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THERAPEUTIC USE OF INSECTS AND INSECT PRODUCTS

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ABSTRACT

Insects and their products have been used as resources of medicines all over the world since ancient times. Insect-derived compounds for therapeutic use have huge promise as they have remedial, analgesic, antibacterial, diuretic, sedative, anticancer and anti-rheumatic properties. In old traditional medicine, insect products such as honey, venom, maggots, silk and cantharidine etc. have been used as a treatment for many human ailments. Therapies based on insects are now finding increased acceptance and importance because of failure of substitute drug delivery methods to deliver many lead compounds in key therapeutic areas. There are a number of new advancements in the development of insect natural compounds as prospective new medicines. This review provides updated information regarding traditional and modern use of insects as medicines across various parts of the world.

Key words: Analgesic, diuretic, anaesthetic, cantharidine, entomotherapy, immunological, therapeutic, maggots, traditional, venom, apitherapy, silk, AMPs, insects models, commercial products

Insects belong to phylum Arthropoda which is the largest phylum of animal kingdom as it comprises more than 80% of all known animal species. Among all these species, insects are one of the most diverse and successful groups of animals in the whole world. As a result of this vast diversity, resources obtained from insects are also very large and diversified (Leonhardt et al., 2020). Insects produce a wide range of biologically active low and high molecular compounds mostly as defence mechanisms. Insect based natural molecules are diverse in structure and function ranging from fatty acids, polyketide, terpenoids, nucleosides etc (Rather et al., 2020). When these compounds (venoms, toxins) are consumed by humans, they may act as drugs as they have medicinal effects or improve the performance (Bordon et al., 2020).

Insects are an excellent source of many valuable natural products. The natural products obtained from insects have marvellous pharmacological potential in comparison to another group of animals (Kumar and Srivastava, 2020). Insects have consistently helped humanity by offering a variety of services. People have been using insects in many ways to make natural products since ancient times (Matthäus et al., 2019). The most commonly used insects were honey bees for products such as honey and wax. Also, the products obtained from apiculture have been used long ago in diet and for phytotherapy due to their positive health effects (Gabriele et al., 2015). Scale insects have been used for production of lac dye, resin, and wax long ago. The history of using lac insects can be traced back to Vedic period (Sharma et al., 2020). Silkworms and their by-products have been used since traditional times due to their remarkable therapeutic properties and other usages. Other than production of silk, silkworms have been utilized as nutrients for human consumption or as cattle feed (Bashir et al., 2022). In indigenous societies with little 'westernization', traditional ethnobiological knowledge and consumption of insects is still practiced. The knowledge about therapeutic uses of insects are a well kept secret and passed from generation to generation (Chakravorty et al., 2011).

The medicinal use of insects and insect-derived products is known as entomotherapy (Costa-Neto, 2005). Insects and the substances derived from them have long been used as medicinal resources in the medical systems. In many social cultures, human beings have exploited animal resources for medicinal reasons since the ancient time, where traditional cures were made from animal body parts or metabolic by products or non-animal materials (Unnikrishnan, 1998). Due to the imbalanced patient-to-healthcare professional ratios, the increased workload for the latter, various side effects of modern medicine, the inability to completely cure chronic diseases, the high cost of new medications, and the emergence of new diseases, alternative medicine has recently attracted renewed public interest (Akter et al., 2021). Insects have shown to be extremely important as sources of modern pharmaceuticals due to their immunological, analgesic, antibacterial, diuretic, anaesthetic and antirheumatic properties (Yamakawa, 1998). In the present times, insect natural secretions have demonstrated wide potential as alternative medicine and many insect resources have been utilized and industrialized for various medicinal therapies (Zhang et al., 2008). Products made from insects have an annual economic value of about $100 million (Kasozi et al., 2020). Therefore, insects offer an endless source of potential therapeutic substances. This paper is reviewed to explore therapeutic utilization of insect resources in ancient and modern times in India and other parts of the world.

Traditional entomotherapy

Around the world

Insects have produced valuable natural products like bee-wax, propolis, pollen and royal jelly etc, which have been utilised in traditional medicine for a long time (Jamasb et al., 2016). Many segments of society continue to use medico-entomological medications to this day in many regions of the world. The identification of biological resources suitable for commercial exploitation has been significantly aided by the traditional medical knowledge of regional cultures all over the world (Feng, 2009). The knowledge and methods about the therapeutic use of insects have been passed down through the generations and they are effectively incorporated into the surrounding culture (Costa-Neto, 2005). In recent years, a lot of studies has been conducted which draws the attention towards the therapeutic value of various species of insects, their products and their developmental stages since the ancient times (Chakravorty et al., 2011). A few examples of traditional use of insects as medicines around the world are explained as:

Maggots have been used for wound healing in folk medicines by the Aborigines and Mayan for thousands of years (Pemberton and Robert, 1999). During Napoleonic and American civil wars, maggots were used for wound cleaning (Ratcliffe et al., 2011). In Iran, Kerman province was endemic area for leishmaniasis and for treating cutaneous leishmaniasis meloid beetles (*Leishmania tropica*) were used as traditional medicine (Nikbakhtzadeh and Tirgari, 2002). In Brazil, tenebrionid beetle (*Palembus dermestoides*) were used to treat asthma, arthritis, tuberculosis and sexual impotence (Costa-Neto, 2005). Amazonian Indians diagnosed diabetes by watching to see whether ants swarmed over urine which in diabetics contains high levels of sugar to attract the ant (Lockhart, 2007).

In various areas of Southeast Asia, as well as all of East Asia, insect is a typical component of contemporary medical care. There are 77 distinct species, 14 families, and 8 orders of insects which have traditionally been used in China to treat cancer and tumours (Jiang, 1990). In Chinese traditional medicine, extracts of insect corpses have been widely utilised to treat a wide range of ailments including flu, cancer and infections of throat and ear (Pemberton and Robert, 1999; Costa-Neto, 2005). The use of Chinese Black Mountain Ant, *Polyrhachis vicina*, is a wonderful example, that is frequently used as a remedy especially by the Chinese elder persons. It is intended to increase virility and fertility, lengthen life, profit from anti-aging, and prolong life. British experts are looking into the extract's potential as a cancer-fighting substance in light of the new interest in the ants' medicinal properties (Chen, 1994). Silkworms (*Bombyx mori* L. 1758) provides another popular example which have been used in Chinese traditional medicine for at least three thousand years and specific fly larvae of species *Lucilia* have been known to be effective healers for infected wounds for generations (Sherman, 2009).

Traditional insect medicine in Africa is highly diverse in comparison to China and India (Srivastava et al., 2009). Unlike Traditional Chinese Medicine and Ayurveda, most bug medicinal remedies are passed down through families and communities as opposed to being taught in universities (Patwardhan et al., 2005). In Africa, grasshoppers are frequently consumed as a delicacy as well as a good source of protein and for medicinal purposes. These insects are typically collected, sun-dried, and then ground into a powder. This powder can then be combined with water or ash to make a paste that can be applied to the forehead to reduce severe headaches (Hill and Goddard, 2012). Fasoranti (1997) explained that mole crickets (*Gryllotalpa africana*) gut contents are applied to infected feet as a treatment in southwest Nigeria.

Since ancient times, the therapeutic powers of several insect species and a wide array of plant species have been recognised in Mexico. In some local markets, insect parts are sold in markets as diuretics, analgesics, anaesthetics and aphrodisiacs. About 43 bug species have been found to be utilised in traditional medicine as ointments, pomades, or infusions (Conconi and Moreno, 1988). Additionally, they have been produced and utilised in a variety of methods to treat a wide range of illnesses, including urogenital immunological and glandular disorders, stomach pain, liver issues and mental breakdowns (Taylor, 1975).

In India

In India, Ayurveda is an ancient and integral part in traditional medical therapy that is almost always utilised in conjunction with Western medicine (Pandey et al., 2013). In the Sanskrit Veda of ancient India, it has been mentioned that honey and honey bee products have healing properties and was a remedy for many disorders (Gupta and Stangaciu, 2014). In ayurvedic scriptures, honey is called madhu and was one of the most important medicines used in ayurvedic period (Liyanage and Mawatha, 2017). Termites were believed to treat a broad variety of illnesses, both specific and general during Ayurvedic era. The termites and the elements of their architectural mounds are ground into a paste that is applied topically to the affected areas or, less frequently, mixed with water and consumed. According to reports, this drug is beneficial in treating anaemia, rheumatic diseases and ulcers and used as a general pain reliever and health enhancer (Figueirêdo et al., 2015). In Atharva Veda, it has been mentioned that lac extract was widely used on open wounds for healing and tissue regeneration (Perveen et al., 2013).

In Ayurveda, another example of therapeutic use of insect was of jatropha leaf miner. It is a lepidopteran which is a major agricultural pest of jatropha. It was believed that topical application of its larvae induce lactation, reduce fever, and soothe gastrointestinal tracts (Srivastava et al., 2009). Even today, traditional knowledge about entomotherepy has been practiced among the ethnic societies of North-East India. This traditional knowledge is a well kept secret and is only transferred from one generation to another (Chakravorty et al., 2011). Earlier several workers described therapeutic use of insects based on traditional knowledge in several tribes of India. Some of the important findings are described in Table 1.

Modern entomotherapy

Since the revolutionary invention of antibiotics, relatively little study has been done in medical entomology, despite the fact that insects have been utilised in medicinal therapy extensively throughout history for almost on every continent (Dossey, 2010). But due to enhancement of antibiotic-resistant infections, pharmaceutical sector explored new resources other than antibiotics (Lojewska and Sakowicz, 2021).

Table 1. Insect orders having therapeutic potential and their primary use in traditional medicine in India

Sl. No.	State	Common name	Scientific name	Insect order	Disease treated	Reference
1.	Assam	Blister beetle	*Melolontha* spp.	Meloidae	Cancer	Verma and Prasad, 2013
2.	West Bengal	Stingless bee	*Lepidotrigona arciferal*	Hymenoptera	Cold and cough, cancer	Biswa et al., 2017
3.	Tamil Nadu	Honey bee	*Apis indica*	Hymenoptera	Used as eye drops	Solovan et al., 2004
4.	Chhattisgarh	Kambal keeda	*Diacrisia oblique*	Lepidoptera	Dog bite	Srivastava et al., 2009
5.	Chhattisgarh	Pod borer	*Helicoverpa armigera*	Lepidoptera	Fever, nervous breakdown, eosinophilia and asthma	Oudhia, 2001
6.	Orissa	Termite spp.	-	Isoptera	Wound healing in cattle	Paul and Sudipta, 2011
7.	Manipur	Cranefly	*Tipula* spp.	Diptera	Healing process and to relieve body aches	Kapesa et al., 2020
8.	Arunachal pradesh	Red tree ant	*Oecophylla smaragdina*	Hymenoptera	Stomachache and Dysentery	Chakravorty et al., 2011
9.	Nagaland	Treehopper	*Darthula hardwickii*	Hemiptera	Body ache, jaundice	Mozhui et al., 2020
10.	Nagaland	Litchi stink bug	*Tessaratoma javanica*	Hemiptera	Warts removal	Pongener et al., 2019

Arthropods are a valuable and mostly untapped source of novel pharmaceutical chemicals (Ebenebe et al., 2021). The secretions produced by these arthropods acts as a defence mechanism. It includes insect venom from honeybees and wasps, blood-feeding insects like blister beetles and maggots, fruit flies, antimicrobial peptides of bee hives etc (Rádis-Baptista and Konno, 2020). Scientists have explored that venoms or toxins produced by arthropods included many inorganic or organic compounds, alkaloids, histamines, enzymes etc (Lee and Bae, 2016). A number of insect based compounds having therapeutic values are developed nowadays which are described as under:

Apitherapy

Apitherapy is the use of bee products such as honey, pollen, propolis, royal jelly, bee venom and wax to treat gastrointestinal, cardiovascular and hepatic diseases as well as to hasten the healing of wounds (Abdulrhman et al., 2010). More than 6000 years ago, ancient Egyptian medicine was the origin of apitherapy. Honey is a naturally sweet material made by honeybees from the nectar of blossoms, plant secretions, or excretions of insects that feed on living plants (Bansal et al., 2005). Honey bees collect these ingredients, transform and combine them with other ingredients, then store and let them develop in the honey comb. There are numerous health benefits of honey due to its antibacterial, wound-healing, antidepressant, anticonvulsant, and anti-anxiety properties (Simon et al., 2005).

Bees use pollen as a basic ingredient to make bee bread. Bee pollen has a complex chemical composition that includes carbohydrates, proteins, amino acids, vitamins and minerals (Silva et al., 2014). It is a highly nutritious food that is good for health because it contains phenolic compounds that have antioxidant activity. Since a long time, bee pollen has been used as an anti-aging and anti-allergic remedy (Basa et al., 2016). Honey bees collect propolis, sometimes known as "bee glue," a resinous honeybee product from a number of plant sources. It has traditionally been used in medicines, for the last many centuries to treat burns, ulcers, bedsores, other wounds difficult to heal and as a mouth disinfectant (Kędzia and Kędzia, 2013). Additionally, a number of biological effects of bee propolis, including anticancer, antioxidant, antibiotic, antifungal and anti-hepatotoxic characteristics, have been reported (Lee and Bae, 2016). Like other honey bee products, royal jelly is nutrient-dense and has a high nutritional value. It has been utilised to increase vigour in the body and fortify the immune system (Adjare, 1990). Bee venom is secreted from the glands connected to sting apparatus in worker bees. In bee venom therapy, live bee stings are used to treat a number of ailment symptoms such as discomfort, lack of coordination and muscle weakness (Uddin et al., 2016). Bee venom has been used to treat a number of inflammatory conditions due to its anti-inflammatory properties, in various ailments like arthritis, bursitis, tendinitis, keloids, herpes, zoster, joint disease and rheumatoid arthritis (Adjare, 1990). Experts in apitherapy hold that some chemicals in bee venom, include melittin, apamin, phospholipase A and adolapin, can lessen inflammation and pain, and that the mixture of all the components in bee venom helps the body to produce natural healing molecules in its own defence (Zhang et al., 2018).

Silk

In order to be used outside of the body, silk is a structured protein that is spun into a fibre in number of insects (Becker et al., 2003). Silks are self-assembling, biodegradable proteins that can be genetically modified to have certain chemical properties, making them suitable for the transport of genes and medications (Xiao et al., 2014). Silk has been long used in biomedical sutures for long time, due to which silkworm silk has been given approval by FDA for its extended biomaterials device usage (Zhou et al., 2017). Due to the diversity and control of size, shape and chemistry, modified or recombinant silk proteins can be created and employed in a number of biomedical applications, including the transportation of bioactive substances (Numata et al., 2009). Research on silk films has focused on tissue engineering scaffolds that support cells, devices for controlled substance (like drug) release and biochemical sensors. The majority of these studies have utilised silk fibroins from the silkworm *B. mori*, although recombinant spider silk proteins may be utilised in a similar manner due to their similar physico-chemical properties (Kim et al., 2004). The silk biopolymer is a cutting-edge substance for modern medicine, but even after many centuries, it is still regarded as a suture material. In order to meet present and future biomedical demands, we will be able to create new "old materials" as we continue to unlock the mysteries of silk (Holland et al., 2019).

Cantharidine

Cantharidine is a substance produced and released by the green blister beetle as a protection mechanism against other organisms. It is generated by the male beetle and supplied as a pre-copulatory gift to the female, who uses it to protect her eggs (Sharma and Singh, 2018). Cantharidine and its derivatives have shown the anti-cancer activity against diseases like leukemia, colorectal carcinoma, hepatoma, bladder carcinoma, and breast cancer (Ratcliffe, 2006). Warts have been treated with cantharidine in clinical trials, where the blistering skin patches return to their prior condition without leaving a scar during the scarring condition in the patient (Maglio et al., 2003). Due to cantharidine's effectiveness in treating cancer, it has been widely used in clinical practise (Zhang et al., 2017). Cantharidine was approved by FDA in 2004 as a therapy for skin condition (warts) and to prevent cancer of kidney, urogenital tract, and ovary (Ratcliffe et al., 2011).

Antimicrobial peptides (AMPs)

Antimicrobial peptides (AMPs) are short proteins which are effective against parasites, fungi, viruses, and bacteria. They support an insect's inherent defences. Most of the known AMPs were first discovered in insects. AMPs from insects represent a potential source of substitute antibiotics in the light of the emergence of antibiotic resistance (Bulet et al., 2004). In 1980, the first AMP was isolated from giant silk moth pupae, and its bactericidal properties were made known for the first time (Hultmark et al., 1980). Currently, more than 1500 AMPs have been identified in a variety of organisms, including plants, fungi, bacteria and mammals. Insects are the main source of AMPs. In traditional Chinese medicine over 1700 different treatments have been created from about 300 bug species (Zylawska and Wyszynska, 2011). Identification challenges, drug toxicity, development costs, and large-scale production are all barriers to the evolution of insect compounds into potential modern medicines (Srivastava et al., 2009). Insect AMPs are divided into three classes based on their structure and amino acid sequence. Among them, Cecropins are present which are linear peptides with a helix but lack cysteine residues. Second most common AMPs in insects are Defensins which have 6–8 conserved cysteine residues, a stabilising array of 3 or 4 disulfide bridges, and three domains consisting of a flexible amino-terminal loop. In the end, Peptide Cecropins, drososocin, attacins, diptericins, defensins, ponericins, drosomycin, and metchnikowin are the most studied insect AMPs (Divyashree et al., 2020).

Maggot therapy

Maggot therapy, also known as larval therapy, is a treatment option for chronic, infected, necrotic and sloughy wounds (Rafter, 2012). The maggots employed in the therepy are the special clinical-grade, aseptically bred maggots of greenbottle fly larvae (*Lucilia sericata*). If it is decided that a wound qualifies for maggot treatment, the therapy can go forward under medical supervision (Hancock et al., 2012). The larvae used in maggot therapy clear the incision of infection as well as dead, sloughy, or necrotic tissue over the course of several days. Maggots are regarded to be beneficial to heal the wounds in three ways as they cause debridement (the removal of dead tissue), disinfection (minimising bacterial infection and biofilm load) of wound which ultimately assists in acceleration of wound healing (Malekian et al., 2019). In 2004, the use of medicinal maggots was approved by Food and Drug Administration (FDA) as a medical device to treat the wounds.

Insects as models

Fruit fly (*Drosophila melanogaster*)

There are various genetic and physiological similarities between insects and mammals. So, the insects are well suited as models for genetics, development, behavior and neurobiology. For this purpose they can be easily housed and bred without need of sophisticated equipment (Jans et al., 2021). The common fruit fly, *Drosophila melanogaster,* is a genetic model organism that has undergone extensive research and is very tractable for examining the molecular causes of human illnesses (Yamamura et al., 2021). *Drosophila* is employed as a model organism because of its many distinguishing characteristics. The fly genome has been entirely sequenced and annotated out of its total four chromosomes, three chromosomes carry the majority of the genome that have been encoded for more than 14,000 genes. It is believed that functional orthologs of almost 75% of the disease-related genes in humans exist in the fruitfly (Lloyd and Taylor, 2010). The overall degree of similarity between a fruitfly and a mammal's nucleotide or protein sequences is typically around 40 % in conserved functional domains, it can be as high as 80 to 90% higher. The fly has a relatively short life cycle. In just 10 to 12 days at 25°C, a single healthy mating pair can produce hundreds of genetically identical offspring (Adams et al., 2000). According to its developmental stage, the fly can be separated into a number of model organisms, including an embryo, a larva, a pupa, and an adult, each of which has a unique set of advantages (Reiter et al., 2001). Basic developmental research typically uses the embryo to examine pattern formation, cell fate determination, organogenesis, neural development and axon path discovery. The larva, especially the third instar wandering larva, is commonly used to study physiological and developmental processes as well as certain basic behaviours like foraging behaviour (Brakel and Blumenthal, 1977).

Red flour beetle (*Tribolium castaneum)*

The red flour beetle *Tribolium castaneum* (Coleoptera: Tenebrionidae) is a universal insect pest of stored grains. There are various applications and strengths of *Tribolium* beetles which are utilised for research in ecology and evolution (Pointer et al., 2021). *Tribolium* is an important model because its mode of short germ band development is more representative than other insect models (Adamski et al. 2019). It has been utilizing food sources varying in nutritional quality (Ming and Cheng, 2012). Therefore, these beetles are suitable for studying the effect of complex food items on longevity for the identification of food–gene interactions affecting stress tolerance (Adamski et al. 2019). The use of *Tribolium* beetles have been done for food safety and functionality studies which ultimately reduce risk to consumer health and economic losses (Piras et al., 2016).

Honey bee (*Apis mellifera*)

Previously, the use of honey bees as models of social behavior, aging and developmental plasticity has been practiced (Shpigler et al., 2017). The honey bee (*Apis mellifera*) gut microbiota is used as model for understanding microbiota functions. There are several advantages of honey bee gut microbiota as it sets up experimental system for understanding the effect gut communities on their hosts. It helps to understand the processes and routes governing particular gut communities impacting host biology (Zheng et al., 2018). Honey bees provide microbiota-free hosts which aids in understanding the mechanism of microbiota influencing host phenotypes along with disease states (Ridaura et al., 2013).

Silk worm (*Bombyx mori)*

Silkworm (*B. mori)* are also used as an experimental animal because of low rearing cost and a few ethical problems (Matsumoto and Sekimizu, 2019). There are various advantages of using silkworm models such as easy rearing, large size (Ishii et al., 2016). The use of silkworms as experimental models have been practiced for pathogens infecting humans (Miyazaki et al., 2012). Matsumoto and Sekimizu (2019) have been reviewed that silkworm based model have been established for various yeast type fungi such as *Candida albicans, C. tropicalis, C. glabrata* and *Cryptococcus neoformans.* Similarly, silkworm infection models have been established for filamentous fungi such as *Aspergillus fumigatus, Arthroderma vanbreuseghemii, Arthroderma benhamiae, Microsporum canis, Trichophyton rubrum* and *Rhizopus oryzae.*

Therapeutic use of insects

A study has been performed by Kasozi and co-workers (2020). In China, it was observed that local beekeepers were immune against Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2). Melittin and phospholipase A2 (PLA2), associated with bee venom have anti-inflammatory properties which shows activity against a large number of enveloped and non-enveloped viruses such as H1N1 and HIV. For the management of respiratory and neurological diseases, bee venom (BV) therapy has been used commonly as it involves group III secretory phospholipase. BV activation of the cellular and humoral immune systems should be explored for the application of complementary medicine for the management of SARS-CoV-2 infections. So, the workers concluded that BV previously showing efficacy against HIV and H1NI provides opportunity as a complementary therapy for protection against SARS-CoV-2 and there is a need to explore the activation of the cellular and humoral immune systems by bee venom in order to develop complementary medicine against SARS-CoV-2 infections.

Several previous studies explained that cantharidin is an inhibitor of protein phosphatase 2A (PP2A) which is responsible for controlling cell cycle, apoptosis (cell death), and cell-fate determination. Li et al. (2010) performed an experiment to investigate the curative effect of cantharidin in pancreatic cancer. The workers observed that cantharidin inhibits G2/M cell-cycle which leads to apoptosis and increased the expressions of pro-apoptotic tumour necrosis factors. The workers also observed that the inhibitory role of cantharidin is independent of oxidative stress in pancreatic cancer cells. This process ultimately inhibits the growth of pancreatic cancer cells without causing any effect on normal pancreatic duct cell.

In North East India, *Brachytrupes orientalis* (Gryllidae) is an edible insect species in many tribes. Dutta and co-workers (2019), conducted an experiment to explore the potentiality of *B. orientalis* against diabetic mellitus as an antioxidant and glucose metabolizing potential in different extracts solvents. On supplementation with hydro-alcoholic (AEBO) solvent, glucose utilisation against high glucose exposure increased significantly in high glucose treated muscle cells. This leads to reduction of intercellular ROS production, lipid peroxidation and hike the protein expression of Nrf2 and GST. Thus, this study suggests the beneficial effect of AEBO on glucose metabolism in diabetes.

Commercial products

A number of insect based products has been developed for the treatment of various ailments and are commercially available in the market. Currently, various companies are developing honey products for the treatment of various ailments such as dry eye symptoms, wounds, minor abrasions, lacerations, minor cuts, minor scalds and burns, diabetic foot ulcers, and burns. Several FDA approved formulations of manuka honey are commercially available in the form of gels, wound dressings, eye drops etc (Hossain et al., 2021). Honey bee pollen or propolis products are available as nutritious supplements, anti-depressant, appetite modulator, as well as tonics to increase endurance in sporting activity, royal jelly as an antibacterial and antifungal agent and is commercially available in the form of capsules (Wang et al., 2016). The products obtained from blister beetles are available in the market under the trade name of cantharone plus developed by Canada based Dormer laboratories for the treatment of warts and canthradine hair oil is manufactured by many pharmaceutical companies in India. Silk scaffolds are available in various forms such as fibrous, porous, and hydrogel for tissue engineering (Babu, 2017). Laboratory reared sterile medical grade maggots has been used for wound healing. In China black ants products are available as powder, capsule, liquid extract or phoenix formula as they are a rich source of zinc, trace minerals and proteins (Tang et al., 2015).

Challenges in adoptoping insects as medicines

Despite all the benefits of using insects as drugs, there are several constraints encountered in the promotion of insects for therapeutic use in both developing and developed countries. This may be due to negative cultural attributes towards insects, particularly in the West (Imathiu, 2020). In Western countries, the barriers for developing modern medicines are more difficult to overcome as compared to countries like China, Brazil with a long tradition in the use of plant and animal extracts as medicines (Ratcliffe et al., 2011). In this area even today, scientific pioneers working is lacking due to political and public pressure in mounting for such drugs (Bordet, 2020). Even with the advancement of modern technology, the majority of insect species, such as crustaceans, go unaddressed for the presence of various natural products in comparison to other insect species, such as ants, beetles, butterflies, moths, and spiders. This uneven knowledge of the structures and functions of insect secondary metabolites is a result of the uneven distribution of insect species. With the exception of a few sex pheromones, the biological roles of even the chemically examined natural compounds have not been thoroughly investigated (Rather et al., 2020). On the basis of several clinical trials, it has been undertaken that use of insect based products such as manuka honey expands the healing times as compared to another synthetic drugs (Tonks et al., 2007; Cherniak, 2010) along with some side effects such as increased granulation tissue in wounds treated with honey or mild to moderate superficial burns (Moran, 1999). Insects can be the carrier of for certain hazards such as chemical substances (venom, antinutrients), parasites, viruses, bacteria and their toxins or fungi etc. In order to reduce potential risks of their consumption specific standards are lacking. Consumer acceptance is another obstacle mainly in the developed countries where insects are regarded in disgust by majority of the population (Lange and Nakamura, 2021).

CONCLUSIONS

Insects appear to be a virtually limitless resource for pharmaceutical study because of the protective compounds they've acquired during millennia of co-evolution with plants and other fauna. Exploitation of animal resources for therapeutic reasons has both ecological and cultural implications. It is concerning that there are a few of insect based items available in the market, despite the fact that many insect natural compounds show significant potential as sources of novel medications. In order to sustain the advantages of insects and products generated from them as an alternative in preventative medicine, safety measures such as quality control for commercial operations, reductions in pesticides, and barcoding for taxonomy are required. Insect variety must be preserved in order to supply future biological diversity and ingredients for new pharmaceutical research in the coming years. These topics should be explored in scientific symposia on conservation biology, public health, resource sustainability, biological prospecting, and patent law. Insects zootherapeutic potential can contribute significantly to the biodiversity debate, as well as lead to the economic and cultural valorization of species that are typically dismissed as worthless. We must pay close attention to the long-term usage of insects.

AUTHOR CONTRIBUTION STATEMENT

All authors equally contributed.

CONFLICT OF INTEREST

No conflict of interest.

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