the point of sustainable and alternative protein sources. Chefs and food innovators worldwide are experimenting with insects into contemporary cuisine, often highlighting their dietary value and unique flavors. Ultimately, whether someone finds wholesome insects enjoyable to eat is a matter of personal taste. For those curious about trying them, sampling dishes prepared by experienced chefs in insect cuisine might offer a new culinary experience. It's important to note that the way insects are cooked and seasoned can significantly affect their taste and appeal. The list of these insects varies worldwide, and different cultures have their preferences regarding insect consumption. It's crucial to emphasize that not all insects are appropriate for human consumption, and some may even be harmful. Therefore, it's essential to source insects from reputable and safe suppliers and ensure that they are properly prepared before consumption. Some commonly consumed insects include crickets, mealworms, grasshoppers, locusts, silkworms, ants, termites, and various beetle species, each with its unique culinary uses and preparations. In India, specific examples of commonly consumed edible insects include red ants and their eggs, moths, caterpillars, and other traditional insect dishes prevalent in certain regional diets.

Insect Nutritional Profile: A Bounty of Protein, Fat, Vitamins, and Minerals

Insects such as crickets (*Acheta domesticus*), mealworms (*Tenebrio molitor*), black soldier fly larvae (*Hermetia illucens*), grasshoppers, and locusts offer a diverse array of nutrients essential for human health. Crickets are notable for their highest protein content, comprising approximately 60-70% of their dry weight, and are considered a complete protein source, providing all essential amino acids (Zhong *et al.,* 2017). Similarly, mealworms are high in protein, constituting about 50-60% of their dry weight, and having essential amino acids crucial for bodily functions. Black soldier fly larvae, known for their elevated fat content ranging from 30-40% of their dry weight, are a source of essential fatty acids, including omega-3,6. Grasshoppers, like the American grasshopper (*Schistocerca americana*), are valued for their B vitamin content, including vitamin B12, along with essential minerals like iron and zinc. Locusts are also recognized as rich source of iron and zinc. Moreover, certain components of these insects, like the exoskeleton of crickets containing chitin, offer great health advantages for the gut, despite being indigestible. Additionally, mealworms have been identified as containing antioxidants, including phenolic compounds, contributing to their nutritional diversity (DeFoliart *et al.,* 1975). It's important to acknowledge that nutrient profiles vary based on factors such as life stage, diet, and preparation methods, and ongoing research is continually enhancing our perception of the nutritional advantages offered by various insect species, thereby supporting their potential inclusion in sustainable and well-rounded diets.

Therapeutic Wonders: Insects in Medicinal Applications

Honeybee (*Apis mellifera*): Propolis: Bees create propolis by mixing saliva and beeswax with exudate gathered from tree buds or sap flows. It contains flavonoids and phenolic substances, showing antimicrobial, anti-inflammatory, and antioxidant properties. It's used in various medicinal products, including throat lozenges and creams for skin health (Silici *et al.,* 2005). Royal Jelly: A secretion produced by worker bees for feeding larvae and the queen bee.

It's rich in proteins, vitamins, and fatty acids and is believed to have potential antioxidant and anti-inflammatory effects. Royal jelly is used in supplements and creams for its purported health benefits. Silkworm (*Bombyx mori*): Silk Proteins: Silk is studied for its potential in injury curing and tissue regeneration due to its unique properties. Extracts from silkworm silk proteins have been used in medical dressings and scaffolds for tissue engineering. Maggots (Various Fly Species): Maggot Therapy Certain fly larvae, like the green bottle fly (*Lucilia sericata*), are used in maggot therapy. Their sterile larvae are applied to wounds to help clean the wound bed by consuming dead tissue (debridement) and potentially aiding in the healing process (Chan *et al.*, 2007). Ants (Various Species): Formic Acid: Some ants produce formic acid, which has been studied for its potential anti-inflammatory and pain-relieving properties. Formic acid extracts have been investigated for their therapeutic applications. Cockroaches (*Periplaneta americana*): Proteins and Peptides: Cockroach extracts have been researched for potential antimicrobial and immunomodulatory properties. Certain proteins and peptides derived from cockroaches are being studied for their therapeutic potential. Butterflies and Moths: Sericulture Silk Production has garnered attention for its potential medical applications such as sutures and tissue scaffolds due to its biocompatibility and strength. Insects, including butterflies and moths, have demonstrated promising therapeutic properties ranging from wound healing to antimicrobial and anti-inflammatory effects (Rajkhowa *et al.,* 2016). However, it's essential to recognize that while certain components or extracts from insects have been investigated for their medicinal potential, further research is often necessary to fully understand their therapeutic benefits and ensure their safety and effectiveness in clinical settings.

Wild Harvesting and Accessibility of Insects

Insects are Easily Available in the forest and Easy to Harvest: Wild Harvesting: Many insects are naturally abundant in the wild, making them accessible to communities without the need for complex farming infrastructure. Sustainable Harvesting: Harvesting insects from the wild can be sustainable if done in moderation, contributing to food safety without putting excessive pressure on ecosystems. Some Etable Insects Can be Easily Domesticated (Silkworms and Honeybees): Sericulture (Silkworms): Silkworms have been successfully domesticated for sericulture, the production of silk (Kusia *et al.*, 2023). This involves controlled breeding and rearing of silkworms in a controlled environment. Beekeeping (Honeybees): Honeybees are commonly domesticated for honey production and pollination services. Beekeeping is a well-established practice that supports livelihoods and agricultural productivity. They Require a Small Area of Land for Rearing and Not Necessarily a Land-Based Activity: Vertical Farming: Insect farming can be adapted to vertical farming practices, utilizing less horizontal space and making it suitable for urban environments. Reduced Land Footprint: Compared to traditional livestock, insect farming requires less land, making it a more efficient use of resources. They Can be Fed on Locally Available Plants: Sustainable Feeding: Insects can be fed with organic waste, agricultural by-products, or locally available plants, reducing the demand for resource-intensive feed crops. Circular Economy: Insect farming can be integrated into circular economy models by utilizing agricultural and food waste as feed, promoting sustainability. Insects exhibit superior water efficiency, requiring less water for survival compared to traditional livestock. This efficiency is reflected in their higher feed conversion efficiency, wherein they convert feed into body mass more effectively than conventional livestock. The water efficiency extends the advantages of insect farming, making it a more sustainable option. Furthermore, insects demonstrate exceptional feed conversion efficiency for protein production, surpassing many conventional livestock animals. For example, crickets exhibit remarkable efficiency in converting feed into protein, requiring approximately 1.7 kg of feed to produce 1 kg of cricket protein (Rumpold *et al.,* 2013). Another notable environmental advantage of insect farming is its reduced greenhouse gas emissions compared to conventional livestock farming, put up to a lower overall environmental footprint. This aligns with global initiatives aimed at mitigating climate change and promoting a more sustainable food production system. In essence, insect farming emerges as a practical and efficient alternative to traditional livestock farming, addressing concerns related to land use, water consumption, and greenhouse gas emissions. These attributes position insects as a promising nutritional resource for a growing global population while advocating for environmental sustainability (Van Huis *et al.,* 2017).

History

Insects have been a presence on Earth for approximately 400 million years, marking them as some of the earliest land animals (Bernard *et al.,* 2017) [4]. The consumption of insects by human's dates back around 7000 years, as evidenced by paleontological studies indicating that insects constituted a significant portion of early human diets (Huis, 2016) [5]. In contemporary times, various insect species are commonly consumed and appreciated for their availability and size. To be easily caught and located, insects need to be sufficiently large and preferably found in substantial quantities. Insects offer versatile culinary possibilities, as they can be eaten at different stages of life and prepared through methods such as raw consumption, frying, boiling, and roasting.

During ancient times, gatherers and hunters relied on insects as a crucial part of their diet due to the abundant nutritional benefits they provide, including ample fat, protein, and essential micronutrients (Fenenga *et al.,* 1978) [6]. Insects were not only consumed but also processed as food. However, there were instances where insects were misidentified due to a lack of accurate information and knowledge. the term "locust" was inaccurately used to describe various insects like crickets, grasshoppers, cicadas, and caterpillars, leading to improper identification and classification in historical records. some insect archaeological records are deemed questionable and potentially misleading.

Entomophagy in India

Entomophagy the term for consuming insects, has deep historical roots globally and is particularly prominent in India. In specific regions such as Mayurbhanj in Odisha and certain parts of Uttar Pradesh, entomophagy is embraced as a traditional and sustainable source of protein (Evans *et al.,* 2015). This practice, however, is not uniform across the country, showcasing the localized nature of insect consumption within diverse cultural and geographical contexts. The global landscape of entomophagy reveals a rich tapestry of culinary traditions associated with insect consumption. Delicacies like escamole in Mexico, hormigaculona in Colombia, akokono (fried palm weevil larvae) in Ghana, and nswaa (insect dish) in Uganda exemplify the cultural diversity and unique flavors linked to entomophagy across the world (Hazarika *et al.*, 2020). Moreover, in Southeast Asia, including Thailand, Vietnam, South Korea, and Japan, insects such as fried crickets, silk worms, cockroaches, and locusts have become popular street foods, seamlessly integrating into daily diets and reflecting the normalization of insect consumption in contemporary culinary practices. The significance of entomophagy extends beyond cultural appreciation to considerations of sustainability and environmental impact. The statement emphasizes that eating insects is not only a traditional practice but also an eco-friendly alternative to traditional livestock farming. Insects, due to their efficient use of resources, including less land, water, and food, present a potentially more sustainable option to meet nutritional needs compared to conventional livestock. The global prevalence of entomophagy is characterized by cultural diversity and regional nuances. India's incorporation of this practice reflects both tradition and sustainability, while worldwide examples underscore the versatility of insects in culinary traditions (Evans *et al.,* 2015). The recognition of these as a sustainable protein source aligns with broader discussions on eco-friendly diets and resource-efficient food sources, positioning entomophagy as a strong solution to address future challenges in food security.

Exploring the History of Entomophagy in India

The historical practice of entomophagy in India traces back to ancient times, with records dating back to the Vedic period. While historically significant, its prevalence has been more notable among economically disadvantaged communities seeking a rational and affordable protein source. Despite its long-standing cultural importance, entomophagy has not been as widespread in India compared to some other regions globally. Nonetheless, recent endeavours are reshaping this narrative, promoting entomophagy as a sustainable and nutritious protein alternative, gaining traction not only within India but also internationally. Ancient practices in India reveal a diverse tapestry of entomophagy, particularly among indigenous and tribal communities, who traditionally collected insects from the wild as a local food source. The Ayurvedic tradition, integral to India's ancient medicinal practices, recognizes the therapeutic properties of certain insects like red ants and their larvae, incorporating them into medicinal preparations. Entomophagy exhibits regional and cultural variations across India. In northeastern states like Nagaland and Manipur, insects such as grasshoppers, caterpillars, and ants are esteemed delicacies and widely consumed. Southern states like Tamil Nadu and Karnataka incorporate insects like red ants and their eggs into traditional dishes. Western and northern states also demonstrate varying degrees of insect consumption, reflecting the country's diverse cultural practices.

In this recent era, challenges persist in the cultural acceptance, with some regions hesitant to adopt insect consumption due to prevailing norms and perceptions. However, a contemporary shift is evident, marked by increased research and awareness initiatives highlighting the nutritional and environmental uses of entomophagy. This renewed interest has spurred a culinary evolution, with chefs and enthusiasts exploring innovative ways to integrate insect-based ingredients into modern cuisine. The history of entomophagy in India, shaped by ancient traditions and contemporary adaptations, unfolds as a dynamic narrative, weaving together cultural richness, culinary diversity, and a growing awareness of sustainable practices.

Exploring the substantial Tradition of Insect Foods in India's Northeast

Eating insects, or entomophagy, is deep-rooted in the cultural and culinary heritage of India's Northeast, particularly in Assam, Nagaland, Manipur, Mizoram, Arunachal Pradesh, and Tripura. This longstanding tradition, integral to the local diets, is celebrated for its nutritional, economic, and ecological benefits. For instance, during Assam's Bohag Bihu festival, red ant larvae are customarily consumed, showcasing the cultural significance of insect foods. The practice extends to various insect species, including crickets, beetles, bees, wasps, grasshoppers, locusts, termites, and dragonflies, with silk worms like eri polu and muga polu being popular choices. Culturally, entomophagy is deeply rooted, with insects playing a role not only as a food source but also in rituals, ceremonies, and traditional celebrations. The Northeast embraces a diversified range of insects in its culinary practices, ranging from simple preparations to elaborate delicacies. Geographically, each state contributes unique insect-based dishes, such as fried bamboo worms in Nagaland, eri silk pupa in Manipur, Mizo ant chutney in Mizoram, and red ant egg curry in Arunachal Pradesh (Singh *et al.,* 2007). Assam showcases inventive dishes like silkworm pupae fritters and Assamese ant egg omelette, while Tripura explores forest insects like bamboo worm fritters and forest beetle curry. Despite the rich tradition, challenges exist in preserving these culinary practices, including changing dietary choices and external influences (Chakravorty *et al.,* 2014). the opportunities for cultural resilience through community celebrations and educational initiatives promoting the beneficial values of insects and sustainable harvesting practices. The Northeast's entomophagy tradition reflects not only culinary diversity also the resourcefulness and cultural identity of communities sustaining this practice for generations.

Diversity of Common Eatable Insects

Insects offer numerous nutritional benefits comparable to traditional animal sources, with their nutritional value and composition closely resembling those of common foods (Raubenheimer *et al.*, 2013). Beyond human consumption, insects also used as a nutrient source for poultry. Globally, it was estimated 6-10 million insect species, with over 2,300 species across 18 orders identified as edible. Various insects, including butterflies, grasshoppers, ants, bees, spiders, termites, and cockroaches, are consumed worldwide. Edible insects provide essential nutrients akin to traditional animal sources, featuring high protein content, healthy fats, vitamins, and minerals (Melgar-Lalanne *et al.,* 2019). Their environmental sustainability, marked by efficient feed conversion and lower ecological impact, positions them as a solution to global food security challenges. Different cultures worldwide consume different edible insect species, reflecting cultural diversity and local culinary practices. While some cultures consume butterflies, caution is advised due to potential ecological impacts. Grasshoppers, known for their high protein and low-fat content, are popular as roasted or fried snacks. Ants, rich in protein, are utilized in various dishes as both snacks and components of traditional meals (Kelemu *et al.*, 2015). Bee larvae and pupae are considered delicacies and provide a good protein source. Spiders and termites, with protein-rich profiles, are eaten in specific regions, while cockroach consumption is rare and requires caution due to potential health risks and cultural aversions. Global insect consumption is deeply rooted in cultural practices, with regions showcasing unique culinary creativity in including insects into street food snacks and traditional dishes. The sustainable nature of insect rearing, requiring less land, water, and feed, positions insects as a potential element in future food systems. Ongoing research aims to integrate insect-based ingredients into modern diets and processed foods, aiming to increase the acceptance of these insects in mainstream cuisine. However, challenges and considerations must be addressed. Cultural acceptance varies widely, and establishing clear regulatory frameworks and safety levels is important to ensure the quality and safety of insects for eating by humans. As awareness of their nutritional uses and environmental sustainability grows, palatable insects have the great role to become an integral and accepted part of future food systems, provided cultural, regulatory, and safety considerations are carefully navigated.

The Art and Method of Ant Collection

The task of collecting ants for consumption involves various actions to ensure efficiency and safety. Weaver ants, known for their silk-reinforced nests on tree leaves, are typically harvested during seasons when both ants and their eggs are abundant. Collection methods include baiting with sweet or protein-rich baits strategically placed in foraging areas, the use of specialized traps, and manual collection using tools like forceps for certain ant species. Subterranean ants may be extracted using a Berlese funnel or by excavating nests, while synthetic ant pheromones can attract worker ants. Trapping with barriers and freezing are employed to subdue and immobilize the collected ants, facilitating handling. It is imperative to conduct ant collection responsibly, especially for rare or endangered species, and compliance with permits and local regulations is crucial, particularly in research or conservation efforts. Ethical considerations and the preservation of ecosystems plays a prominent role in shaping ant collection practices. capturing and utilization of ants as food have deep-rooted traditional practices across various cultures. Baiting, trapping, hand collection, and even nest excavation are methods employed for this purpose. Ants are eaten in different ways, from raw snacks to cooked dishes such as stir-fries, sautés, and deep-fried snacks. They are used in condiments like chutneys or as garnishes on salads, showcasing the versatility of their culinary applications (Shmygelska *et al.,* 2005). In some cultures, ants have cultural significance, being part of rituals and celebrations, while others attribute medicinal properties to them. In the modern culinary landscape, insects, including ants, have found their way into fine dining and gastronomy. Chefs experiment with ant-based dishes, and insect-based products, such as snacks, contribute to alternative protein sources. Responsible harvesting practices are emphasized to preserve ecosystems and biodiversity, considering the potential impact of overharvesting on local environments. Additionally, cultural sensitivity plays a role in acquiring of ants as food, with varying perspectives around different cultures. Overall, the collecting and eating of ants represent a dynamic interplay between traditional practices, culinary innovation, and sustainability considerations.

The Nutritious Advantages of Eating Insects

The enriched value of red ants, particularly in the form of Kai chutney, is highly regarded for its spicy flavor and medicinal properties. Red ants are known to be rich in protein, providing essential amino acids crucial for muscle development, repair, and overall growth. As whole protein sources, they offer a comprehensive profile of essential amino acids necessary for various physiological functions, making them beneficial for individuals, especially those following vegetarian or vegan diets lacking in Vitamin B-12. Additionally, red ants contain essential vitamins and minerals such as Vitamin B-12, iron, zinc, magnesium, and sodium, contributing to overall health and well-being. Apart from their nutritional content, red ants have been traditionally used in medicinal practices, with historical records documenting their effectiveness in treating ailments like coughs, colds, jaundice, and vision problems. Some studies even suggest that red ants, along with other insects, possess antioxidant properties, further enhancing their potential health benefits. The cultural significance of consuming red ants underscores the integration of local resources into dietary habits, highlighting the intersection of nutrition and cultural heritage. Moreover, the consumption of red ants aligns with sustainable and ecological considerations, as insects are highly efficient in converting feed into protein, resulting in a lower environmental impact compared to traditional livestock. However, it's essential to consider individual variations and potential allergies, especially in cultures where insect consumption may be unconventional. Adhering to hygienic practices in the collection, preparation, and eating of insects minimizes health threats associated with unconventional dietary choices. As individuals explore the use of red ants in their food, consulting with healthcare professionals provides personalized guidance and ensures a holistic approach to incorporating unconventional yet nutritious elements into culinary practices. Overall, the nutritional richness of red ants offers a unique combination of benefits, emphasizing their role as a sustainable and nutritious food source with cultural and ecological significance.

The Sustainable Practice of Insect Consumption

Embracing entomophagy, the consumption of insects, has garnered support from advocates and food scientists who believe it holds the key to addressing global hunger challenges. However, before large-scale production can commence, it is imperative for the Ministry of Aayush to implement stringent safeguard measures and hygiene protocols to ensure standardized production. The regulation of chutney production, including the incorporation of insects, seeks to destigmatize tribal cuisine and foster a more positive public perception. For those seeking sustainable and nutritious protein sources, entomophagy presents an avenue worth exploring.

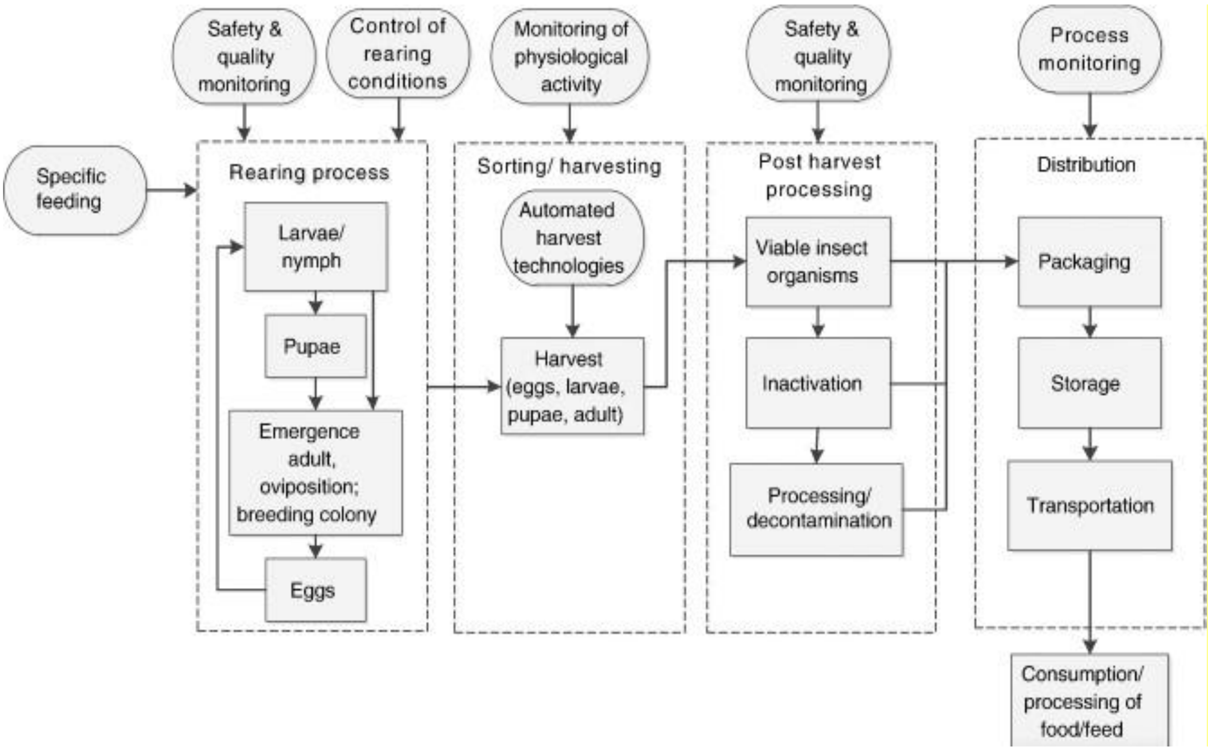
Understanding the benefits involves considering various factors. Insects are not only a rich source of high-quality protein, providing essential amino acids vital for human health, but many also contain vitamins and minerals for a well-rounded nutritional profile. Sustainability is a key advantage, as insect farming has a less environmental impact, requires less land, water, and feed. Furthermore, insects produce fewer greenhouse gas emissions, positioning them as an eco-friendlier protein source. With high feed conversion efficiency, insects can contribute significantly to global food security, offering a reliable and efficient food source. The cultural significance of entomophagy, especially in tribal communities, helps preserve culinary heritage, promoting cultural diversity and culinary practices. Regulatory safeguards, led by bodies such as the Ministry of Aayush, play a crucial role in establishing guidelines for safety, hygiene, and standardized production of insect-based foods. The regulation of chutney production not only aims to ensure safety but also strives to remove the stigma associated with tribal cuisine, fostering a positive public perception. Beyond their nutritional spectrum, some edible insects, like red ants used in Kai chutney, are believed to have medicinal properties, contributing to holistic health practices. Culinary exploration becomes a unique experience with entomophagy, introducing diverse and innovative flavours. Education and awareness initiatives are pivotal for dispelling myths and fostering public acceptance of insect consumption. This approach encourages innovation in food production, leading to a more diversified food market with insect-based products. As India participates in the global interest in entomophagy, collaboration, knowledge-sharing, and staying informed about sustainable food practices become integral. Addressing hunger and malnutrition, especially in regions facing challenges, becomes more feasible as insects emerge as accessible and affordable protein sources. As awareness continues to grow and regulatory frameworks are solidified, entomophagy has the pivotal role to play a significant role in sustainable and nutritious food practices, contributing to a more resilient global food system.

Table 1: Various insects that are consumed in different countries

Consumption of Insect	Country
Giant water beetle	Thailand
Butterfly, Grasshoppers, crickets, Cicadas, Ants Flies, Bees and Wasps,	South America
Caterpillars, Mopane worm, Termites and Locusts	Africa
Giant queen ants, Palm grubs and Caterpillars	Colombia
Papua, Palm grubs, Grasshoppers, Crickets, Stick insects, Mantids and Locust	Pacific Islands
Grasshoppers, Crickets, Silk worm pupapa, Dragonflies, Termites, and Beetles.	Asia
Honey ants, Grubs, Moth, Bardi grubs and Cerambycid beetle	Australia
Termite, Dragonfly, Grasshopper, Ants and Mulberry silkworm, Honey bee, Cricket.	India
Silkworm pupa, Fly larvae, Cricket, Termites and Locusts	China

Mass Production of Palatable Insects

Large-scale production of edible insects as a viable form of micro livestock has a rich historical background, spanning over 7000 years and encompassing various purposes such as sericulture (silk), apiculture (honey), biological pest control, and the production of medicinal products and shellac (Rumpold and Schluter 2013b). While progress has been made in artificial rearing diets and controlled conditions, challenges hinder the scalability of insect farming for human and animal consumption. One primary challenge is the identification of an ideal insect species for mass rearing. Domestication, as seen in silkworms, has resulted in adaptations that may hinder survival in the wild, emphasizing the need for careful species selection (Defoliart 1995). Crickets and palm weevils are mass-reared in Thailand, but their reliance on high-quality chicken feed makes them suboptimal choices. The ideal insect species should exhibit characteristics such as high egg production, efficient egg hatch, a brief larval stage, synchronized pupation, substantial larval or pupal weights, high productivity with low feed costs, resistance to diseases, ability to thrive in high densities, and a high-quality protein content (Rumpold and Schluter 2013b). While the black soldier fly (*Hermetia illucens*) aligns with these criteria, optimizing farming techniques remains a challenge.



Unlike conventional livestock systems, where automation is widespread, insect farms still heavily rely on manual labor for tasks like feeding, collection, cleaning, and rehousing, contributing to higher production costs (Rumpold and Schluter, 2013b). even though few companies are experimenting with automation, further development is imporatnt to make insect farming a cost-effective alternative to traditional protein sources like beef and poultry. and to labor costs, controlling environmental conditions in the rearing facility is vital for successful mass production. Factors such as temperature, light, humidity, ventilation, rearing containers, population density, oviposition sites, feed and water availability, feed composition and quality, and microbial contaminants must be carefully managed (Rumpold and Schluter, 2013b). Insect farming for feed products presents various challenges, with processing being a critical aspect that requires attention. Unlike conventional livestock, there is a lack of standardized processing procedures for insects, primarily due to insufficient data on the impact of different techniques on food safety and nutritional content. Ideally, a robust insect production system would involve clear standards and production protocols, encompassing factors such as species selection, automation, environmental control, and the establishment of standardized processing procedures.

However, challenges persist in addressing these aspects, including the consideration of ideal feeds sourced from bio-waste. Research on bio-waste feed sources, particularly food waste, is limited and has yet to reflect mass-rearing practices. Addressing these challenges in insect farming for mass consumption requires comprehensive efforts aimed at developing standardized processing procedures, exploring ideal feed sources from bio-waste, and integrating automation and environmental control measures into production systems.

Nutritional Value of Consumable Insect

The nutritional profile of insects is diverse and subject to variations determined by factors such as species, metamorphic stage, origin, diet, and processing methods (Finke M.D *et al.*, 2014). Different insect species exhibit significant differences in nutritional content, creating a dynamic and multifaceted value dependent on various elements.

Energy: The energy content of these insects is impacted by their composition, particularly the content of fat, with larvae or pupae generally being richer in energy compared to adults. Insects with high protein content tend to have lower energy content. The fat content ranges from 10 to 60% in dry matter, with caterpillars having one of the highest fat contents. The fatty acid profile is influenced by the insects' diet (Finke M.D *et al.,* 2014).

Proteins: Most insects maintain a relatively consistent total protein content, with exceptions like the wax moth (G. mellonella). The amino acid composition includes essential amino acids, meeting amino acid requirements. Essential amino acids represent 46–96% of the total amino acids.

Lipids: these insects contain 10 to 60% fat in dry matter, with higher fat content in larval stages than in adults. Caterpillars, termites, and caterpillars (Lepidoptera) are among the insects with the highest fat contents. The fatty acid profile includes oleic, linoleic, and linolenic acids.

Fibre: Edible insects contain good amounts of fibre, primarily in the form of insoluble chitin found in their exoskeleton. Chitin is considered an indigestible fibre, also called as "animal fibre" (Finke M.D *et al.,* 2014).

Minerals: Insects are rich in potassium, calcium, iron, magnesium, selenium, and zinc. Certain insects, like mopane caterpillars, can be excellent sources of specific minerals such as zinc.

Vitamins: Insects offer various vitamins, with bee brood being rich in vitamin A and D, and caterpillars rich in B vitamins. Riboflavin content ranges from 0.11 to 8.9 mg per 100 vitamin B12 is found abundantly in specific insect species.

Palatable Attributes and Processing: In some places, insects are eaten alive or processed through methods like scalding, roasting, boiling, baking, frying, or drying.

Sensory Characteristics of Insects

Taste: Taste is a pivotal factor in food selection, governed by sensory characteristics. While human taste receptors may be similar, individual preferences can vary.

Odour: Olfactory perception is vital for food acceptability, influencing the judgment of edibility. Despite their pungent odour, stinkbugs are favored in certain regions.

Visual Appearance: Coloration in insects gives information on developmental stage, nutritional content, and value, aiding in their selection for consumption.

Textural Aspects: Texture plays a significant role in determining the acceptability of an item as food. Smoother, softer surfaces are generally more appealing than rough surfaces, and spiny appendages are often removed before consumption

The nutritional richness of insects, combined with their sensory characteristics, positions them as a promising and diverse source of alternative protein with potential benefits for human consumption (Finke M.D *et al.*, 2014).

Table 2: Common nutritional value of edible insect g/100g dry weight

Species (order)	Protein	Fat	Mineral	Carbohydrate	Energy Kcal
Caterpillar (Lepidoptera)	15-60	7-77	3-8	2-29	323-450
Beetles (Coleoptera)	21-54	18-52	1-7	6-23	138-447
Cockroach (Blattodea)	20-23	6-8	1-2	5-7	200-220
Bees (Hymenoptera)	1-81	4-62	0-6	1-6	416-655
Cricket (Orthoptera)	8-25	34	2-17	4-11	120-323
Spider (Arachnida)	63	9-10	0.5-1 0	0	320-390

Conclusions:

In conclusion, edible insects offer a promising and sustainable alternative as a protein source, boasting a well-balanced nutrient profile that fulfills human amino acid requirements while being abundant in polyunsaturated fatty acids, vitamins, and minerals. Their integration into the diets of consumers in India and other developing nations, where malnutrition is prevalent, presents a chance to serve as both a staple food and a nutritional supplement, especially for vulnerable groups and athletes. Careful selection of suitable insect species, taking into account their feasibility for mass production and intended utilization, is crucial. Insect farming showcases environmental friendliness by producing less greenhouse gases, consuming less water, and needs less land. With the escalating global demand for food and mounting concerns about the environmental repercussions of conventional agriculture, insects emerge as a culturally ingrained and nutritionally diverse solution to confront these challenges. The practice of entomophagy observed in regions like India's Northeast not only reflects cultural heritage but also underscores the nutritional resilience of communities, highlighting the varied and valuable nutritional contributions of edible insects to human diets, particularly during festive occasions.

Future Recommendations:

Looking forward, the scale-up of insect production for both human and animal consumption requires careful planning and consideration. The initial step involves identifying suitable insects used for large-scale rearing, prioritizing traits like more egg production, short larval stages, and disease resistance. To improve the economic viability of insect-based protein, further advancement in automation within insect rearing is crucial, focusing on processes like feeding, collection, cleaning, and housing to minimize labour costs. Establishing clear standards and protocols for insect processing is essential to ensure food safety and preserve optimal nutritional quality. Exploring alternative feed sources, particularly bio-waste materials, has the potential to improve the sustainability of insect farming. To note the challenges associated with scaling up insect production, ongoing research and development efforts are necessary to refine farming methods and establish best practices. Selective breeding programs can also contribute to improving desirable traits for efficient mass production. Developing a comprehensive regulatory framework is vital, encompassing quality standards, food safety protocols, and cultural considerations. Public awareness campaigns highlighting the nutritional benefits, sustainability, and safety of consuming nutritive insects are crucial for fostering broader acceptance. Implementing these recommendations can facilitate a more efficient, sustainable, and culturally embraced practice of insect farming, thereby making significant contributions to global food security and environmental conservation efforts.

Environmental and Nutritional Implications:

From an environmental perspective, insect farming offers notable ecological advantages. Insects demand less land, water, and food resources compared to traditional livestock, rendering them a more sustainable protein source. As the global population continues to expand, integrating insects into mainstream diets holds the potential to significantly enhance food security while reducing the environmental strain associated with conventional agriculture. Moreover, the nutritional richness of edible insects, characterized by their high protein content and diverse micronutrient profile, positions them as valuable supplements in addressing malnutrition and catering to the dietary requirements of various populations. Embracing entomophagy and advancing insect farming techniques could pave the way for a more supportable and nourishing future within the global food ecosystem.

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POLLINATION ECONOMY: CULTIVATING PROSPERITY THROUGH POLLINATOR PARTNERSHIPS IN AGRICULTURE

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Abstract:

Pollination boosts the yield of most crop species, which accounts for the world's crop production. In fact, pollinators such as bees, birds, and bats contribute 35 percent of the world's agricultural yield. Many types of bees can be raised and sold professionally, including honeybees, solitary bees, leafcutter bees, dammer bees, mason bees, and others. However, honeybees are the most efficient in raising crop output and productivity. However, the number of wild, native, and managed pollinators is currently dropping due to changes in their food and nesting grounds, shrinking natural ecosystems, chemical poisoning, alien species, diseases, pests and climate change etc. Hence rearing of bees artificially may be a superior way to increase crop yield and productivity.

Introduction:

Pollinators play a crucial role in ecosystems and agriculture. Nearly 90% of flowering plants require pollinators such as bees to transport pollen for effective sexual reproduction. This process is essential for the production of fruits and seeds. The importance of pollinators extends to various aspects of the environment, biodiversity, and human well-being. Plants, in turn, play an important role in the functioning of ecosystems. They provide food, habitat, and a variety of other resources to many animal species, and as a result, play an important role in regulating ecosystem services that support food production, habitats, and natural resources. They are critical for preserving biodiversity and adapting human food production systems to climate change. They have an important and growing part in the food production process. Over the last five decades, the number of pollinator-dependent crops produced has increased thrice, increasing our reliance on pollination.

Honeybees are crucial for agricultural pollination around the world, accounting for 80% of insect pollination (Klein *et al.,* 2007). Bee pollination therefore boosts fruit production by 50% over wind pollination. Apart from bees, other insects such as beetles, wasps, butterflies and moths pollinate at a significant rate. Bats are the primary pollinators among mammals, fertilizing a wide range of economically and ecologically significant plants such as agave and cacti. Hummingbirds, honeyeaters, sunbirds, and perching birds are important bird pollinators. Other pollinators include flies, ants, midges, monkeys, rodents, mosquitoes, flying foxes, fruit bats, snails, slugs, and even humans. Improved pollination can also shorten the time between flowering and fruit set, minimizing the risk of fruit exposure to pests, disease, adverse conditions of weather, agrochemicals etc (Anonymous, 2010). Animal pollination accounts for approximately 5% to 8% of current global agricultural production, which amounts to between 235 and 577 billion US dollars globally. They also provide essential resources like biofuels, textiles such as cotton and linen, and building materials.

Many developing countries like India, South Asia, and sub-Saharan Africa rely more on natural pollinators for agricultural production that provides important nutrients (Ken *et al.*, 2012). However, Due to changes in their food and nesting habitats, the shrinkage of natural ecosystems (forests and grasslands), pesticide poisoning, alien species, diseases, and pests, smuggling and trading in some rare and endangered species, human activity, climate change, etc., the population of wild, native, and managed pollinators is rapidly declining. (Abrol *et al.*, 2016).

Honeybees, namely *Apis mellifera*, continue to be the most economically beneficial pollinators of crops globally (Watanabe 1994). This is also demonstrated for a number of single crops, where the absence of these pollinators results in yield reductions of more than 90% for some fruit, seed, and nut crops (Southwick & Southwick 1992). Farmers frequently have no other option than to use managed honeybee hives to guarantee crop pollination when wild bees do not visit agricultural fields.

Pollinator's Role in Crop Production

In reality, pollinators like bees, birds, and bats contribute about 35% of global agricultural production, increasing outputs of 87 of the leading food crops worldwide, as well as many plant-derived medicines. The agricultural economy in the United States has relied significantly on honeybees for pollination. Hay crops grown from bee-pollinated seeds occupy around 40 million acres. Approximately 6 million acres were dedicated to the production of fruits, vegetables, and nuts, the majority of which are pollinated by insects (McGregor, 1976). These plants account for around 15% of human diet. Pollinating insects increase crop yields by around three-quarters. Though Arabica coffee may set berries through self-pollination, when bee visits are permitted, the berry set nearly doubles (Belavadi *et al.*, 2013).

Value of Pollination:

The primary crops that feed the world's population depend on insect pollinators like bees, whose pollination services brought in an estimated €153 billion in 2005 (Gallai *et al.*, 2009). Over 100,000 honeybee colonies are managed by 3,000 registered beekeepers in Ontario. The controlled bumble and honeybee populations in Ontario produce approximately $897 million of the honeybee sales revenue for agricultural products. This amounts to roughly 13% of the province's annual crop value. The main pollinator in greenhouses is commercially produced bumble bees, and the crops they assist in pollinating bring in about $502 million for Ontario's economy annually (Pindar *et al.,* 2017). There was significant variation in the vulnerability ratio across crop categories, with a maximum of 39% for stimulants (coffee and cocoa are pollinated by insects), 31% for nuts, and 23% for fruits (Vanyi *et al.*, 2010).

Vegetable crops pollinated by different pollinators.

Crops	Crops Pollinators / Visitors
Tomato	Honey bees, Wild bees, halictid bee (*Augochloropsis ignita* Smith), bumble bees (*Examalopsis glubosa*), wild solitary bees (*Anthophora urbana*).
Brinjal	Bumble bees, carpenter bees and honey bees
Okra	Bumble bees and Honey bees
Onion	Flies, honey bees, small syrphid flies, halictid bees and drone flies.
Lettuce	Honey bee, flies, wild bees and butterflies.
Field beans	Honey bees, short toungue bumble bees, carpenter bee
Cowpea	Bumble bees

(Thamburaj and Singh, 2001)

Fruit crops pollinated by different pollinators

Mango	Honeybees (*Apis cerana* and *Apis mellifera*), allodapine bee (*Braunsapis hewitti*), sweat bees (*Halictus* sp. and *Lassioglossum* spp.), *Chrysomya megacephala*, *Chrysomya pinguis*, and *Musca domestica*
Cashew	*A. mellifera* and *Trigona spinipes*
Strawberry	*Bombus lucorum* and *A. mellifera* in greenhouses
Banana	Honeybees (*A. cerana indica*, *A. mellifera* and *A. dorsata*); wasps (*Polistes haebraceous* & *Vespa orientalis*) and sting less bees
Apple	Bees
Litchi	European honey bee (*A. mellifera*)
Cherries and plums	Honey bees
Fig	Female fig wasps

Yield increase due to bee pollination in different crops

Crops	Percent yield increase (%)
Mustard	43
Sunflower	32-48
Cotton	17-19
Lucerne	112
Onion	93
Apple	44
Coriander	187
Cardamon	21-37

Commercial Production of Pollinators

Commercial production of pollinators for pollination is a process in which pollinator species are raised and bred for the purpose of assisting in the pollination of plants in agricultural or horticultural settings. This is done to ensure effective and efficient pollination, thereby maximizing crop yields. The commercial production of pollinators involves creating suitable habitats for the pollinators, providing them with appropriate nesting materials, and ensuring a continuous supply of floral resources for their sustenance.

Commercial production of pollinators enables farmers and growers to enhance crop productivity and improve the quality of their yields. It also helps to safeguard the diversity and abundance of pollinators, which is crucial for maintaining ecosystem health and biodiversity.

Bumble Bees:

There are five commonly farmed species of bumble bee (genus Bombus) in the world: *B. terrestris, B. lucorum, B. occidentalis, B. ignitus,* and *B. impatiens*. On a global basis, *Bombus terrestris* is the most commonly used, however in North America, *B. impatiens* is the most commonly used.

Pollination by bumble bees improves the quality of tomatoes, cranberries, blueberries, and many other crops. Bumble bees are also more tolerant to severe winds than honeybees and will even forage in mild rain. Honeybees remain inactive at temperatures below 50°F (10°C), whereas bumble bees can forage at temperatures as low as 45°F (7.2°C). Bumble bees are ideal for greenhouses. Their nests are easily transportable and can be kept in greenhouses.

Most greenhouse tomatoes rely on bumble bees as key pollinators. Buzz pollination causes tomatoes to produce larger, more uniform fruits. Prior to the commercialization of bumble bees, tomato blooms were pollinated by honeybees or by manually operated vibrating machinery. They are far more efficient and less expensive than the alternatives. In eastern North America, the species Bombus impatiens is widely available for purchase for use in greenhouses.

After bumble bees were commercially available in the early 1990s, the greenhouse tomato industry flourished substantially. Between the early 1990s and 2003, the North American greenhouse tomato producing area is expected to have increased by around 600 percent. Bumble bees' exposure to pesticides used in greenhouses can be reduced by sealing the entrance to the bee colony before pesticides are administered.

Only mated queen bees may produce a whole colony of bees. Allow it to lay eggs. Workers are transported to a larger box once they have emerged. As she builds her nest, feed the queen nectar and pollen. Give the queen a pea-sized pollen ball. Unless there is evidence of eggs being laid on the pollen ball, replace it every few days. Bumble bee colonies are usually raised in a dark environment with 50 percent relative humidity, at temperatures above 70°F (21.1°C).

Three firms are now the world's leading suppliers of bumble bees: Biobest (established by Dr. de Jonghe), Koppert (a Dutch company), and Buntin Brinkman Bees (another Dutch company). Koppert is the largest supplier in the United States.

Honeybees:

Honeybees are raised for honey production, biodiversity conservation, agricultural pollination, beeswax, propolis, royal jelly, venom, apitherapy, and revenue generation. Pollination by honeybees and wild bees boosted yield quantity and quality by up to 62% on average, but pollinator exclusion caused a yield gap of 37% in cotton and 59% in sesame. In India honeybees like Apis mellifera and *Apis cerana* are reared for commercial purpose. Government of India launched several schemes to promote honeybee farming in the country. The National Beekeeping and Honey Mission (NBHM) is one of the initiatives under the National Mission for Sustainable Agriculture (NMSA). The government has also launched Pradhan Mantri Kisan Samman Nidhi (PM-KISAN) scheme to provide financial assistance to small and medium famers.

The small-scale operation cost may range from Rs. 10000 to 20000, medium-scale operation costs up to 2 lakhs. Large scale can cost up to 5 lakhs. Example: Sunflower production was enhanced by adapting three colonies of *Apis mellifera* per acre (Abbasi *et al.*, 2021).

Dammer bees:

The majority of tribal people utilize artificial bee hives constructed from split bamboo poles. A single artificial hive can produce 600–700 grammes annually. There are numerous medical benefits of this honey.

United States rents commercial bee colonies, with more than 60,000 hives, Brett Adee is among the biggest commercial beekeepers in the United States. Contracted bees are transported to pollination sites by truck and can be shipped across the country on tractor trailers which typically carry between 400 and 500 hives each Adee, 2014). Depending on the number of frames and overall health of the hive, individual hives typically have a single queen and 10,000-30,000 worker bees; by midsummer, a colony may have as many as 50,000–60,000 worker bees (Pettis, 2013).

Mason Bees:

The "mason bees" are currently used to refer to numerous species of bees of the Megachilidae family's genus Osmia. Their habit of creating nests-sealing off the compartments in which they deposit their eggs gives them their name. There are about 140 species of mason bees in North America. These bees are solitary and do not live in colonies. Species of the genus include the orchard mason bee *O. lignaria*, the blueberry bee *O. ribifloris*, the hornfaced bee *O. cornifrons*, and the red mason bee *O. bicornis*. the first two are native to the America, the third to eastern Asia, and the last to the European continent. *O. lignaria* and *O. cornifrons* have been used for commercial purposes. These bees are metallic green or blue and sometimes black. Osmia often pollinate early spring blooms in the family Rosaceae and will even forage in unfavorable weather circumstances. Mason bees are extremely productive. Only two or three females are necessary to fertilize mature apple trees. A day, these bees can visit up to 2000 flowers. They can also co-exist with honeybees.

Mason bees are distinct from bumblebees and honeybees due to their lack of a queen, lack of hives, and lack of honey production. They usually don't sting and are safe. Six Mason Bees can pollinate one fruit tree, compared to 10,000 Honeybees. Female usually build their nests in natural tubular cavities and small openings. Their nests are not dug by them. The cell material can be made of chewed plant tissue, dirt, clay, or grit.

These bees need to visit flowers more frequently because their capacity to carry pollen back to the nest is limited. This is because they carry pollen in a specialized structure called a scopa on their belly rather than internally or on their hind legs. They are extremely good pollinators because of their behavior inside the flower, which also covers them in pollen.

Management of Mason Bees:

Artificial nests made of wood blocks with multiple holes drilled in them, cardboard tubes with one end plugged, or sections of bamboo and reed with a stem node intact on one end (forming a dead end) are all relatively simple ways to keep mason bees under control. Artificial nests should have internal tunnel dimensions roughly 5⁄16 of an inch in diameter and with a depth of 6 to 8 inches. In order to resemble a group of naturally occurring hollow cavities, these nests are gathered together and suspended horizontally across the orchard (several feet above ground level) beneath a waterproof cover. These nests are generally left outside depending on location, and surrounding bee population.

Jim Watts, the proprietor of Mason Bees, also rents these out. He launched a business because of his passion. His areas of specialization are raising native bees and providing pollination support to nearby plants.

Leaf Cutter Bees:

In North America, leaf cutting bees are an important native pollinator. They build their nests in cavities (usually in decaying wood) using chopped leaves. The nest is of cigar shape, they make several cells, each containing a single larva and pollen for the larvae to consume. The bee will nest near its neighbours even though it is a solitary. These are important pollinators of wildflowers, fruits, vegetables and other crops. Certain species of leaf cutting bees, called Osmia spp., are even employed commercially on crops like alfalfa and blueberries as pollinators, much like honeybees. Pollen is carried by female bees on hairs on the underside of the abdomen, not on the hind legs as other bees do, with the exception of the parasitic Coelioxys. when bee's abdomen has a pale yellow to deep gold colour, it indicates that it is carrying pollen.

Host Plants

Almost any broadleaf deciduous plant's leaves can be used by leaf cutting bees to build their nests. In addition to leaves, several species of leaf cutting bees also consume petals and resin. Decorative plants with thin, smooth leaves, like roses, azaleas, ash, redbud, bougainvillea, and other plants, are frequently sliced into circles by these bees.

The ability of the lucerne leafcutter bee, one of the few commercially managed pollinators apart from the honeybee, to pollinate the wild blueberry crop in the Atlantic region has been studied since the early 1990s. In addition to a wide range of other crops, Canada presently produces 4 billion lucerne leaf cutter bees per year, which are used to promote both foreign and local lucerne seed crops.

Alfalfa leaf cutter bee females graze primarily on the plants. These bees have a pollination success rate of over 85% and visit eight flowers on average every minute when foraging. An additional advantage of these bees is their highly adjustable incubation cycle, which may be timed to align with the crop's flowering season. In experiments done in Nova Scotia, it increased fruit set from 9% to 24% at stocking rates ranging from 14,000 to 22,000 bees per acre. There is a substantial positive correlation between alfalfa leaf cutter density, foraging, and the extent of fruit set rise Javorek *et al.*, 1994).

Conclusion:

The critical role of pollinators, particularly bees, in agricultural production and ecosystem health cannot be overstated. Pollination by bees substantially boosts crop yields, contributes to the production of fruits, nuts, and seeds, and supports biodiversity and ecosystem services. However, the population of wild, native, and managed pollinators is facing several challenges, including habitat loss, pesticide use, diseases, and climate change, leading to a decline in their numbers. In response to these challenges, the commercial production of pollinators has emerged as a viable solution to enhance crop productivity and ensure effective pollination in agricultural settings. Various species of bees, such as honeybees, bumble bees, dammer bees, mason bees, and leafcutter bees, are being raised and managed for pollination services. This approach not only benefits farmers by increasing yields but also contributes to the conservation of pollinator populations and the maintenance of ecosystem health.

Future Prospects:

Looking ahead, there are several promising prospects for the commercial production of pollinators and its impact on agriculture and biodiversity:

- Research and Innovation: Continued research and innovation in bee breeding, management techniques, and sustainable practices will further improve the efficiency and effectiveness of commercial pollination services.
- Collaboration and Partnerships: Collaboration between government agencies, research institutions, beekeepers, farmers, and other stakeholders will be essential to address challenges facing pollinators and promote sustainable beekeeping practices.
- Education and Awareness: Increasing public awareness about the importance of pollinators and the need for their conservation can foster greater support for initiatives aimed at protecting pollinator populations and their habitats.
- Policy and Regulation: Implementing policies and regulations that support sustainable beekeeping practices, reduce pesticide use, and protect pollinator habitats will be crucial for ensuring the long-term viability of pollinator populations.
- Diversification of Pollinators: Exploring the use of alternative pollinators, such as flies, beetles, and butterflies, in addition to bees, can provide resilience against environmental challenges and enhance crop pollination.

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BLACK SOLDIER FLY FARMING

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Abstract:

One of the most pressing and severe environmental issues facing urban governments in low- and middle-income nations is municipal solid waste management explains the relatively new method of biowaste conversion by insect larvae, which has garnered a lot of attention in the last 10 years, using the Black Soldier Fly (BSF), *Hermetia illucens*, as an example. *Hermetia illucens*, the black soldier fly, belongs to the family Stratiomyidae and is a true fly (Diptera). Despite being native to the Americas, it can now be found in tropical and temperate locations all over the world. The black soldier fly breaks down several kinds of organic waste and produces high-value biomasses like proteins and oils. Black soldier fly larvae (BSFL) (*Hermetia illucens* L.) are an excellent source of protein since they are heavy in fat, protein, and other nutrients. Moreover, BSFL are easily raised and multiplied on any nutritional substrate, including straw, agricultural remnants, food scraps, animal dung, and plant leftovers. In terms of cost, availability, legality, and customer acceptability, there are certain obstacles associated with the use of BSFL in animal feed. In Asia, such a use of BSFL might be advantageous, particularly in nations where organic waste processing equipment is not easily accessible. But this needs to be weighed against the current protein feed scarcity and the nutritional benefits of BSFL, which is significant for animal production.

Introduction:

Urban solid waste management is considered one of the most immediate and serious environmental problems confronting urban governments in low- and middle-income countries. The severity of this challenge will increase in the future given the trends of rapid urbanisation and growth in urban population (Hussein *et al.*, 2018). Due to growing public pressure and environmental concerns, waste experts worldwide are being called upon to develop more sustainable methods of dealing with municipal waste that embrace the concept of a circular economy. Recycling organic waste material (biowaste) is still fairly limited, especially in low- and middle-income settings, although this is by far the largest fraction of all generated municipal waste. It describes the fairly novel approach of biowaste conversion by insect larvae, using the example of the Black Soldier Fly (BSF), *Hermetia illucens*, an approach that has obtained much attention in the past decade. Its popularity links to the promising opportunities of using the harvested BSF larvae as a source of protein for animal feed, thus, providing a valuable alternative to conventional feed (Dortmans *et al.,* 2017).

Hermetia illucens, the black soldier fly, belongs to the family Stratiomyidae and is a true fly (Diptera). Although it originated in the Americas, it is now found around the planet in tropical and temperate climates (Čičková *et al.,* 2015), and its inability to withstand cold weather prevents it from spreading to non-native areas like Northern Europe. Adults just drink water, avoid human contact, do not bite or sting, and do not carry or spread any particular diseases. The massive variety of organic material that black soldier fly larvae (BSFL) are known to feed on has led to their use in small-scale waste management applications, where they have been used on substrates like manure (Sheppard, 1983), rice straw, food waste, distillers' grains (Webster *et al.,* 2015), faecal sludge (Banks *et al.,* 2015), animal offal, kitchen waste, and so forth (Nguyen *et al.,* 2015). They may be the most efficient fly species in terms of the variety of substrates they can handleMoreover, BSFL have been investigated and shown to be edible. Their feed conversion ratios are known to be higher than those of mealworms and crickets, and their phosphorus and nitrogen compositions and BSFL survival rate do not change much with diet in comparison to those two. It is believed that they are not harmful (Blum, 1994). In order to be used as energy by the non-feeding adult, BSFL gather lipids from their diet to the point where they can be transformed into biodiesel. Their nitrogen-rich frass and anything they don't eat can be combined to make fertiliser (Lalander *et al.,* 2015).

Business Ideas Black Soldier Fly Farming. Black Soldier Fly larvae farming is presently profitable business in the world. Black Soldier Fly Farm is the best business for Entrepreneurs with short time, low cost, low labor and high profit. Soldier Fly larvae farming is presently the most widespread form of insect farming in the world. Black soldier fly life cycle A to Z. Start Business Black Soldier Fly Farming. Black soldier fly production business can be Very easily started in the backyard or in any abandoned place. In their spare time, men as well as women can do this business. Farming BusinessThe black soldier fly larvae is quickly emerging as a viable poultry and fishmeal alternative in aquafeeds based on nutritional value and ability for eco-friendly production. Large scale production of larvae from Black Soldier Fly will create employment for many people on the one hand and meet the food needs of poultry and fish on the other. And a huge amount of organic fertilizer will be prepared from here. black soldier fly compost is very powerful. Black Soldier Fly is made from foul-smelling food, a mixture of garbage, vegetable residue, chicken droppings, chicken intestines, rotten or live fish or any kind of waste. Each fly dies with 900 to 1,000 pupae. These pupae are taken in a container and kept in smelly food. Larvae are born from these pupae in 14 to 18 days. Fly Larvae from the 'Black Soldier Fly' need mosquito nets, a few pots and a few pieces of wood.

Distribution

An Indian black soldier flies over a crape jasmine leaf in West Bengal.Although this species is native to the Neotropics, it has become almost universal in recent decades, spreading over all continents. The majority of North America and Europe are home to it, including the Iberian Peninsula, southern France, Italy, Croatia, Malta, the Canary Islands, Switzerland, and the Krasnodar Territory on Russia's Black Sea coast. Moreover, it is present in the Nearctic, East Palaearctic, Afrotropical, Australasian, North and Southern African, and Indo-Malayan regions (Gladun, 2019).

Life Cycle

A mature female can lay anywhere from 206 to 639 eggs at once. These eggs hatch in around 4 days and are usually laid in cracks or on surfaces above or next to decomposing materials like manure or compost. At the end of the larval stage, newly emerging larvae can grow to a length of 25 millimetres (1 in) and a weight of 0.10 to 0.22 grammes (1.5 to 3.4 gr). They are currently 1.0 millimetres (0.04 in) long (Sheppard *et al.*, 2002). The larvae may consume a broad range of organic materials and can adjust to diets with varying nutrient contents.

Depending on the food substrates given to the larvae, the larval stage can last anywhere from 18 to 36 days (Bruno *et al.*, 2018). The postfeeding (prepupal) stage lasts for around 7 days. Low temperatures or a shortage of food can cause the larval stage to last several months longer than expected. One to two weeks make up the pupal stage (Holmes *et al.*, 2013). When given water and food, such as sugar in captivity or nectar in the environment, adults can live for 47–73 days on average. Alternatively, they can survive for 8–10 days on fat reserves stored during the larval stage when given water (Tomberlin *et al.*, 2002). Adults and larvae are not regarded as vectors or pests.

Rather, black soldier fly larvae are vital decomposers that aid in the breakdown of organic substrates and the replenishment of soil nutrients, much like redworms. The larvae can be utilised to compost agricultural waste items and leftover food from homes because of their ravenous appetites. Furthermore, according to Kupusamy *et al.* (2020), black soldier fly larvae offer an alternate source of protein for aquaculture, animal feed, pet food, and human nutrition. Biotechnology businesses like InnovaFeed and Protix, which operates the largest insect factory farm in the world in the Netherlands, manufacture and process the larvae in large-scale insect factories across the world.

Regular Nutrition Facts of BSF

The pros of black soldier flies include that they contain amino acids that are a good source of protein. This insect also has the ability to synthesize and process unsaturated fatty acids, which are important in the diet of Live Stock. Black soldier fly larvae are also rich in minerals such as calcium, iron, magnesium, sodium, zinc, and potassium. These minerals are important in the diet of humans and animals, and their presence in the larvae of black soldier flies makes them a good food item for consumption.

At a time when the world is running out of land and water to grow soybeans and corn for animal feed, Black Soldier Fly larvae have the potential to revolutionize the global food system by turning almost any organic waste stream into protein, fats, and minerals. BSF larvae are rich in a range of nutrients. Dried BSF larvae contain up to 50% protein, 35% fat (with an amino acid composition similar to fishmeal), 6% Calcium, 1.2% Phosphorus, 1% Magnesium, 0.3% sodium. Therefore, BSF larvae are recognized and used as high-quality protein and fat sources for poultry, pigs, chickens, fish, shrimp, prawns, alternative commercial fish meal (Zulkifli *et al.*, 2022).

Nutritional Value of BSFL From by Different Food Sources

Black soldier fly larva (BSFL) is larvae of black soldier fly (BSF). It has been widely consumed by animals. Because of the nutritional benefits of BSFL, it can be used as animal feed. The larvae are high in protein and low in fat. Black soldier fly larvae can be found in different types of environments, but they are most commonly found in moist, decaying organic matter, such as manure. Other types of larvae, like midges and gnat larvae, can also appear in manure. BSFL larvae are large and fat, which makes them easy to collect and feed to animals (Lu *et al.*, 2022). Protein and Fat Value, are the two most important things to make food for animal feed. The nutritional composition of BSF larvae will vary when BSFLs are fed with different food sources. So, the nutrient composition of BSF larvae is variable. So, to know the nutritional composition of the black soldier fly more or less you have to know which food sources to eat. The table that compares the nutritional composition of BSF varies greatly based on the food Larvae eat (Shumo *et al.*, 2019).

The Table of Food sources that Affect to Nutritional Value of BSFL:

BSF larvae are off-white in color with grayish-brown stripes, and their length varies from 0.25 to 0.5 cm with a diameter of 0.1 – 0.15 cm. The larvae are fed on organic materials such as vegetable and fruit peels, food processing wastes, manures, feathers, and poultry or fish waste (Fischer and Romano, 2021).

Sl No	Food Sources	% Protein	% Fat
1.	Animal Manure	39.1 – 45.7	29 – 35.1
2.	Food Wastes	39 – 41.8	27.2 – 35.1
3.	Green Waste	31.2 – 36.4	5.2 – 6.63
4.	Raw Rice Bran	42.3 – 45.7	27.5 – 27.8

BSF Mass Production

The biggest challenge in farming is finding BSFL or eggs to establish or repopulate the colony. Usually, to accomplish this, one must get soldier flies to lay their eggs in tiny holes above the grub bin. Clusters of eggs are laid by adult flies around the edges of corrugated plastic or cardboard. Although natural soldier flies can be utilised to create or sustain viable larvae colonies in some areas, many of the items used to attract soldier flies also attract nuisance species, such as houseflies and blowflies (such as fermented chicken feed).

They may reproduce all year round in tropical or subtropical climes, but in other climates, obtaining eggs during the cooler months may require a greenhouse. Compared to redworms, the grubs are more resilient and can withstand greater temperatures and more acidic environments. When there are a lot of grubs, insulation, or compost heat (produced by the microorganisms in the grub bin or compost pile), larvae can withstand harsh winters. Heat encourages grubs to crawl off, pupate, and hatch; apparently, breeding requires a lot of both heat and light (Miranda *et al.,* 2020). The larval colonies of numerous small-scale grub farmers are constructed from eggs laid by wild soldier flies.

Space and Shape

Newly emerged soldier flies perform the beginning of their mating ritual in flight. The male grabs onto the female, and then grasps the female's ovipositor with his genitals. They mate while stationary and connected.

Getting Started

As noted earlier in the article, the *Hermetia illucens* (Figure 3) can be found in most parts of the world, having adapted itself from its native region of the Americas into a now commonly seen insect species. To start a BSF production system, flies can either be captured from the wild or purchased from a local source. This article assumes the latter, that the reader is starting with eggs, larvae, or adult flies already in hand.

Establishing a Mating Enclosure

The establishment of a mating enclosure is critical to the production of eggs, the primary step in producing BSF larvae. Such enclosures depend on the targeted scale of the enterprise, with many options and adaptations available. Mating enclosures can range from large screened-in rooms or smaller systems that utilize mosquito nets or even mesh laundry baskets. No matter the scale or design, it is necessary that the mating enclosure maintain adequate moisture and temperature. It is also critical that these enclosures remain sealed environments, both to keep the BSF in, and pests such as bird and rats out. Within this enclosure a few provisions should be made for the adult flies, including a water source, some vegetation and surface on which to hide and mate, and a 'dark room' inside of which females will lay their eggs. At his stage in their life cycle, neither the pupae nor the mature adults will eat any food, therefore only a small food source is provided for the purposes of enticing the females to lay their eggs (Barragan-Fonseca *et al.,* 2017).

Collecting Eggs

In order to collect the eggs of the adult female BSF, provisions must be made within the mating enclosure. small blocks of wood work well, providing both an inviting egg-laying environment for the female flies and a convenient mode of egg collection for staff. It is common practice to use small pieces of cardboard as egg laying material (Wong, 2020), however we prefer the aforementioned method as it is more convenient for the collection of eggs and tends to result in higher quantities of eggs. At this stage it is important to note that BSF do not lay their eggs directly on (or in) a food source, but rather nearby to one. Therefore, laying blocks should be situated nearby a food source n order to collect eggs, blocks should be removed, separated, and carefully scraped off. It is important to note at this stage that eggs can be of different ages if the blocks are not removed each day. By having eggs of different ages, the larvae will hatch and grow at different stages, requiring additional sorting and separating at maturity. Ideally, when producing larger batches of BSF, it is better to have larvae at uniform age and maturity. Typically, a mature female will produce anywhere from three to four hundred eggs in her lifetime.

Transitioning from Eggs to Larvae

Once eggs have been collected, they can be transferred to a food source where they will hatch and crawl their way to the nearby feedstock provided. Eggs will typically hatch within 4 days of being laid. At this stage, when larvae remain small, plastic trays can be used to hold small quantities of feed/waste and larvae. Mesh screen is used to keep the eggs from directly contacting the food source.

Selecting Appropriate Feedstock

One of the great benefits of the Black Soldier Fly is its ability to consume a wide array of different products, consuming market waste (fruit and vegetable), manure, table scraps, bone meal, and most other products. This article will not provide a prescriptive list of feed sources, but rather encourages the producer to identify the so-called 'waste' resources available to him/her. Ideally, low-cost, or even free, waste by-products should be targeted, including market waste, cafeteria food scraps, rice bran, brewer's spent grains, soy cake, etc… In order to ensure a balanced, or 'complete' feed source, it is recommended to mix a number of various waste resources together. This helps 'bulk up' the feedstock to ensure higher yields of larvae produced, but is not necessary.

Stepping Up Production

As larvae hatch and feed, they will need to be 'stepped up' into larger containers or bays for adequate production. During this step, additional feedstock is provided and larvae are left to eat.

Knowing When to Harvest Larvae

Within the next 13 to 18 days larvae will feed voraciously, eating as much as twice their own body weight each day. It is critical during this time to identify the desired stage at which to harvest the larvae. At the end of the larval stage, before reaching the pre-pupae stage (Figure 11), larvae will reach their maximum nutronal capacity as a feed resource (Barragan-Fonseca *et al.*, 2017). If harvested too late the producer runs the risk of lower feed quality, whicle harvesing too early might mean missing out on additional weight and size, and therefore potentially higher yields.

It is important to note that the decision to harvest larvae at this stage, before reaching maturity, will likely require some form of sorting or sizing, or separation of larvae from their feed material. This can be a laborious task and it is recommended that screens of various sizes be used in this process. Mechanized shakers do exist and can be repurposed for this purpose, or it can be done manually.

Sorting and Sizing

In order to produce larvae at their peak nutritional stage they must be 'harvested' from their feed material. This involves some level of sorting and screening to isolate the larvae. This can be done with various sizes of screens and is made easier by transferring larvae to a finer feed source at the end of their production, allowing for easier separation. This can be done by hand or through investment in mechanized shakers, similar to technologies used in vermicast systems. For larvae that are fed directly, it may not be necessary to clean them completely.

The Final Product

These larvae are at their final and most nutritionally rich stage, before turning into pupae, at which time their nutritional value will begin to decline.

Raising Pupae for Reproduction Purposes

Many BSF systems take advantage of the 'self-harvesting' nature of the BSF pupae. At this stage in its life, a BSF pupae will migrate from its food source in search of a dark quiet place to transform into a mature fly. As seen in the example above (Figure 14), many set-ups have been designed to funnel the crawling pupae out of the food source and into a bucket or other catchment arrangement. This is an extremely convenient phenomenon, but as noted earlier, only happens at the pupal stage when the BSF has already passed its prime as a feed source.

Production Challenges to Consider

Pests

Pests such as birds, rats, and other critters should be considered before establishing a BSF system of any scale. Closed systems are necessary to keep flies in and unwanted pests out. Unfortunately, this necessary process of installing screens and nets can become expensive, and adds significantly to a producer's bottom line.

Foul Smells

As previously mentioned, it is critical to the success of any BSF system to control moisture properly. Many food wastes, such as fruit scraps, contain high moisture contents and can lead to systems that become anaerobic. Preventing this from happening is not only crucial to the success of the overall system, but also to overall smell and subsequent perception of neighbors and clients. As previously mentioned, it is recommended to install drainage options and to keep on hand substances such as rice bran and rice flour that can be added to rapidly absorb moisture.

Factors Affecting BSFL Growth and Food Waste Treatment Efficiency

Although BSFL can withstand a wide range of climatic circumstances based on their extensive regional distribution, Figure 2 illustrates that there are ideal growing conditions for BSFL. The natural environment in many Asian nations is suitable for raising BSF. According to Barragan-Fonseca *et al.,* (2017), the ideal temperature and relative humidity for raising BSF are 26–27 °C and 60–70%, respectively. According to Barragan-Fonseca *et al.,* (2017), the ideal moisture content of substrates is 52–70%, which is comparable to relative humidity. The ideal light intensity is 135–200 µmol/m2 [26], which is greatly dependent on weather and seasonal variations.

Considering the extreme heat and humidity seen in many Asian nations, particularly those in Southeast Asia, BSF cultivation-related companies have a lot of promise if established in these regions. Larval density is another factor to take into account when using BSFL to break down food waste. Larval competition alters colony behaviour and negatively impacts larval survival rate (Pastor *et al.,* 2015). As a result, when cultivating larvae, the larval density needs to be managed in accordance with substrate parameters. According to reports, the ideal ratio for growing BSFL is 2:1 (larvae per gramme of substrate) (Pastor *et al.,* 2015) (Picture 1).

Aspects of larval development can be analysed to track the growth of BSFL during the treatment of organic wastes. According to Noor *et al.,* (2018), the final larval weight, growth rate, survival rate, and larval development time are reported to be 15–36.7 days, 154–271 mg, 2.3–37 mg/d, and 85.6–97.1%, respectively. Depending on the kinds of substrates and rearing circumstances, BSFL growth can vary. For instance, when fed with food waste, fruits and vegetables, and chicken feed, respectively, the survival rates of BSFL were 87%, 90%, and 93%. Nevertheless, the survival rate dropped to 39% when given digested sludge (Lalander *et al.,* 2019).

Optimal environmental conditions and food sources for the larvae can be summarized as:

- Warm climate: the ideal temperature is between 24 and 30°C. If too hot, the larvae will crawl away from the food in search of a cooler location. If too cold, the larvae will slow down their metabolism, eat less and develop slower.

- Shaded environment: larvae avoid light and will always search for a shaded environment, away from sunlight. If their food source is exposed to light, they will move deeper into the layer of food to escape the light.
- Water content of the food: the food source has to be quite moist with a water content between 60% and 90% so that the larvae can ingest the substance.
- Nutrient requirements of the food: substrates rich in protein and easily available carbohydrates result in good larval growth. Ongoing research indicates that waste may be more easily consumed by the larvae if it has already undergone some bacterial or fungal decomposition process.
- Particle size of the food: as the larvae have no chewing mouthparts, access to nutrients is easier if the substrate comes in small pieces or even in a liquid or pasty form.

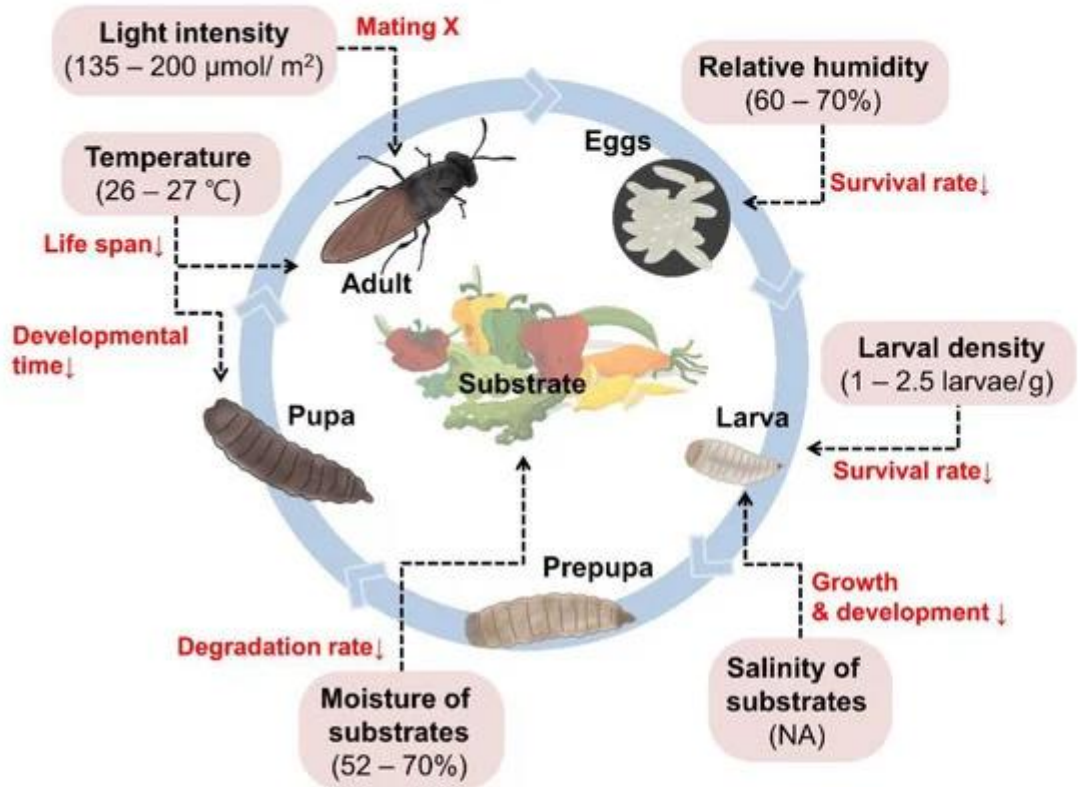

Figure 1: Optimal environmental conditions for the development of BSF larvae

As Decomposers / in Composting

Using black soldier fly larvae (BSFL), garbage can be composted or turned into animal feed. Fresh manure and food wastes from both vegetable and animal sources are among the wastes. Among the creatures that are best at turning biomass into feed are fly larvae.

After going through six instars of development, the larvae enter a stage known as the "prepupa" during which they stop feeding and move towards cool, dark, and dry substrates in order to pupate. Grub composting bins exploit this prepupal migrating instinct to capture the adult larvae on their own (Barros *et al.,* 2019). The prepupae can climb out of the composter and fall into a collection area thanks to the ramps or openings on the sides of these containers.

Application of BSFL after Food Waste Treatment

Because BSFL is used as a substrate, less waste is produced during the food waste treatment process. Substrates that BSFL consume for growth are transformed into BSFL's nutritional components. Larval biomass is produced as a result of this bioconversion process and can be used for other waste valorization applications (Manurung *et al.,* 2016). Feeding and the subsequent growth of BSFL are crucial since the production of well-grown BSFL biomass is a requirement for high-quality animal feed and biodiesel (Wong *et al.,* 2020) (Figure 3The amount of biomass produced and the conversion of proteins are closely correlated with waste reduction efficiency. the ratios of protein conversion, biomass conversion, and substrate reduction. The biomass conversion ratio and substrate reduction ratio are often reported to be roughly 13% and 50%, respectively; yet, the protein conversion ratio varies throughout research, most likely as a result of the varied substrate source.

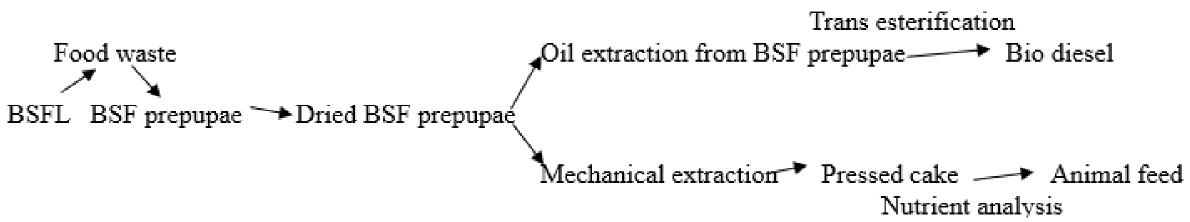

Figure 2: process of food waste treatment using BSFL and production of biodiesel and animal feed from BSF

As Feed

Larvae of black soldier flies are fed to animals. Fish, pigs, turtles, lizards, dogs, and fowl all consume the pupae and prepupae that have been harvested (Lei *et al.,* 2019). This insect is among the few species permitted for use as feed in EU aquaculture.

Black soldier flies are at their most nutrient-rich during the pupal stage. They have a several-week shelf life at room temperature and a maximum shelf life of 10 to 16°C (50 to 60°F) at room temperature (Chia and colleagues, 2018).

As Human Food

It is hard to discover records of *H. illucens* being consumed by humans. A tabletop insect breeding farm dubbed "Farm 432" was created in 2013 by Austrian designer Katharina Unger, enabling individuals to cultivate delicious fly larvae at home. It is a plastic device with multiple chambers that resembles a kitchen appliance. It has the capacity to generate 500 grammes (1.1 lb) of larvae or two meals every week.

It is reported that the larvae have a very unique flavour. Unger: "They have a slightly potato-like fragrance when they're cooked. The texture is similar to soft meat on the inside and slightly tougher on the outside. It has a slightly meaty and nutty flavour.

For Producing Grease

When it comes to making grease, BSFL can be used in place of other vegetable oils like palm oil in the pharmaceutical business (cosmetics, surfactants for shower gel), or it can be used to make feed (Verheyen *et al.*, 2018).

For Producing Chitin

It is possible to synthesise chitin using BSFL. In shipping, chitin serves as a biofouling agent. It's also applied to the filtration of water. According to Debode *et al.,* (2018), chitin may potentially be used as a soil additive to increase plant resistance and soil fertility.

For Producing Organic Plant Fertilizer

The remains of the larvae's decomposition process, or "frass," consist of undigested material, exoskeletons that have shed, and larval excrement. One of the principal outputs of commercial black soldier fly rearing is frass. Due to a favourable ratio of the three main plant nutrients—nitrogen, phosphorus, and potassium—the chemical composition of the frass varies depending on the substrate that the larvae feed on, but generally speaking, it is regarded as a versatile organic plant fertiliser (Gärttling and Schulz, 2022). Typically, the frass is mixed directly into the soil and used as a long-term fertiliser that releases nutrients gradually.However, studies on plants have also revealed short-term fertilising benefits that are on par with those of synthetic, fast-acting fertilizers.

In addition to providing nutrients, the frass may also contain other elements that improve soil fertility and health. One of these is the soil enhancer chitin, which enters the frass through the larvae's chitin-rich shed exoskeletons. Furthermore, the makeup of the soil microbial community, which is essential for soil fertility, can be significantly changed by applying black soldier fly rearing frass as fertiliser (Fuhrmann *et al.*, 2022).

There is disagreement about whether the frass from BSFL rearing may be applied directly as fertiliser or if it needs to go through additional composting first. Some believe that additional composting might lessen any potential phytotoxic effects. For safety concerns, insect frass in the European Union must be treated for one hour at 70 °C (158 °F) before to commercialization; this also holds true for animal dung in general (Song and Colleagues, 2020).

In Bioremediation

In a 36-day bioremediation experiment, up to 49% of dry weight maize leaves contaminated with zinc or cadmium were used to feed the *H. illucens* larvae (Bulak *et al.*, 2018). Here, artificially contaminated maize leaves are used as a model plant material to represent plant biomass contaminated through phytoextraction. In comparison to composting, which is one of the commonly suggested pretreatments for biomass polluted after phytoextraction, the 49% loss of polluted dry weight is a better outcome. The degree of use was unaffected by the type of heavy metal. Zinc accumulates in the adult fly, but cadmium largely accumulates in the puparium. Entomoremediation is the term for using insects for bioremediation (Ewuim, 2013).

Economic, Environmental, and Social Aspects of BSFL-Based Resources

Little research has been done on the bioconversion of insects, even though many studies have examined the life cycle assessment (LCA) of this process. (Salomone *et al.,* 2017). However, because of the previously described benefits of BSFL, applications like biodiesel and the food industry have a lot of potential in the context of waste valorization. Thus, further research on LCA evaluation on BSFL is required. Prior research has indicated that the bioconversion of bone shoals from biomass has a lower environmental impact than the conversion from other animal sources, such fishmeal and chicken meat (Ravi *et al.,* 2020). In comparison to traditional composting with nitrogen fertiliser, the process of producing biodiesel based on BSFL decreased CO2 net emission and the global warming potential index (Salomone *et al.,* 2017).

For the food business to utilise more environmentally friendly BSFL, public acceptability is essential. The odour, flavour, and texture differences between livestock fed conventional feed and feed containing BSFL did not significantly affect the meat quality or flavour (Cullere *et al.,* 2018). Furthermore, it was verified that the amounts of ash, protein, lipids, and water in the meat supplied to BSFL and the control group were comparable. As a result, BSFL can take the place of the present source of fat, soybean oil. Furthermore, there were no nutritional differences between ordinary sausages and sausages containing BSFL, nor were there any variations in taste-determining characteristics including texture and gumminess (Bessa *et al.,* 2019).

However, because of concerns regarding its safety, the public may not embrace the consumption of BSFL. However, during heating steps like boiling, the majority of the microorganisms that might be present in BSFL are eliminated. Furthermore, insects like mealworms are already consumed as food in Asia and Europe, despite the differences in their eating habits (Bessa *et al.,* 2020). To address the issue of food scarcity and promote sustainable development resulting from population growth, there is a need to raise public awareness of the uses of BSFL as food.

Conclusions:

Using BSFL for food waste treatment has attracted a lot of attention because of its benefits, which include sustainability and the potential to use resources obtained from BSFL. By treating food waste with BSFL, one can significantly lessen the amount of hazardous compounds produced by current disposal techniques, such as incineration and landfills, as well as a number of other environmental issues. Furthermore, useful items like oils and proteins can be made with

BSFL. High-quality biodiesel that has been bioconverted from food waste can be obtained from BSFL through a series of manufacturing stages. Furthermore, because BSFL contain nutritional properties that are similar to those of current animal diets, they can be used as animal feed. Given that abiotic variables like light, temperature, and salinity have a significant impact on BSFL production, the advancement of culture technology is crucial to the profitability of BSFL applications in Asian nations. Small enterprises could achieve significant returns with minimal investment by cultivating black soybean leaves (BSFL) in Asian countries with sufficient light and a temperate climate. Thus, in Asia, where it is challenging to obtain the technology needed to treat organic waste, food waste disposal via BSFL would be a suitable approach to put into practice. Asian nations can benefit from industrial uses of BSFL by conducting more research on energy production and waste treatment, particularly with regard to culture techniques.

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COMMERCIAL PRODUCTION OF MACRO BIOLOGICAL BIOCONTROL AGENTS FOR SUSTAINABLE PEST MANAGEMENT IN INDIA

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Abstract:

The utilization of biocontrol agents, including parasitoids and predators, has gained significant momentum in India over the last decade. Various successful instances of biocontrol application have been observed, such as the control of lantana weed growth and sugarcane pyrilla infestations. Additionally, *Trichogramma* species have been effectively employed against sugarcane borers and cotton bollworms. However, despite these successes, the production and usage of biocontrol agents remain limited, meeting less than 1% of the demand for cropped areas. There is a growing need for increased investment and private participation to bridge this gap and enhance production**.**

Macrobial Biopesticides

The major macrobial products used in India are parasitoids and predators. Parasitoids attack and develop in all insect stages, e.g egg parasitoid. Parasitoids may attack an earlier stage than the one from which emergence may occur, e.g. attacks larva, emerges from pupa, larval-pupal parasitoid. The host range is variable; broad vs narrow (Ballal and Verghese, 2015). To rear parasitoids, we need to rear the factitious host in large numbers which would serve as host for the natural enemy. In the following paragraphs we would discuss in detail how to rear most common insect parasitoids.

Status of Bio-control agents / Bio-pesticide usage in India

The last ten years have seen a huge advancement in biopesticide research, particularly in the standardisation of methods for producing a variety of microorganisms that can be used to combat a wide range of illnesses and insect pests.

- There are a number of instances where bio control agents have been successfully employed in India. Some examples of these are given below:
- Telonemia scrupulosa was utilised to manage the growth of lantana weed.
- Several States have effectively managed sugarcane pyrilla by introducing Epiricania melanoleuca and Tetrastictus pyrillae, the plant's natural enemies.

- To combat sugarcane borers, *Trichogramma*, a parasite that consumes their eggs, has been employed in Tamil Nadu, Rajasthan, Uttar Pradesh, Bihar, and Haryana.
- Similarly, the management of cotton bollworms involves the use of *Trichogramma*, Bracon, Chelonus, and Chrysopa spp. *Trichogramma* has also been utilised to combat leaf folders and rice stem borer.
- Predatory coccinellid beetles in Uttar Pradesh, West Bengal, Gujarat, and Karnataka have been successful in controlling the sugarcane scale bug. Lately, the use of bio-pesticides has grown due to the significant improvement in their efficacy brought about by thorough and methodical study.
- Additionally, in recent years, methods for producing biopesticides in large quantities, storing them, transporting them, and applying them have improved.

Scope for Commercial Production of Bio-control agents

Even with the 140 or so biopesticide production facilities that the nation now has, they are unable to supply the needs of more than 1% of the planted area. There is a large gap that can only be filled by expanding the number of units used to produce biopesticides. Given that the need for biological control agents is growing yearly, there is potential to boost their production and application in the future. Both private involvement and significant investment are needed for this.

As this field has garnered a great deal of enthusiastic acclaim over the past century, workers in the biological control of insects, mites, and seed pest suppression must continue to deepen and widen their efforts in the years ahead. These researchers demonstrated effective real-world outcomes in over 60 nations. The field that is now underutilised has multiple potential avenues for growth.

1. Promoting Basic Research:

There is a great deal of room to expand the research that can enhance and complement biological control. Studying basic study areas in biology, ecology, biosystematics, behaviour, biochemistry, population dynamics, and other related fields is important since they contribute significantly to the understanding of biological suppression. This studio would support grenuy in implementing pest management techniques.

2. Scope to Exploit the Bioagent on Crop Pest:

Approximately 98% of insect pests are spontaneously controlled by their natural enemies. Nevertheless, according to reports, entomophage introduction has only ever been used for 5% of the world's insect problem species (DeBack, 1974). Seventy percent of parasitic hymenoptera are thought to still be undiscovered species.

3. Help to Reduce Pollution Hazards:

By lowering the amount of harmful pesticides and their adverse effects, the use of bioagents can aid in the construction of a strategy for controlling the population of dangerous pests.

4. Necessity to Intensify of New Horizons of Biological Control:

The popular idea of biological control involves the importation and utilisation of parasitoids and predators, which has shown promising results in a number of cases. Similar to this, new trends like the utilisation of parasite hybrids, biotypes, strains, and novel biopesticides like viruses and entomogenous fungi must be thoroughly investigated and their harmonic application in pest control must be fully realised.

5. Adoption of Biological Control Methods in Agro Industries:

While using bioagents has numerous advantages, other approaches, such as chemical pest management, must be adjusted. The pesticides must be recognised and used in pest control suppression; they should be less harmful to natural adversaries. For instance, Endosulfan is safe for a wide variety of insects and predators.

Biological control helps in maintaining 'Balance of Nature' as it is the phase of natural control.

Location of Commercial Bio-control Agents Production Unit

Facilities for biopesticides should be established in regions with suitable climates in order to get the best outcomes. because places without harsh weather tend to have less expensive temperature regulation. In addition to the weather, the location's closeness to the market is crucial. To avoid contamination of the production facilities by pesticides from the agricultural regions, care must be made to position the facilities at least a quarter of a mile away from the farming areas. Additionally, the manufacturing of biopesticides should be situated far from urban and industrial regions because air pollution can harm them.

1. Objectives of Commercial Production of Bio-control agents

- Establishing the bankability of mass multiplication of different bio-agents mentioned in the models is the main goal of bio-pesticide initiatives.
- To provide guidelines for lending money to business owners who could be considering establishing biopesticide units.
- To encourage the establishment of further bio-control production units and to widely distribute the technology

Practical use of natural enemies (parasitoids, predators and pathogens) in insect pest management is more recent following the knowledge of population dynamics and the factors regulating the abundance of pests in nature. In many instances, the varied level of failures observed in Classical Biological Control programmes has been attributed to:

1. Inadequate procedures,
2. Ecological asynchrony,
3. Competition from local natural enemies,
4. Lack of alternate hosts or food,
5. Feeding niche of target pests which is inaccessible to natural enemies,
6. Inadequate knowledge of host and natural enemy taxonomy and
7. Insufficient time and effort spent on the biological control project.

Since low-quality and insufficient natural enemy populations employed in releases may result in ineffective pest suppression, quality management of mass-reared natural enemies is a crucial component of augmentation. The three main areas of quality control are: (i) production control, which involves keeping an eye on the general practices used in raising the host and its natural enemies; (ii) process control, which involves keeping an eye on the quality of the unfinished product, such as the percentage of hatching, pupation, larval and pupal weight, etc.; and (iii) quality control, which involves keeping an eye on the quality of the finished product, such as the percentage of emergence, sex ratio, fecundity, longevity, searching ability, etc.

2. Before Initiation of Biological Control of any Insect Pest Following Factors are to be Considered:

1. Identification of proper stage of the insect pest for application of biological control agents: Identification of the vulnerable stage of the insect pest plays a major role in the success of any biocontrol programme. We have very little knowledge about the activities and presence of the insect pest in the offseason period. Knowledge on precise hibernating or aestivating site of the insect pests is lacking. In absence of these facts success of biocontrol programmes is always a debatable issue.
2. Identification of effective biological control agents: Biological control is a serious endeavor for professionals: it cannot become a panacea for enthusiasts having little of the formal training and understanding of the basis of this discipline. It is challenging to evaluate the biological effects of exotic biological control agents on target pests, and only a small number of cases have been extensively documented, which makes economic analysis challenging. It would be much more difficult to factor into the calculation the monetary value of beneficial side effects (such as the advantage society gains from lessening or doing away with the use of undesirable pesticides) brought about by the advent of an efficient natural adversary. In comparison to a single natural enemy species, many natural enemy species that have established themselves on the same host are more likely to parasitize it over a larger geographic area. It is commonly known that the behaviour and morphology of wild parasitoid populations vary depending on the season and location. Differences include aggressiveness, heat and cold tolerance, uniparentalism,

gregarious versus solitary development, the number of eggs deposited into a single host, larval cannibalism intensity and parasitoid size.

3. Price of organic produce versus non-organic produce: This is a serious issue and a major hurdle in adoption of biological control practices by Indian farmers. In India on an average the buyers do not differentiate between organically grown product and non-organic produce. When a crop is grown organically the yield are compromised so the cost of production per unit increases, however if the cost of environmental is considered then obviously it is cheaper. The average Indian buyer is not concerned with the reduction of pesticide load in the marketable product so the real benefit can never be estimated. Of late health conscious people staying in metro cities and most of the other state capital have started recognizing the benefits of organically grown products and are ready to pay a premium for it. But this is awareness is still in infancy only.

4. Influence of synthetic pesticide marketing professionals: In rural India an average farmer talk to the pesticide shopkeeper for the insecticide to be used for insect pest management. The pesticide company representatives give expert guidance for pest management using their company products. Even with the presence of effective natural control, growers may still visualize a high positive risk of pest outbreak and may apply cheap pesticides as insurance against risk of pests, but in paying the premium they may become stuck in a treadmill of pesticide use. Actually, the root of the problem is that pesticides are preferred because the social costs are not paid by the users.

Once these factors are considered, it is imperative to consider the best biocontrol agent required for effective management of the pest. Broadly the biopesticides are classified into two types viz., micro (microbials, biochemicals and plant incorporated protectants) and macro types (parasitoids and predators). The requirement of each of the above mentioned class depends on the availability of the natural enemy in the local market. A farmer usually does not have any choice among the available biopesticides.

An entrepreneur needs to consider these factors and decide whether to establish a microbial/macrobial product laboratory. The entrepreneur must bear in mind that microbial products can be stored for couple of months but macrobial products are highly perishable and cannot be stored more than a fortnight under the best possible conditions or else the efficacy would be drastically reduced.

Commercial Production of Biocontrol Agents

Commercial biological control laboratories can play an important role in meeting the ever-increasing demand for predators and parasitoids. These are essentially biofactories where the natural enemies are mass produced with professional expertise and made available at reasonable prices with necessary handling instructions (Smitha *et al.*, 2023). Efforts are on for in titre maring to reduce costs and make rearing possible under optimum nutritional conditions on a large scale. Un pitre production of *Trichogramma* spp. coccinellids, chrysopids, grocorids, tachninids, etc, has been attempted with varying degree of success in different countries. Internationally, more than 125 species of entomophagous arthropods are commercially available for augmentative biological control programmes, including 37 commonly used species, such as the spider mite predator, *Playteseisles persimiles*, the whitefly parasitoid, *Encarsia formosa* and the moth e83 parasitoid, *Trichogramma* spp. Based on sale figures of the natural enemies used th main pest species targeted for augmentative biological control in glasshouse crops are whiteflies (33%), thrips (22%), spider mites (16%), aphids (13%) and others (16%) (Kundoo and Khan, 2017).

There are many commercial insectaries operating in USA, Canada, and the erstwhile USSR, which, in turn, are supported by several smaller production units. Similar insectaries also eust in the Netherlands, Germany and other countries. In the People's Republic of China, mass production centers are located in the communes of several provinces. These produce millions of predators and parasitoids of a variety of pests and supply them to the needy farmers (Parrella and Lewis, 2017). The industry providing natural enemies has grown tremendously over the last 30 years in the USA. There are more than 142 commercial suppliers over 130 different species of beneficial organisms, of which 53 are arthropod predators and 46 are parasitoids. The categories of organisms included 17 predatory mites, 4 stored product pest parasitoids and predators, 17 aphid parasitoids and predators, 9 whitefly parasitoids and predators, 23 greenhouse pest parasitoids and predators, 7 scale and mealy bug parasitoids and predators, 12 insect egg parasitoids, 6 moth and butterfly larvae parasitoids, 8 filth fly parasitoids, 4 other insect parasitoids and 21 general predators. Annual sales of natural enemies in the USA amount to about $ 9-10 million and about 60 million globally (El-Wakeil, and Gaafar, 2020).

In Europe, major use of parasitoids and predators has been for the control of insect pests in greenhouses. As early as 1968, *P. persimilis* was commercially produced and released for the control of two-spotted spider mite, *Tetranychus urticae* in glasshouse cucumber. Presently, more than 20 species of biological control agents are sold commercially for use in cucumber, tomato, sweet pepper, eggplant, bean, melon, strawberry and ornamentais. Europe has 15 natural enemy producers including the world's three largest, whereas there are about 50 commercial producers worldwide. The three largest companies serve more than 75 per cent of the greenhouse biological control market. Of the about 125 biological control agents that are marketed internationally, about thirty make up 90 per cent of the total sales. The total market for greenhouse natural enemies at end-user level was estimated to be more than US $ 30 million in 1993 The most important markets are The Netherlands, UK and France, followed by North America. Together these countries account for about two thirds of the total market. The largest commercial producer of biological control agents i.e. Koppert Biological Systems, The Netherlands rears about 15 billion arthropod natural enemies annually, with production of about 600 million individuals during a peak week and about 300 million individuals in more quiet weeks. Production of 15 billion natural enemies demands the rearing of 60 billion host insects. Based on these data, it has been estimated that the world-wide commercial production of arthopod natural enemies concerns about 30-40 billion organisms per year. n India, the first state run biofactory was established in 1930 to produce *Trichogramma*tids. The first private insectary Biocontrol Research Laboratory was established at Bangalore in 1981 Since then, numerous companies have come up countrywide, producing predators (mainly coccinellids and chrysopids) and a variety of parasitoids (notably *Trichogramma* spp. and its various strains).

To create bioagents for augmentation, there are 26 Central Integrated Pest Management Centres (CIPMC) spread throughout several states. An information database on government and private bioagent producers in India has been assembled by the National Bureau of Agriculturally Important Insects (NBAII). This indicates that 128 organizations—80 of which are commercial businesses—produce bioagents, together with 26 pest control facilities, 10 agricultural universities, 8 ICAR institutions, and 4 breeding labs. Production of several species of *Trichogramma*, primarily *T. chilonis,* involves a maximum of 34 units. There are eleven predators made by various companies, the two most common being *Cryptolaemus montrouzieri* and *Chrysoperla carnea*.

For the first time in India, private commercial biocontrol research laboratories have been set up and these include Biocontrol Research Laboratory of Pest Control (India) Ltd. at Bangalore, the main Biocontrol Laboratory of the Tamil Nadu Cooperative Sugar Federation, Chingleput and the Biocontrol Laboratory of Nawanshaher Cooperative Sugar Mills in Punjab. The Bangalore Laboratory supplies parasitoids and predators for the control of grape mealy bugs, coconut laboratories in Punjab leaf caterpillar, sugarcane cane borers, etc. The sugar mill and Tamil Nadu produce *Trichogramma* spp. for the control of sugarcane borers. The Department of Biotechnology has come out with a scheme of setting up pilot plants for mass production of *Trichogramma/ Chrysoperla* and microbial pesticides in Tamil Nadu to cover 5000 ha area through biological control (Jayaraj *et al.*, 1994). A similar area of sugarcane crop is also being covered in Pakistan under a collaborating project between International Institute of Biological Control (IIBC) and Habib Sugar Mills Ltd.

Agricultural universities and research institutes should strive to develop cost effective techniques for mass production of biocontrol agents using indigenous materials. The Government development departments and Cooperatives should come forward to mass produce biocontrol agents and supply these to farmers at subsidised rates. Farm graduates and unemployed rural youth may be trained in the mass production techniques and encouraged to set up biocontrol units in rural areas for gainful employment (Jayaraj, 1995).

Successful Bio-Control Programmes in India

Sugarcane Pyrilla (*Pyrilla perpusilla*):

During 1972–1973, there was a serious Sugarcane Pyrilla outbreak in the states of Punjab, Haryana, Uttar Pradesh, and Bihar. This outbreak was effectively contained by using possible biocontrol agents, such as the nymphal predator Epipyrops melanoleuca and the egg parasitoid Tetrastichus pyrillae. The Government Exchequer was spared an amount of Rs. 11,000 crores as a result. In a similar vein, in 1987, this problem resurfaced in a few states that grow sugarcane, and this time, the government's coffers were spared a whopping Rs. 16.00 crores thanks to the plant's potential bioagents. Potential biocontrol agents of this pest effectively reduced its severe occurrence in Karnataka in 1994.

Apple woolly aphid (*Eriosoma lanigerum*) and Sanjose scale (*Quadraspidiotus perniciosus*)

In the apple-growing states of the nation, bioagents such as Encarsia perniciosi, Aphytis spp., Chilocorus bijugus, Pharoscymnus spp., etc., in the case of the Sanjose scale, and Aphelinus mali, Syrphus confrater, Chrysopa scelestes, etc., in the case of the apple woolly aphid

Water hyacinth (*Eichhornia crassipes*):

This aquatic weed was successfully controlled in Southern states of India through its two exotic phytophagous weevils i.e. *Neochetinae ichhorniae* and *N. Bruchi.*

Sugarcane white woolly aphid (*Seratovacuna lanigera*):

Bio agents such as Dipha aphidivora, Chrysoperla spp., Coccinellid beetles, Syrphid flies, and some spiders were also effective in controlling this sugarcane pest in the states of Maharashtra and Karnataka, where it had caused significant financial harm to farmers during its 2003–2004 outbreak.

Laboratory Requirements for Macrobial Biocontrol Agent

To establish a commercial macrobial biocontrol agent laboratory the following factors must be looked into and considered.

Critical Factors

- **Knowledge intensive business**: The person should be well trained and should get intensive knowledge of this technology before starting this business. In addition, intensive management and planning, record keeping, and patience will also be required.
- **Mites infestation in host culture (*C. cephalonica*):** *C. cephalonica* is used as a host culture for mass rearing of *Trichogramma sp.* Mites infestation in *C. cephalonica* is a very common problem which causes mortality of *C. cephalonica*. Mortality of host culture can undermine mass production of *Trichogramma sp.*
- **Sex ratio of *Trichogramma sp.*:** Rearing without adopting standard protocols may yield more number of *Trichogramma* males than females. It will adversely affect the mass production of *Trichgramma sp.*

- **Fecundity of factitious host insect (*C. cephalonica*) and egg parasitoid (*Trichogramma sp.*):** Low fecundity of hosts insects and parasitoids will decrease the mass production of parasitoids.
- **Continuous electricity supply for mass rearing facility**: Uninterrupted supply of electricity is required to maintain optimum environment (temperature, humidity, photo period) for successful production of parasitoids and hosts, otherwise culture of host insects and parasitoids will be lost. For continuous electricity supply, a powerful energy backup (generator) will be required.
- **Mortality of bio-control agents caused by pesticide spray:** Insecticide sprays in field would cause mortality of parasitoids.
- **Regular monitoring of parasitoids and pests:** The farmers using Tricho cards should visit and monitor his crop and parasitoid cards regularly. Tricho cards needs to be replaced as and when felt necessary so that parasitoids should remain available in the field.
- **Frequent releases of Tricho cards:** Tricho cards should be applied in the field at 10 days interval regularly, so that *Trichogramma sp.* presence in the field would not allow pest population build up.
- **Effective marketing:** The person involved in bio-control business should contact the farmers in different areas to convince them for biological control and sale of bio-control agents (Tricho cards).
- **Installed and operational capacities:** This pre-feasibility suggests that the proposed bio-control laboratory has the capacity to produce 100000 Tricho cards that will be sufficient for management of tissue bores in 1000 acres for one year.

Geographical Potential for Investment

Vegetable/rice/cotton growing areas.

✓ **Potential target market**

Farmers involved in agriculture would be the main clients. The above mentioned areas are suitable. The investor has to work hard for marketing as done by pesticide companies.

✓ **Production process flow**

Active period for the production of Tricho cards will be 6 months that is period of kharif/rainy season when tissue borer infestation in the field is relatively high. Rest of the period will be utilized for the management of host and parasitoid culture

✓ **Project cost summary**

A detailed financial model has to be developed to analyze the commercial viability of biocontrol laboratory under the different Loan Schemes of government of India. Various cost and revenue related assumptions, along with results of the analysis, are to be prepared well in advance before establishment of the commercial production facility.

- ✓ **Space requirement**

The total operation of producing Trico cards requires one room of 12x12 area and a store room of 8x8.

- ✓ **Raw material requirements**

Following raw material is required for one year

- ✓ **Human resource requirement**

Total number of skilled human resource is 5. One entomologist/microbiologist, two laboratory technicians are required. Two labors will be hired.

Conclusion:

The commercial production of macrobial biocontrol agents presents significant opportunities for addressing pest management challenges in India. While successful instances of biocontrol application have been demonstrated, there is still considerable scope for expansion and improvement. Key factors such as proper identification of vulnerable pest stages, selection of effective biocontrol agents, and consideration of market dynamics need to be addressed. Additionally, attention to quality control in mass rearing facilities and the development of cost-effective production techniques using indigenous materials are crucial. With concerted efforts from stakeholders, including government agencies, cooperatives, and entrepreneurs, the widespread adoption of biocontrol methods can contribute to sustainable pest management practices and reduce reliance on chemical pesticides.

Future Prospects for the Commercial Production of Macrobiological Biocontrol Agents in India:

- Increased Investment and Private Participation: There is a growing need for increased investment and private participation in the production of biocontrol agents. Currently, there are only about 140 biopesticide production units in the country, meeting less than 1% of the demand for cropped areas. This presents a significant opportunity for entrepreneurs and investors to establish more production units and bridge the gap in supply.
- Scope for Expansion: With the demand for biocontrol agents increasing every year, there is ample scope for expanding production in the coming years. This expansion would require setting up more biocontrol production units across different regions of the country.
- Promoting Basic Research: Increased research is required in the fundamental biological control-related disciplines of biology, ecology, biosystematics, behaviour, and biochemistry. This research can help with two things: improving biological suppression effectiveness and developing integrated pest management (IPM) strategies.
- Exploiting Bioagents on Crop Pests: While about 98% of insect pests are naturally regulated by natural enemies, only a small percentage of insect pest species have been targeted for biological control. There is potential to expand the use of bioagents by identifying and exploiting more natural enemies for effective pest management.

- Reducing Pollution Hazards: The utilization of bioagents can help reduce the reliance on chemical pesticides, thereby reducing pollution hazards associated with their use. This aspect of biological control aligns with the goal of establishing a population regulation process for pests while minimizing the use of toxic chemicals.
- Exploring New Horizons: Investigating innovative biopesticides such entomogenous fungi and viruses, as well as new trends and techniques in biological control, is necessary. Examples of these include the utilisation of biotypes, strains, and hybrids of parasites. Furthermore, while making sure that biological control techniques are compatible with other pest management strategies, it should be encouraged for agro-industries to employ these techniques.
- Government Support and Initiatives: Government agencies, agricultural universities, and research institutes should continue to support the development of cost-effective techniques for mass production of biocontrol agents. Initiatives to train farm graduates and unemployed rural youth in mass production techniques can also contribute to the growth of the biocontrol industry.

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COMMERCIAL PRODUCTION OF MICROBIOLOGICAL BIOCONTROL AGENTS FOR SUSTAINABLE PEST MANAGEMENT IN INDIA

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Abstract:

Microbial biopesticides have emerged as vital tools in agricultural pest management strategies in India, driven by concerns over synthetic pesticide hazards, environmental sustainability, and the increasing demand for organic produce. This review highlights the diverse range of microbial agents employed, including bacteria, viruses, fungi, nematodes, and protozoa, along with their applications and commercialization trends. It discusses the regulatory landscape, adoption drivers, and the significant growth of the biopesticides market. Drawing on historical perspectives and current trends, the review outlines key strategies for future development and adoption, emphasizing the need for efficacy validation, affordability, supply chain enhancement, and leveraging India's rich biodiversity and traditional knowledge for sustainable agricultural practices.

Microbial Biopesticides

The major microbial products used in India for insect pest management are nuclear polyhedrosis viruses (NPV), *Bacillus thuringiensis*, *Bacillus sphericus*, *Metarhizium anisopliae*, *Beauvaria bassiana* and *Verticillium lecani*. Pathogens attack and develop in all insect stages, e.g eggs, larvae, pupae and adults. The host range is variable; broad vs narrow. Most of the viral pathogens are highly specific to genus level, however some of the NPVs are species specific also. The bacterial pathogens are mostly pathogenic to larval stages of lepidopterans, coleopterans and dipterans. The fungal pathogens are non-specific in nature and may equally infect the beneficial insects also. In the following paragraphs we would discuss in detail how to mass produce the most common insect pathogens. A total of 970 biopesticides registered in India by Central Insecticide Board and Registration Committee (CIB&RC) under the 1968 Insecticide Act which include microbial biopesticides of *Bacillus thuringiensis var. kurstaki* (42), *var. israelensis* (22), var. *sphaericus (*05), var. *galleriae* (01), *Pseudomonas fluorescence* (196), *Bacillus subtilis* (04), *Trichoderma viride* (289), T. harzianum (51), Ampyliomyces quisqualis (02), Beauveria bassiana (106), *Metarhizium anisopliae* (30), *Verticillium lecani* (93), *Verticillium chlamydosporium* (03), *Helicoverpa armigera* NPV (30) and *Spodoptera litura* NPV (03) and only 38 biopesticidal formulations. Fungal based- (*Trichderma* sp.) and *Pseudomonas* based- biopesticides are popular in India consumption-wise while *Bacillus thuringiensis* based formulations are widely used for plant protection of abroad agriculture

Use of Pathogens in Insect Biocontrol

Insect pathogens are used in biological control in at least three different ways: inundative applications, inoculative releases, management of naturally occurring pathogens, and introduction of exotic pathogens as classical biological control agents.

Inundative Applications:

- They are those in which insect pathogens are applied in large quantities with the goal of killing as many individuals of the pest population as quickly as possible.
- Pathogens used in this manner are called microbial insecticides.
- Replication of the pathogen in the host and production of additional infectious propagules may be desirable, but is not usually required for microbial insecticides to be effective

Inoculative applications:

- Inoculative applications are those in which small quantities of insect pathogens are applied or released into an insect host population.
- The goal is to produce infections in at least a few hosts, which will, in turn, produce numerous infectious propagules that will infect many more susceptible hosts.

Introduction of exotic pathogens as biocontrol agents:

- Hundreds of exotic parasitoids and predators have been introduced into different countries as classical biological control agents however few exotic species of pathogens have been intentionally introduced.
- Difficulties in identifying and isolating insect pathogens, along with regulatory uncertainties, have contributed to the under-utilization of insect pathogens as exotic biological control agents.

What's Driving Biopesticide Adoption in India?

The world population is expected to reach 9 billion by 2050. This population growth of 2 to 3 billion people over the next 30 years, combined with the changing diets, would result in a predicted increase in food demand of around 70% by 2050 (UNDESA, 2009). Less per capita arable land and water are needed to provide more food and livelihood options for the growing population. Damage caused by insect and pest is one of the major limiting factors foragricultural food grain production. A major portion of expenditure on pesticides is for protecting the crop in the field (Kumar, 2013). Pesticides are used in most countries around the world to protect agricultural and horticultural crops against damage by pests and diseases. Injudicious use and unintentional poisoning of synthetic pesticides resulted deadly consequences. Exposure to chemical pesticides can have effects that are acute, chronic and long-term. Unregulated misuse of chemical pesticides leads to mobilization of toxic residues across the food chain, increasing bioaccumulation and environmental persistence. Non-target organisms, beneficial insects, land

and aquatic animals are badly affected with the excessive use of chemical pesticides. Additionally, chemical pesticide poisoning poses a global concern due to unnatural death caused by mishandling of chemical pesticides. Biopesticide is one of the promising alternatives which can manage menace caused by pests in agriculture, persistency of pesticides, environmental pollutions, toxic and ill effects on nontarget species (Singh *et al.*,2011). The development of biopesticides stimulates modernization of agriculture and will, without a doubt, gradually largely gradually replace chemical pesticides.

With a compound annual growth rate (CAGR) of 9.38%, the biopesticides market in India is expected to reach $130.37 million by 2029. The focus on crop protection techniques and the growing market for organic and biological goods are the main drivers of this increase. As per a recent Agribusiness Global DIRECT issue, farmers are increasingly adopting biopesticides because of their efficaciousness in managing illnesses, soil-borne pathogens, and soil erosion.

Increased fruit and vegetable exports, farmers' knowledge of the benefits of biopesticides, the use of integrated pest management techniques, and the expansion of organic farming land are all factors driving the market. The majority of the biopesticides produced in India are microbial biopesticides, which shield crops from bacteria, fungi, and other contaminants. Numerous microbial biopesticides have been produced by companies such as Coramandal International. The biofungicides, bioherbicides, and bioinsecticides segments make up the Indian biopesticides market. The nation's tropical climate is contributing to the bioinsecticides market's faster growth. In India, biopesticides are mostly used on fruits and vegetables, then oilseeds and grains.

Biopesticides are biodegradable, action-specific, and can respond to chemical-pesticide-mediated pest resistance issues (Mishra *et al*.,2020). Biopesticide-driven sustainable agriculture promotes economic productivity, social equity, and environmental preservation. The tripartite notion of sustainable development is made up of all three components. Because of their effective control over the green chemistry principles (GC principles) and the tripartite idea of sustainable development, biopesticides are highly influential in the field of sustainable agriculture management (Fenibo *et al.,* 2020). Biopesticides are becoming more and more popular since they are seen as safer than traditional pesticides. By their very nature, biopesticides are less toxic than regular pesticides and are more targeted towards the specific pests. Additionally, biopesticides can be applied sparingly and break down quickly without leaving behind any undesirable residues, which may reduce the requirement for conventional pesticides in integrated pest management (IPM) programmes. (Swati *et al.,* 2016)

Biopesticide use accounts for about 9% of all pesticide use in India (Rajni *et al.,* 2022), and by 2050, it's expected to account for as much as 50% of the pesticide market (Keswani, 2020).2.5 percent per year is the anticipated growth rate (Rajni *et al.,* 2022). But as of right now, the biopesticide business is still modest compared to the market for synthetic pesticides and has not grown as much as expected (Keswani, 2020). Due to several obstacles at the industrial and policy levels, the production is relatively lower. However, the National Farmer Policy of 2007 has supported the use of biopesticides for sustainable farming (Dar *et al.,* 2019). Furthermore, data indicates that during the previous three decades, India has used more biopesticides. During the period of 1994–1995 to 1999–2000, the consumption of neem, one of the most commonly used biopesticides in India, increased from 83 metric tonnes (MT) to 686 MT, while the use of Bacillus thuringiensis (Bt) decreased from 40 to 71 MT. Between 1994 and 1995, the usage of biopesticides rose to 123 metric tonnes (MT) and 8110 MT in 2011 and 2012, respectively, exceeding projections (Anindita *et al.,* 2022). According to PPQS figures (GOI,2022), the total amount of biopesticides used in India increased by 40% between 2014–2015 and 2018–2019. Over time, this amount reached 8847 and 8645 metric tonnes in 2019–2020 and 2020–2021, respectively (Rajni *et al.,* 2022). In the meantime, the amount of chemical pesticides consumed dropped dramatically during the same period, from 56,114 MT to 43,584 MT (Bikramjit and Biswas, 2008).

The Insecticides Act of 1968 registers and regulates biopesticides. According to the Insecticide Act of 1968, only 12 different types of biopesticides have been registered in India 9 (Rajni *et al.*, 2022). They are:

1. *Bacillus thuringiensis var. israelensis;*
2. *Bacillus thuringiensis var. kurstaki*;
3. *Bacillus thuringiensis var. galleriae;*
4. *Bacillus sphaericus;*
5. *Trichoderma viride;*
6. *Trichoderma harzianum;*
7. *Pseudomonas fluorescens;*
8. NPV of *Helicoverpa armigera;*
9. *Beauveria bassiana;*
10. NPV of *Spodoptera litura;*
11. Neem-based pesticides;
12. Cymbopogon.

The bulk of biopesticides are employed in public health, with the exception of a small number that are used in agriculture.

Commercialization

The organisms that comprise the microbial pest control market are bacteria, viruses, fungi, nematodes and protozoa. The annual market for microbial pesticides has been steady at around £ 20-25 million. However, the scenario has changed during the last decade. While the current growth in the chemical insecticide market is around 1-2 per cent per annum, the growth in the microbial pest control market is now running at around 10 per cent per year. Some estimates have even projected growth for microbial pesticides to be as high as 25 per cent per annum

Bacteria

Although more than 100 bacteria have been identified as arthropod pathogens, only Bacillus thuringiensis has achieved commercial success for pest suppression. Thisbacterium has been registered for use on a diversity of pests in over 100 different formulations throughout North America and Europe. Two other bacilli, *B. popilliae* and *B. sphaericus* have been used in more specialised niches, and are likely to undergo further commercial development in the future. The only nonbacillus microbial insecticide to have been registered for use on an insect pest comprises the application of *Serratia entomophila* to control the pastureland grub, *Costelytra zealandica,* in New Zealand. To date, bacterial pesticides have been used to control an enormous diversity of lepidopteran, dipteran and coleopteran pests in agriculture, forestry and public health, Registration of Bts has been comparatively easier because they are naturally occurring insect pathogens with relatively less effects on non-target organisms. They nave been registered for use on a wide variety of crops, including many niche markets not available to synthetic insecticides. The Bts are currently registered in USA on over 50 vegetable crops, 10 small fruits and berries, 20 nuts, citrus, pome and stone fruits, 9 legumes, 30 field crops, 15 herbs and spices, bedding plants, flowers, ornamentals, turf, forestry, landscape trees and shrubs, and various tropical crops. Most of the current products registered for the control of lepidopteran pests are based on Btk strain HD-1.

Dulmage (1970) reported an isolate of subsp. kurstaki, that later was produced by Abbot Laboratories as the first major commercial Bt product called Dipel. Presently, kurstaki HD-1 based products are registered for nearly 30 crops and against over 100 pest insect species worldwide.

In India, the credit for production of an indigenous Bt product on a pilot scale in 1968 goes to Prof. S. K. Majumdar and his team of research workers at the Central Food Technological Research Institute (CFTRI), Mysore and it was named as Lepidopterocide (Majumdar, 1968). Subsequently, indigenously isolated Bt strains were obtained from various crop pests at many places but no serious efforts were made to exploit these bacteria anywhere in India. Recently, the interest in production and utilization of these eco-safe locally available Bt isolates has again picked up. Bt var. kenyte isolated from *Ephestia cautella* (Walker) by scientists at Bhaba Atomic Research Centre (BARC), Trombay, has shown effectiveness against several economically important pest insect species. Pilot-scale production of Bt var. israelensis was also successfully accomplished in 1001 fermentation chambers in South India. Local strains of Bt are being investigated for development of bacterial insecticides in almost all the agricultural universities/research institutes in India (Battu and Arora, 1997). Several Bt based products are being marketed in India by various agrochemical industries. These are mainly effective against lepidopteran pests.

Viruses

A number of viral pesticides have been registered for commercial use for control of lepidopteran pests of agricultural and horticultural crops. However, the most successful use of viruses to date has been against the temperate forest pests where high damage thresholds and limited pest complexes exist. For example, both the pine sawfly, *Neodiprion sertifer* and Douglas fir tussock moth, *Orgyia pseudotsugata*, are successfully controlled by baculovirus pesticides. It is because these products are usually registered for use by government departments and they are not available to the general public. To date, no virus-based pesticides have been developed for the control of mosquitoes, flies or other dipteran pests.

Elcar (Sandoz Inc.), the NPV of *Helicoverpa zea* (Boddie), was the first baculovirus to be created for commercial use. It was mainly created for use on cotton and was registered by the Environmental Protection Agency in the United States in 1975 (Ignoffo, 1981). Elcar was effective in controlling soybean, sorghum, corn, tomato, chickpea and navy beans and was infectious against all main Helicoverpa/Heliothis species. Elcar's popularity declined with the introduction of synthetic pyrethroids in the late 1970s, and manufacturing was halted in 1982. Nonetheless, a number of GVs and NPVs have been registered for use in insect pest control in Europe and other regions of the world over the past 20 years (Table 8.6). Biosys launched GemStar LC in 1996 as a liquid concentrated formulation of HzNPV for *H. zea* and *H. virescens* (Fabricius) in US cotton. The NPV of soybean caterpillar, Anticarsia gemmatalis (Hubner) is the most widely used viral pesticide and is applied annually on more than 1 million ha of soybean crop in Brazil. The virus is produced directly in the farmers' fields to lower rearing costs (Moscardi, 1999).

Fungi

Of over 800 species of fungi known to be pathogenic to insects, only seven have been commercialized. The first mycoinsecticide to be registered was *Hirsutella thompsonii* produced by Abbott Labs under the trade name of Mycar It received full registration in USA in 1981, which was cancelled in 1988. Subsequently, a British firm registered two strains of *Verticillium lecanii*; Vertalec was effective against aphids and Mycotal was targeted for the control of greenhouse whitefly. Currently, the most widely used fungal insecticide is Beauveria bassiana. There are at least three major strains of *B. bassiana* being marketed in USA, Europe and South America. *B. bassiana* strain Bb-147 is registered on maize (Ostrinil) in Europe for the control of the European corn borer, *Ostrinia nubilalis* and the Asiatic corn borer, *Ostrinia furnacalis*. B. *hassiana* strain GHA is registered in USA for control of aphids, whitefly, thrips and mealy bugs (Mycotrol and Botanigard). *B. bassiana* strain ATCC 74040 is registered against many soft-bodied insects in the orders Homoptera and Coleoptera (Naturalis).

There are currently two registered fungal insecticides in the genus Metarhizium. *M. anisopliae* is registered in USA for use in roach traps (Biopath) and for control of termites (Bioblasť). *M. flavoviride* has been registered by the International Institute of Biological Control for the control of grasshoppers and locusts in Africa and the tropics. *Parcilomyces fumosoroseus* has recently been registered in USA for the control of whitefly, thrips, aphids and mites. Three species of fungi, viz. *B. bassiana*, *M. anisopliae* and *Paecilomyces* sp. are currently commercially available in India.

Nematodes

More than 300 nematode-insect relationships have been described to-date. However, mainly two families of the nematodes, Heterorhabditidae and *Steinernema*tidae, have been extensively used to develop commercial formulations. The first commercially available formulation was *Romanomermis culicivorax*, which was registered against mosquitoes in USA in 1976. The registration was subsequently cancelled due to the success of alternative products. Currently, there are eight species of nematodes (7 for insect pests and 1 for slugs) that are available for pest control (Table 5.7). These are Nematodes from three genera and are being sold/and or manufactured by over a dozen companies offering 36 different products. The attributes of these nematode based formulations that make them amenable to production and use are ease of mass production, efficacy comparable to synthetic pesticides and safety to non-target organisms.

In general, *Steinernema*tids and heterorhabditids have shown excellent results in habitats where high humidity could be maintained, e.g. soil inhabiting insects and borersPraxis continues to offer *Steinernema glaseri* in the USA for grub control. Thermo Trilogy has just registered *S. ribobrave* for the management of many pests, including citrus root weevil (*Pachnaeus litus*), blue-green weevil (*P. opalus*), sugarcane rootstalk borer (*Diaprepes abbreviatus*), and mole crickets (*Scapteriscus* spp.). S. scapterisci was first generated by Biosys (now Thermo Trilogy), who licenced it to Ecogen. It was isolated from mole crickets in South America. There are two species of heterorhabditids that are currently commercially available. *Heterorhabditis megidis* is sold mostly in Europe for weevil and soil insect control. *H. bacteriophora* is effective against a wide range of soil insects but is sold primarily for the control of Japanese beetle.

In India, both steinenematidis and heterorhabditids are marketed by Bio-Sense Crop Protection (Eco-Max Agrosystems Ltd.), Mumbai. *Steinernema* sp. is commercially available for the control of Amercian bollworm, pink bollworm, tobacco caterpillar, white grub, shoot borer, stem borer, tuber moth, spotted bollworm and leaf eating caterpillar on crops like cotton, groundnut, sugarcane, rice, potato, tomato, chilies, okra, sunflower and legumes. *Heterorhabditis* sp. is available for the control of white grub, flea beetle, grey weevil, and red palm weevil on groundnuts and coconut.

Protozoa

At present, there is only one registered protozoan insecticide targeted against grasshoppers and the Mormon cricket. The microsporidian *Nosema locustae* is known to infect at least 60 species of grasshoppers and crickets. It is sold in the western USA as Nolo Bait by M & R Sait by Durango go and Grasshopper Control Semaspore Bait Berteficial Insectary. Both the products are formulated on bean that is consumed by the grasshoppers. However, the utility of N. locustae as a grasshopper control agent remains questionable and after more than a decade of use, its field effectiveness in USA, Canada and Africa is known to vary. Moreover, protozoan formulations are very expensive to manufacture and tend to cause chronic rather than acute infections.

Opportunities in India

Harmful impact of chemicals such as higher pesticides residues in food crops, specifically on grains and increasing pest resistance has brought into focus the use of safer and effective alternative such as bioagents/biopesticides. Furthermore, the area used for organic crop farming is expanding due to the rising demand for organic food brought on by people's increased awareness of their health. This suggests that the biopesticide industry has enormous room to grow. The biopesticides industry is predicted to grow more, according to analysts (Desai, 1997). India has a wealth of options for natural biological control organisms and plant-based natural insecticides because of its rich biodiversity. The rich traditional knowledge base that India's highly diverse indigenous tribes have access to could hold important secrets for creating more advanced and potent biopesticides. The promotion of biopesticides has been highly advocated by the National Farmer Policy 2007 as a means of boosting agricultural output while maintaining the environment and farmer health. It also states that biopesticides will receive the same level of support and promotion as chemical pesticides. Further requirements for increased adoption are:

1. Verifiable proof of biopesticides' effectiveness in reducing crop damage and boosting crop yield
2. The availability of reasonably priced, excellent products
3. Increasing the use of biopesticides by fortifying supply chain management. In this sense, a reliable method of transporting biopesticides from the factory to the farm where they are needed is crucial.

Issues with Microbiological Process Contamination

Evaluation of the concepts and procedures for removing microbial contamination from fermentation processes should take into account multiple factors:

a. The kind of metabolite that is produced;
b. Particular characteristics of the culture;
c. Process machinery and gear;
d. Nutrient medium and the ingredients needed to prepare it;

e. Technology utilised in the process.

Contaminating microorganisms adversely affect the microbial process by:

a. Destroying the cells of the production strain;
b. Inactivating the synthesized metabolites;
c. Producing substances affecting the producer's metabolism and thus decreasing the production of the required metabolite;
d. Exhausting compounds crucial for growth and product synthesis from the medium.

It is frequently challenging to identify contamination in the absence of a decline in metabolite or spore production, which is not always the case when a contaminating microbe is present. Failure in a semi-solid fermentation process is not necessarily the result of contamination. Gram-negative microorganisms enter the medium through cooling system leaks, while Gram-positive germs from the air are typically the result of poor packing or failed air filters.

Facilities required for Commercial Production

In line with the technology and objective of biopesticide production, various facilities are required for the successful implementation of such projects which are indicated below.

Land: It is required to set up laboratory and other facilities and office. Space may also be required for installing tube well/dug well and parking of vehicles. A minimum of 1500 - 3000 sq.mt of land is required for setting up of a 200 TPA unit. Preferably, the entire site should be fenced with barbed wire or compound wall with gates at suitable places. The boundary may be planted with thick and all season growing tree species like Asoka, Eucalyptus etc to filter air and reduce dust.

Layout and Buildings: The factory building for the laboratory, carrier preparation and enrichment, sterilisation, inoculation and quality control, culture maturation, mixing and packing, storage/staff, etc., is included in the civil works. The manufacturing of products and other utilities require a total covered area of around 6000-9000 square feet. Future growth will require the remaining land space.

Plant and Machinery: Manufacture of biopesticides needs a good number of laboratory equipments as well as other production facilities such as fermenters, culture medium tank, fermenter assembly, autoclaves, boiler, broth dispensers, demineralising plant, air compressor etc,. All the machines are manufactured in the country. Some of the suppliers may undertake the installing of units on a turnkey basis.

Manufacturing Process and Source of Technology: The mother cultures of various strains of biopesticides are supplied from Agricultural Universities, Research Institutes and National / Regional Centres of Organic Farming (MOA). Biopesticide strains are available with technology dissemination centres and as per the requirements of license. The unit generally comprises of media preparation room, media store room, inoculation room, growth room, culture transfer room, sterilization, mixing and packing etc. The floor plan should be designed to promote maximum efficiency and minimum contamination. The design should facilitate maintenance of optimum temperature, humidity and ventilation. Inside air of the unit should be free from dust particles.

Infrastructural facilities for raw material, carrier material and utilities: The raw materials needed to produce biopesticides include carrier, growing medium ingredients for broth formation, and packaging materials such bottles, corrugated boxes, and polythene packets.

Utilities

1. **Power:** Normally a three phase electric supply is required for these plants. The normal requirements of a 200 TPA unit is about 40-75 KVA (depending upon the type of machineries and fuel used). Depending upon the position of power supply, stand by generator may be needed.
2. **Water:** A biopesticide production unit requires water mainly for steam generation for sterilization of carrier, broth preparation and cleaning of equipments. Accordingly, well/bore well of appropriate capacity and according to the quality of water demineralisation equipments are to be installed. The average per day requirement of water for 200 TPA capacities shall be about 3500 to 4000 liters.
3. **Compressed air:** It will be required for various pneumatic operations as well as for controlled air supply to fermenters, sterilization/cleaning operations etc,

Manpower

For a unit manufacturing 200 TPA biofertilisers the requirements of manpower is as under:

One chief Entomologist/Microbiologist, two Assistant Entomologist/Microbiologist, two Sales Officer, one Accountant and clerical Assistant, two drivers, one Floor Supervisor/Production Supervisor, one/two Technical Staff (boiler operator where boiling operation is required, mechanical maintenance, packing machine operators, electrical maintenance), four/five Skilled laborers, seven/eight Semi-skilled laborers, depending upon the volume of production

Unit of Size: The size of a biopesticide unit could be expressed in terms of the capacity of production for various types/strains of biopesticide per annum. The projects so far set up in our country vary from 10 TPA to 2000 TPA. The size envisaged in the present model is 200 TPA in one shift. The capacity can be easily expanded by adding a few additional equipments like fermenters and automation in packaging.

Environmental aspects and Pollution Control

No hazardous effluents are generated from biopesticide unit.

Requirement of Registration/License

All production facilities and trading units are required to register and obtain necessary license for production/sale of biopesticide from state controlling authorities (Department of Agriculture). Biopesticides are covered under Central Insecticides Act and all manufacturers are required to obtain mandatory license from Central Insecticides Board, Govt. of India, Faridabad.

Capital Cost of the Project

Broadly, the capital cost includes the cost of land, development of land, fencing, civil works (plant building, office, godown etc.) plant and machinery, preliminary and preoperative expenses etc.

Subsidy from Government of India

Ministry of Agriculture, Department of Agriculture and Cooperation, Government of India is implementing a National Project on Organic Farming (NPOF) for the production, promotion & market development of organic farming in the country through National Centre of Organic Farming (NCOF), Ghaziabad and its six Regional Centre of Organic Farming (RCOF) located at Bangalore, Bhubaneswar, Hissar, Imphal, Jabalpur and Nagpur. One of the important components of the project includes financial assistance for setting up of commercial biopesticide production units. Under the project subsidy is being provided through NABARD/NCDC @ 25% of total financial out lay (TFO) or Rs. 40 lakh per unit whichever is less for establishment of biopesticide production units with installed production capacity of 200 MT per year. Assistance is also available to the existing units for technological up-gradation, strengthening and capacity addition on similar terms and conditions restricted to 25% of financial out lay for additional cost, restricted to Rs. 40 lakh whichever is less. Subsidy assistance is available through commercial banks as credit linked back-ended subsidy.

Economics of the Project

The project's economics have been calculated throughout the duration of the project or until the bank loan is repaid, taking into account a number of techno-economic factors. The sale of biopesticides is one of the revenue sources. The cost of raw materials, commission and transportation, electricity, fuel, packing, distribution, pay and wages, maintenance and repairs, insurance, advertising, and other overheads are all included in the expense. Every year's income and expenses are calculated and put through a cash flow analysis.

The critical factors which are responsible for the effectiveness of these bio-inputs are as follows:

- Suitability of the species to the target crop/pest
- Suitability of the stain
- Determining which strains are appropriate for the agro-eco system, taking into account the pH and moisture content of the soil. Research has allowed for the identification of particular strains that are suitable for a given soil and habitat, and pure mother cultures are kept in labs to be supplied to commercial manufacturers.
- The aseptic conditions of manufacturing, the cell count of living organism present in the

carrier material, purity and level of contamination.

- The conditions of carrier material in which the culture is packed and the quality of the packing material, which determine the shelf life.
- The conditions, in which the packed materials are stored, distributed and kept with the farmers before it is applied.
- Soil conditions particularly pH, organic matter content and moisture level; and agronomic practices.

Points to be considered for commercial manufacture of biopesticides

The manufacturing process in short involves the following steps

i. Selection of suitable strain of the organism for which market demand is identified.
ii. Mass multiplication.
iii. Mixing of the culture with carrier material and packing.

The steps involved are as follows:

Culture Selection and Maintenance

Many agricultural universities, IARI, some ICAR facilities, National/Regional Centres of Organic Farming of MOA, and other organisations preserve pure mother cultures of different strains. International supply sources including IRRI, NifTAL, and others are also available. One can obtain the appropriate strain's mother culture in test tubes from the sources that have been identified. They must be further sub-cultured and kept exclusively for mass manufacturing using conventional methods while being supervised by a qualified microbiologist.

Culture Augmentation

In the next stage the culture need to be up-scaled in steps from small mother culture to broth in required quantities. A defined synthetic medium (specific to each organism) is prepared, sterilized and inoculated by requisite mother culture. Fully grown bacterial broth is ready within 5-7 days time. Depending upon the quantity to be harvested a series of fermentation vessels are needed.

Formulation of Product

Carrier Sterilization (for carrier based powdered formulations): While the broth is getting ready in the fermenter the carrier material, which may contain contaminants, is sterilized in autoclaves and kept ready for mixing with the both. The carrier is either sterilized in bulk or it is packed and then the packets are sterilized. However the system will depend on the specific methodology which has been standardized.

Mixing and packing: There are 2-3 alternatives depending upon the sophistication and automation of the unit.

- ✓ Under non sterile system, the broth is harvested from the fermenter and mixed with sterilized carrier - the mixing is done mechanically under aseptic condition and packed in polythene bags of desired quantity.

- ✓ In a slightly upgraded method, the broth and sterilized carrier are poured and sealed in polythene bags simultaneously under sterile conditions through automatic form-fill and seal machines. Prepared packets are manually smudged to ensure mixing. In such cases carrier need to be fortified with suitable dispersing agents.

The carrier is sealed and packed in autoclavable polypropylene bags under a sterile system. After that, these packages are autoclaved to achieve sterility. These packages are directly filled with fermentation broth using a measured volume dispenser. The injection hole is shut right away. The packets are stored in the store room after approximately a week of incubation. It is advised that the sterile packaging system, which uses an auto syringe and dispenser, be used for all new units as it is the best approach.

Formulation and packaging of liquid biofertilizers Liquid formulations are formulated into final product in the fermenters at the time of fermentation and are packed directly into pre-sterilized polypropylene bottles with the help of automatic bottle filling machines under sterile conditions. Absolute sterility can be obtained by placing these machines in sterile cabins provided with forced sterile air facilities.

Equipment Needed: The equipments needed for manufacture and lab are listed below. They are available through scientific and laboratory equipment suppliers.

Layout of the Production Unit: The biopesticide plant should be housed in a suitable building complex. The main production unit should have separate channels for bacteriological work, carrier making and mixing and customer and visitor/marketing way. In addition there should be rooms with separate entrance for utilities like power, steam generator and stores. Appropriate design can be adopted in consultation with scientists/engineers.

Raw Material: The chief raw materials needed for the production of biopesticide are as follows.

- Mother cultures
- Chemicals for growth medium
- Emulsifying agents, thickening agents, stickers, dispersing agents, stabilizers etc.
- Carrier material – Talc, bentonite, barium sulphate, fumes of silica, diatomaceous earth, Fuller's earth etc. or other materials of desired quality in powder from (100-200 mesh) etc.
- Polythene bags, polypropylene bottles, HDPE bags, cardboard cartons etc.

Quality Control: Biopesticides are covered under Central Insecticides Act and specifications and quality requirements are prescribed. All the requirements under FCO are mandatory and need to be followed.

Limitations and Constraints: The major limiting factors include:

At Product Level

- Narrow genetic base of mother cultures and lack of efficient and virulent strains suitable to various agro-environments.
- Unsatisfactory carrier material in respect of uniformity and good quality against imported

peat material.

- High contamination in broth mixing and packing stages, not using completely closed system of production.
- Unsatisfactory packing material which reduces shelf life.
- Poor storage conditions, especially while the product is being distributed. The microbial culture is destroyed by exposure to sunshine and hot temperatures. It is best to store them in a cold storage environment. Not employing properly trained microbiologist.
- Lack of awareness among farmers for its proper application.

At Field Level

The efficiency when applied to crops is limited by several factors; most important among them being, drought and high summer temperature, water logging, contamination by other organisms and nutrient deficiency. There is an acute shortage of awareness among the farmers on the subject.

Conclusion:

Microbial biopesticides have emerged as promising alternatives to synthetic pesticides in India, driven by concerns over environmental sustainability and human health. The country's biopesticides market has witnessed significant growth, propelled by factors such as increasing demand for organic produce, regulatory support, and technological advancements. However, challenges persist, including the need for robust efficacy validation, affordability, and efficient supply chain management. Leveraging India's rich biodiversity and traditional knowledge presents opportunities for developing novel biopesticides and enhancing their adoption. Moving forward, collaborative efforts among stakeholders, including government agencies, research institutions, and industry players, are essential to realize the full potential of microbial biopesticides in sustainable agricultural practices.

Future Prospects:

The future of microbial biopesticides in India holds promise, with opportunities for innovation and expansion. Continued research and development efforts aimed at enhancing efficacy, affordability, and environmental sustainability will be crucial. Leveraging advances in biotechnology, such as genetic engineering and nanotechnology, can further enhance the effectiveness of microbial biopesticides. Strengthening partnerships between academia, industry, and government agencies will facilitate technology transfer and commercialization. Additionally, investments in infrastructure, training, and capacity-building initiatives will support the development and adoption of biopesticides across diverse agricultural landscapes. By capitalizing on India's rich biodiversity and traditional knowledge systems, the country can position itself as a global leader in sustainable agricultural practices, contributing to food security, environmental conservation, and rural livelihoods.

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From Bugs to Bucks:
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