Insect-Derived Bioactive Compounds in Therapeutic Applications: A Review Focused on Hemiptera and Beyond

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Abstract:

Comprising 80–90% of the world's biodiversity, insects are the most varied group of species on the planet. Insects have long been utilized in medicine, but in recent years, scientists have focused on them as potential sources of new bioactive substances. The medicinal potential of compounds obtained from insects is examined in this review, with a focus on the Hemiptera order and related species. We summarize evidence for antidepressant, anti-inflammatory, anticancer, and metabolic benefits, as well as the use of insect oils in medicine and agriculture, highlighting research from traditional entomotherapy to more recent experimental studies. These findings underscore the importance of biodiversity in drug discovery and the need for further research to harness the full potential of insect-based therapies.

Keywords: Insect therapeutics, Hemiptera, entomotherapy, bioactive compounds, traditional medicine, modern pharmacology

1. Introduction

Around 80–90% of the world's biodiversity is found in insects, the largest and most diverse species on the planet. The Hemiptera order, which includes more than 50,000 known species like bed bugs, assassin bugs, and shield bugs, has been the subject of increased research as a potential source of bioactive compounds (Lis et al., 1996; Hellmann and Sanders, 2007). Modern research is just now starting to validate and clarify the mechanisms behind the ancient cultural practices of entomotherapy, or the use of insects for medicinal purposes (Costa-Neto, 1999, 2002). This review summarizes current developments in the investigation of chemicals originating from insects, emphasizing both established uses and new pharmacological possibilities.

2. Insect Therapeutics: Traditional and Contemporary Perspectives

2.1. Entomotherapy in Cultural Context

Insects have been used both as food and as treatments for a wide range of illnesses in various civilizations. The medicinal qualities of these insects may be changed by conventional cooking techniques like roasting or frying. However, these customs highlight entomotherapy's strong cultural ties and its applicability in conventional medical systems. Insects have long been included in the pharmacopeia of traditional medical systems, especially in places like Mexico and India. More than 400 bug species have been used medicinally, according to ethnopharmacological surveys; more than 90% of these are used to treat internal illnesses like respiratory, dermatological, and digestive issues. Such a wide range of uses not only demonstrates entomotherapy cultural relevance but also points to a multitude of of pharmacologically active substances that have not yet been thoroughly investigated.

3. Insect Sources and Their Traditional Medicinal Uses

3.1. Polyphaga Plancyi and Kinase Inhibition

According to Das et al. (2007), Polyphaga plancyi, a related species of Eupolyphaga sinensis, has long been used to treat fractures and amenorrhea. Particularly, five novel chemicals that inhibit JAK3 and DDR1 kinases—two new targets in cancer treatment—have been identified from P. plancyi in recent investigations. Based on these discoveries, chemicals derived from insects may provide new ways to treat inflammation and cancer.

3.2. Aquatic Bugs In Traditional Medicine

Various aquatic bugs, including Belostoma indica, Gerris spinola, Nepa cinerea, and Lohita grandis, have been used medicinally by a number of authors, including Costa et al. (2007) and Costa (2005). These species are used for gonorrhea treatment, wound healing, and excessive

bleeding reduction. Inhaling these insects' odors can sometimes help people with asthma. Furthermore, several species of leafhoppers, or Cicadellidae, have been shown to be effective in treating urticaria, ulcers, skin eruptions, and ear-related ailments such infections and hearing brought on by ear pus.

3.3. Terrestrial Insects For Blood And Digestive Disorders

Horseflies, or Tabanus species, are used to treat blood problems, dyspepsia, amenorrhea, and abdominal blood stasis, according to Wilsan et al. (2007). According to other conventional wisdom, mantis eggs have been shown to increase male libido. Impotence is historically treated in China with species like Statillia maculate, Mantis religiosa L., and Hierodula saussurei Kirby. Some species (such as those from the genera Xamues and Pachilis gigas) are roasted, powdered, and used to treat whooping cough because of their high vitamin content and nutritional value, according to Hoffmann et al. (2006). Additionally, quarternal fevers, headaches, constipation, ulcers, arthritis, and sleep difficulties have all been linked to bedbugs (Cimex lectularius and C. hemipterus).

3.4. Insect Ants, Termites And Other Sources

According to Kou et al. (2005), Polyrachisla mellidens, a Chinese medicinal ant, has potent analgesic and anti-inflammatory qualities that make it appropriate for the treatment of inflammatory and rheumatic conditions. According to Wilsan (2005), the termite species O. formosanus is also used to treat rheumatoid arthritis, anemia, ulcers, and general body aches, as well as to enhance breastfeeding. According to Mariod, A.A. (2020), a sweet oil is extracted from the bug A. viduatus. This oil is utilized as an edible oil in Sudan and is famous for having a high palmitoleic acid concentration. Additionally, Costa-Neto, E.M. (2005) stated that termite species, including those belonging to the genera Macrotermes and Cubitermes, are used as aphrodisiacs, to treat malnutrition in children, and to treat rheumatic illnesses and anemia.

3.5. Hemiptera and Medicinal Applications

Many species in the Hemiptera order have been reported to have therapeutic qualities. Hemiptera species are used to treat a variety of internal illnesses, such as respiratory, digestive, and skin issues, in places like Mexico. A rich ethnomedical heritage and the unrealized pharmacological potential of these insects are indicated by the fact that 92.6% of the 411 bug species that have been documented for use as medicine globally are used to treat internal illnesses.

3.6. Bee Venom and Other Insect Toxins

According to H. Hu et al. (2006), melittin is one of the more than 18 active ingredients in bee venom that have been demonstrated to have anticancer properties against leukemia, prostate, bladder, lung, liver, kidney, and breast malignancies. According to recent research, melittin may limit NF-κB's ability to bind DNA by blocking its phosphorylation, which would alter the

expression of inflammatory genes. Ants, maggots, and other preparations generated from insects have long been employed for their medicinal qualities in treating ailments ranging from arthritis and gynecological diseases to paralysis and severe colds, according to several publications (Ramos-Elorduy et al., 2001).

4. Additional Reports and Diverse Applications

• **Grasshoppers and locusts**: According to Costa-Neto (2002), grasshoppers (Tropidacris sp.) are used to treat skin conditions and stroke recovery, and their powdered form is brewed into tea. Hepatitis and asthma are treated with locust powder or sun-dried locusts.

• **Tenebrionid Beetles**: According to Costa-Neto (2002), the beetle Palembus dermestoides is used in Brazil to treat TB, arthritis, asthma, and impotence.

• **Cooking Oils and Heart Issues**: According to Van Huis (2002), in Sudan, camel scab disease is treated and cooking is done using oil from Agonoscelis pubescens, while bugs from the genera Nezara and Triatoma are used to cure a variety of heart issues.

• **Traditional Remedies**: According to Stephen Trowell (2003), insects contain a variety of biologically active compounds, such as peptides, poisons, and enzymes, which may be used for everything from antimicrobial therapy to anticancer treatments.

The numerous traditional uses of insects, such as the use of blowfly larvae in maggot therapy, the application of silkworm larvae for wound healing, and the use of various insect-derived neurotoxins for possible neurological applications, are further demonstrated by other reports (e.g., Groark, 2001; Ramos-Elorduy et al., 2001; Costa-Neto, E.M., 2005).

5. Recent Advances in Insect-Based Research

5.1. Neuroprotective and Antidepressant Effects

Lavisha et al. (2024) described the antidepressant properties of an oil extract made from the insect Aethoscytus foveolus in India. The oil extract showed anti-neurodegenerative potential and reduced depressive-like behaviors in a mouse model of stress-induced depression, indicating that chemicals obtained from insects may provide new therapeutic treatments for depression and neurodegenerative diseases.

5.2. Insect Oils in Agricultural and Therapeutic Applications

The fatty acid profile of milk and meat can be improved and diet energy density increased by using oils derived from insect defatting as novel lipid supplements in ruminant feeding, according to Hervás et al. (2022). Insect oils from mealworms, crickets, and maggots can lower

methane emissions during rumen fermentation, according to complementary research by Jayanegara et al. (2020), indicating a dual benefit in animal nutrition and environmental sustainability.

5.3. Traditional Medicinal Uses and Emerging Evidence

Several studies have reviewed the use of diverse insect species in traditional medicine:

- Mozhui et al. (2021) found fifty insect species that are used medicinally to treat respiratory, dermatological, and gastrointestinal conditions. These species include Mecopoda elongata, Odontotermes spp., and Darthula hardwickii.

- Marianello et al.2021 described the traditional use of Eupolyphaga sinensis (Tubiechong) to treat postpartum problems, fractures, and bruising. Its bioactive ingredients include anticancer, antioxidant, and anticoagulant effects.

- Kamesa et al. (2020) emphasized the use of Darthula hardwickii (Treehopper) as an appetite stimulant and in the treatment of high blood pressure, diabetes, and jaundice.

5.4. Additional Bioactive Compounds and Nutritional Benefits

Other insect-derived substances have shown diverse bioactivities:

Mozhui et al. (2020) and Ghosh et al. (2020) reported that Apis dorsata larvae and pupae have significant nutritional advantages due to their vital amino acids, minerals, and fatty acids, and are used to treat sunburn, exhaustion, and mouth ulcers.
Bombyx mori larvae contain polyunsaturated fatty acids and α-linolenic acid, which decrease accumulation of lipids in human hepatocyte cells, according to Luo et al. (2020).
According to Park et al. (2020), tetrahydroquinolines derived from Allomyrna dichotoma have the ability to lower neutrophil migration and vascular adhesion molecule levels, increasing the survival rates of septic mice.

6. Environmental and Nutritional Applications

Compounds obtained from insects have potential applications in sustainable nutrition and environmental management in addition to direct medical purposes. Insect oils may help reduce greenhouse gas emissions in ruminant systems in addition to enhancing the nutritional value of cattle products. Edible insects are positioned as alternative nutritional resources in the face of global food insecurity due to their high protein content and rich vitamin profile.

7. Conclusion and Future Directions

A potential area of research in pharmacology, nutrition, and sustainable agriculture is represented by bioactive chemicals produced from insects. They may be used to treat

inflammatory diseases, metabolic abnormalities, and neurological issues, according to research. To evaluate clinical efficacy, standardize extraction techniques, and investigate biotechnological applications, more research is necessary. Unlocking the full medicinal potential of chemicals derived from insects will require combining traditional knowledge with new research.

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