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Review on Insect-Mediated Composting Methods

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ABSTRACT

Composting is a natural process of decomposing organic materials such as food scraps, yard waste, and other biodegradable materials under controlled conditions. It is a process that mimics nature's way of breaking down organic matter into a rich, dark, and earthy-smelling soil amendment called compost. Composting can be done in various ways, including using a compost bin, a compost tumbler, or simply creating a compost pile.

Insect-mediated composting is a method of composting organic waste using the larvae of certain insects, such as black soldier flies, red runner cockroaches, dermestid beetles etc. In this process, the insects consume the organic waste, breaking it down into simpler compounds and producing nutrient-rich compost. Insect-mediated composting is a sustainable and efficient way to manage organic waste, and it has gained attention as a potential solution for addressing the growing problem of waste management in many countries.

Information on insect-mediated composting was gathered from secondary data sources. These sources identified black soldier fly larvae, red runner cockroaches, dermestid beetles, dung beetles, mealworms, and soldier beetles as suitable insects for composting. However, challenges were encountered while collecting data from various sources. Future research could explore comparative studies of these insects in the composting process.

The present paper concludes that the insects used in composting are Black Soldier Fly Larvae, Red Runner Cockroaches, Dermestid Beetles, Dung Beetles, Meal worms, Soldier beetle. It was observed from table 2 that majority of the insects (Dermestid Beetles , Dung beetles, Meal worm, Soldier Beetles) undergo four main stages i.e Egg, Larvae, pupae and adult in life cycle. However black soldier fly larvae (BSFL) have five stages of family life cycle while red runner coackroach has 3 stages of life cycle. Larval stage was the longest phase of the life cycle for dermestid beetles, dung beetles, Mealworms and soldier beetles; adult stage was longest phase for red runner coach where as larvae and pupae stages are the longest phases for black soldier fly larvae (BSFL). Table 3 revealed that more or less same steps were found in processing the compost by these six types of insects. feasibility of rearing of the insects at household level was observed, only black soldier fly larvae (BSFL) found to have low space requirements, low maintenance with efficient waste reduction and production of protein(Table 4). It was observed from table 5 that all 6 types of insects can compost at commercial level by following the same steps that have been observed in household-level composting. Organic waste, such as fruit and vegetable scraps, food waste, agricultural waste, and animal manure, is collected from different sources. The waste is sorted and processed to remove any non-biodegradable materials. Reasons for the feasibility of black soldier fly larvae (BSFL) rearing at commercial level revealed that high reproduction rate, high feed conversion efficiency, low maintenance, multiple revenue strings and environmental benefits (Table 6). Various countries were rearing different types of insects for composting the waste. Except soldier beetle rest of the five types of the insects are being reared in USA (Table 7). When insect rearing places were observed in India it showed that soldier beetle is not being reared in India at all. While Karnataka, Tamilnadu and Maharashtra states are rearing other five types of insects (Table 8). Since these insects are pretentious food, its consumption and acceptance in different countries was observed (Table 9). Mexico Thailand, China, Vietnam, Cambodia and many African countries consume these insects by roasting or frying. In US and Europe there is a growing interest in edible insects. However several constraints were observed to promote insects for consumption in India (Table 10) i.e majorly cultural barriers followed by lack of awareness, regulatory challenges, environmental concerns and legal barriers. The technology and equipment is necessary for large scale production and processing of insects for human consumption is not readily available. Compost generated by these six types of insects has good nutrient content so that it can be used for plants as fertilizer (Table 11). Insect composting has a positive effect on reducing the release of green house gases (Table 12).It was noticed that insect mediated compost reduces the emission of carbon dioxide, methane and nitrous oxide. Benefits of the insect mediated compost were analysed in Table 13.Various advantages observed were reduced waste disposal cost, increased nutrient value, improved soil health, reduced green house gases emissions, reduced water usage and enhanced biodiversity, plant growth and yield. Advantages of insect mediated rearing in India were found to be effective organic waste management, biodiversity conservation, sustainable lively hood, reduction in chemical fertilizer use and low maintenance (Table 15).

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Insect mediate rearing in India found to face certain disadvantages like high cost of infrastructure and maintenance lack of technical knowledge rules and regulations , limited market demand and climate sensivity. India has a large growing population that present's the significant market for insect based enterprises which depend on various factors like demand for insect byproducts in the market, interest in sustainable agriculture, resilient to climate change, regulatory requirements, market demand and rate of investment (Table18). Different by products are generated from insect mediated composting which include larvae, oil, frass, chitin and protein powder exclusively from BSFL (Table19). Table 20 revealed the cost of insect mediated composting affected by several factors such as labour cost, infrastructure cost, feed stock cost, equipment cost marketing and distribution cost. Equipment cost includes the cost of containers or bins for the compost, Labour cost include the size of operation and number of people involved in managing the compost. The cost of insect mediated compost based on quality revealed that high quality red runner coackroach compost is very expensive i.e 300 rupees per kg while high quality compost for dung beetles is 150 Rs per Kg (Table 21). Any insect based compost cost can be estimated based on the amount of feed stock requirement and amount of labour required, cost of equipment and infrastructure (Scale of operation) : Cost of feed stock such as food waste, agricultural waste and yard waste and transportation cost (Table 22).

Keywords: *decomposing , compost, organic materials, biodegradable materials, food scraps, yard waste, compost bin, compost tumbler, a compost pile, larvae, egg, pupae, adult, life cycle, efficiency, low maintenance, multiple revenue strings, black soldier flies, red runner cockroaches, dermestid beetles, dung beetles, meal worms, soldier beetles, byproducts, equipment, infrastructure, consumption.*

Introduction

Composting is a natural process of decomposing organic materials such as food scraps, yard waste, and other biodegradable materials under controlled conditions.The process involves microorganisms such as bacteria, fungi, and other decomposers that break down the organic materials into simpler forms that can be used as plant nutrients. Composting can be done in various ways, including using a compost bin, a compost tumbler, or simply creating a compost pile. The resulting compost can be used to enrich soil, improve plant growth, and reduce the need for chemical fertilizers.

Insect-mediated composting is a method of composting organic waste using the larvae of certain insects, such as black soldier flies, red runner cockroaches, dermestid beetles etc. In this process, the insects consume the organic waste, breaking it down into simpler compounds and producing nutrient-rich compost. The larvae of black soldier flies, red runner cockroaches, dermestid beetles etcare particularly efficient at consuming organic waste and can significantly reduce the time it takes to compost compared to traditional composting methods.

Table – 1 Insects Used in Composting

S.No	Name of the Insect	Scientific Name	Family Name
1.	Black soldier fly larvae	Hermetia illucens	Stratiomyidae
2.	Red runner Cockroaches	Shelfordella lateralis	Blattidae
3.	Dermestid Beetles	Dermestes maculatus	Dermestidae
4.	Dung beetles	African dung beetle	Scarabaeidae
5.	Meal worm	Tenebrio molitor.	Tenebrionidae
6.	Soldier Beetles	Cantharis rustica	Cantharidae

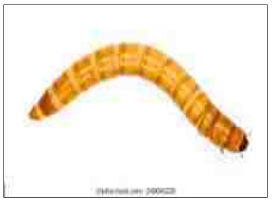
The Insects used in composting are Black Soldier Fly Larvae, Red Runner Cockroaches, Dermestid Beetles, Dung Beetles, Meal worms, Soldier beetle. (Diener, S., Zurbrügg, C., &Tockner, K. (2009))

Black soldier fly larvae

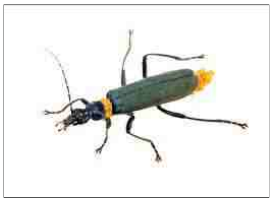
Red Runner Cockroaches

Dermestid Beetles

Dung Beetles



Meal worms



Soldier Beetles

Table – 2 Life cycle of the insects used in the composting

S.No	Name of the Insect	Life Cycle Stages					Longest phase of the life cycle	Eggs Production	Total life cycle	Days taken for harvesting compost
		Egg	Larvae	Prepupae	Pupae	Adult				
1.	Black soldier fly larvae	√	√	√	√	√	Larva, Pupa stage	500 -900	38 days	21 days
2.	Red runner Cockroaches	√	Nymph	√	X	X	Adult stage	300 - 800	6 -12 months	Several weeks to months
3.	Dermestid Beetles	√	√	X	X	X	Larval stage	300 - 2000	Few months to year	Several weeks to months
4.	Dung beetles	√	√	X	√	√	Larval stage	100-200	few weeks to several months	several Weeks

5.	Meal worm	√	√	X	√	√	Larval stage	500	several months to years	Several weeks to months
6.	Soldier Beetles	√	√	X	√	√	Larval stage	1300	Weeks to months	several Weeks to months

It was observed from table 2 that the majority of the insects (Dermestid Beetles , Dung beetles, Meal worm, Soldier Beetles) undergo four main stages i.e Egg, Larvae, pupae and adultin life cycle.However black soldier fly larvae (BSFL) have five stages of family life cycle while red runner coackroach has 3 stages of life cycle.Larval stage was the longest phase of the life cycle for dermestid beetles,dung beetles, Mealworms and soldier beetles;adult stage was the longest phase for red runner coach where as larvae and pupae stages are the longest phases for black soldier fly larvae (BSFL).

Dermestid beetles lay a maximum number of eggs i.e 300 -2000 followed by soldier beetles i.e up to 1300 and the minimum number was laid by dung beetles i.e 100 -200 number.When total life cycle is compared, red runner coackroach and Dermisted beetles have few months to year while dung beetle and soldier beetle has life cycle of few weeks to months and only black soldier fly larvae(BSFL) has shortest life cycle i.e 38 days. The number of days taken for composting by bsfl was minimum i.e 21 days while rest of the insects takes several weeks to months to compost the waste.

Table – 3 Process of composting at household level

S.No	Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
1.	Get a container	Choosing a bin	Choose a container	Choose a location	Choose a container	Collect your composting materials:
2.	Add organic waste	Adding bedding material	Adding bedding material	Build your compost pile	Add bedding	Prepare the compost bin
3.	Introduce insect	Introducing the red runner cockroaches	Add food scraps	Introduce dung beetles	Add mealworms	Add the organic materials
4.	Provide food and water	Adding organic waste	Add the beetles	Monitor the compost pile	Maintain the compost	Introduce soldier beetles:
5.	Harvest the compost	Maintaining the bin	Monitor and maintain:	Turn the compost pile	Harvest the compost	Maintain the compost bin
6.	-	Harvesting the compost	Harvest the compost:	Harvest the compost:	-	Harvest the compost

Composting by insects is an efficient and sustainable way to convert organic waste into nutrient-rich fertilizer. The basic process of composting by any insect includes choosing the right bin, adding bedding material, adding waste, introducing the insect, maintaining the bin and harvesting the compost. Table 3 revealed that more or less same steps were found in processing the compost by these six types of insects. Normally plastic/metal or even wooden box containers are used. Bedding material include food scraps, yard waste and other organic materials. During harvesting process, compost can be scooped out to be used in the gardens or flower beds.

Table – 4 Feasibility of the insects rearing at the household level

S.No	Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
1.	Low space requirement	Space	Available space	Climate	Climate	It is not feasible to rear soldier beetles
2.	Low maintenance	Equipment	Time	Availability of dung	Low startup cost	natural predators and feed on a wide variety of insects
3.	Efficient waste reduction	Raw materials	Resources	Space	Food waste management	
4.	Sustainable source of protein	Management	Local regulations	Knowledge	Nutritional value	
5.	Educational opportunity	Odor control		Benefits	Market demand	

feasibility of rearing of the insects at household level was observed, only black soldier fly larvae(BSFL) found to have low space requirement, low maintenance with efficient waste reduction and production of protein(Table 4). When soldier beetle was most difficult to rear at household level. While others insects require more space, specificequipment and appropriate climate.

Table – 5 Process of composting at commercial level with insects in India

S.No	Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
1.	Collection of organic waste	composting facility	Choose a location	Choose a location	Choose a site	Collecting composting materials
2.	Pre-composting	building the composting bins	Set up the containers	Build your compost pile,	Set up infrastructure	Prepare the compost bin
3.	Feeding the larvae	preparing the bedding material	Add bedding material	Introduce dung beetles,	Acquire supplies,	Add the organic materials,
4.	Harvesting of the larvae	introducing the red runner cockroaches	Add food scraps	Monitor the compost pile	Add food waste and bedding material	Introduce soldier beetles,
5.	Separating the compost	adding organic waste	Add the beetles	Turn the compost pile	Maintain the compost,	Maintain the compost bin
6.	Sale of larvae and compost:	harvesting the compost	Harvest the compost	Harvest the compost	Harvest the compost	Harvest the compost

It was observed from table 5 that all 6 types of insects can compost at commercial level by following the same steps that have been observed in household level composting.Organic waste, such as fruit and vegetable scraps, food waste, agricultural waste, and animal manure, is collected from different sources. The waste is sorted and processed to remove any non-biodegradable materials.This organic waste is mixed with carbon-rich materials like dried leaves or straw and water to create a compost pile. Which is left to sit for several days to allow for initial decomposition to occur. After pre composting larvae is fed ,compost is collected and separated from any undigested materials and finally put for sale as a nutrient rich fertilizer.

Table -6 Feasibility of the insects rearing in commercial level

S.No	Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
1.	High reproduction rate	High rate of decomposition	Market demand	Demand	Require minimal space	Availability of suitable breeding and rearing
2.	High feed conversion efficiency	high-quality compost production	Infrastructure	Infrastructure	Converting feed into protein	Availability of suitable food sources
3.	Low maintenance	reduced waste disposal costs	Cost of inputs	Quality assurance	Lack of infrastructure	Demand for soldier beetles and their by-products,
4.	Multiple revenue streams	revenue generation	Regulations	Knowledge	Technical know-how	Facilities
5.	Environmental benefits	eco-friendly and sustainable	Risk management.	Regulations		cost of production

Reasons for feasibility of black soldier fly larvae (BSFL) rearing at commercial level revealed that high reproduction rate, high feed conversion efficiency, low maintenance, multiple revenue strings and environmental benefits (Table 6). The reasons for composting red runner cockroaches are its high rate of decomposition, high quality compost production,reduced waste disposal cost, revenue generation, eco friendly and sustainability. More or less similar observations were made relating to the composting of other insects.

Table – 7 Insects rearing places in various countries used for composting

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
• Canada • European Union countries • South Africa • Australia • China • India • Indonesia • Malaysia • Thailand • Philippines • Brazil • Mexico • Colombia	• USA • Australia • South Africa • China • Mexico.	• USA • Canada • United Kingdom • Australia • South Africa • India	• Australia • South Africa • USA • Brazil • India	• USA • Canada • Netherlands • Australia • India	• North America • Europe • Asia • Australia

• Peru • Argentina • Nigeria • Kenya • Uganda • Rwanda					

Various countries were rearing different types of insects for composting the waste. Except soldier beetle rest of the five types of the insects are being reared in USA (Table 7). black soldier fly larvae (BSFL) is being reared in more than 20 countries while other insects are being reared in 3 – 4 countries which implies that bsfl can survive and sustain any kind of environment.

Table – 8 Insects rearing places in India

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Bangalore Karnataka Chennai Tamil Nadu Hyderabad Telangana Pune Maharashtra Delhi	• Karnataka • Tamil Nadu • Maharashtra • Andhra Pradesh • Kerala	• Tamil Nadu • Kerala • Maharashtra • Uttar Pradesh • Karnataka • Delhi	• Gujarat • Tamil Nadu • Maharashtra • Punjab • Karnataka	• Maharashtra • Karnataka • Tamil Nadu • Delhi • West Bengal • Gujarat	No states are working on it

When insect rearing places were observed in India it showed that soldier beetle is not being reared in India at all. While Karnataka, Tamilnadu and Maharashtra states are rearing other five types of insects (Table8)

Table – 9 Insect'sconsumption and its acceptance in different countries

Countries	Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Thailand	delicacy	stir fries and snacks	used in forensic entomology, museums, and taxidermy to clean animal remains	grilled and fried snacks	traditionaldiet	
Mexico		traditional food			traditionally used in local quizzing	
Africa				roasted or fried snack, soups and stees		
China					traditional diet	
North America in Europe						nutritional diet
Japan and Middle east countries		roasted or grilled delicacy			local diet	

Since these insects are protenatious food, its consumption and acceptance in different countries was observed(Table9). Mexico Thailand, China, Vietnam, Cambodiaand many African countries consume these insects by roasting or frying. In US and Europe there is a growing interest in edible insects.

Table – 10 Constraints to promote insects for consumption in India

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Cultural barriers	Cultural barriers	Cultural barriers	Cultural barriers	Cultural and social barriers	Cultural barriers
Lack of awareness	Regulatory issues	Lack of awareness	Lack of awareness	Lack of awareness and knowledge	Availability
Regulatory challenges	Lack of awareness	Availability	Food safety concerns	Limited availability	Regulations
Infrastructure limitations	Availability	Safety concerns	Legal barriers	Regulatory challenges	Consumer preferences
Cost considerations	Lack of infrastructure	Regulatory issues	Environmental concerns	Cost	
			Availability	Competition from traditional protein sources:	

However several constraints were observed to promote insects for consumption in India (Table 10) i.e majorly cultural barriers followed by lack of awareness, regulatory challenges, environmental concerns and legal barriers.The technology and equipment is necessary for large scale production and processing of insects for human consumption is not readily available.

Table – 11 Compost effect on nutrition of plants

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Increased nutrient availability	Positive effect on the nutrition of plants	Having higher content of nitrogen, phosphorus, and potassium	Increases nutrient cycling	Nutrient content	improves soil structure
Improved soil structure	Rich in nutrients	Used as a fertilizer	Improves soil fertility	Soil structure	water-holding capacity
Reduced need for synthetic fertilizers	Improvesresistance to disease and pests	Balanced and nutrient-rich	Improves soil structure	Microbial activity	nutrient availability
Increased microbial activity			Water retention	Ph balance	Improves overall health and productivity of plants
				Disease resistance	

The compost generated by these six types of insects is rich in nutrients, making it a valuable fertilizer for plants (Table 11). Due to its high nitrogen, phosphorus, and potassium content, this compost can enhance soil structure, increase nutrient cycling and water retention, and improve resistance to diseases and pests.

Table – 12 Effect of the insect mediated compost generation on the release of green house gases

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Reduced methane emissions	Minimizing the production of methane and a potent greenhouse gas	Positive impact on reducing greenhouse gas emissions	Improved soil structure and aeration	No Methane emissions becausethey do not possess the gut bacteria	Lowers emissions of carbon dioxide, methane, and nitrous oxide
Reduced carbon dioxide emissions	Improve soil health and fertility	Reduced methane emissions	Reduced methane production	Carbon sequestration	Lower environmental impact
Reduced nitrous oxide emissions		Reduced the amount of waste sent to landfills	Mitigates the environmental impact	Less nitrous oxide emission	Sustainable and environmentally friendly waste management system
		Reduces the need for chemical fertilizers			

Insect composting has a positive effect on reducing the release of green house gases (Table 12).It was noticed that insect mediated compost reduces the emission of carbon dioxide,methane and nitrous oxide. Thus reducing the need for using chemical fertilizers and maintains sustainable environment.

Table – 13 Benefits of the insect mediated compost in cost benefit ration

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Reduced waste disposal costs	Nutrient-Rich Soil Amendment	Efficient Decomposition	Nutrient Recycling	Waste Reduction	Organic Waste Reduction
Increased nutrient value	Improved Soil Structure	Clean and Dry Bones	Soil Aeration	Nutrient Recycling	Natural Pest Control
Improved soil health	Microbial Activity	Reduced Odour and Mess	Reduced Parasite Transmission	Protein Production	Pollination Assistance
Reduced greenhouse gas emissions	Reduced Need for Chemical Fertilizers	Reusability	Improved Pasture Quality	Low Environmental Impact	Biodiversity Support
Reduced water usage	Enhanced Plant Growth and Yield	Minimal Environmental Impact	Greenhouse Gas Mitigation	Reduced Methane Emissions	Low Environmental Impact
	Water Conservation	Educational and Recreational Use	Decreased Fly Nuisance	Educational and Research Value	Low Maintenance Requirements
	Soil Health and Biodiversity	Top of Form	Enhanced Biodiversity	Community Engagement	No Chemical Residues
			Reduced Chemical Inputs		Potential Economic Value

Benefits of the insect mediated compost were analysed in Table 13.Various advantages observed were reduced waste disposal cost,increased nutrient value,improved soil health,reduced green house gases emissions, reduced water usage and enhanced biodiversity, plant growth and yield.

Table – 14 Problems faced in insect mediated composting

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Temperature control	Temperature control	Slow composting process	Availability of dung beetles	Temperature requirements	Temperature requirements
Moisture control	Odor control	Limited types of organic matter	Temperature and moisture levels	Moisture levels	Moisture levels
Odour management	Nutrient balance	Temperature and humidity requirements	Predation	Nutrient balance	Nutrient requirements
Pest control	Predation	Odour and pest issues	Other decomposers	Contamination	Management and containment
Harvesting difficulties	Public perception	Regulatory issues	Chemical contamination	Scale	
			Scale	Odour	

Table 14 revealed the problems faced in insect mediated composting. Irrespective of the type of insect used for composting, certain common problems encountered were difficulty in temperature control, moisture control, odour control, predator control and harvesting difficulties. If temperature and moisture are not maintained properly larvae of any insect will develop mould growth and produces an unpleasant odour. As mature larvae in compost burry themselves, harvesting becomes a very challenging task. Hence screens or sieves are used to separate the larvae from the compost but requires time and effort.

Table – 15 Advantages of insect mediated rearing in India

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Waste Management	Low cost	Efficient at breaking down organic material	Organic waste management	Sustainable protein source	Effective pest control
Sustainable Protein Source	Efficient waste management	Natural and non-toxic	Reduction in chemical fertilizer use	Food waste management	Easy to rear
Low Cost	High nutritional value	Low-maintenance	Increased crop yields	Low cost and easy to rear	Nutritious animal feed
High Growth Rate	Sustainable	Sustainable	Reduction in greenhouse gas emissions	Nutritious	Sustainable waste management
Environmentally Friendly	Disease control	Useful in multiple applications	Biodiversity conservation	Potential income source	Potential income source
			Sustainable livelihoods	Environmental benefits	

Advantages of insect mediated rearing in India were found to be effective organic waste management, biodiversity conservation, sustainable lively hood, reduction in chemical fertilizer use and low maintenance (Table 15).

Table – 16 Disadvantages of insect mediated rearing in India

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Regulation	Escape risk	Odour	Cost of infrastructure and maintenance	Odour	Climate limitations
Limited Market	Odour	Temperature and humidity requirements	Limited market demand	Space requirements	Limited pest control efficacy
Climate Sensitivity	Regulatory issues	Potential for escape	Lack of technical knowledge	Health risks	Limited market demand
Labor Intensive	Health risks	Potential for spreading disease	Health and safety concerns	Limited market	Time and labor-intensive
Limited Infrastructure		Legal considerations	Potential ecological impacts	Regulatory issues	Limited research
				Limited technology	

Insect mediate rearing in India found to face certain disadvantages like high cost of infrastructure and maintenance lack of technical knowledge rules and regulations , limited market demand and climate sensivity.

Table – 17 Cost estimation for setting up of insectbased enterprises in India

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Land and Building	Infrastructure and facilities	Equipment and facilities	Infrastructure costs	Infrastructure	Rearing infrastructure
Equipment and Supplies	Equipment	Land and location	Dung beetle stock	Cost of Mealworms	Supplies
Labor	Red runner cockroach stock	Labor costs	Operating costs	Equipment	Labor
Other Expenses	Operating expenses	Materials and supplies	Marketing and distribution costs	Operational expenses	Marketing and distribution
		Regulatory compliance		Marketing expenses	

The cost of setting up insect based enterprises in India can vary depending on several factors such as availability of infrastructure and fecilities, equipment needed, operating cost, location of the facility (Table 17).

Table – 18 Feasibility of setting up insect based enterprise

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Low initial investment	Demand for cockroach byproducts in the market	Market demand	Availability of resources	High demand for protein	Abundance of waste
High feed conversion rate	Availability of resources	Infrastructure	Market demand	Availability of food waste	High demand for organic products
Diverse market opportunities	Regulatory requirements	Cost of inputs	Regulatory environment	Low cost and easy to rear	Low capital investment
Eco-friendly and sustainable	Cost of production	Regulatory compliance	Technical expertise	Growing interest in sustainable agriculture	Easy to rear
Resilience to climate change		Expertise		Government support	Potential for export
		Risk management		Potential for exports	

India has a large growing population that present's the significant market for insect based enterprises which depend on various factors like demand for insect byproducts in the market, interest in sustainable agriculture, resilient to climate change, regulatory requirements, market demand and rate of investment (Table18).

Table – 19 By products generated from composting different insects

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Frass	High-quality compost	Castings	Compost	Compost	High-quality compost
Pupae	Protein-rich insect meal	Larvae	Worms	Castings	Larvae
Oil	Cockroach frass	Adult beetles	Methane reduction	Larvae	Pupae
Protein powder	Liquid leachate	Clean bones	Water retention	Oil	Adults
Chitin			Reduced waste disposal costs	Chitin	Frass

Different by products are generated from insect mediated composting which include larvae,oil,frass,chitin and protein powder exclusively from BSFL (Table19). Chitin can be used in the production of biomedical materials, as a natural preservative in food industry as a sizing agent in textile industry. Oil can be used in production of biodiesel, soaps and cosmetics. Frass can be used as fertilizer for plants. Protein can be used in the production of animal feed,pet food and human food.

Table – 20 Factors affecting the cost of insect mediated composting

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Feedstock cost	Quality of the compost – higher quality higher price and lower quality lower price	Based on the raw materials	availability of dung beetles	Feedstock cost	Based on quality
Labor cost	Based on the availability of alternative products	Specialized equipment is required	Labor	Labor cost	based on market demand and value
Infrastructure cost	Based on the demand	Labor cost	Inputs	Equipment cost	feedstock materials
	Labor costs	Marketing and distribution	Marketing	Transportation cost	labor cost
			Regulatory compliance		

Table 20 revealed the cost of insect mediated composting affected by several factors such as labour cost,infrastructure cost,feed stock cost, equipment cost marketing and distribution cost.Equipment cost includes the cost of containers or bins for the compost, Labour cost include the size of operation and number of people involved in managing the compost. Field stock cost depends on availability and cost of organic waste materials.While infrastructurecost is associated with building or renovating facility for composting, electricity,water and waste disposal cost.While marketing and distribution cost include packaging and transportation cost

Table – 21 Cost estimation of insect mediated compost based on quality in India

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
High-quality compost - INR 250 per kg	High-quality compost – 300 INR	High-quality compost - INR 200 per kg	High-quality compost - INR 150 per kg	High-quality compost - INR 200 per kg	High-quality compost - INR 200 per kg
Low-quality compost- INR 80 per kg.	Low-quality compost- 100 INR	Low-quality compost- INR 80 per kg.	Low-quality compost- INR 50 per kg.	Low-quality compost- INR 60 per kg.	Low-quality compost- INR 70 per kg.

The cost of insect mediated compost based on quality revealed that high quality red runner coackroach compost is very expensive i.e 300 rupees per kg while high quality compost for dung beetles is 150 Rs per Kg (Table 21).When low quality compost price was compared compost from dung beetles was least expensive i.e 50rs per kg, compost from red runner coackroach i.e most expensive i.e 100 Rs per kg.

Table – 22 Cost estimation of insect mediated compost based on variables

Black Soldier Fly Larvae	Red Runner Cockroaches	Dermestid Beetles	Dung Beetles	Meal worms	Soldier beetle
Scale of operation	Scale of the operation	Raw Materials	Scale	Feedstock cost	Quality of the compost
Type and quality of feedstock	Cost of feedstock	Labor	Location	Labor cost	Demand for the product
Technology and infrastructure	Labor costs	Equipment	Type of waste	Equipment cost	Availability of competing products.
Labor costs	Other expenses	Market demand	Dung beetle species	Transportation cost	
Input costs			Infrastructure		
			Marketing		

Any insect based compost cost can be estimated based on the amount of feed stock requirement and amount of labour required,cost of equipment and infrastructure (Scale of operation) : Cost of feed stock such as food waste, agricultural waste and yard waste and transportation cost (Table 22). Therefore it is important to calculate the past factors, consider the local conditions and market demand before estimating the cost of producing compost.

Conclusion

Insect-mediated composting is a sustainable and efficient method for managing organic waste. By utilizing insects to break down organic matter, this process reduces landfill waste, greenhouse gas emissions, and produces high-quality compost that benefits soil health and plant growth. A significant research gap lies in the lack of specialized composting bins designed for rearing insects at both household and commercial levels. Additionally, there is a need to mitigate odors associated with insect rearing to make this practice more acceptable in residential and commercial settings. By reducing waste and generating valuable byproducts, insect-mediated composting can provide economic benefits. Further research is necessary to explore the use of Black Soldier Fly Larvae, Red Runner Cockroaches, Dermestid Beetles, Dung Beetles, Mealworms, and Soldier Beetles for waste management in India and internationally. The byproducts of these insects can potentially create a new revenue stream, transforming waste into wealth.

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