Pharmaceuticals from Nature: Exploring Insect By-products as Potential Pest Repellents in Medical and Agricultural Entomology

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ABSTRACT

Several medical and agricultural entomology studies on insect repellents have been spurred by the long-term study of the general interest in ecologically friendly pest management strategies. Drosophila has been eradicated in the majority of developed nations with the right adoption of pest management techniques and awareness of the proliferation of unpleasant insects like mosquitoes, but emerging nations are still having difficulties. Consequently, in the last ten years, the amount of in-depth research on the topic has dramatically expanded. Insect frass accumulates as a considerable byproduct in artificial rearing settings and can supplement or replace commercial fertilizers. Insects are not harmful to soil hygiene and can be used to provide nutrients to the soil. The development of biological repellents using insect by-products from insects like the Black Soldier Fly (BSF), Drosophila, and Weaver ants has received comparatively little attention. Their conspicuous qualities, which tend to exhibit potential characteristics, might be taken into account as one of the key factors in their selection as pest repellents. We discussed many types of repulsive using the olfactory route, particular receptors, excellency, irritancy, deterrence, smell masking, and visual masking as action mechanisms, and we intend to describe behavioural bioassays to separate them.

Keywords: *repellency*, *olfactory mechanism*, *gustatory mechanism*, *plant-derived products*, *Synthetic repellents*

INTRODUCTION

The general interest in using ecologically friendly pest control techniques has been studied for a prolonged period, which has prompted several studies on insect repellents in entomology, in both medical and agricultural fields. With adequate awareness of pest control methods and proper implementations of the growth of disease-spreading insects such as mosquitoes, Drosophila have been eliminated in most of the developed countries, but the developing countries are still struggling. Hence, over the past decade, extensive research has exponentially increased on the subject. Currently, a repellant is characterized as a behavioural reaction to a stimulus, and the distinctions between behavioural reactions might vary depending on the individual. In the past, a variety of occurrences have been referred to as "repellent." Hence, the ability to move away from an odour source while still being unable to locate the host is another way to characterize a repelling phenomenon [**1, 2**]. A device that prevents an insect from being drawn to a source of odour can also be regarded as a repellent. Based on observed insect behaviour, we can identify various types of repellents using this broad interpretation:

- True repellent or spatial repellent corresponding to the insect's directed flight away from a source of odour without making direct contact
- A reduction in the host's attractiveness or a disturbance in the host's localization by the smell cue are both examples of odour masking or attraction inhibition.
- An insect moving deliberately away from a chemical is known as contact irritancy or landing inhibition.
- Using a visual cue to visually disguise the host's attractiveness, as in flowers, can stop pollination.

We focused on these repellent phenomena, trying to illustrate them with experimental results. Following a summary of the gustatory and olfactory pathways, we also identified future repellent action mechanisms. To show how repellant can be used to manage insects and protect people or vegetation, we also reviewed several repellent action mechanisms, including the olfactory pathway, specific receptors, deterrence, irritancy, excellency, odour masking, and visual masking, and plan to describe behavioural bioassays to differentiate them.

About: Repellency

In various fields of science, repellency holds a completely different perspective. In medical entomology [**2**], for instance, a true repellent—well described as an excellent one—iis a substance that induces directed egress from the odour source [**3-5**]. Aphid alarm pheromone is one such example, causing dispersal in response to a predator's attack. (E)-b-farnesene is one of the most valued components in most species, causing aphid dispersal [**6**]. Moving away from the smell's source can come naturally or be learned through experience [**7**]. Creating an odour barrier to keep pests out of an area where a possible host may be present and functioning as a "safe zone" to minimize insect contact with hosts is the goal of a real repellent in pest management [**8**].

In nature, there are many insects that have been shown to be potential pest repellents that could be utilized in pest control. Ant species are one such species that have demonstrated their effectiveness as pest insect control agents in a wide range of crops [**9**]. For example, Weaver ants (*Oecophylla smaragdina* and *O. longinoda*) are reported to manage more than 50 different pests in 12 different crops and boost farmers' net income by more than 70% when traditional chemical regimes are replaced [**10, 11**]. Due to their predatory behaviour against other insects, especially herbivores, ants can directly eliminate nuisance insects. Moreover, communication relies on chemical cues that might serve as warning signals for possible prey or as a means for symbionts to maintain contact with their ant hosts. So, the sheer presence of ant pheromones may be enough to deter pest insects from ant colonies, and the pheromones may also be crucial in attracting symbionts, which may be required for efficient plant defense. This is further confirmed by the observation that ants not only leave pheromone trails but also more durable chemical signals. For instance, weaver ants create anal spots that they utilize to mark their territories and navigate. Even if they have been washed by rainwater and have been there for several months, ants can still find these deposits [**12**]. The density of the spots is positively connected with the likelihood of being discovered by an ant since these deposits are not only scattered throughout a colony's area but also strategically placed to reinforce ant trails [**13, 14**]. In conclusion, these deposits seem to be trustworthy warning signals to potential prey, and as a result, they may evolve the ability to recognize and avoid them ancient, yet very promising for integrated pest management.

Insects are essential for decomposition, pollination, and the spread of infections to humans and animals, as well as being the most obvious crop pests. Mosquito bites cause serious health problems and transmit a variety of diseases as vectors. Female mosquitoes, for example, feed on blood and spread parasites like *Wuchereria bancrofti* and *Plasmodium* to their hosts, as well as viral infections. While mosquitoes have numerous negative effects, the methods used to combat them are limited and ineffective. Controlling the mosquito population includes using insecticides, pesticides, repellents, and mosquito traps. Several insecticides used to control mosquitoes, such as pyrethroids and organophosphates, have both acute and long-term adverse effects. There is a definite possibility of mosquitoes developing pesticide resistance even with this compromise [**15**]. The majority of insect repellents contain DEET (N, N-diethyl-meta-toluamide), a popular chemical that deters mosquitoes but does not completely get rid of them. In addition, the majority of pesticides and medications used to control mosquitoes in any form have the potential to harm other benign or helpful insects and disturb the environment when used frequently [**16**]. Research continues, but there is yet no practical way to control mosquitoes.

One way to achieve a 'mosquito-free environment' is to destroy the communication system that mosquitoes use to identify their hosts. A recent discovery revealed that the receptors expressed in mosquito CpA neurons interpret both CO2 and odour to locate their hosts, opening up a new avenue in this direction [**17**]. Research also demonstrated that Drosophila or fruit flies can be used to analyze mosquito behaviour, opening up a new avenue for addressing this significant public health problem, especially in a nation like India. The use of Drosophila as a model to understand the mosquito olfactory system has received substantial support from numerous studies. It opens the door to finding substances or plant extracts/preparations that can function as ligands, both mosquito attractants and repellents for Drosophila.

This strategy can be strengthened by employing transgenic Drosophila bearing both the mosquito CO_2 receptor and mutants or knockdown flies with the popular UAS-GAL4 system of endogenous receptors (loss of receptors responsive to CO2 in ab1c neurons) [**18**]. Drosophila has been a strong model for understanding the mosquito olfactory system in numerous studies. It opens the door for the identification of plant extract-like chemicals in insect ligands that can work as both mosquito and Drosophila attractants and repellents [**19**]. This strategy can also be strengthened by utilizing transgenic Drosophila that has been genetically altered for mosquito olfaction (mutants or knockdown flies) with the popular UAS-GAL4 system of endogenous receptors as well as the mosquito's CO2 receptor. The genetics and genome of Drosophila can be utilized to explain the molecular causes and mechanisms of insect behaviour [**20**].

We review these repulsive phenomena here, discussing them briefly with experimental results. We also review the gustatory and olfactory pathways before talking about putative-repellent effect mechanisms. We looked at numerous techniques to show how repellents can be used to manage pests and protect people or plants.

Salient features of a pest repellant

The repellency can be tested in two ways:

- Utilizing a bioassay that prevents the insect from coming into contact with the stimulus directly
- Without the host present because the host may have a masking effect or otherwise irritate the tested insect.

To explore repellency, a tube olfactometer that delivers odors in a finely regulated manner can be used, positioned vertically or horizontally with moving or stationary air for assaying *Drosophila* *melanogaster* [**21**]. The insect's position could be visually tracked. The repellent odors caused decreased activity followed by downwind movement, whereas appealing odors cause upwind movement. Steck along with his co-workers showed that this approach could produce a genuine repellent reaction to the well-known repellent chemical benzaldehyde [**22**]. Most other aversive compounds, on the other hand, elicited neither attraction nor aversion. Pettersson's four-arm olfactometer can also be used to study appealing or repulsive odors [**23**]. The test odor is delivered by one arm, while the other three arms serve as controls [**19-21**]. The same method can be used to test a repellent [**22**]. An olfactometer is difficult to use to study a repellent because if the substance is repellent, the insect won't travel to the choice zone. To solve this issue, we can either physically position the insect at the desired location or use a T-maze [**23**]. Grieco et al. (2005), for example, placed Aedes aegypti mosquitoes in the center of a three-part cylinder [**24**]. The mosquitos were given the option of a treated (repellent odor) or untreated chamber.

ACTION MECHANISMS

Olfactory Pathway (Fig.1)

Different types of sensilla are found on the antennae and maxillary or labial palps of insects, which are their olfactory organs. Sensillium is a prominent sensory structure in most insects, positioning up to four olfactory receptor neurons [**25**]. A study by Crumb et al. showed that the receptors expressed in the mosquito CpA neurons can interpret both CO2 and smell, aiding them in detecting their hosts, opening a new potential in this direction [**26**]. Mosquito receptors expressed by CpA neurons interpret both CO2 and odour to locate their hosts. Many insects have chemosensory neurons that detect CO2 in their antennae or appendages. Gr21a and Gr66a ORNs respond to CO2 levels expressed in ab1C neurons, providing an excellent model for olfaction mechanisms that can be used to identify ligands that can interact with such receptors and disrupt mosquito communication systems [**26**]. indicating it to be an effective model for determining whether, in addition to responding to CO2, the receptors Gr1, Gr2, and Gr3 in mosquito CpA neurons also react to other ligands and human odour [**26**]. In addition to mosquitoes and fruit flies, the presence of ant pheromones affects other functional groups of insects, providing evidence for their prevalence and importance in insect communities. For example, *lepidopteran* larvae can detect the pheromones left behind by their host ants while living as symbionts inside weaver ant nests [**27, 28**].

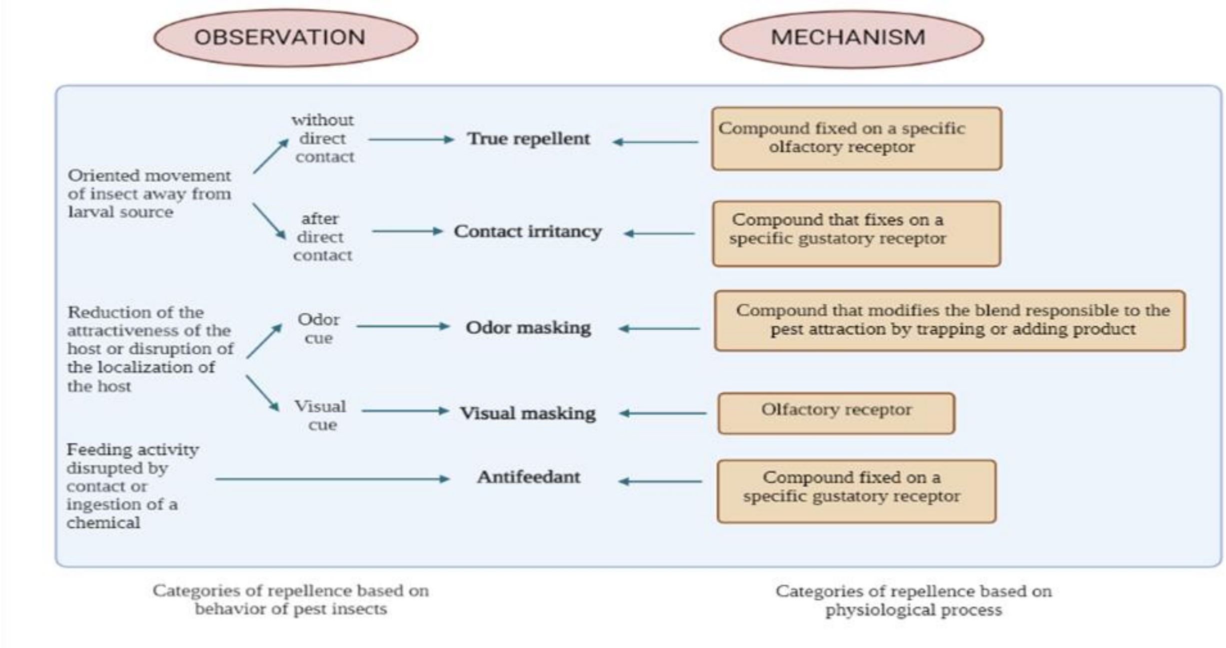
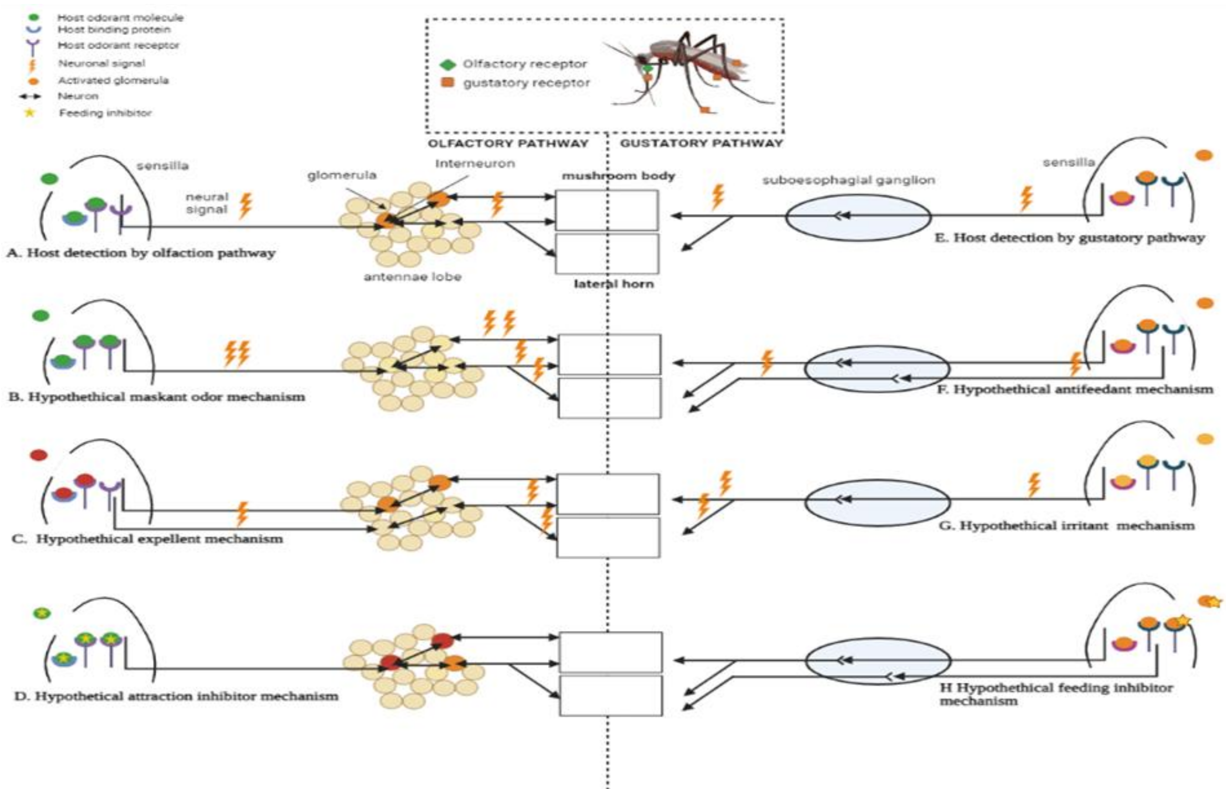


Fig.1. The figure describes pest classification based on observational and mechanism characterizations.

Based on the behavior of the insects, it was possible to deduce that the insects'-oriented movement could be away from the larval source without actual direct contact. This is referred to as true repellant or expellant, and it can be demonstrated using tubular olfactory bioassay. It obtains as a result of the unique insect mechanism of compounds fixed on a specific olfactory receptor. Some pests exhibit irritancy after direct contact due to a compound attached to a specific gustatory receptor of taste. This compound is linked to the test organism's movement away from the source. The cone test can be used to demonstrate testing the organism through direct contact. Another method of reducing host attractiveness or disrupting host localization could be demonstrated by odor masking (using odor cue) by olfactometer, for example, by trapping or adding products that modify the blend responsible for pest attraction. Another method is to disrupt feeding activity by contacting or ingesting an antifeedant chemical. A compound binds to a specific gustatory receptor, causing the test organism to move away from the host.

Gustatory pathway (Fig.2)

In insects, taste organs are strewed over a variety of body parts, including the mouth (maxillary palps, mouth cavity, pharynx), wings, and legs [**29, 30**]. With the help of these gustatory cells, the insect may taste possible food sources without actually eating them [**31, 32**]. In contrast to olfactory sensilla, which are multiporous, external gustatory sensilla are uniparous [**33**]. Gustatory sensilla contain four types of gustatory receptor neuron cells that respond to sugar (S cells), tap water (W cells), low salt concentrations (L1 cells), high salt concentrations, and bitterness. Gustatory sensilla also contain two types of gustatory receptor neuron cells that respond to either attractive or aversive tastes (L2 cells) [**34**]. Chemosensory neurons and other kinds of accessory cells are among them [**35, 36**]. Similar to odorant-binding proteins in the olfactory system, gustatory sensilla lymph also expresses odorant-binding proteins [**35**]. Similar to olfactory receptors, gustatory receptors also associate with other receptors, such as Gr64f, to create heterodimers. Chemical information is transferred by gustatory receptor neurons when chemicals come into contact with taste receptor cells made of transmembrane proteins in the mouthparts [**37**]. Like the olfactory system, the gustatory system codes substances according to their quantity, quality, ratio, and existence in space and time [**38, 39**]. The topographical binding sites of gustatory receptors may be responsible for the variations. Gustatory receptor neurons co-express a large number of gustatory receptors. Several gustatory receptor subsets are expressed in a single taste neuron, in contrast to the olfactory system, where one receptor corresponds to one neuron. The ligand range may be widened by many receptors, but discrimination performance may be lowered [**39**]. The figure describes pest classification based on observational and mechanism characterizations.



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MECHANISM OF ACTION AND PATHWAYS

Plant-derived products

Depending on the intended use and particular product, plant-based repellents display a variety of modes of action and pathways. For example:

- *Antibacterial*: Many plant-derived compounds have antibacterial qualities that damage the cell wall or membrane of bacteria, prevent protein synthesis, or obstruct vital procedures like DNA replication.
- *Antifungal*: Plant-derived substances having antifungal activities can prevent the manufacture of fungal cell walls, modify the composition and structure of fungal membranes, or interfere with fungal metabolism.
- *Antiviral:* Some compounds made from plants can prevent viral replication or entry into host cells. They can alter how the host immune system reacts to viral infections.
- *Antioxidant*: Plant-derived compounds can act as antioxidants, preventing free radical damage and preserving cells and tissues.
- *Anti-inflammatory*: Several plant-derived products can reduce inflammation by reducing the activity of inflammatory enzymes, inhibiting the synthesis of pro-inflammatory cytokines, or modulating immunological response.
- *Analgesic*: Some items made from plants can inhibit pain signals going to the brain or lessen inflammation.

Plant-derived compounds may have anti-cancer qualities that function by causing cancer cells to die, preventing angiogenesis, or altering the immune system's response to cancer. Overall, plant-derived products' modes of action and routes are complex and varied, depending on the particular product and the use to which it is put.

Synthetic Repellents

Insects that are attracted to certain smells or tastes produced by synthetic repellents are deterred from landing on and biting the skin. The individual repellent's mode of action varies; however, a few popular forms of synthetic repellents and their workings are as follows: One of the most widely used active chemicals in insect repellents is DEET (N, N-diethyl-meta-toluamide). It functions by obstructing the insect's ability to locate a target for a bite by blocking the receptors on its antennae that sense human sweat and other substances. Picaridin, also called icaridin, is a synthetic substance with a structure resembling that of piperine, a naturally occurring substance present in black pepper. By suppressing the insect's smell receptors, it prevents the bug from locating a host. The synthetic amino acid derivative known as IR3535 (3-[N-Butyl-N-acetyl]-amino propionic acid ethyl ester) is structurally related to the amino acid alanine. It functions by producing an offensive odor and taste that discourages insects from touching or biting the skin. Clothing and equipment are treated with the synthetic pesticide permethrin. When insects come into touch with treated surfaces, it kills or repels them. In general, the way that synthetic repellents work by impeding an insect's ability to find and feed on a human host.

Pros and cons of plant-derived and synthetic pest repellents

Repellents serve as indispensable tools for safeguarding humans and animals against diverse pests like mosquitoes, ticks, and insects. They exist in two forms: plant-derived and synthetic, each possessing unique merits and demerits. Plant-derived repellents also referred to as natural repellents, are derived from plant extracts and essential oils. These age-old remedies have garnered usage over centuries for deterring pests. Natural repellents are commonly perceived as safer alternatives due to their origins in natural sources. They generally exhibit lower toxicity levels, resulting in a reduced likelihood of skin irritation and adverse reactions in humans. Moreover, plant-derived repellents are typically biodegradable, thus imposing lesser environmental impact compared to synthetic counterparts. They tend to leave fewer residues and do not accumulate in the ecosystem. However, the efficacy of plant-derived repellents can vary depending on factors such as formulation, concentration, and application method. Some natural repellents may exhibit limited or shorter-lasting effectiveness when compared to synthetic repellents. Moreover, the distinct odors associated with plant-derived repellents may be disease-spreading for certain individuals. Furthermore, specific plant extracts might induce skin sensitivity or allergic reactions in susceptible individuals.

Conversely, synthetic repellents comprise chemically formulated compounds designed explicitly for repelling pests. These repellents have undergone extensive research and development to optimize effectiveness and provide prolonged protection. Examples such as DEET (N, N-diethyl-meta-toluamide) and picaridin have demonstrated high efficacy in repelling a wide range of pests and offering an enduring defense. They are often efficacious against diverse pest species and suitable for various outdoor activities and geographical regions. Nevertheless, some synthetic repellents have been linked to potential health risks, including skin irritation, allergic reactions, and neurotoxic effects. Additionally, they may exhibit greater environmental persistence, accumulating in water bodies and potentially impacting aquatic ecosystems.

REPELLENTS AFFECTING HUMANS AND ANIMALS

Repellents are frequently employed to safeguard individuals and animals against the annoyance, detriment, or impairment caused by these organisms. Nevertheless, numerous repellents can exhibit deleterious effects on both humans and animals, thus necessitating a comprehensive comprehension of these effects before employment. Various categories of repellents exist, encompassing insect, rodent, and animal repellents. Examples of commonly employed repellents include DEET, picaridin, and lemon eucalyptus oil for insects, as well as peppermint oil, mothballs, ultrasonic devices for rodents, predator urine, motion-activated sprinklers, and fencing for animals. Insect repellents are frequently used to safeguard humans against mosquito-borne diseases, such as malaria and dengue fever. Nonetheless, these repellents can yield adverse effects on humans, particularly when utilized in high concentrations or for prolonged durations. Prevalent effects of insect repellents on humans comprise skin irritation, eye irritation, and respiratory complications. The most widely employed insect repellent, DEET, has been associated with numerous health issues, including seizures, memory loss, and skin reactions. However, the risk of encountering these effects is typically low when the repellent is used as directed and at appropriate concentrations. Repellents can also induce detrimental effects on animals, particularly when ingested or when the animal's skin or eyes come into contact with them. Consumption of certain types of repellents can prove fatal to animals, while others can lead to long-term health problems such as liver damage or neurological disorders. Predator urine, frequently employed as an animal repellent, has demonstrated the potential to cause stress in animals, particularly when utilized in excessive concentrations or for extended periods. On the other hand, other animal repellents such as motion-activated sprinklers and fencing are generally regarded as safe and effective, as they do not involve the use of chemicals or other potentially harmful substances. Repellents can effectively safeguard humans and animals from the nuisance and harm caused by specific organisms. However, the careful utilization of these products and a thorough understanding of their potential risks and side effects are crucial. When employing repellents, it is imperative to meticulously adhere to the provided instructions and utilize them only as directed.

PEST-REPELLENT PROPERTIES IN INSECTS

Different insects have different working mechanisms to cope with the environment, in an e similar way some exclusive insects show some specific properties and can behave as pest repellents, and eventually, this behavioral aspect helps to decide how to perform the extraction and analysis of the taken insect, so it becomes very obvious to know about the pest repellent properties of insects to proceed further. It was discovered that a particular type of ant known as the weaver ant is capable of controlling more than 50 different pests in 12 different crops, efficient control agents are present which can directly prey on pest insects, it also releases some ant pheromones and chemical signals. Anal spots by weaver ants along with the Semi chemical properties of ant pheromones have increased potential in integrated pest management. Also, the signaling qualities of these pheromones can be investigated and used to improve their usage in future sustainable pest management. The effect of ant pheromones on herbivores appears promising [**40**].

Similarly, in some other studies, it is stated that drosophila Receptors expressing some CpA neurons of the mosquitoes are the reason behind which interpretation of both CO2 and odor to locate their hosts. The Chemosensory involvement of neurons in detecting CO2 is found in antennae or appendages in many insects. Gr21a and Gr66a ORNs respond to CO2 levels expressed in ab1C neurons. This provides a fantastic model for the olfactory mechanism to find compounds that interact with such receptors to disrupt mosquito communication systems [**41**]. Drosophila has an efficient method to ascertain whether mosquito CpA neurons' Gr1, Gr2, and Gr3 receptors, which respond to CO2, may also respond to other ligands and human odor. In drosophila mutants, homozygous 0R83b null flies showed reduced general olfactory capacities and yet sense CO2 [**42**]. The odorants cyclopentanone and ethyl pyruvate are among those that the mutants react to. Genetically modified transgenic drosophila bearing CO2 receptors and the popular UAS-GAL4 system of endogenous receptors for mosquito olfaction [**43**]. In insects like Black soldier flies (Hermetia illucens L.): significant larval components show pest properties. Its larval components create an inhibitory effect that repels other insects. The larvae of black soldier flies are scavengers that consume organic stuff that is degrading, including algae, carrion, compost piles, manure, mold, plant waste, and beehive waste. They can shred and eat rubbish because of their big, robust chewing mouthparts. Black soldier fly larvae (BSFL) contain an amino acid composition, up to 35% lipids, and a dry weight of up to 50% crude protein (CP) [**44**].

COMPARISON OF EFFECTS OF PEST REPELLENTS ON PLANTS, INSECTS (WEAVER ANTS, DROSOPHILA), AND ANIMALS (RODENTS).

A diverse range of pest repellents holds the potential for effective pest management and crop protection; however, it is essential to acknowledge their potential adverse impact on non-target organisms and the environment. The effects of pest repellents on plants encompass both beneficial and detrimental aspects. While they can exhibit positive outcomes, certain repellents have been found to impede plant growth, and development, and even lead to plant mortality. A commonly utilized insecticide, Imidacloprid, employed in crops like corn and soybeans, exemplifies this phenomenon. While effective against pests, Imidacloprid has demonstrated detrimental consequences on plant physiology, including reduced plant height, leaf area, biomass, and prolonged time to maturity. **[45-47]**

Regarding insects, pest repellents can serve as control measures against specific species such as weaver ants and Drosophila. Weaver ants are frequently employed as biological control agents to manage crop pests. Nevertheless, the utilization of insecticides and repellents may hinder the effectiveness of weaver ants by repelling them alongside the pests they aim to control. Drosophila, commonly known as fruit flies, are prevalent pests in fruit crops. While insecticides and repellents can effectively control Drosophila populations, their application also poses risks to non-target organisms, including pollinators and beneficial insects.

Pest repellents are also applicable for the control of rodents, such as rats and mice. However, it is crucial to acknowledge the potential harm they can inflict on non-target organisms, including pets and wildlife. For instance, the usage of rodenticides like brodifacoum has been associated with the mortality of birds of prey and other wildlife species. These rodenticides can also have detrimental effects on pets, as dogs and cats may be exposed to the chemicals when consuming poisoned rodents. **[48]**

POTENTIAL APPLICATIONS OF INSECTS AND INSECT-DERIVED PRODUCTS IN THE PHARMACEUTICAL SECTOR

Insects and their byproducts are gaining popularity in various businesses, including the pharmaceutical industry. In the pharmaceutical sector, insects and insect-derived products are used for a variety of purposes, including: **[49-53]**

- **Medicinal chemical compounds**: Insects create a diverse spectrum of biologically active chemicals with potential medicinal use. Antimicrobial agents, anti-inflammatory chemicals, and other bioactive molecules that could be employed in the creation of new medications or treatments are examples of these compounds.
- **Wound Healing**: Because of their capacity to clean and debride wounds effectively, certain insects, such as maggots, have been employed in traditional medicine for wound healing. In modern pharmacological applications, insect-derived chemicals could be employed to speed up wound healing.
- **Antimicrobial Peptides**: As part of their immunological response, insects have created a variety of antimicrobial peptides. These peptides show promise as potential antibiotic replacements, particularly in light of developing antibiotic resistance.
- **Pain Relief**: Insect venom and other insect-derived substances have been researched for their potential analgesic qualities, which could aid in the development of new pain-relief drugs.
- **Anticoagulants**: When feeding on their hosts, several insects create anticoagulant chemicals in their saliva or venom to inhibit blood coagulation. These compounds could be used in the creation of anticoagulant medicines for medicinal uses.
- **Anti-cancer Agents**: Researchers are investigating the anti-cancer potential of insect-derived chemicals. Some substances appear to have the potential to limit cancer cell development and induce apoptosis (cell death) in cancer cells.
- **Drug Delivery**: The inherent ability of insects to carry and transport items can be used for medicine administration. Nanoparticles or microparticles created from insect leftovers, for example, could be utilized to deliver medications to specific areas within the body more effectively.
- **Stem Cell Research**: Insect-derived chemicals have showed promise in stimulating stem cell differentiation and proliferation, which could be useful in regenerative medicine and tissue engineering.
- **Immunomodulators:** Some insect-derived chemicals can affect the immune system, potentially making them useful in the treatment of autoimmune diseases and other immunological disorders.
- **Nutraceuticals:** Insect-derived products such as chitin (a polymer found in insect exoskeletons) have been studied for their nutraceutical qualities, which include potential advantages for joint and digestive health.

LIMITATIONS OF INSECT-DERIVED PEST REPELLENTS: A NATURAL ALTERNATIVE WITH DRAWBACKS

In comparison to alternative sources of pest repellents, such as synthetic chemicals and natural plant extract, insect-derived repellents have some drawbacks. These restrictions include, among others: **[53]**

- **Limited effectiveness**: It's possible that insect-based repellents don't work as well as synthetic chemicals do at keeping pests away. While they might be useful against some insects, they might not be as powerful against others**.**
- **Shorter duration:** Compared to synthetic compounds, which can offer longer-lasting protection, insect-derived pest repellents may have a shorter period of action.
- **Limited variety of pests:** While synthetic compounds can frequently deter a wider range of insects, insect-derived repellents may only be effective against a narrow range of pests. Accessibility: In comparison to synthetic chemicals or plant extracts, which are widely available in stores, insect-derived pest repellents may be more challenging to find.
- **Environmental impact:** Despite being more environmentally benign than synthetic pesticides, insect-derived pest repellents can nevertheless affect the environment if applied carelessly or excessively.

In general, insect-derived pest repellents can be a practical and natural alternative for warding off pests, they may have limitations in terms of their potency, longevity, and variety of pests they can ward off. When selecting a repellent, it's crucial to keep these restrictions in mind. You should also use all products carefully and sensibly. Instead of getting rid of pests, insect repellents aim to make people less drawn to them. They are less successful at controlling pests than other techniques, like using pesticides or biological management. acoustic pest It has also not been demonstrated that pest repellents that release high-frequency sounds are effective4. Although they can help prevent bites, insect repellents have limitations in terms of coverage, potency, and wind conditions. As a result, in comparison to other techniques, they might not be the greatest choice for pest management.

CONCLUSION

To defend themselves against predators and pests, insects have evolved a variety of defense strategies, including the generation of chemical substances with repulsive qualities. These substances can be utilized as organic pest deterrents in domestic and agricultural settings. An assortment of insects, such as ladybirds, ants, centipedes, crickets, bees, stink bugs, and spiders, have been shown to have pest-repelling qualities. As there are advantages to employing insect-based repellents over synthetic ones, there is a promise for using them as a sustainable and natural approach to pest control. Pest deterrents made from insects are less harmful to the environment, safer for people and their pets, sustainable, effective at repelling certain pests, affordable, and biodegradable. These organic repellents can be made responsibly and are frequently sourced from plants or insects. They are biodegradable, naturally degrading over time, and can be targeted to specific pests, reducing harm to beneficial insects and other organisms. Overall, there are many benefits to using insect-based repellents over synthetic ones.

FUTURE OF INSECT DERIVED PEST REPELLENTS

The future of insect-based insect repellents is bright. Sustainable and natural pest management techniques are in greater demand as society becomes more ecologically concerned. Since they are frequently kinder to the environment, less dangerous for people and animals, and can be manufactured sustainably, insect-based pest repellents can address this demand. The creation of novel insect chemicals that could be employed as potent pest repellents is a focus of continuing research and development in this field. The identification and characterization of these substances are being sped up by technological developments like metabolomics and genomics. Integrated pest management programs, which aim to control pests using a combination of different strategies, including biological, cultural, and chemical control, are also gaining popularity for using insect-based pest repellents. Insect-based insect repellents can be an important part of these programs, reducing the need for synthetic pesticides and encouraging more environmentally friendly and sustainable methods of pest control. Overall, insect-derived pest repellents have a promising future since they outperform synthetic alternatives in some ways and are ideally adapted to address the rising demand for environmentally friendly, all-natural pest management techniques.

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