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REVIEW

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Insects as sources of food and bioproducts: a review from Colombia

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Abstract

Background: Insects are known to be important sources of food and bioproducts, and companies around the world are currently offering goods and services based on their production and use. Colombia is one of the richest countries in the world in terms of biodiversity, with a great variety of insects that are not exploited for these uses at this time. Most studies relating to insects in Colombia are focused on agricultural pests or disease transmitters, and in most cases the advantages and potential applications of insects in the areas of agro-industry, medicine, biotechnology, and food are poorly known. To recognize the native species previously considered as a source of bioproducts, it is necessary to better evaluate their potential uses, as well as the possibilities of innovating with products derived from them. It is also important to consider advantages and disadvantages of using insects for specific purposes, minimum quality requirements and national and international regulations for production and marketing.

Main body: The growing world population has led to an increase in the demand for food and animal products, increasing the need for animal production. This has resulted in high pressure on the environment, water resources and biodiversity, which also contribute to climate change. New strategies are required, and emerging solutions include the use of alternative sources for bioproducts or meat, changing diets, and migrating to sustainable production systems. In the present study, available information pertaining to 107 species of insects reported in Colombia that have been indicated to be sources to produce bioproducts, or that are currently being used for that purpose is revised and analyzed. The insects documented are from 67 genera and mainly include the orders Hymenoptera (59%), Coleoptera (10%), and Blattaria (11%). Seventy-one percent (71%) of the insect species included are important as foods or food supplements, with 9% related to established or commercial products currently in development; and 36% currently recognized for their importance in obtaining valuable non-edible bioproducts within the pharmaceutical industry, medicine, biotechnology, and agro-inputs sectors. A list of species is presented and uses and applications are discussed.

Conclusions: Despite Colombia's enormous potential for sustainable development of insect-derived products, there is a lack of studies in this area. Most of the insects reported in this work are related to local and traditional knowledge and folk medicine of some populations in the country. In addition to apiculture, there are not industrialized insect farms in Colombia; however, there have been some initiatives to produce crickets of the species *Acheta domestica* and mealworms *Tenebrio mollitor* for human and animal consumption. Recently the traditional consumption of ants and certain termite species in some areas of the country has been refreshed by some chefs experimenting with insects in gourmet restaurants. There are few studies on the nutritional value or pharmaceutical uses of the local species and there is no clear regulation for breeding or use. This highlights the need for in-depth study and discussion of the advantages and disadvantages for potential use in the country.

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Background

Insects are very diverse and abundant (comprising 85% of the fauna on the planet) and they represent vast resources of natural bioproducts and macromolecules; however, until a few years ago (c.a. approximately 1980), most of them had not been explored in these capacities (Govorushko, 2019; Seabrooks & Hu, 2017; Shrivastava & Prakash, 2015).

Although it is well-known that insects constitute a promising source of novel natural bioproducts for the pharmaceutical industry, interest in their applications in biotechnology and agriculture has recently been growing worldwide (Hemmati & Tabein, 2022; Mlcek et al., 2014; Seabrooks & Hu, 2017).

The potential for tropical countries like Colombia to be sources for the production and development of insect-derived products is enormous, both due to the natural biodiversity that they contain and also due to local knowledge of traditional insect uses (Torres & Velho, 2009; Gasca-Alvarez & Costa-Neto, 2021). Several industries and scientists from Colombia currently are working on the identification of novel compounds with potential commercial uses, as demand for these bioproducts is growing around the world. Also, due to the large diversity of natural products and their potential contributions to the development of new drugs and medicines, bioprospecting has become an active field that is becoming increasingly more important in the marketplace (Calixto, 2019; Gasco et al., 2020), and Colombia has the scientific and technological capacity to participate more actively in this activity (Duarte, 2011; Gasca-Alvarez & Costa-Neto, 2021).

Entomotherapy and entomophagy have been widely documented as common practices for different native cultures in the Americas (Cahuich-Campos & Granados, 2014; Costa-Neto et al., 2006). Many of the therapeutic and curative properties of the insect species used in folk medicine have been verified by modern medicine (Cahuich-Campos & Granados, 2014) and more than 2000 species of edible insects are known and currently used as source of food, including: beetles, caterpillars, bees, wasps and ants (Kouřimská & Adámková, 2016; Kim et al., 2019).

The economic and environmental advantages of using insects as food have been widely documented. Insect farming produces lower greenhouse gas emissions, requires less land and water use compared to traditional livestock farming (Collins et al., 2019; Govorushko, 2019).

More recently controversial aspects as microbial contamination of insect-derived foods, chitin allergies or even phobias, are subject of great debate and consideration (Govorushko, 2019; Avendaño et al., 2020; Grabowski et al., 2021).

In Colombia, Paoletti et al. (2000) documented that more than 115 insects have been traditionally consumed in the Amazon basin, and according to their estimates, more than 100 belong to order Blattaria, while thousands belong to the order Coleoptera. Many insects used as food are also considered to be pests of crops of economic importance, including sugar cane, corn, cassava, pineapple, tomato and oil palm (Cerritos, 2009).

The present study presents information related to several insects whose use and application has been explored with the aim of obtaining products and compounds of importance in the fields of biotechnology, medicine, industry, and agro-inputs. The potential uses of these insects have been reported in Colombia, as there are a few initiatives for their industrial production. For example, in 2015, the ArthroFood SAS company was founded in Bogota with the purpose of producing insect protein foods for rural communities and for commercial distribution. Other initiatives were recently socialized at congresses and academic events that were open to the public have sought to provide opportunities for attendees to experience insect consumption with the purposes of introducing people to entomophagy and of highlighting the importance of insects as sources of protein and nutrients. There are many promising aspects for a future insect bioeconomy in Colombia, both for startups and for potential investors. This article provides basic information as a starting point for further study.

Main text

Insects used as food

Insects constitute a significant source of proteins and a sustainable alternative to supply global dietary demands and to enhance food security (Churchward-Venne et al., 2017; Govorushko, 2019; Kim et al., 2019; Silva et al., 2020). There are at least 72 species of insects present in Colombia which are currently or may potentially be used as food sources. Most of the insects that are used directly for human consumption are from the orders Coleoptera, Blattaria, Lepidoptera and Hymenoptera. Hymenoptera is the order of greatest representation (64%) and includes several edible insects such as ants and wasps.4 However, a wide variety of bees comprises most of the

Table 1 Insects used as food and feed

Family	Genus	Species	Application	References
Order: Blattaria				
Termitidae	*Labiotermes*	*Labiotermes labralis* (Holmgren, 1906)	Human food	Paoletti et al. (2000)
Termitidae	*Nasutitermes*	*Nasutitermes corniger* (Motschulsky, 1855)	Human food	Paoletti et al. (2000)
Termitidae	*Nasutitermes*	*Nasutitermes ephratae* (Holmgren, 1910)	Human food	Paoletti et al. (2000)
Termitidae	*Nasutitermes*	*Nasutitermes macrocephalus* (Silvestri, 1903)	Human food	Paoletti et al. (2000)
Termitidae	*Nasutitermes*	*Nasutitermes surinamensis* (Holmgren, 1910)	Human food	Paoletti et al. (2000)
Termitidae	*Syntermes*	*Syntermes snyderi* (Emerson, 1924)	Human food	Paoletti et al. (2000)
Termitidae	*Syntermes*	*Syntermes parallelus* (Silvestri, 1923)	Human food	Paoletti et al. (2000)
Termitidae	*Syntermes*	*Syntermes spinosus* (Latreille, 1804)	Human food	Paoletti et al. (2000)
Termitidae	*Syntermes*	*Syntermes tanygnathus* (Constantino, 1995)	Human food	Paoletti et al. (2000)
Order: Coleoptera				
Cerambycidae	*Acrocinus*	*Acrocinus longimanus* (Linnaeus, 1785)	Human food	Dufour (1987)
Curculionidae	*Anthonomus*	*Anthonomus* spp.	Human food	Ruddle (1973)
Bruchidae	*Caryobruchus*	*Caryobruchus* spp.	Human food	Dufour (1987)
Tettigoniidae	*Conocephalus*	*Conocephalus angustifrons* (Redtenbacher, 1891)	Human food	Ruddle (1973)
Scarabaeidae	*Dynastes*	*Dynastes Hercules* (Linnaeus, 1758)	Human food	Ramos-Elorduy et al. (2009)
Elmidae	*Elmis*	*Elmis condimentaria* (Philippi, 1864)	Human food	Müller et al. (2017)
Buprestidae	*Euchroma*	*Euchroma gigantea* (Linnaeus, 1758)	Human food	Dufour (1987)
Scarabaeidae	*Megaceras*	*Megaceras Crassum* (Prell, 1914)	Human food	Dufour (1987)
Scarabaeidae	*Podischnus*	*Podischnus agenor* (Olivier, 1789)	Human food	Dufour (1987)
Curculionidae	*Rhynchophorus*	*Rhynchophorus palmarum* (Linnaeus, 1758)	Human food	Dufour (1987)
Curculionidae	*Rhynchophorus*	*Rhynchophorus* sp.	Human food	Dufour (1987)
Passalidae	*Veturius*	*Veturius sinosus* (Drapiez, 1820)	Human food	Dufour (1987)
Tenebrionidae	*Zophobas*	*Zophobas morio*		Benzertiha et al. (2019)
Order: Diptera				
Stratiomyidae	*Chrysochlorina*	*Chrysochlorina* spp.	Human food	Ruddle (1973)
Stratiomyidae	*Hermetia*	*Hermetia illucens* (Linnaeus, 1758)	Animal feed	Makkar et al. (2014)
Calliphoridae	*Lucilia*	*Lucilia sericata* (Meigen, 1825)	Animal feed	Varelas (2019)
Muscidae	*Musca*	*Musca domestica* (Linnaeus, 1758)	Animal feed	Wang et al. (2017)
Order: Homoptera				
Membracidae	*Umbonia*	*Umbonia spinosa* (Fabricius, 1775)	Human food	Dufour (1987)
Order: Hymenoptera				
Vespidae	*Agelaia*	*Agelaia angulate* (Fabricius, 1804)	Human food	Dufour (1987)
Apidae	*Apis*	*Apis mellifera* (Linnaeus, 1758)	Human food	Alvarez-Suarez (2017)
Vespidae	*Apoica*	*Apoica thoracica* (Buysson, 1906)	Human food	Dufour (1987)
Formicidae	*Atta*	*Atta cephalotes* (Linnaeus, 1758)	Human food	Paoletti et al. (2000)
Formicidae	*Atta*	*Atta laevigata* (Smith, 1858)	Human food	Paoletti et al. (2000)
Formicidae	*Atta*	*Atta sexdens* (Linneo, 1758)	Human food	Paoletti et al. (2000)
Apidae	*Melipona*	*Melipona bradyeli* (Schwarz 1932)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona captiosa* (Moure, 1962)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona compressipes compressipes* (Fabricius, 1804)	Human food	Ávila et al. (2018)
Apidae	*Melipona*	*Melipona compressipes oblitescens* (Cockerell, 1919)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona compressipes salti* (Schwarz, 1932)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona eburnea* (Friese, 1900)	Human food	Ávila et al. (2018)
Apidae	*Melipona*	*Melipona eburnea fuscopilosa*	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona fasciata* (Latreille, 1811)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona fasciata cramptoni* (Cockerell, 1920)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona fasciata melanopleura* (Cockerell, 1919)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona fasciata paraenesis* (Ducke, 1919)	Human food	Nates-Parra (2001)

Table 1 (continued)

Family	Genus	Species	Application	References
Apidae	*Melipona*	*Melipona favosa* (Fabricius, 1798)	Human food	Ávila et al. (2018)
Apidae	*Melipona*	*Melipona favosa favosa* (Fabricius)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona favosa orbigny* (Guerin, 1844)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona favosa phenax* (Cockerell, 1919)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona flavolineata* (Friese, 1900)	Human food	Ávila et al. (2018)
Apidae	*Melipona*	*Melipona fuliginosa* (Lepeletier 1836)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona fulva* (Lepeletier 1836)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona grandis* (Guerin 1844)	Human food	Ávila et al. (2018)
Apidae	*Melipona*	*Melipona indecisa* (Cockerell 1919)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona interrupta* (Latreille, 1811)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona laterallis*(Erichson, 1840)	Human food	Ávila et al. (2018)
Apidae	*Melipona*	*Melipona marginata* (Lepeletier, 1836)	Human food	Ávila et al. (2018)
Apidae	*Melipona*	*Melipona merrillae* (Cockerell 1919)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona nebulosa* (Camargo, 1988)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona nigrescens* (Friese, 1900)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona phenax* (Cockerell, 1919)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona rufescens* (Friese, 1900)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona rufiventris* (Lepeletier 1836)	Human food	Nates-Parra (2001)
Apidae	*Melipona*	*Melipona salti* (Schwarz, 1932)	Human food	Ávila et al. (2018)
Apidae	*Melipona*	*Melipona scutellaris* (Latreille, 1811)	Human food	Ávila et al. (2018)
Apidae	*Melipona*	*Melipona seminigra* (Friese, 1903)	Human food	Ávila et al. (2018)
Vespoidea	*Mischocyttarus*	*Mischocyttarus* spp.	Human food	Ruddle (1973)
Apidae	*Nannotrigona*	*Nannotrigona testaceicornis* (Lepeletier 1836)	Human food	Fuenmayor et al. (2013)
Apidae	*Partamona*	*Partamona peckolti musarum* (Cockerell, 1917)	Human food	Nates-Parra (2001)
Apidae	*Partamona*	*Partamona peckolti peckolti* (Friese, 1900)	Human food	Fuenmayor et al. (2013)
Apidae	*Paratrigona*	*Paratrigona opaca* (Cockerell, 1917)	Human food	Fuenmayor et al. (2013)
Eumenidae	*Polistes*	*Polistes canadensis* (Linnaeus, 1758)	Human food	Ruddle (1973)
Eumenidae	*Polistes*	*Polistes erythrocephalus* (Latreille, 1813)	Human food	Ruddle (1973)
Eumenidae	*Polistes*	*Polistes pacificus* (Fabricius, 1804)	Human food	Ruddle (1973)
Eumenidae	*Polistes*	*Polistes versicolor* (Olivier, 1791)	Human food	Ruddle (1973)
Eumenidae	*Polybia*	*Polybia ignobilis* (Haliday, 1836)	Human food	Ruddle (1973)
Vespidae	*Polybia*	*Polybia rejecta* (Cameron, 1906	Human food	Dufour (1987)
Apidae		*Scaptotrigona limae*	Human food	Fuenmayor et al. (2013)
Vespidae	*Stelopolybia*	*Stelopolybia angulata*	Human food	Dufour (1987)
Apidae	*Tetragonisca*	*Tetragonisca angustula* (Latreille, 1825)	Human food	Ávila et al. (2018)
Apidae	*Tetragona*	*Tetragona clavipes* (Fabricius, 1804)	Human food	Ávila et al. (2018)
Apidae	*Trigona*	*Trigona fuscipennis* (Friese, 1900)	Human food	Ávila et al. (2018)
Order: Lepidoptera				
Bombycidae	*Bombyx*	*Bombyx mori*	Human food and animal feed	Paul and Dey (2014)
Saturnidae	*Dirphia*	*Dirphia* sp.	Human food	Dufour (1987)
Sphingidae	*Erinnyis*	*Erinnyis ello* (Linnaeus, 1758)	Human food	Dufour (1987)
Noctuidae	*Mocis*	*Mocis repanda* (Fabricius, 1794)	Human food	Ruddle (1973)
Order: Megaloptera				
Corydalidae	*Corydalus*	*Corydalus* spp.	Human food	Ruddle (1973)
Order: Orthoptera				
Acrididae	*Aidemona*	*Aidemona azteca* (Sauss, 1861)	Human food	Ruddle (1973)
Gryllidae	*Gryllus*	*Gryllus assimilis* (Fabricius, 1775)	Human food and animal feed	Rosa and Thys (2019)
Acrididae	*Osmilia*	*Osmilia flavolineata* (DeGeer)	Human food	Ruddle (1973)
Acrididae	*Osmilia*	*Osmilia* spp.	Human food	Ruddle (1973)

Table 1 (continued)

Family	Genus	Species	Application	References
Acrididae	*Orpbuella*	*Orpbuella* spp.	Human food	Ruddle (1973)
Acrididae	*Schistocerca*	*Schistocerca Americana* (Drury, 1770)	Human food and animal feed	Hinks and Erlandson (1994)
Acrididae	*Schistocerca*	*Schistocerca* spp.	Human food	Ruddle (1973)
Acrididae	*Tropidacris*	*Tropidacris latreillei* (Perty, 1832)	Human food	Ruddle (1973)
Order: Trichoptera				
Hydropsychidae	*Leptonema*	*Leptonema* spp.	Human food	Ruddle (1973)

species listed, many of which are used to produce honey and other natural products. Table 1 lists the insect species that have been used or can be considered as sources for food production.

Documented cases of insects used as food in Colombia

Although entomophagy is not a widespread practice in all regions of Colombia, there are reports of consumption of a wide variety of insects by different indigenous groups. According to Gasca-Álvarez and Costa-Neto (2021), 69 edible insects are currently reported as food resources, ingested in approximately 13 ethnic groups belonging principally to the Amazon and Caribbean regions. Several insect species are commonly consumed by indigenous amazonian peoples (Dufour, 1987; Paoletti et al., 2000; Gasca & González, 2021). Some authors have documented the insect consumption preferences of several indigenous groups including the Yukpa, the Guajibos, the Yanomamos and the Tukanoans. These groups consume a large variety of insects (grasshoppers, earthworms, flies, battle larvae, wasp, ants and termites), with a preference for immature forms in many cases. In addition, as Ruddle (1973) mentioned in his article, most of the insects consumed are crop pests, thus, this is a practice that may help to reduce agricultural losses without resorting to the use of insecticides.

Dufour (1987) documented the use of 20 insect species by the Tukanoans belonging to the orders Coleoptera, Lepidoptera, Blattaria and Hymenoptera. The coleopteran species commonly used by these people are *Euchroma gigantea*, *Rhynchophorus* spp., *Acrocinus longimanus* and *Megaceras crassum* (Dufour, 1987). The beetle *Dynastes hercules* is also eaten by some indigenous groups (Ramos-Elorduy et al., 2009; Ratcliffe, 2006). This scarab has a wide distribution, ranging from Mexico to South America (Dutrillaux & Dutrillaux, 2013) and can easily be bred in captivity (Gasca, 2011). In general, beetle larvae are widely appreciated by indigenous groups due to their high caloric and protein contributions to the diet (Dufour, 1987; Gasca & González, 2021).

Several authors have reported the consumption of Hymenopteran ants of the genus *Atta* by different indigenous groups in the amazonian region (Dufour, 1987; Paoletti et al., 2000). There is evidence that ants of the genus *Atta* were reared for eating by the Panches indigenous community in the Magdalena region (Patiño, 1990); nevertheless, the consumption of these ants is also widespread throughout the country. Ants are collected manually from nests and roasted after the removal of their wings and legs (Granados et al., 2013).

Tukanoans eat the wasps *Agelaia angulate*, *Apoica thoracica* and *Polybia rejecta* (Dufour, 1987). Ruddle (1973) reported that the Yukpa tribe frequently consumed larvae from the genus *Polistes* by first collecting and then eating their nests (Ruddle, 1973). There are also reports of the harvesting and consumption of bee larvae after honey is extracted (Patiño, 1990). The stingless bees *Trigona clavipes* and *Trigona trinidadensis* are also important in the diet of the Yukpa tribe (Ruddle, 1973).

Termites from the order Blattaria, particularly those belonging to the genera *Syntermes*, *Nasutitermes* and *Labiotermes* are also widely consumed (Dufour, 1987; Paoletti et al., 2000; Ruddle, 1973). The Tucumans also included termites of the genus *Termes* as part of their diet (Patiño, 1990).

Of the lepidopterans, Dufour (1987) showed evidence that caterpillars from the families Lacosomidae and Saturniidae were collected by Tukanoans. In a study by Patiño in 1990, species of Orthoptera were also reported as consumed; communities from Tucumán collected grasshoppers of the genus *Schistocerca* and natives from islands near Cartagena filled baskets with dried crickets and grasshoppers for trading.

Natural products

Most of the natural insect products marketed in Colombia come from bees, mainly from *Apis mellifera*. Bees offer several products such as honey, pollen, wax and propolis; however, honey is still the most commercialized product. In fact, although Colombia has the potential to produce very high-quality propolis, the amount of production does not supply national demand (Velasquez & Montenegro, 2017). Other products, such as mead are also produced artisanally on a small scale (Quicazán et al., 2018).

Meliponiculture has recently emerged in Colombia and is becoming important as an economic activity which generates environmental services and products that contribute to food security and that provide additional income for producers (Fuenmayor et al., 2013; Nates-parra & Rosso-londoño, 2013; Salatino et al., 2019). Around 120 native species have been identified in Colombia for this purpose, among which *Tetragonisca angustula* is the most common species reared (comprising 57% of registered colonies) (Jaramillo et al., 2019; Nates-parra & Rosso-londoño, 2013). According to Nates-Parra and Rosso-Londoño (2013), 34 species of stingless bees are reared in Colombia, belonging to the genera *Tetragonisca, Melipona, Paratrigona* and *Nannotrigona* (Jaramillo et al., 2019). Despite this, there are a dearth of studies that elucidate the characteristics, uses and practices used to obtain products from these bees, and there is also a lack of knowledge about their biology and therefore techniques for breeding and handling products that are obtained from them (Nates-Parra & Rosso-Londoño, 2013; Salomon et al., 2021).

Processed products

Several edible insects present in the country can be cultivated on a large scale and are suitable for obtaining edible products for human and animal consumption in the forms of fried, dried, roasted and cooked insects; as well as powder made from dried insects and feed for breeding animals and pets (Grabowski & Klein, 2017; Mutungi et al., 2019). However, many insects that have been produced on a large scale in other countries to produce goods and services related to the food and agricultural industries have neither been explored nor seen as economic alternatives in Colombia (Dicke et al., 2020).

Based on its nutritional properties and ease of rearing, the cricket *Gryllus assimilis* is a promising alternative for the development of human and animal dietary supplements (Alfaro et al., 2019; Ruiz et al., 2016; Soares et al., 2019). Previous studies have shown that *G. assimilis* has a high protein content (varying from 51 to 65% dry mass) and essential amino acids and minerals such as Fe and Zn (Adámková et al., 2017; Mwangi et al., 2018; Soares et al., 2019). In particular, Rosa and Thys (2019) evaluated the use of cricket powder from this species as an alternative for the enrichment of gluten-free breads, which allowed them to obtain a product with a high protein content and therefore better nutritional quality. The same authors reported a 40% increase in the dry matter protein content of breads with a 10% addition of cricket powder by dry mass (Rosa & Thys, 2019).

The giant mealworm (*Zophobas morio*) can be also produced on a large scale due to its easy handling and growth requirements (Heckmann et al., 2018). Benzertiha et al. (2019) showed that when this insect is added in small supplemental quantities to the diet of broiler chicken, it did not have negative effects on nutrient digestibility, and it improves the health of the animals by reducing pathogenic bacteria associated with its microbiota. A replacement of 25–50% of fish meal with giant mealworm meal also improved the growth performance of Nile tilapia and increased the percentage of protein found in fish fed with this experimental diet (Jabir et al., 2012).

The black soldier fly *Hermetia illucens* has been one of the most widely used insects in the world for the industrial bioconversion of organic waste into products with high protein value (Barragan-Fonseca et al., 2017; Dicke et al., 2020; Müller et al., 2017); *H. illucens* larvae can also be used directly as food for animals (e.g., for aquaculture of fishes and for poultry and pig breeding) (Barragan-Fonseca et al., 2017; Müller et al., 2017). Additionally, this fly is suitable for the bioconversion of low value products such as residues from agro-industry, crops, and food waste into high value products that can be reincorporated into the market (Cammack & Tomberlin, 2017; Sprangers et al., 2017).

Similarly, the housefly *Musca domestica* has been evaluated for the replacement of fishmeal; Ido et al. (2015) reported that the dietary supplementation of the red sea bream with housefly pupae resulted in better feed conversion and digestibility of plant protein, as well as the stimulation of its immune system response. Wang et al. (2017) found that Nile tilapia fed with *M. domestica* maggots had better muscle firmness and therefore better flesh quality. Similar results were reported by Shin and Lee (2021) for feeding Pacific white shrimp with natural and commercial products obtained from insects.

Insects as sources of bioproducts for disease prevention and treatment

Numerous bioactive compounds have been identified from extracts and natural products of different insect species. These compounds cover a wide range of applications due to their antimicrobial, anti-viral and anti-carcinogenic activity, as well as their analgesic and anti-inflammatory effects. Additionally, given the demand for new antibiotic compounds due to growing bacterial resistance in human and animal populations, a wide variety of insect peptide extracts and natural products have been studied for their antimicrobial properties. The discovery of new biologically active peptides and proteins have led to the chemical synthesis and production of recombinant proteins derived from insects (Riascos, 2021).

There are at least 40 species of insects in Colombia that have been studied regarding their production of natural products and biologically active compounds. Most records found for insects present in Colombia correspond to species of the orders Hymenoptera (51%), Diptera (15%), Blattaria (10%) and Coleoptera (13%). Other orders have lower percentages of total species reported, including Lepidoptera (5%), Dermaptera (3%), and Hemiptera (3%). The results above not only reflect a smaller amount of research activity at present for the orders with the lowest participation, but also the poor documentation of species in Colombia, considering that there are only 11,764 species recorded as compared to an estimate of more than 300,000 total species in the country (Amat-garcía & Fernández, 2011; GBIF, 2022). Table 2 provides a list of different compounds and substances with antimicrobial properties obtained from insects.

Hymenoptera

The order Hymenoptera comprises more than 153,000 described species and is one of the richest orders (Aguiar et al., 2013; Forbes et al., 2018). The species of interest investigated from this order in Colombia were from the families Apidae and Formicidae. Most of the substances and bioactive compounds studied from this order correspond to bee species and have been studied for their antimicrobial action against bacteria, fungi and other parasites.

Apidae

Natural products such as honey, propolis, royal jelly, bee pollen, venom and wax have been widely studied for their medicinal properties (Alvarez-Suarez, 2017; Israili, 2014; Kwakman & Zaat, 2012). These compounds are either chemically synthesized by the insect itself or are derived from plants and subsequently modified by bees for their own uses (Alvarez-Suarez, 2017).

Many beneficial health properties have been attributed to honey. In fact, the use of different types of honey have been approved for several clinical applications (Kwakman & Zaat, 2012). The antimicrobial activity of honey against Gram-positive and Gram-negative bacteria as well as fungus and viruses is well documented (Ahmed et al., 2018; Watanabe et al., 2014). Also, honey has been used to treat common conditions such as wounds, edemas, and ulcers due its anti-inflammatory effects (Almasaudi et al., 2016; Borsato et al., 2014).

Honey produced by stingless bees is highly regarded due to its medicinal properties (Fletcher et al., 2020; Nates-parra & Rosso-londoño, 2013). Many of the properties observed in stingless bee honey have been correlated to its high content of flavonoids and phenolic acids (Silva et al., 2013; Biluca et al., 2017; Ávila et al., 2018). Phenolic acids from different species exhibit different profiles, which are related to the different types of pollens, nectars, resins, and oils that are available for the bees (Ávila et al., 2018; Cardona et al., 2019).

A significant correlation has been observed between the antioxidant capacity of honey and its relevant amounts of some phenolic and flavonoid acids (Biluca et al., 2017). Due to its antioxidant effects, honey provides protection against free radical and reactive oxygen species, which are responsible for different pathologies such as disturbances in the metabolism and cardiovascular diseases (Ajibola et al., 2012). Also, the antioxidant activity of honey helps wound healing (Ahmed et al., 2018).

Inhibition by propolis of bacteria and fungus growth has also been reported. In addition, propolis has anti-inflammatory properties due its ability to modulate the immune response (Armutcu et al., 2015; Li et al., 2017; Touzani et al., 2019; Wang et al., 2015). Propolis from stingless bees contains several phenolic compounds that have antimicrobial properties against bacteria and fungus, including: flavonones, flavones, diterpenic acid and pentacyclic acids (Barrera et al., 2015; Çelemli, 2013; Sanches et al., 2017). The major chemical groups found in Colombian samples of propolis are diterpenes, triterpenes, benzophenones, flavonoids, alkylresorcinols and fatty acids (Barrera et al., 2015; Pardo et al., 2019; Rodríguez et al., 2012). Colombian propolis samples from several regions have active ingredients that provide protection against a wide variety of Gram-positive and Gram-negative bacteria of importance in health and food (Ferreira et al., 2011; Samara-Ortega et al., 2011; Só et al., 2015).

Moreover, bee venom has been extensively studied with regard to its antimicrobial and anti-inflammatory activity (Leandro et al., 2015; Lee et al., 2016). Bee venom of *Apis mellifera* has been tested in the treatment of diseases such as acne, neural inflammation, asthmatic inflammation, amyotrophic lateral sclerosis, atherosclerosis, arthritis and hepatic inflammation (Saad Rached et al., 2010; Kim et al., 2011, 2015; Suk et al., 2013; Lee et al., 2015; Lee & Bae, 2016).

The anti-tumor effects of bee products have also been studied. Honey has antiproliferative, antimutagenic and apoptotic activities on different types of tumor cell lines, including breast, liver, colorectal and prostate (Erejuwa et al., 2014; Jaganathan et al., 2014; Porcza et al., 2016). Also, bee venom reduces the proliferation of carcinoma cells and tumors (Premratanachai & Chanchao, 2014). In particular, bee venom has exhibited cytotoxic activity against different cancer cells, such as: breast, lung, cervical, liver, prostate, bladder, blood (e.g., leukemia), hepatic

Table 2 Insects as a source of compound with antimicrobial activity (antibacterial, antifungal and antiviral)

Species	Substance tested or bioactive compound	Source	Results	References
Acrocinus longimanus	Alopeptides	Hemolymph	Antifungal activity	Barbault et al. (2003)
Apis mellifera	Abaecin peptide	Honey	Antibacterial activity	Luiz et al. (2017)
Apis mellifera	Honey sample	Honey	Antibacterial activity against Gram-positive and Gram-negative bacteria and antiviral activity against herpes, influenza and varicella zoster virus	Ahmed et al. (2018), Watanabe et al. (2014)
Apis mellifera	Galangin and Pinocembrin (flavonoids)	Propolis	Antimicrobial activity against different pathogens	Velasquez and Montenegro (2017)
Apis mellifera	Ferulic and caffeic acid and derivatives of benzoic acid	Propolis	Antimicrobial activity against different pathogens	Velasquez and Montenegro (2017)
Apis mellifera	Propolis extracts	Propolis	Antibacterial activity against Gram-positive and Gram-negative bacteria, including methicillin- resistant Staphylococcus aureus	Klhar et al. (2019), Só et al. (2015)
Apis mellifera	Apitoxin	Bee venom	Antibacterial activity against Gram positive and Gram-negative bacteria	Leandro et al. (2015)
Apis mellifera	Melitin	Bee venom	Antimicrobial and antiviral activity	Oršolić (2012), Só et al. (2015)
Apis mellifera	Secapin	Bee venom	Antimicrobial activity against Gram positive and Gram-negative bacteria as well as fungus	Lee et al. (2016)
Apis mellifera	Royal jelly samples	Royal jelly	Antibacterial activity against Gram positive and Gram-negative bacteria	Fratini et al. (2016)
Apis mellifera	Royalisin	Royal jelly	Antimicrobial activity against fungus, as well as Gram positive and Gram-negative bacteria	Bílikova et al. (2015)
Apoica pallens	Protein c-type lectin 6	Venom	Antimicrobial activity	Mendonça et al. (2019)
Acromyrmex octospinosus	Secretions	Metapleural and mandibular glands, and integument	Antibacterial and antifungal activity	Samuels et al. (2013)
Acromyrmex subterraneus	Secretions	Metapleural and mandibular glands, and integument	Antibacterial and antifungal activity	Samuels et al. (2013)
Acromyrmex octospinosus	Candicidin	Streptomyces associated to the integument	Antifungal activity	Barke et al. (2010)
Atta sexdens	Secretions	Metapleural and mandibular glands, and integument	Antibacterial and antifungal compounds	Samuels et al. (2013)
Bombyx mori	Cecropins	Hemolymph	Antimicrobial activity against bacteria and fungus	Buhroo et al. (2018)
Bombyx mori	Gloverin A2	Hemolymph	Antimicrobial activity against bacteria and fungus	Buhroo et al. (2018)
Bombyx mori	Defensins	Hemolymph	Antimicrobial activity against bacteria and fungus	Buhroo et al. (2018)

Table 2 (continued)

Species	Substance tested or bioactive compound	Source	Results	References
Bombyx mori	Lebocin	Hemolymph	Antimicrobial activity against bacteria and fungus	Buhroo et al. (2018)
Bombyx mori	Lysozymes, attacins and moricin peptides	Hemolymph	Antimicrobial activity	Buhroo et al. (2018), Islam et al. (2016)
Chrysomya megacephala	Hemolymph samples	Larva and pupae	Antibacterial activity against Gram-positive and Gram-negative bacteria	Sahalan and Omar (2006)
Chrysomya megacephala	Proteins	Salivary glands	Antimicrobial activity	Tait et al. (2018)
Euschistus crenator	Tannins	–	Antiviral activity	Dossey et al. (2016)
Forficula auricularia	2-Methyl-1,4-benzoquinone and 2-ethyl-1,4-benzoquinone	Adult and larvae secretions	Antibacterial activity against Gram-positive and Gram-negative bacteria	Gasch and Vilcinskas (2014)
Hermetia illucens	Extracts	Larva	Antibacterial activity against Gram-positive and Gram-negative bacteria	Müller et al. (2017)
Hermetia illucens	Defensins	Hemolymph of immunized larvae	Antimicrobial activity against Gram-positive bacteria	Park et al. (2015)
Hermetia illucens	Cecropins, sarcotoxin and stomoxyn peptides	Hemolymph	Antimicrobial activity against bacteria and fungus	Elhag et al. (2017)
Lucilia sericata	Attacins, cecropins, diptericins and proline rich peptides	Hemolymph, Excretion/Secretion products	Antimicrobial activity against Gram-negative and Gram-positive bacteria	Pöppel et al. (2015)
Lucilia sericata	Lucimycin	Hemolymph, Excretion/Secretion products	Antimicrobial activity against Gram-negative and Gram-positive bacteria as well fungus	Pöppel et al. (2015)
Lucilia sericata	Lucifensin	Hemolymph, fat body, gut, salivary glands and Excretion/Secretion products from maggots	Antimicrobial activity against Gram-negative and Gram-positive bacteria	Pöppel et al. (2015), Valachova et al. (2014)
Lucilia sericata	Sarcotoxin and stomoxyn peptides	Larva	Antimicrobial activity	Hirsch et al. (2019)
Lucilia sericata	Crude protein extracts	Larva	Antibacterial activity against *S. aureus*	Zhang et al. (2013)
Lucilia sericata	Extracts	Larva (whole-body)	Antibacterial activity against *Micrococcus luteus*	Valachova et al. (2014)
Melipona fasciculata	Propolis extracts	Propolis	Antimicrobial activity against *S. mutans* and *C. albicans*	Liberio et al. (2011)
Melipona quadrifasciata	Hydro-alcoholic propolis extract	Propolis	Antibacterial activity against Gram-positive and Gram-negative	Biluca et al. (2017)
Musca domestica	Cecropins	Larva	Antimicrobial activity against Gram-positive and Gram-negative bacteria, including multidrug resistant *E. coli*	Tang et al. (2014)
Musca domestica	Attacins, defensins, diptericins peptides	Larva	Antimicrobial activity	Tang et al. (2014)
Musca domestica	Lysozymes	Larva	Antimicrobial activity	Tang et al. (2014)

Table 2 (continued)

Species	Substance tested or bioactive compound	Source	Results	References
Musca domestica	Domesticin and muscin peptides	Larva	Antibacterial activity against *Serratia marcescens* and *Micrococcus luteus*	Tang et al. (2014)
Musca domestica	Novel antimicrobial protein	Larva	Antifungal activity against *C. albicans*	Guo et al. (2017)
Musca domestica	Haemolymph samples	Larva	Antibacterial activity against *S. aureus*, *Staphylococcus epidermidis*, and *P. aeruginosa*	Kawasaki and Andoh (2017)
Musca domestica	Defensin	Immunized pupae	This defensin was active against Gram-positive bacteria and had a lower activity against Gram-negative bacteria	Dang et al. (2010)
Musca domestica	Protein enriched fraction	Larva	Antiviral activity against *Bombyx mori* nuclear polyhydrosis and *Autographa califórnica* Multicapsid Nucleopolyhedrovirus virus	Ai et al. (2013)
Musca domestica	Chitosan	Chitin from larvae	Antifungal and antiviral activity	Ai et al. (2012)
Periplaneta americana	Extracts	Whole body	Antimicrobial activity	Ali et al. (2017)
Periplaneta americana	Isoflavone compounds	Methanolic extracts	Antibacterial activity against *Bacillus subtilis*	Gao et al. (2016)
Periplaneta americana	Extracts	Brain, hemolymph and muscles	Antibacterial activity against the methicillin resistant *Staphylococcus aureus* and neuropathogenic *Escherichia coli*	Ali et al. (2017)
Periplaneta americana	3-Acetylbenzamide	Produced by actinomycete strain isolated from the intestinal tract	Antifungal activity	Fang et al. (2018)
Periplaneta americana	Periplanetasin-2 peptide	Immunized cockroach	Antifungal activity	Yun et al. (2017)
Protopolybia exigua	Mastoparan peptides	Venom	Antimicrobial activity	Murata et al. (2009)
Sarconesiopsis magellanica	Excretion/secretion products	Larva	Antimicrobial activity	Díaz-Roa et al. (2019)
Sarconesiopsis magellanica	Extracts	Hemolymph	Antibacterial activity	Góngora et al. (2015)
Sarconesiopsis magellanica	Extracts	Fat body	Antibacterial activity	Góngora et al. (2015)
Spodoptera frugiperda	Peptides and proteins: cecropins, defensins and lysozymes	Hemolymph	Antimicrobial activity against Gram-positive and Gram-negative bacteria	Chapelle et al. (2009)
Stingless bee	Honey samples	Honey	Antimicrobial activity	Silva et al. (2013)
Synoeca surinama	Peptides	Venom	Antibacterial activity against Gram-positive and Gram-negative bacteria	Freire et al. (2020)
Tetragonisca angustula	Honey sample	Honey	Bactericidal effect	Gamboa and Figueroa (2009)
Ulomoides dermestoides	Hexanoic and acetonic extracts	Adults (whole body)	Antibacterial activity against gram positive and gram negative	Morales et al. (2020)
Zophobas morio	Extracts	Larva (whole-body)	Antimicrobial activity against gram positive and gram negative	Mohtar et al. (2014)

(e.g., hepatocellular carcinoma) and renal (Eze et al., 2016; Oršolić, 2012; Sobral et al., 2016).

The anti-carcinogenic activity of propolis has been documented for different types of cancer and it is related to its high content of phenolic compounds, which possess antiproliferative and cytotoxic effects on tumor cells (Bonamigo et al., 2017; Vit et al., 2015). Pardo et al. (2019) reported that Colombian propolis samples significantly reduced the cell viability of osteosarcoma cells, an observation that was correlated with its high content of benzophenones.

Formicidae

Ants of the *Atta* and *Acromyrmex* genera, including species such as *Atta sexdens rubropilosa*, *Acromyrmex octospinouses* and *Acromyrmex subterraneus subterraneus*, have been studied with regard to their ability to secrete antibiotic and antifungal compounds thanks to bacteria associated with their integument and their metapleural and mandibular glands (Lima et al., 2009; Samuels et al., 2013). Actinobacteria associated with their cuticles include *Streptomyces* and *Pseudonocardia* (Cavalheiro, 2017; Samuels et al., 2013). Their mandibular gland secretions contain tannins, terpenoids and pheromones which are able to inhibit a range of microorganisms (Lima et al., 2009; Samuels et al., 2013). The antimicrobial activity of these compounds and those secreted by their metaupleral glands have been tested in vitro against bacteria and fungus with very promising results (Lima et al., 2009; Wang et al., 2020).

Furthermore, myrmexins obtained from the venom of *Pseudomyrmex triplarinus* are a protein complex with anti-inflammatory and analgesic activities (Mans et al., 2016; Pan & Hink, 2000). There are reports indicating that indigenous groups use ants of the genus *Pseudomyrmex* as therapeutic agents in several ways: for example, they allow them to bite them in order to relieve joint pain and they crush them to relieve toothaches (Mushtaq et al., 2018).

Vespidae

The efficacy of products from several social wasps from the Vespidae family has been documented in the treatment of common respiratory conditions. Costa-Neto (2002) documented the use of honey from the social wasp *Brachygastra lecheguana* in northern Brazil for the treatment of cough and asthma. Similarly, indigenous groups in the region use infusions or preparations from *Apoica pallens* and *Polistes canadensis* nests to treat asthma and other respiratory conditions such as whooping cough (Costa-Neto, 2002; Costa-Neto et al., 2006). On the other hand, people in the region who have suffered strokes use inhalations of smoke from burned nests of *Protopolybia exigua, Polybia sericea* and *A. pallens* species for their therapeutic effects (Costa-Neto, 2002; Costa-Neto et al., 2006).

The venom of *A pallens* contains a great variety of proteins with different biological functions, including compounds that are neurotoxins, proteins of the type 6 lectin that have biological activity against pathogens, toxic peptides, and proteins with cytolytic and proteolytic action (Mendonça et al., 2019). *Synoeca surinama* venom showed potential antibacterial activity against Gram-positive and Gram-negative bacteria which was associated with the presence of antimicrobial peptides such as synoeca-MP (Dantas et al., 2019; Freire et al., 2020; Mortari et al., 2012). Also, venom from *Protopolybia exigua* exhibited antimicrobial activity due to the mastoparan peptides it contains (Mendes et al., 2005; Murata et al., 2009).

Coleoptera

The order Coleoptera includes the largest number of insect species, with more than 380,000 species described (Zhang et al., 2018). Although it is the most diverse group, there are few reports of uses of Coleoptera species in medicine or applied studies that have obtained and identified bioactive molecules beneficial to humans. The studies reviewed here were related to species of the Tenebrionidae, Curculionidae, Cerambycidae and Dryophthoridae families.

Extracts of the whole body of *Ullomoides dermestoides* exhibited antimicrobial activity against several Gram-positive and Gram-negative bacteria (Morales et al., 2020); also, organic and aqueous extracts from this species exerted antioxidant and anti-inflammatory activity linked to the presence of phenols, flavonoids, quinones, fatty acids and monoterpenes such as limonene, alpha-terpinene and alpha-pinene (Mendoza & Saavedra, 2013; Mendoza et al., 2016; Morales et al., 2020). Furthermore, antiproliferative, cytotoxic and genotoxic activities have been documented in extracts of *U. dermestoides* (Dávila-vega et al., 2017; Deloya-Brito & Deloya, 2014; Mendoza & España-Puccini, 2016).

Whole-body extracts of *Zophobas morio* larvae inhibited the growth of various bacteria strains, which may be due to the presence of antimicrobial peptides (Mohtar et al., 2014). Also, the Curculionidae species *Rhynchophorus palmarum* and *Rhina barbirostris* have been used to treat common afflictions such as fever and headaches (Alves & Alves, 2011). There are also reports of the use of *Rhinostomus barbirostris* by indigenous people to treat these same conditions (Alves & Alves, 2011; Alves & Dias, 2010).

Diptera

The order Diptera is one of the most diverse insect groups and includes approximately 160,000 species (Pape et al., 2011). Several species of the Calliphoridae family have aroused interest because of their potential usefulness in larva therapy, which is directly related to the anti-inflammatory and antimicrobial action of their larval secretions. Traditionally, *Lucilia sericata* maggots have been used to treat chronic and non-healing wounds through proteolytic digestion of necrotic tissue and through the removal of bacterial biofilms (Bian et al., 2017; Choudhary et al., 2016; Tamura et al., 2017; Tombulturk et al., 2018). Maggot extracts accelerate the healing processes of burn wounds and reduce levels of oxidative stress (Bian et al., 2017). Also, the excretion/secretion (ES) products of *L. sericata* can be used for the treatment of wounds in diabetic patients, as they increase NF-κB (nuclear factor kappa-light-chain-enhancer of activated B cells) activity and collagen synthesis and promote wound contraction (Tombulturk et al., 2018). Furthermore, the neotropical species *Lucilia eximia* can also be used in larval therapy, considering it has also demonstrated its effectiveness in the treatment of chronic wounds in both humans and animals. (Calderón-Arguedas et al., 2014; Retana et al., 2014; Wolff et al., 2010).

According to Wolff et al. (2010), *L. eximia* has been used in Colombia since 2002 in larval debridement therapy and for the reduction of the odor produced by bacterial decomposition in large wounds.

The larvae of *L. sericata* produce at least 47 peptides with antimicrobial activity against Gram- negative and Gram- positive bacteria (Pöppel et al., 2015). These antimicrobial peptides have been found in the hemolymph and in the excretion/secretion (ES) products from these maggots (Nygaard et al., 2012). Peptides isolated from ES products have exerted antimicrobial activity against a wide variety of microorganisms and parasites, including bacteria, fungus and the pathogen that causes leishmaniasis (Kruglikova, 2011; Kruglikova & Chernysh, 2011; Riascos, 2021; Sanei-Dehkordi et al., 2016).

The species *Chrysomya megacephala* and *Sarconesiopsis magellanica* are also promising insects for use in larva therapy and in the discovery of new bioactive compounds. The hemolypmh of *C. megacephala* larvae and pupae exhibited antibacterial activity against Gram-positive and Gram-negative bacteria (Sahalan & Omar, 2006). In addition, the salivary glands of *C. megacephala* contain a considerable variety of substances with antimicrobial activity and proteolytic enzymes (Tait et al., 2018). Moreover, the ES products of *S. magellanica* enhanced cell proliferation, tissue regeneration and wound healing due to the presence of proteolytic enzymes, serine proteases and antimicrobial compounds (Díaz-Roa et al., 2014, 2019; Góngora et al., 2015; Pinilla et al., 2015). It has also been demonstrated that the hemolymph and body fat extracts of *S. magellanica* conferred significant antibacterial activity (Góngora et al., 2015).

The antimicrobial peptides cecropin, attacin, defensin and diptericin, as well as lysozymes play important roles in the immune system of *Musca domestica* (Tang et al., 2014). These peptides have been tested against various bacteria and fungus strains (Jiangfan et al., 2016; Kawasaki & Andoh, 2017) and their expression can be induced by injuring or infecting the maggots (Dang et al., 2010; Jiangfan et al., 2016; Kawasaki & Andoh, 2017). An increase in the antibacterial activity of the hemolymph has also been observed in *L. sericata* maggots after septic injury (Valachova et al., 2014). Furthermore, the antimicrobial activity of the extracts and hemolymph of the Black Soldier Fly larvae (*Hermetia illucens*) is well reported (Müller et al., 2017; Park et al., 2015). Several antimicrobial peptides including cecropins, attacins and defensins have been identified and isolated from immunized *H. illucens* larvae (Elhag et al., 2017; Xia et al., 2021; Zdybicka-Barabas et al., 2017).

Blattaria

The order Blattaria includes approximately 7500 described species of termites and cockroaches (Evangelista et al., 2019). Some species of termites have been used in folk medicine. For example, *Nasutitermes macrocephalus, Nasutitermes corniger* and *Microcerotermes exiguus* have been used in traditional medicines to treat asthma, cough, flu, hoarseness, sore throat, and sinusitis (Figueirêdo et al., 2015; Ahmad et al., 2018). Moreover, the potential of the *Nasutitermes* genus as a natural source of antimicrobial peptides has been documented (Choudhury et al., 2017; Figueirêdo et al., 2015).

Periplaneta americana is an insect species that is widespread throughout the world, and it is considered to be a domestic pest (Luo et al., 2014). *P. americana* extracts and many derivate drugs are utilized in modern and traditional Chinese medicine to promote wound healing and blood circulation and for the treatment of fever, pain, ulcers, burns, chronic heart failure and cancer (Li et al., 2016; Nguyen et al., 2020; Shen et al., 2017; Zeng et al., 2019).

A broad range of compounds with antimicrobial properties have been obtained from *P. americana* extracts, such as the isoquinoline group, chromene derivatives, thiazine groups, pyrrole-containing analogues, sulfonamides, furanones and flavonones (Ali et al., 2017; Huang et al., 2017).

The anti-inflammatory and wound healing properties of *P. americana* extracts are associated with the promotion of keratinocytes, with endothelial cell proliferation, with fibroblast accumulation and with the secretion of related growth factors. In addition, *P. americana* extracts have displayed anticarcinogenic action and stimulate tissue cell regeneration (Luo et al., 2014; Zhao et al., 2017). The anti-tumor effects of *P. americana* extracts can be understood through different mechanisms of action, such as the induction of apoptosis, the reversal of drug resistance, the suppression of angiogenesis and the induction of cell cycle arrest (Zhao et al., 2017).

Lepidoptera

The order Lepidoptera is one of the most numerous insect orders, comprising more than 159,000 described species (Garwood et al., 2021; Nieukerken et al., 2011).

Bombyx mori is one of the world's most researched and best-known insects. This insect, which belongs to Bombycidae family, has been commonly reared to produce silk; however, a wide variety of peptides with significant antimicrobial activity have been found and isolated from it that have potential applications in medicine and agriculture (Buhroo et al., 2018; Chen & Lu, 2018; Islam et al., 2016). Cecropins, defensins, lebocin, lysozymes, attacin and moricin are peptides produced by *Bombyx mori* that have been well documented for their antibacterial properties (Buhroo et al., 2018; Islam et al., 2016).

Spodoptera frugiperda produces several immune system related peptides and proteins that have antimicrobial activity against Gram-positive and Gram-negative bacteria and fungi (Duvic et al., 2012). The presence of antimicrobial peptides of the cecropin, defensin and lysozyme families has been reported for *S. frugiperda* (Chapelle et al., 2009; Duvic et al., 2012; Riascos, 2021; Volkoff et al., 2003).

Dermaptera

The order Dermaptera comprises approximately 2000 described species (Engel et al., 2015). In the research conducted for the present study, only one record was found for this order; conversely, several studies of the chemical profile of *Forficula auricularia* secretions have been reported. Both larvae and adults of *F. auricularia* secrete a strong substance to repel potential predators (Gasch & Vilcinskas, 2014; Gasch et al., 2013; Hoffman, 2014). However, these secretions have also exhibited antimicrobial properties against Gram-positive and Gram-negative bacteria, as well as against entomopathogenic fungi (Gasch et al., 2013).

Recombinant proteins

Insects can also be used as a platform for recombinant protein production through the Insect Cell-Baculovirus expression system (Felberbaum, 2015; Kollewe & Vilcinskas, 2013; Van Oers et al., 2015). In this system, insect cells are infected with genetically modified bacuoloviruses, which replicate and use their cellular machinery for the expression of recombinant proteins (Contreras-Gómez et al., 2014; Kollewe & Vilcinskas, 2013;). In contrast with prokaryotic organisms, insect cells can make post-translational modifications to proteins (Felberbaum, 2015). Using this approach, insect cell cultures have been used for vaccine production, for gene therapy, as biosensors, for the production of viral vectors and in nanotechnology (Van Oers et al., 2015). The lepidopteran cell lines of *Spodoptera frugiperda* (IPBL-sf21-AE and its clonal isolate sf9) and *Trichoplusia ni* (BTI-Tn-5B1-4] are the most widely commercialized variants (Contreras-Gómez et al., 2014).

In this process, a scale-up of the insect cells is required to produce a large enough quantity of recombinant proteins (Van Oers et al., 2015) for effective use. In order to do this, recombinant proteins are usually produced in bioreactors to support insect cell growth and virus production (Gallo-Ramírez et al., 2015). However, the costs associated with the maintenance of the suspended cells and the equipment required remain considerably high. Thus, the use of insects as living biofactories has been proposed as an alternative to insect cell cultures (Gomez-Casado et al., 2011). By using insect larvae or pupae as biofactories, it is possible to obtain higher levels of recombinant protein expression of antibodies, enzymes, vaccines and hormones that are useful for diagnostic and therapeutic purposes (Zhou et al., 2011; Gómez-Sebastián et al., 2012; Salomon et al., 2021; Buonocore et al., 2021). As the life cycle of the silkworm (*Bombyx mori*), as well as its rearing and maintenance are well known, *B. mori* is a suitable model for the expression of heterologous genes through the whole insect model (Kato et al., 2010). At the time of the present study, both *B. mori* larvae and pupae have been used for the efficient production of relevant recombinant proteins (Kato et al., 2010; Kollewe & Vilcinskas, 2013; Manohar et al., 2010). In addition, the expression of recombinant proteins in the silk gland of *B. mori* has become an interesting alternative to produce valuable pharmaceutical proteins as well as human- and animal-derived proteins (Zdybicka-barabas & Vilcinskas, 2016).

Since 1998, different companies have produced vaccines and therapies based on baculovirus expression technology which have been approved for use with humans and in veterinary medicine (Cox, 2021; Felberbaum, 2015; Van Oers et al., 2015). Some examples include vaccines and therapies for influenza, papilloma virus, swine fever and porcine circovirus, as well as pharmaceutical products for gene therapy and immunotherapy (Felberbaum, 2015; Milián & Kamen, 2015; Van Oers et al., 2015).

Insects as enzyme sources

Insects produce a wide variety of enzymes that allow them to make use of multiple organic substrates for feeding (Mika et al., 2014). Insect-derived enzymes include hydrolytic enzymes, cellulases, lipases and oxidative enzymes that provide interesting alternatives in industrial biotechnology applications (Alves et al., 2019; Mika et al., 2013).

Food proteins such as gluten and casein can cause immune reactions and allergies in some people. Celiac disease, which is caused by wheat gluten and similar proteins from oat, barley and rye requires sufferers to maintain diets with many restrictions that affect their quality of life (Mika et al., 2013, 2014). In this regard, Mika et al. (2014) found that enzyme extracts from several beetles considered to be cereal pests can be used to hydrolyze gluten, casein, rice protein and bovine serum albumin. According to the authors, serine and cysteine peptidases were the most common extracts found (Mika et al., 2014).

The hydrolytic enzymes alpha, beta, gluco- and isoamylase are digestive enzymes produced by plants, animals and microorganism in order to degrade starch and glycogen (Mika et al., 2013). Although amylases are mostly obtained from bacteria and fungi, they can also be found in insects (Mehrabadi et al., 2011; Mika et al., 2013). Amylases have been widely studied for their applications in the pharmaceutical, food, brewing, paper, detergent, and textile industries (Saini et al., 2017). In particular, Easa et al., (2017) performed an extraction of crude amylase from *Z. morio* which exhibited high enzymatic activity. Also, Mehrabadi et al. (2011) obtained and characterized alpha-amylases from the midgut of several coleopteran pests.

On the other hand, termites have displayed an interesting capacity for lignocellulose degradation. The mechanism they use is not only mediated by the microbiota associated with their hindgut but is also due to the action of hydrolytic enzymes in the host (Arneodo, 2018). The synergistic action of endoglucanases and beta-glucosidases contributes to cellulose degradation. Both endoglucanases and beta-glucosidases were detected in their salivary glands and midgut (Arneodo, 2018). Beta-glucosidases enzymes have also been found in the digestive tracts of the palm weevil *R. palmarum* and the lepidopteran species *B. mori* and *S. frugiperda* (Gyeong et al., 2005; Yapi et al., 2009; Watanabe et al., 2013).

DNA barcoding as a quality control measure for insect products

The authentication of an insect species is important not only for assuring its identity, but also for assuring biosafety, food security and the quality of insect products (Sgamma et al., 2017; Siozios et al., 2020). The morphological identification of a specific taxon to the species level requires a great amount of expertise and an advanced knowledge of the group of interest (Khaksar et al., 2015). Thus, traditional methods for species identification may prove to be impractical, as previous studies of commercially available products from insects have exposed mislabelling or incorrect attribution of species names (Siozios et al., 2020).

Based on the growing interest in developing new insect products, it is important to develop public policies that guarantee the authenticity of the raw material and that do not endanger consumers (Siozios et al., 2020). In this regard, DNA barcoding is a useful method for the rapid identification of specimens through the use of the mitochondrial fragment cytochrome oxidase subunit I (COI), which is widely used due to its variability among species of the same genus (Kress et al., 2015; Paz et al., 2011; Siozios et al., 2020).

Previously, DNA barcoding has been successfully used to identify and ensure the quality of products in the herbal and seafood industries, as well as other types of food products that are susceptible to misidentification or adulteration (Christiansen et al., 2018; Sgamma et al., 2017; Willette et al., 2017). Thus, it may be applicable for the identification and quality control of important insect products in the pharmaceutical, food and biotechnology industries.

DNA barcoding methods involve the amplification of a genetic marker and then its comparison to a template of voucher specimens (Kress et al., 2015). Consequently, the identification of insect species using this technique requires a reference database (Kress et al., 2015; Paz et al., 2011). However, despite the efforts to contribute data to global databases such as BOLD and GenBank, there is still a lack of information for Colombia. According to previous estimates, there are around 320,000 insect species in Colombia (Amat-garcía & Fernández, 2011), whereas the barcode sequences recorded in BOLD so far barely contain 1803 species.

Conclusions

This paper presents an overview of the uses and applications of a wide range of insects, many often considered pests, with an emphasis on those found in Colombia. The great diversity and distribution of insects throughout the planet implies their evolutionary success and high degree of genetic variability. Insects have also developed multiple adaptations and survival strategies that involve the expression of a wide variety of molecules associated with their immune systems, as well as a great degree of versatility that can be used to benefit humans.

Although Colombia is one of the most biologically diverse countries in the world, the work of species description is still far from done. There is still a lack of studies directed toward the recognition of important and beneficial insect species and their potential use.

The use of insects as food is influenced for the nutritional value that varies in the amount and quality of proteins, amino acids, and other chemical compounds that also vary among insects. This variability must be estimated and compared in local species and evaluated according to the breeding necessities and possibilities. Limitations related to communities' behavior, preferences, and health issues, including the possible existence of allergies to chitin or other insect components, need to be addressed.

National and international production and marketing standards are not completely defined, and issues as bioeconomy and species conservation vs commercial use, must also be revised. Despite this shortcoming, it is considered that Colombia has great potential for the sustainable industrial development of insect-based products.

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References

Adámková, A., Mlček, J., Kouřimská, L., Borkovcová. M., Bušina, T., Adámek, M., Bednářová, M., & Krajsa, J. (2017). Nutritional potential of selected insect species reared on the Island of Sumatra. *International Journal of Environmental Research and Public Health*, *14*(5), 521. https://doi.org/10.3390/ijerph14050521

Aguiar, A. P., Deans, A. R., Engel, M. S., Forshage, M., Huber, J. T., Jennnings, J. T., Johnson, N. F., Lelej, A. S., Longino J. T, Lohrmann, V., Mikó, I., Ohl, M., Rasmussen, C., Taeger, A., & Yu, D. S. K. (2013). Order hymenoptera. *Zootaxa*, *3703*(1), 051–062. https://doi.org/10.11646/zootaxa.3703.1.12

Ahmad, T., Nabi, S., & Humera, Q. (2018). Biotechnology, a tool in termite management. In M. A. Khan & W. Ahmad (Eds.), *Termites and Sustainable Management* (pp. 289–315). Springer.

Ahmed, S., Sulaiman, S. A., Baig, A. A., Ibrahim, M., Liaqat, S., Fatima, S., Jabeen, S., Shamim, N., & Othman, N. H. (2018). Honey as a potential natural antioxidant medicine, an insight into its molecular mechanisms of action. *Oxidative Medicine and Cellular Longevity, 2018*(11), 19p. https://doi.org/10.1155/2018/8367846

Ai, H., Wang, F., Xia, Y., Chen, X., & Lei, C. (2012). Antioxidant, antifungal and antiviral activities of chitosan from the larvae of housefly, *Musca domestica* L. *Food Chemistry, 132*(1), 493–498. https://doi.org/10.1016/j.foodchem.2011.11.033

Ai, H., Wang, F., Zhang, N., Zhang, L., & Lei, C. (2013). Antiviral, immunomodulatory, and free radical scavenging activities of a protein-enriched fraction from the larvae of the housefly, *Musca domestica*. *Journal of Insect Science, 13*(112), 1–16. https://doi.org/10.1673/031.013.11201

Ajibola, A., Chamunorwa, J. P., & Erlwanger, K. H. (2012). Nutraceutical values of natural honey and its contribution to human health and wealth. *Nutrition and Metabolism, 9*, 1–12. https://doi.org/10.1186/1743-7075-9-61

Alfaro, A. O., Núñez, W. L., Marcia, J., & Fernández, I. M. (2019). The cricket (*Gryllus assimilis*) as an alternative food versus commercial concentrate for tilapia (Oreochromis sp.) in the nursery stage. *Journal of Agricultural Science, 11*(6), 97. https://doi.org/10.5539/jas.v11n6p97

Ali, S. M., Siddiqui, R., Ong, S. K., Shah, M. R., Anwar, A., Heard, P. J., & Khan, N. A. (2017). Identification and characterization of antibacterial compound(s) of cockroaches (*Periplaneta americana*). *Applied Microbiology and Biotechnology, 101*(1), 253–286. https://doi.org/10.1007/s00253-016-7872-2

Almasaudi, S. B., El-Shitany, N. A., Abbas, A. T., Abdel-Dayem, U. A., Ali, S. S., Al Jaouni, S. K., & Harakeh, S. (2016). Antioxidant, anti-inflammatory, and antiulcer potential of manuka honey against gastric ulcer in rats. *Oxidative Medicine and Cellular Longevity, 2016*, 10. https://doi.org/10.1155/2016/3643824

Alvarez-Suarez, J. M. (2017). *Bee products—Chemical and biological properties*. Springer. https://doi.org/10.1007/978-3-319-59689-1

Alves, R. R. N., & Alves, H. N. (2011). The faunal drugstore, animal-based remedies used in traditional medicines in Latin America. *Journal of Ethnobiology and Ethnomedicine, 7*, 1–43. https://doi.org/10.1186/1746-4269-7-9

Alves, R. R. N., & Dias, T. L. P. (2010). Usos de invertebrados na medicina popular no brasil e suas implicações para conservação. *Tropical Conservation Science, 3*(2), 159–174. https://doi.org/10.1177/194008291000300204

Alves, S., Muller, C., Bonatto, C., Scapini, T., Camargo, A., Fongaro, G., & Treichel, H. (2019). Bioprospection of enzymes and microorganisms in insects to improve second- generation ethanol production. *Industrail Bioltechnology*. https://doi.org/10.1089/ind.2019.0019

Amat-García, G., & Fernández, F. (2011). Diversity of Lower Insects (Arthropoda, Hexapoda) in Colombia, I. Entognatha to Polyneoptera. *Acta Biológica Colombiana, 16*(2), 205–219.

Armutcu, F., Akyol, S., Ustunsoy, S., & Turan, F. F. (2015). Therapeutic potential of caffeic acid phenethyl ester and its anti-inflammatory and immunomodulatory effects (Review). *Experimental and Therapeutic Medicine, 9*(5), 1582–1588. https://doi.org/10.3892/etm.2015.2346

Arneodo, P. T., & J. (2018). Lignocellulose degradation by termites. In M. A. Khan & W. Ahmad (Eds.), *Termites and sustainable management* (pp. 101–117). Springer.

Avendaño, C., Sánchez, M., & Valenzuela, C. (2020). Insects: An alternative for animal and human feeding. *Revista Chilena De Nutricion, 47*(6), 1029–1037. https://doi.org/10.4067/S0717-75182020000601029

Ávila, S., Beux, M. R., Ribani, R. H., & Zambiazi, R. C. (2018). Stingless bee honey, quality parameters, bioactive compounds, health-promotion properties and modification detection strategies. *Trends in Food Science and Technology, 81*(2018), 37–50. https://doi.org/10.1016/j.tifs.2018.09.002

Barbault, F., Landon, C., Guenneugues, M., Meyer, J. P., Schott, V., Dimarcq, J. L., & Vovelle, F. (2003). Solution structure of Alo-3, a new knottin-type antifungal peptide from the insect *Acrocinus longimanus*. *Biochemistry, 42*(49), 14434–14442. https://doi.org/10.1021/bi035400o

Barke, J., Seipke, R. F., Grüschow, S., Heavens, D., Drou, N., Bibb, M. J., Goss, R. J. M., Yu, D. W., & Hutchings, M. I. (2010). A mixed community of actinomycetes produce multiple antibiotics for the fungus farming ant *Acromyrmex octospinosus*. *BMC Biology*. https://doi.org/10.1186/1741-7007-8-109

Barragan-Fonseca, K. B., Dicke, M., & Van Loon, J. J. A. (2017). Nutritional value of the black soldier fly (*Hermetia illucens* L.) and its suitability as animal feed—A review. *Journal of Insects as Food and Feed, 3*(2), 105–120. https://doi.org/10.3920/JIFF2016.0055

Barrera, E., Gil, J., Restrepo, A., Mosquera, K., & Durango, D. (2015). A coating of chitosan and propolis extract for the postharvest treatment of papaya (*Carica papaya* L. cv. Hawaiiana). *Revista Facultad Nacional de Agronomía Medellín, 68*(2), 7667–7678. https://doi.org/10.15446/rfnam.v68n2.50982

Benzertiha, A., Kierończyk, B., Rawski, M., Józefiak, A., Kozłowski, K., Jankowski, J., & Józefiak, D. (2019). *Tenebrio molitor* and *Zophobas morio* full-fat meals in broiler chicken diets, effects on nutrients digestibility, digestive enzyme activities, and cecal microbiome. *Animals, 9*(12), 1128. https://doi.org/10.3390/ani9121128

Bian, H., Yang, Q., Ma, T., Li, W., Duan, J., Wei, G., Duan, J., Wei, G., Wu, X., Mu, F., Lin, R., Wen, A., & Xi, M. (2017). Beneficial effects of extracts from *Lucilia sericata* maggots on burn wounds in rats. *Molecular Medicine Reports, 16*(5), 7213–7220. https://doi.org/10.3892/mmr.2017.7566

Bílikova, K., Huang, S. C., Lin, I. P., Šimuth, J., & Peng, C. C. (2015). Structure and antimicrobial activity relationship of royalisin, an antimicrobial peptide from royal jelly of *Apis mellifera*. *Peptides, 68*, 190–196. https://doi.org/10.1016/j.peptides.2015.03.001

Biluca, F. C., Gois, J. S., Schulz, M., Braghini, F., Gonzaga, L. V., Maltez, H. F., Rodrigues, E., Vitali, L., Micke, G. A., Borges, D. L. G., Oliveira, A. C., & Fett, R. (2017). Phenolic compounds, antioxidant capacity and bioaccessibility of minerals of stingless bee honey (Meliponinae). *Journal of Food Composition and Analysis, 63*(3), 89–97. https://doi.org/10.1016/j.jfca.2017.07.039

Bonamigo, T., Campos, J. F., Alfredo, T. M., Balestieri, J. B. P., Cardoso, C. A. L., Paredes-Gamero, E. J., Picoli, K. S., & Santos, E. L. (2017). Antioxidant, cytotoxic, and toxic activities of propolis from two native bees in Brazil, Scaptotrigona depilis and Melipona quadrifasciata anthidioides. *Oxidative Medicine and Cellular Longevity, 2017*(2), 12p. https://doi.org/10.1155/2017/1038153

Borsato, D. M., Prudente, A. S., Döll-Boscardin, P. M., Borsato, A. V., Luz, C. F. P., Maia, B. H. L. N. S., Otuki, M. F., Miguel, M. D., Farago, P. V., & Miguel, O. G. (2014). Topical anti-inflammatory activity of a monofloral honey of *Mimosa scabrella* provided by melipona marginata during winter in Southern Brazil. *Journal of Medicinal Food, 17*(7), 817–825. https://doi.org/10.1089/jmf.2013.0024

Buhroo, Z. I., Bhat, M. A., Bali, G. K., Kamili, A. S., & Ganai, N. A. (2018). Antimicrobial peptides from insects with special reference to silkworm *Bombyx mori* L.: A review. *Journal of Entomology and Zoology Studies, 6*(4), 752–759.

Buonocore, F., Fausto, A., Pelle, D., Roncevic, T., Gerdol, M., & Picchietti, S. (2021). Attacins: A promising class of insect antimicrobial peptides. *Antibiotics, 10*, 212. https://doi.org/10.3390/antibiotics10020212

Cahuich-Campos, D., & Granados, F. F. (2014). Entomoterapia, curaciones entre los antiguos pueblos mayas de la península de Yucatán, México. *Elohi, 2014*(5–6), 39–54. https://doi.org/10.4000/elohi.712

Calderón-Arguedas, Ó., Belfort, K., Troyo, A., Gamboa, M., & Del, M. (2014). Maggot therapy with *Lucilia eximia* (Diptera, Calliphoridae) of Costa Rica in an experimental model. *Revista Chilena De Entomología, 39*, 57–65.

Calixto, J. B. (2019). The role of natural products in modern drug discovery. *Anais Da Academia Brasileira De Ciencias, 91*, 1–7. https://doi.org/10.1590/0001-3765201920190105

Cammack, J. A., & Tomberlin, J. K. (2017). The impact of diet protein and carbohydrate on select life-history traits of the black soldier fly *Hermetia illucens* (L.) (Diptera, Stratiomyidae). *InSects*. https://doi.org/10.3390/insects8020056

Cardona, Y., Torres, A., & Hoffmann, W. (2019). Colombian stingless bee honeys characterized by multivariate analysis of physicochemical properties. *Apidologie, 50*(6), 881–892. https://doi.org/10.1007/s13592-019-00698-5

Cavalheiro, A. H. (2017). Bacteria symbionts associated with social insects as sources of bioactive natural products. *Issues in Biological Sciences and Pharmaceutical Research, 5*(1), 1–4. https://doi.org/10.15739/ibspr.17.001

Çelemli, Ö. G. (2013). Chemical Properties of Propolis Collected by Stingless Bees. In Vit, P., Pedro, S. R. M., Roubik, D. (Eds). *Pot-Honey* (pp. 525–537). https://doi.org/10.1007/978-1-4614-4960-7_39

Cerritos, R. (2009). Insects as food, An ecological, social and economical approach. *Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*. https://doi.org/10.1079/PAVSNNR20094027

Chapelle, M., Girard, P. A., Cousserans, F., Volkoff, N. A., & Duvic, B. (2009). Lysozymes and lysozyme-like proteins from the fall armyworm, *Spodoptera Frugiperda*. *Molecular Immunology, 47*(2–3), 261–269. https://doi.org/10.1016/j.molimm.2009.09.028

Chen, K., & Lu, Z. (2018). Immune responses to bacterial and fungal infections in the silkworm, Bombyx mori. *Developmental and Comparative Immunology, 83*, 3–11. https://doi.org/10.1016/j.dci.2017.12.024

Choudhary, V., Choudhary, M., Pandey, S., Chauhan, V. D., & Hasnani, J. J. (2016). Maggot debridement therapy as primary tool to treat chronic wound of animals. *Veterinary World, 9*(4), 403–409. https://doi.org/10.14202/vetworld.2016.403-409

Choudhury, S., Das, K. S., & Nonglait, K. C. L. (2017). Ecological and medicinal importance of termite fauna. *The NEHU Journal, 15*(1), 79–87.

Christiansen, H., Fournier, N., Hellemans, B., & Volckaert, F. A. M. (2018). Seafood substitution and mislabeling in Brussels' restaurants and canteens. *Food Control, 85*, 66–75. https://doi.org/10.1016/j.foodcont.2017.09.005

Churchward-Venne, T. A., Pinckaers, P. J. M., Van Loon, J. J. A., & Van Loon, L. J. C. (2017). Consideration of insects as a source of dietary protein for human consumption. *Nutrition Reviews, 75*(12), 1035–1045. https://doi.org/10.1093/nutrit/nux057

Collins, C. M., Vaskou, P., & Kountouris, Y. (2019). Insect food products in the western world: Assessing the potential of a new "green" market. *Annals of the Entomological Society of America, 112*(6), 518–528. https://doi.org/10.1093/aesa/saz015

Contreras-Gómez, A., Sánchez-Mirón, A., García-Camacho, F., Molina-Grima, E., & Chisti, Y. (2014). Protein production using the baculovirus-insect cell expression system. *Biotechnology Progress, 30*(1), 1–18. https://doi.org/10.1002/btpr.1842

Costa-Neto, E., Ramos-Elorduy, J., & Pino, J. M. (2006). Los insectos medicinales de Brasil, primeros resultados. *Boletín Sociedad Entomológica Aragonesa, 38*, 395–414.

Cox, M. M. J. (2021). Innovations in the insect cell expression system for industrial recombinant vaccine antigen production. *Vaccines*. https://doi.org/10.3390/VACCINES9121504

Dang, X. L., Wang, Y. S., Huang, Y. D., Yu, X. Q., & Zhang, W. Q. (2010). Purification and characterization of an antimicrobial peptide, insect defensin, from immunized house fly (Diptera, Muscidae). *Journal of Medical Entomology, 47*(6), 1141–1145. https://doi.org/10.1603/me10016

Dantas, E. M. G. L., Lima, S. M. F., Cantuária, A. P. C., Amorim, I. A., Almeida, J. A., Cunha, T. F., Franco, O. L., & Rezende, T. M. B. (2019). Synergistic activity of chlorhexidine and synoeca-MP peptide against *Pseudomonas aeruginosa*. *Journal of Cellular Physiology, 234*(9), 16068–16079. https://doi.org/10.1002/jcp.28265

Dávila-Vega, J. P., Duarte-Martínez, H. E., López-Aguirre, C. A., Pérez-Arteaga, E., Zagal-Salinas, A. A., Karla, G. E., & Martínez-Elizalde, S. (2017). Efecto Antiproliferativo del Extracto Metanólico de *Ulomoides dermestoides* Chevrolat (Coleoptera, Tenebrionidae) en linfocitos humanos. *Entomología Mexicana, 4*, 560–565.

Deloya-Brito, G. G., & Deloya, C. (2014). Substances produced by the beetle *Ulomoides dermestoides* (Chevrolat, 1878) (Insecta, Coleoptera, Tenebrionidae), inflammatory and cytotoxic effect Efecto anti-inflamatorio y citotóxico. *Acta Zoológica Mexicana, 30*(3), 655–661.

Díaz-Roa, A., Espinoza-Culupú, A., Torres-García, O., Borges, M. M., Avino, I. N., Alves, F. L., Silva, P. I., & Bello, F. J. (2019). Sarconesin II, a new antimicrobial peptide isolated from *Sarconesiopsis magellanica* excretions and secretions. *Molecules, 24*(11), 1–27. https://doi.org/10.3390/molecules24112077

Díaz-Roa, A., Gaona, M. A., Segura, N. A., Suárez, D., Patarroyo, M. A., & Bello, F. J. (2014). *Sarconesiopsis magellanica* (Diptera, Calliphoridae) excretions and secretions have potent antibacterial activity. *Acta Tropica, 136*(1), 37–43. https://doi.org/10.1016/j.actatropica.2014.04.018

Dicke, M., Aartsma, Y., & Barragan, K. (2020). Protein transition in Colombia Insects as feed in a circular agriculture. *Tropsector Agri&Food*. https://edepot.wur.nl/545408

Dossey, A. T., Morales-Ramos, J. A., & Rojas, M. G. (2016). *Insects as sustainable food ingredients, production, processing and food applications*. Academic Press.

Duarte, O. (2011). La bioprospección en Colombia. *Revista Expeditĭo, 7*, 16–25.

Dufour, D. L. (1987). Insects as food, a case study from the Northwest Amazon. *American Anthropologist*, *89*(2), 383–397.

Dutrillaux, B., & Dutrillaux, A. M. (2013). A South American origin of the genus *Dynastes* (Coleoptera, Scarabaeidae, Dynastinae) demonstrated by chromosomal analyses. *Cytogenetic and Genome Research, 141*(1), 37–42. https://doi.org/10.1159/000351210

Duvic, B., Jouan, V., Essa, N., Girard, P. A., Pagès, S., Khattar, Z. A., Volkoff, N. A., Givaudan, A., Destoumieux-Garzon, D., & Escoubas, J. M. (2012). Cecropins as a marker of *Spodoptera frugiperda* immunosuppression during entomopathogenic bacterial challenge. *Journal of Insect Physiology, 58*(6), 881–888. https://doi.org/10.1016/j.jinsphys.2012.04.001

Easa, M. N., Yusof, F., & Abd. Halim, A. (2017). Characterization of cross-linked enzyme aggregates (CLEA)-amylase from *Zophobas morio*. *International Food Research Journal, 24*(12), 335–339.

Elhag, O., Zhou, D., Song, Q., Soomro, A. A., Cai, M., Zheng, L., Yu, Z., & Zhang, J. (2017). Screening, expression, purification and functional characterization of novel antimicrobial peptide genes from *Hermetia illucens* (L.). *PLoS ONE, 12*(1), 1–15. https://doi.org/10.1371/journal.pone.0169582

Engel, M. S., Peris, D., Delclòs, X., & Chatzimanolis, S. (2015). An earwig (Insecta, Dermaptera) in Early Cretaceous amber from Spain. *Insect Systematics and Evolution, 46*(3), 291–300. https://doi.org/10.1163/1876312X-45032121

Erejuwa, O. O., Sulaiman, S. A., & Ab Wahab, M. S. (2014). Effects of honey and its mechanisms of action on the development and progression of cancer. *Molecules, 19*(2), 2497–2522. https://doi.org/10.3390/molecules19022497

Evangelista, D. A., Wipfler, B., Béthoux, O., Donath, A., Fujita, M., Kohli, M. K., Legendre, F., Liu, S., Machida, R., Misof, B., Peters, R. S., Podsiadlowski, L., Rust, J., Schuette, K., Tollenaar, W., Ware, J. L., Wappler, T., Zhou, X., Meusemann, K., & Simon, S. (2019). An integrative phylogenomic approach illuminates the evolutionary history of cockroaches and termites (Blattodea). *Proceedings of the Royal Society B, Biological Sciences*. https://doi.org/10.1098/rspb.2018.2076

Eze, O. B. L., Nwodo, O. F. C., & Ogugua, V. N. (2016). Therapeutic effect of honey bee venom. *Journal of Pharmaceutical, Chemical and Biological Sciences, 4*(1), 48–53.

Fang, X., Shen, J., Wang, J., Chen, Z., Lin, P., Chen, Z., Liu, L., Zeng, Hu., & Jin, X. (2018). Antifungal activity of 3-acetylbenzamide produced by actinomycete WA23-4-4 from the intestinal tract of *Periplaneta americana*. *Journal of Microbiology, 56*(7), 516–523. https://doi.org/10.1007/s12275-018-7510-z

Felberbaum, R. S. (2015). The baculovirus expression vector system: A commercial manufacturing platform for viral vaccines and gene therapy vectors. *Biotechnology Journal, 10*(5), 702–714. https://doi.org/10.1002/biot.201400438

Ferreira, E. M. A., Guzmán, D., Figueroa, J., Tello, J., & Oliveira, D. (2011). Caracterización antimicrobiana y fisicoquímica de propóleos de *Apis mellifera* L. (Hymenoptera, Apidae) de la región Andina Colombiana. *Acta Biológica Colombiana, 16*(1), 175-184.

Figueirêdo, R. E. C. R., Vasconcellos, A., Policarpo, I. S., & Alves, R. R. N. (2015). Edible and medicinal termites: A global overview. *Journal of Ethnobiology and Ethnomedicine*. https://doi.org/10.1186/s13002-015-0016-4

Fletcher, M., Hungerford, N., Webber, D., Carpinelli, M., Zhang, J., Stone, I., Blanchfield, J., & Zawawi, N. (2020). Stingless bee honey, a novel sourse of trehalulose: A biologically active disaccharide with health benefits. *Scientific Reports., 10*, 12128. https://doi.org/10.1038/s41598-020-68940-0

Forbes, A., Bagley, R., Beer, M., Hippee, A., & Widmayer, H. (2018). Quantifying the unquantifiable: Why Hymeoptera, not Coleoptera, is the most speciose animal order. *BMC Ecology, 18*, 21. https://doi.org/10.1186/s12898-018-0176-x

Fratini, F., Cilia, G., Mancini, S., & Felicioli, A. (2016). Royal jelly: An ancient remedy with remarkable antibacterial properties. *Microbiological Research*, *192*, 130–141. https://doi.org/10.1016/j.micres.2016.06.007

Freire, D. O., Cunha, N. B., Leite, M. L., Kostopoulos, A. G. C., Silva, S. N. B., Souza, A. C. B., Nolasco, D. O., Franco, O. L., Mortari, M. R., & Dias, S. C. (2020). Wasp venom peptide, synoeca-MP, from *Synoeca surinama* shows antimicrobial activity against human and animal pathogenic microorganisms. *Peptide Science, 112*(3), 1–6. https://doi.org/10.1002/pep2.24141

Fuenmayor, C. A., Díaz-Moreno, A. C., Zuluaga-Domínguez, C. M., & Quicazán, M. C. (2013). Honey of Colombian stingless bees, nutritional characteristics and physicochemical quality indicators. In P. Vit, S. R. M. Pedro, & D. Roubik (Eds.), *Pot-honey* (pp. 383–394). Springer.

Gallo-Ramírez, L. E., Nikolay, A., Genzel, Y., & Reichl, U. (2015). Bioreactor concepts for cell culture-based viral vaccine production. *Expert Review of Vaccines, 14*(9), 1181–1195. https://doi.org/10.1586/14760584.2015.1067144

Gamboa, M. V., & Figueroa, J. (2009). Poder antibacterial de mieles de *Tetragonisca angustula*, valorada por concentración mínima inhibitoria. *Acta Biológica Colombiana, 14*(2), 97–106.

Gao, J. Y., Jiang, Y. L., Niu, L. L., Li, H. D., & Yin, W. P. (2016). Novel isoflavone from the cockroach *Periplaneta americana*. *Chemestry of Natural Compounds, 52*(3), 362–364. https://doi.org/10.1007/s10600-016-1661-0

Garwood, K., Huertas, B., Ríos-Málaver I. C. & Jaramillo, J. G. (2021). Mariposas de Colombia Lista de chequeo / Checklist of Colombian Butterflies (*Lepidoptera: Papilionoidea*). BioButterfly Database. V1. 300 pp. http://www.butterflycatalogs.com

Gasca, H. (2011). Beetle breeding and its applicability in conservation. *Scarabs, 59*(10), 1–20.

Gasca, H., & Gonzalez, W. (2021). Approac to the use of edidle insects by indigenous communities of the eastern Colombia amazon. *Revista Peruana De Biología., 28*(4), e21227.

Gasca-Álvarez, H. J., & Costa-Neto, E. M. (2021). Insects as a food source for indigenous communities in Colombia: a review and research perspectives. *Journal of Insects as Food and Feed*. In Press, pp. 1–12. https://doi.org/10.3920/JIFF2021.0148

Gasch, T., Schott, M., Wehrenfennig, C., Düring, R., & Vilcinskas, A. (2013). Multifunctional weaponry: The chemical defenses of earwigs. *Journal of Insect Physiology, 59*(12), 1186–1193. https://doi.org/10.1016/j.jinsphys.2013.09.006

Gasch, T., & Vilcinskas, A. (2014). The chemical defense in larvae of the earwig *Forficula auricularia*. *Journal of Insect Physiology, 67*, 1–8. https://doi.org/10.1016/j.jinsphys.2014.05.019

Gasco, L., Biancarosa, I., & Liland, N. S. (2020). From waste to feed: A review of recent knowledge on insects as producers of protein and fat for animal feeds. *Current Opinion in Green and Sustainable Chemistry, 23*, 67–79. https://doi.org/10.1016/j.cogsc.2020.03.003

GBIF.org. (2022). GBIF Occurrence Download https://doi.org/10.15468/dl.j8qnx4

Gómez-Casado, E., Gómez-Sebastián, S., Núñez, M. C., Lasa-Covarrubias, R., Martínez-Pulgarín, S., & Escribano, J. M. (2011). Insect larvae biofactories as a platform for influenza vaccine production. *Protein Expression and Purification, 79*(1), 35–43. https://doi.org/10.1016/j.pep.2011.03.007

Gómez-Sebastián, S., Nuñez, M. C., Garaicoechea, L., Alvarado, C., Mozgovoj, M., Lasa, R., Kahl, A., Wigdorovitz, A., Parreño, V., & Escribano, J. M. (2012). Rotavirus A-specific single-domain antibodies produced in baculovirus-infected insect larvae are protective in vivo. *BMC Biotechnology*. https://doi.org/10.1186/1472-6750-12-59

Góngora, J., Díaz-Roa, A., Gaona, M. A., Cortés-Vecino, J., & Bello, F. (2015). Evaluación de la actividad antibacterial de los extractos de cuerpos grasos y hemolinfa derivados de la mosca Sarconesiopsis magellanica (Diptera, Calliphoridae). *Infectio, 19*(1), 3–9. https://doi.org/10.1016/j.infect.2014.09.003

Govorushko, S. (2019). Global status of insects as food and feed source: A review. *Trends in Food Science and Technology, 91*(March), 436–445. https://doi.org/10.1016/j.tifs.2019.07.032

Grabowski, N., Abdulmawjood, A., Acheuk, F., Barragan, K., Chhay, T., Medeiros, E., Ferri, M., Franco, O., Gonzalez, D., Keo, D., Lertpatarakomol, R., Miech, P., Piofczyk, T., Proscia, F., Mitchaothai, J., M'Saad, M., Sayed, W., Tchibozo, S., & Plotz, M. (2021). Review: Insects—A source of safe and sustainable food?—"Jein" (Yes and No). *Frontiers in Sustainable Food Systems*. https://doi.org/10.3389/fsufs.2021.701797

Grabowski, N. T., & Klein, G. (2017). Microbiology of processed edible insect products—Results of a preliminary survey. *International Journal of Food Microbiology, 243*, 103–107. https://doi.org/10.1016/j.ijfoodmicro.2016.11.005

Granados, C., Acevedo, D., & Guzman, L. E. (2013). Tostado y harina de la hormiga santandereana "*Atta laevigata*". *Biotecnología En El Sector Agropecuario y Agroindustrial, 11*(1), 68–74.

Guo, G., Tao, R., Li, Y., Ma, H., Xiu, J., Fu, P., & Wu, J. (2017). Identification and characterization of a novel antimicrobial protein from the housefly Musca domestica. *Biochemical and Biophysical Research Communications*, *490*(3), 746–752. https://doi.org/10.1016/j.bbrc.2017.06.112

Gyeong, M. B., Kwang, S. L., Zhong, Z. G., Kim, I., Pil, D. K., Sang, M. L., Hung, D. S., & Jin, B. R. (2005). A digestive β-glucosidase from the silkworm, *Bombyx mori*, cDNA cloning, expression and enzymatic characterization. *Comparative Biochemistry and Physiology - B Biochemistry and Molecular Biology, 141*(4), 418–427. https://doi.org/10.1016/j.cbpc.2005.05.001

Heckmann, L.-H., Andersen, J. L., Gianotten, N., Calis, M., Fischer, C. H., & Calis, H. (2018). Sustainable mealworm production for feed and food. In A. Halloran, R. Flore, P. Vantomme, & N. Roos (Eds.), *Edible insects in sustainable food systems* (pp. 321–328). Springer. https://doi.org/10.1007/978-3-319-74011-9

Hemmati, S., & Tabein, S. (2022). Insect protease inhibitors; promising inhibitory compounds againt SARS-CoV2 main protease. *Computers in Biology and Medicine., 142*(19), 105228. https://doi.org/10.1016/j.compbiomed.2022.105228

Hinks, C. F., & Erlandson, M. A. (1994). Rearing grasshoppers and locusts: Review, rationale and update. *Journal of Orthoptera Research*, *3*(3), 1–10.

Hirsch, R., Wiesner, J., Marker, A., Pfeifer, Y., Bauer, A., Hammann, P. E., & Vilcinskas, A. (2019). Profiling antimicrobial peptides from the medical maggot *Lucilia sericata* as potential antibiotics for MDR Gram-negative bacteria. *Journal of Antimicrobial Chemotherapy, 74*(1), 96–107. https://doi.org/10.1093/jac/dky386

Hoffman, K. (2014). *Insect molecular biology and ecology*. CRC Press.

Huang, Y. F., Li, L. J., Gao, S. Q., Chu, Y., Niu, J., Geng, F. N., Shen, Y. M., & Peng, L. H. (2017). Evidence based anti-osteoporosis effects of *Periplaneta americana* L on osteoblasts, osteoclasts, vascular endothelial cells and bone marrow derived mesenchymal stem cells. *BMC Complementary and Alternative Medicine, 17*(1), 1–13. https://doi.org/10.1186/s12906-017-1917-7

Ido, A., Iwai, T., Ito, K., Ohta, T., Mizushige, T., Kishida, T., Miura, C., & Miura, T. (2015). Dietary effects of housefly (*Musca domestica*) (Diptera, Muscidae) pupae on the growth performance and the resistance against bacterial pathogen in red sea bream (*Pagrus major*) (Perciformes, Sparidae). *Applied Entomology and Zoology, 50*(2), 213–221. https://doi.org/10.1007/s13355-015-0325-z

Islam, S., Bezbaruah, S., & Kalita, J. (2016). A review on antimicrobial peptides from *Bombyx mori* L and their application in plant and animal disease control. *Journal of Advances in Biology & Biotechnology, 9*(3), 1–15. https://doi.org/10.9734/jabb/2016/27539

Israili, Z. H. (2014). Antimicrobial properties of honey. *American Journal of Therapeutics, 21*(4), 304–323. https://doi.org/10.1097/MJT.0b013e318293b09b

Jabir, A. R., Razak, S. A., & Vikineswary, S. (2012). Nutritive potential and utilization of super worm (*Zophobas morio*) meal in the diet of Nile tilapia (*Oreochromis niloticus*) juvenile. *African Journal of Biotechnology, 11*(24), 6592–6598. https://doi.org/10.5897/ajb11.1084

Jaganathan, S., Balaji, A., Vellayappan, M., Asokan, M., Subramanian, A., John, A., Supriyanto, E., Razak, S., & Marvibaigi, M. (2014). A review on antiproliferative and apoptotic activities of natural honey. *Anti-Cancer Agents in Medicinal Chemistry, 15*(1), 48–56. https://doi.org/10.2174/1871520614666140722084747

Jaramillo, J., Ospina, R., & González, V. (2019). Stingless bees of the genus Nannotrigona Cockerell (Hymenoptera: Apidae: Meliponini) in Colombia. *Zootaxa, 4706*(2), 349–365.

Jiangfan, X., Tao, W., Yu, W., Jianwei, W., Guo, G., Yingchun, Z., & Xiaoli, S. (2016). Histological observation and expression patterns of antimicrobial peptides during fungal Infection in *Musca domestica* (Diptera, Muscidae) larvae. *Brazilian Archives of Biology and Technology, 59*, 1–13. https://doi.org/10.1590/1678-4324-2016160147

Kato, T., Kajikawa, M., Maenaka, K., & Park, E. Y. (2010). Silkworm expression system as a platform technology in life science. *Applied Microbiology and Biotechnology, 85*(3), 459–470. https://doi.org/10.1007/s00253-009-2267-2

Kawasaki, K., & Andoh, M. (2017). Properties of induced antimicrobial activity in *Musca domestica* larvae. *Drug Discoveries & Therapeutics, 11*(3), 156–160. https://doi.org/10.5582/ddt.2017.01027

Khaksar, R., Carlson, T., Schaffner D. W., Ghorashi, M., Best, D., Jandhyala, S., Traverso, J., & Amini, S. (2015). Unmasking seafood mislabeling in U.S. markets: DNA barcoding as a unique technology for food authentication and quality control. *Food Control*, *56*, 71–76. https://doi.org/10.1016/j.foodcont.2015.03.007

Kim, J. I., Yang, E. J., Lee, M. S., Kim, Y. S., Huh, Y., Cho, I. H., Sungkeel, K., & Koh, H. K. (2011). Bee venom reduces neuroinflammation in the MPTP-induced model of Parkinson's disease. *International Journal of Neuroscience, 121*(4), 209–217. https://doi.org/10.3109/00207454.2010.548613

Kim, J. Y., Lee, W. R., Kim, K. H., An, H. J., Chang, Y. C., Han, S. M., Park, Y. Y., Park, S. C., & Park, K. K. (2015). Effects of bee venom against Propionibacterium acnes-induced inflammation in human keratinocytes and monocytes. *International Journal of Molecular Medicine, 35*(6), 1651–1656. https://doi.org/10.3892/ijmm.2015.2180

Kim, T. K., Yong, H. I., Kim, Y. B., Kim, H. W., & Choi, Y. S. (2019). Edible insects as a protein source: A review of public perception, processing technology, and research trends. *Food Science of Animal Resources, 39*(4), 521–540. https://doi.org/10.5851/kosfa.2019.e53

Klhar, G. T., Isola, J. V., Rosa, C. S., Giehl, D. Z., Martins, A. A., Bartmer, M. E., & Segabinazzi, L. R. (2019). Antimicrobial activity of the ethanolic extract of propolis against bacteria that cause mastitis in cattle. *Biotemas, 32*(1), 1–10. https://doi.org/10.5007/2175-7925.2019v32n1p1

Kollewe, C., & Vilcinskas, A. (2013). Production of recombinant proteins in insect cells. *American Journal of Biochemistry and Biotechnology, 9*(3), 255–271. https://doi.org/10.3844/ajbbsp.2013.255.271

Kouřimská, L., & Adámková, A. (2016). Nutritional and sensory quality of edible insects. *NFS Journal*, *4*, 22–26. https://doi.org/10.1016/j.nfs.2016.07.001

Kress, W. J., García-Robledo, C., Uriarte, M., & Erickson, D. L. (2015). DNA barcodes for ecology, evolution, and conservation. *Trends in Ecology and Evolution, 30*(1), 25–35. https://doi.org/10.1016/j.tree.2014.10.008

Kruglikova, A. A. (2011). Antimicrobial components of haemolymph and exosecretion of larvae *Lucilia sericata* (Meigen) (Diptera, Calliphoridae). *Journal of Evolutionary Biochemistry and Physiology, 47*(6), 534–542. https://doi.org/10.1134/S0022093011060044

Kruglikova, A. A., & Chernysh, S. I. (2011). Antimicrobial compounds from the excretions of surgical maggots, *Lucilia sericata* (Meigen) (Diptera, Calliphoridae). *Entomological Review, 91*(7), 813–819. https://doi.org/10.1134/S0013873811070013

Kwakman, P. H. S., & Zaat, S. A. J. (2012). Antibacterial components of honey. *IUBMB Life, 64*(1), 48–55. https://doi.org/10.1002/iub.578

Leandro, L. F., Mendes, C. A., Casemiro, L. A., Vinholis, A. H. C., Cunha, W. R., De Almeida, R., & Martins, C. H. G. (2015). Antimicrobial activity of apitoxin, melittin and phospholipase A2 of honey bee (*Apis mellifera*) venom against oral pathogens. *Anais Da Academia Brasileira De Ciencias, 87*(1), 147–155. https://doi.org/10.1590/0001-3765201520130511

Lee, G., & Bae, H. (2016). Anti-inflammatory applications of melittin, a major component of bee venom: Detailed mechanism of action and adverse effects. *Molecules*. https://doi.org/10.3390/molecules21050616

Lee, K. S., Kim, B. Y., Yoon, H. J., Choi, Y. S., & Jin, B. R. (2016). Secapin, a bee venom peptide, exhibits anti-fibrinolytic, anti-elastolytic, and antimicrobial activities. *Developmental and Comparative Immunology, 63*, 27–35. https://doi.org/10.1016/j.dci.2016.05.011

Lee, W., Pak, S. C., & Park, K. (2015). The protective effect of bee venom on fibrosis causing inflammatory diseases. *Toxins, 7*(11), 4758–4772. https://doi.org/10.3390/toxins7114758

Li, L., Sun, W., Wu, T., Lu, R., & Shi, B. (2017). Caffeic acid phenethyl ester attenuates lipopolysaccharide-stimulated proinflammatory responses in human gingival fibroblasts via NF-κB and PI3K/Akt signaling pathway. *European Journal of Pharmacology, 794*(6), 61–68. https://doi.org/10.1016/j.ejphar.2016.11.003

Li, N., Lu, R., Yu, Y., Lu, Y., Huang, L., Jin, J., Zhang, L., & Chen, J. (2016). Protective effect of Periplaneta americana extract in ulcerative colitis rats induced by dinitrochlorobenzene and acetic acid. *Pharmaceutical Biology, 0209*(6), 0–8. https://doi.org/10.3109/13880209.2016.1170862

Liberio, S. A., Pereira, A. L. A., Dutra, R. P., Reis, A. S., Araújo, M. J. A. M., Mattar, N. S., Silva, L. A., Ribeiro, M. N. S., Nascimento, F. R. F., Guerra, R. N., & Monteiro-Neto, V. (2011). Antimicrobial activity against oral pathogens and immunomodulatory effects and toxicity of geopropolis produced by the stingless bee Melipona fasciculata Smith. *BMC Complementary and Alternative Medicine*. https://doi.org/10.1186/1472-6882-11-108

Lima, A. M., Silva, C. E., De Mesquita, F. L. T., Silva Campos, R., Nascimento, R. R., Azevedo, E. C. P. X., & Sant'Ana, A. E. G. (2009). Antimicrobial activities of components of the glandular secretions of leaf cutting ants of the genus *Atta*. *Antonie Van Leeuwenhoek, 95*(4), 295–303. https://doi.org/10.1007/s10482-009-9312-0

Luiz, D. P., Almeida, J. F., Goulart, L. R., Nicolau-Junior, N., & Ueira-Vieira, C. (2017). Heterologous expression of abaecin peptide from Apis mellifera in Pichia pastoris. *Microbial Cell Factories*, *16*(1), 76. https://doi.org/10.1186/s12934-017-0689-6

Luo, S. L., Huang, X. J., Wang, Y., Jiang, R. W., Wang, L., Bai, L. L., Peng, Q. L., Song, C. L., Zhang, D. M., & Ye, W. C. (2014). Isocoumarins from American cockroach (*Periplaneta americana*) and their cytotoxic activities. *Fitoterapia, 95*, 115–120. https://doi.org/10.1016/j.fitote.2014.03.004

Manohar, S. L., Kanamasa, S., Nishina, T., Kato, T., & Park, E. Y. (2010). Enhanced gene expression in insect cells and silkworm larva by modified polyhedrin promoter using repeated burst sequence and very late transcriptional factor-1. *Biotechnology and Bioengineering, 107*(6), 909–916. https://doi.org/10.1002/bit.22896

Mans, D. R. A., Sairras, S., Ganga, D., & Kartopawiro, J. (2016). Exploring the global animal biodiversity in the search for new drugs–insects. *Journal of Translational Science, 3*(1), 371–386. https://doi.org/10.15761/JTS.1000164

Makkar, H. P. S., Tran, G., Heuzé, V., & Ankers, P. (2014). State-of-the-art on use of insects as animal feed. *Animal Feed Science and Technology*, *197*, 1–33. https://doi.org/10.1016/j.anifeedsci.2014.07.008

Medeiros Costa-Neto, E. (2002). The use of insects in folk medicine iin the state of Bahia, Northeastern Brazil, with notes on insects reported elsewhere in Brazilian folk medicine. *Human Ecology, 30*(2), 245–263.

Mehrabadi, M., Bandani, A. R., Saadati, F., & Mahmudvand, M. (2011). α-amylase activity of stored products insects and its inhibition by medicinal plant extracts. *Journal of Agricultural Science and Technology, 13*, 1173–1182.

Mendes, M. A., Souza, B. M., & Palma, M. S. (2005). Structural and biological characterization of three novel mastoparan peptides from the venom of the neotropical social wasp *Protopolybia exigua* (Saussure). *Toxicon, 45*(1), 101–106. https://doi.org/10.1016/j.toxicon.2004.09.015

Mendonça, A., Bernardi Marchiotti, R. C., Firmino, E. L. B., Santos, P. P., Sguarizi Antonio, D., Serrão, J. E., Cardoso, C. A. L., & Antonialli, W. F. J. (2019). Proteomic analysis of the venom of the social wasp *Apoica pallens* (Hymenoptera, Vespidae). *Revista Brasileira De Entomologia, 63*(4), 322–330. https://doi.org/10.1016/j.rbe.2019.10.001

Mendoza, D., Sánchez, K., & Saavedra, S. (2016). Caracterización bioquímica de extractos acuosos de *Ulomoides dermestoides* (Coleoptera, Tenebrionidae), exploración de la inhibición dual de la lipoxigenasa (15-LOX) y ciclooxigenasas (COX-1 Y COX-2). *Biosalud, 15*(2), 37–54. https://doi.org/10.17151/biosa.2016.15.2.5

Mendoza, D., & Saavedra, S. (2013). Chemical composition and anti-irritant capacity of whole-body extracts of *Ulomoides dermestoides* (Coleoptera, Tenebrionidae). *Vitae, 20*(1), 41–48.

Mendoza, D. L., & España-Puccini, P. (2016). Cytotoxic and genotoxic activity of phenolic fractions from *Ulomoides desmestoides* fairmaire, 1893 (Coleoptera, Tenebrionidae), in HACAT cells. TIP. *Revista Especializada En Ciencias Químico-Biológicas, 19*(2), 83–91.

Mika, N., Zorn, H., & Rühl, M. (2013). Insect-derived enzymes, a treasure for industrial biotechnology and food biotechnology. In A. Vilcinskas (Ed.), *Yellow Biotechnology II. Insect Biotechnology in Plant Protection and Industry.* Springer (pp. 1–14). https://doi.org/10.1007/978-3-642-39902-2

Mika, N., Gorshkov, V., Spengler, B., Zorn, H., & Rühl, M. (2014). Characterization of novel insect associated peptidases for hydrolysis of food proteins. *European Food Research and Technology, 240*(2), 431–439. https://doi.org/10.1007/s00217-014-2342-5

Milián, E., & Kamen, A. A. (2015). Current and emerging cell culture manufacturing technologies for influenza vaccines. *BioMed Research International*. https://doi.org/10.1155/2015/504831

Mlcek, J., Borkovcova, M., & Bednarova, M. (2014). Biologically active substances of edible insects and their use in agriculture, veterinary and human medicine—A review. *Journal of Central European Agriculture, 15*(4), 225–237. https://doi.org/10.5513/JCEA01/15.4.1533

Mohtar, J. A., Yusof, F., & Ali, N. M. H. (2014). Screening of novel acidified solvents for maximal antimicrobial peptide extraction from *Zophobas morio* Fabricius. *Advances in Environmental Biology, 8*(3), 803–809.

Morales, S. M., Crescente, O., Herrera, B., Hernández, J. V., Muñoz, M., & Oliveros, M. J. (2020). Composition and Biological activity of extracts from *Ulomoides dermestoides* (Tenebrionidae) processed under different conditions in Cumana, Sucre State. *FACSALUD-UNEMI, 17*, 3–16.

Mortari, M. R., Couto, L. L., Anjos, L. C., Mourão, C. B. F., Camargos, T. S., Vargas, J. A. G., Oliveira, F. N., Gati, C. C., & Schwartz, E. F. (2012). Pharmacological characterization of Synoeca cyanea venom: An aggressive social wasp widely distributed in the Neotropical region. *Toxicon, 59*(1), 163–170. https://doi.org/10.1016/j.toxicon.2011.11.002

Müller, A., Wolf, D., & Gutzeit, H. O. (2017). The black soldier fly, *Hermetia illucens*—A promising source for sustainable production of proteins, lipids and bioactive substances. *Zeitschrift Fur Naturforschung - Section C Journal of Biosciences, 72*(9–10), 351–363. https://doi.org/10.1515/znc-2017-0030

Murata, K., Shinada, T., Ohfune, Y., Hisada, M., Yasuda, A., Naoki, H., & Nakajima, T. (2009). Novel mastoparan and protonectin analogs isolated from a solitary wasp, *Orancistrocerus drewseni drewseni*. *Amino Acids, 37*(2), 389–394. https://doi.org/10.1007/s00726-008-0166-y

Mushtaq, S., Abbasi, B. H., Uzair, B., & Abbasi, R. (2018). Natural products as reservois of novel therapeutic agents. *EXCLI Journal, 17*, 420–451.

Mutungi, C., Irungu, F. G., Nduko, J., Mutua, F., Affognon, H., Nakimbugwe, D., Ekesi, S., & Fiaboe, K. K. M. (2019). Postharvest processes of edible insects in Africa: A review of processing methods, and the implications for nutrition, safety and new products development. *Critical Reviews in Food Science and Nutrition, 59*(2), 276–298. https://doi.org/10.1080/10408398.2017.1365330

Mwangi, M. N., Oonincx, D. G. A. B., Stouten, T., Veenenbos, M., Melse-Boonstra, A., Dicke, M., & Van Loon, J. J. A. (2018). Insects as sources of iron and zinc in human nutrition. *Nutrition Research Reviews, 31*(2), 248–255. https://doi.org/10.1017/S0954422418000094

Nates-Parra, G. (2001). Las Abejas sin Aguijón (Hymenoptera, Apidae). *Biota Colombiana, 2*(3), 233–248.

Nates-Parra, G., & Rosso-Londoño, J. M. (2013). Diversity of stingless bees (Hymenoptera, Meliponini) used in meliponiculture in Colombia. *Acta Biológica Colombiana, 18*, 415–426.

Nguyen, T., Chen, X., Chai, J., Li, R., Han, X., Chen, X., Liu, S., Chen, M., & Xu, X. (2020). Antipyretic, anti-inflammatory and analgesic activities of *Periplaneta americana* extract and underlying mechanisms. *Biomedicine and Pharmacotherapy*. https://doi.org/10.1016/j.biopha.2019.109753

Nieukerken, E. J., Lauri Kaila, I. J. K., Kristensen, N. P., Lees, D. C., Minet, J., Mitter, C., Mutanen, M., Regier, J. C., Simonsen, T. J., Wahlberg, N., Yen, S. H., Zahiri, R., Adamski, D., Baixeras, J., Bartsch, D., Bengtsson, B. Å., Brown, J. W., Bucheli, S. R., Davis, D. R., Prins, J., Prins, W., Epstein, M. E., Gentili-Poole, P., Gielis, C., Hättenschwiler, P., Hausmann, A., Holloway, J. D., Kallies, A., Karsholt, O., Kawahara, A. Y., Koster, S., Kozlov, M. V., Lafontaine, J. D., Lamas, G., Landry, J. F., Lee, S., Nuss, M., Park, K. T., Penz, C., Rota, J., Schintlmeister, A., Schmidt, B. C., Sohn, J. C., Solis, M. A., Tarmann, G. M., Warren, A. D., Weller, S., Yakovlev, R. V., Zolotuhin, V. V., & Zwick, A. (2011). Order Lepidoptera Linnaeus, 1758. In Zhang, Z.-Q. (Ed.). Animal biodiversity, an outline of higher-level classification and survey of taxonomic richness. *Zootaxa, 3148*(1), 56. https://doi.org/10.11646/zootaxa.3148.1.9

Nygaard, M. K. E., Andersen, A. S., Kristensen, H. H., Krogfelt, K. A., Fojan, P., & Wimmer, R. (2012). The insect defensin lucifensin from *Lucilia sericata*. *Journal of Biomolecular NMR, 52*(3), 277–282. https://doi.org/10.1007/s10858-012-9608-7

Oršolić, N. (2012). Bee venom in cancer therapy. *Cancer and Metastasis Reviews, 31*(1–2), 173–194. https://doi.org/10.1007/s10555-011-9339-3

Pan, J., & Hink, W. F. (2000). Isolation and characterization of myrmexins, six isoforms of venom proteins with anti- inflammatory activity from the tropical ant, *Pseudomyrmex triplarinus*. *Toxicon, 38*, 1403–1413.

Paoletti, M. G., Buscardo, E., & Dufour, D. L. (2000). Edible invertebrates among Amazonian Indians: A critical review of disappearing knowledge. *Environment, Development and Sustainability, 2*, 195–225.

Pape, T., Blagoderov, V., & Mostovski, M. B. (2011). Order Diptera Linnaeus, 1758. In Zhang, Z.-Q. (Ed.) Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness. *Zootaxa, 3148*, 222–229. Retrieved from http://www.mapress.com/zootaxa/2011/f/zt03148p229.pdf

Pardo, D. P., Santiago, K. B., Conti, B. J., Oliveira, E. C., Conte, F. L., Garcia, L. P., Golim, M. A., Cruz, J. F., Gutiérrez, R. M., Buitrago, M. R., Popova, M., Trusheva, B., Bankova, V., Torres, O., & Sforcin, J. M. (2019). The chemical composition and events related to the cytotoxic effects of propolis on

osteosarcoma cells: A comparative assessment of Colombian samples. *Phytotherapy Research, 33*(3), 591–601. https://doi.org/10.1002/ptr.6246
Park, S. I., Kim, J. W., & Yoe, S. M. (2015). Purification and characterization of a novel antibacterial peptide from black soldier fly (*Hermetia illucens*) larvae. *Developmental and Comparative Immunology, 52*(1), 98–106. https://doi.org/10.1016/j.dci.2015.04.018
Patiño, V. M. (1990). Historia de la Cultura Material en la América Equinoccial. *Imprenta Patriótica del Instituto Caro y Cuervo (Bogotá)*. 356p.
Paul, D., & Dey, S. (2014). Essential amino acids lipid profile and fat-soluble vitamins of the edible silkworm Bombyx mori (Lepidoptera: Bombycidae). *International Journal of Tropical Insect Science*, *34*(04), 239–247. https://doi.org/10.1017/S1742758414000526
Paz, A., Gonzalez, M., Ph, D., & Andrew, J. (2011). DNA barcode of life, an introduction and perspective. *Acta Biológica Colombiana, 16*(3), 161–175.
Pinilla, Y. T., Patarroyo, M. A., Velandia, M. L., Segura, N. A., & Bello, F. J. (2015). The effects of *Sarconesiopsis magellanica* larvae (Diptera, Calliphoridae) excretions and secretions on fibroblasts. *Acta Tropica, 142*, 26–33. https://doi.org/10.1016/j.actatropica.2014.11.003
Pöppel, A. K., Vogel, H., Wiesner, J., & Vilcinskas, A. (2015). Antimicrobial peptides expressed in medicinal maggots of the blow fly Lucilia sericata show combinatorial activity against bacteria. *Antimicrobial Agents and Chemotherapy, 59*(5), 2508–2514. https://doi.org/10.1128/AAC.05180-14
Porcza, L., Simms, C., & Chopra, M. (2016). Honey and cancer, current ctatus and future directions. *Diseases, 4*(4), 30. https://doi.org/10.3390/diseases4040030
Premratanachai, P., & Chanchao, C. (2014). Review of the anticancer activities of bee products. *Asian Pacific Journal of Tropical Biomedicine, 4*(5), 337–344. https://doi.org/10.12980/APJTB.4.2014C1262
Quicazán, M. C., Cuenca, M. M., & Blanco, A. (2018). *Producción de hidromiel en el contexto de la apicultura en Colombia* (Primera edición). Universidad Nacional de Colombia. Facultad de Ciencias Agrarias, Vicerrectoría de Sede Dirección de Investigación y Extensión DIEB, Vicerrectoría de Investigación. Colombia Editorial, 2018.
Ramos-Elorduy, J., Pino Moreno, J. M., & Martínez Camacho, V. H. (2009). Edible aquatic Coleoptera of the world with an emphasis on Mexico. *Journal of Ethnobiology and Ethnomedicine*. https://doi.org/10.1186/1746-4269-5-11
Ratcliffe, B. C. (2006). Scarab beetles in human culture. *The Coleopterists Bulletin, 60*(5), 85–101. https://doi.org/10.1649/0010-065x(2006)60[85,sbihc]2.0.co,2
Retana, L., Belfort, K., Calderón, O., Troyo, A., & Gamboa, M. M. (2014). Development and evaluation of a method to obtain sterile *Lucilia eximia* larvae for use in larval therapy. *Revista Cubana De Investigaciones Biomedicas, 33*(1), 44–51.
Riascos. (2021). Insectos de la familia Culicida y péptidos antimicrobianos: ¿Qué debemos saber? *Boletín Museo Entomológico Francisco Luís Gallego, 13*(1), 22–31.
Rodríguez, Y., Sánchez-Catalán, F., Rojano, B., Durango, D., Gil, J., & Marín-Loaiza, J. (2012). Physicochemical characterization and evaluation of antioxidant activity of propolis collected in the Atlántic Department, Colombia. *Revista u.d.c.a Actualidad & Divulgación Científica, 15*(2), 303–311.
Rosa, C. M., & Thys, R. C. S. (2019). Cricket powder (*Gryllus assimilis*) as a new alternative protein source for gluten-free breads. *Innovative Food Science and Emerging Technologies*. https://doi.org/10.1016/j.ifset.2019.102180
Ruddle, K. (1973). The human use of insects, examples from the Yukpa and conservation. *Biotropica, 5*(2), 94–101.
Ruiz, A. T., Morales-Ramos, J. A., & Tomberlin, J. (2016). *Insect mass production technologies.*https://doi.org/10.1016/B978-0-12-802856-8.00006-5
Saad Rached, I. C. F., Castro, F. M., Guzzo, M. L., & De Mello, S. B. V. (2010). Anti-inflammatory effect of bee venom on antigen-induced arthritis in rabbits, Influence of endogenous glucocorticoids. *Journal of Ethnopharmacology, 130*(1), 175–178. https://doi.org/10.1016/j.jep.2010.04.015
Sahalan, A. Z., & Omar, B. (2006). Antibacterial activity of extracted hemolymph from larvae and pupae of local fly species, *Musca domestica and Chrysomya megacephala*. *Malaysian Journal of Health Sciences, 4*(2), 1–11.
Saini, R., Saini, H. S., & Dahiya, A. (2017). Amylases: Characteristics and industrial applications. *Journal of Pharmacognosy and Phytochemistry, 6*(5), 1865–1871.
Salatino, A., Pereira, L. R. L., & Salatino, M. L. F. (2019). The emerging market of propolis of stingless bees in tropical countries. *MOJ Food Processing & Technology, 7*(2), 27–29. https://doi.org/10.15406/mojfpt.2019.07.00215
Salomón, V., Gianni De Carvalho, K., Arroyo, F., Maldonado, L. M., Gennari, G. P., Vera, N. R., & Romero, C. M. (2021). Biopolymer production by bacteria isolated from native stingless bee honey, *Scaptotrigona Jujuyensis*. *Food Bioscience, 42*(43), 101077.
Samara-Ortega, N., Benitez-Campo, N., & Cabezas-Fajardo, F. A. (2011). Actividad antibacteriana y composicion cualitativa de propoleos provenientes de dos zonas climaticas del departamento del Cauca. *Biotecnología en el Sector Agropecuario y Agroindustrial, BSAA*, (Colombia). *9*(1), 8–16.
Samuels, R. I., Mattoso, T. C., & Moreira, D. D. O. (2013). Chemical warfare: Leaf-cutting ants defend themselves and their gardens against parasite attack by deploying antibiotic secreting bacteria. *Communicative and Integrative Biology*. https://doi.org/10.4161/cib.23095
Sanches, M. A., Pereira, A. M. S., & Serrão, J. E. (2017). Acciones farmacológicas de extractos de propóleos de abejas sin aguijón (Meliponini). *Journal of Apicultural Research, 56*(1), 50–57. https://doi.org/10.1080/00218839.2016.1260856
Sanei-Dehkordi, A., Khamesipour, A., Akbarzadeh, K., Akhavan, A. A., Mir Amin Mohammadi, A., Mohammadi, Y., Rassi, Y., Oshaghi, M. A., Alebrahim, Z., Eskandari, S. E., & Rafinejad, J. (2016). Anti Leishmania activity of *Lucilia sericata* and *Calliphora vicina* maggots in laboratory models. *Experimental Parasitology, 170*, 59–65. https://doi.org/10.1016/j.exppara.2016.08.007
Seabrooks, L., & Hu, L. (2017). Insects: An underrepresented resource for the discovery of biologically active natural products. *Acta Pharmaceutica Sinica B., 7*(4), 409–426. https://doi.org/10.1016/j.apsb.2017.05.001
Sgamma, T., Lockie-Williams, C., Kreuzer, M., Williams, S., Scheyhing, U., Koch, E., Slater, A., & Howard, C. (2017). DNA barcoding for industrial quality assurance. *Planta Medica (germany), 83*(14–15), 1117–1129. https://doi.org/10.1055/s-0043-113448
Shen, Y., Sun, J., Niu, C., Yu, D., Chen, Z., Cong, W., & Geng, F. (2017). Mechanistic evaluation of gastroprotective effects of Kangfuxin on ethanol-induced gastric ulcer in mice. *Chemico-Biological Interactions, 273*, 115–124. https://doi.org/10.1016/j.cbi.2017.06.007
Shin, J., & Lee, K. (2021). Digestibility of insect meal for Pacific white shrimp (Litopenaeus vannamei) and their performance for growth, feed utilization and immune responses. *PLoS ONE, 16*(11), e0260305. https://doi.org/10.1371/journal.pone.0260305
Shrivastava, S. K., & Prakash, A. (2015). Entomotherapy, an un-explored frontier for make in India: A review. *Journal of Applied Zoological Researches, 26*(2), 113–123.
Silva, A. J., Menegon, L., Rocha, M., & Prentice, C. (2020). Edible insects: An alternative of nutritional, functional and bioactive compounds. *Food Chemistry*. https://doi.org/10.1016/j.foodchem.2019.126022
Silva, I. A. A., Silva, T. M. S., Camara, C. A., Queiroz, N., Magnani, M., Novais, J. S., Soledade, L. E. B., Lima, E. O., & Souza, A. G. (2013). Phenolic profile, antioxidant activity and palynological analysis of stingless bee honey from Amazonas, Northern Brazil. *Food Chemistry, 141*(4), 3552–3558. https://doi.org/10.1016/j.foodchem.2013.06.072
Siozios, S., Massa, A., Parr, C. L., Verspoor, R. L., & Hurst, G. D. D. (2020). DNA barcoding reveals incorrect labelling of insects sold as food in the UK. *PeerJ, 2020*(2), 1–12. https://doi.org/10.7717/peerj.8496
Só, M. V. R., Volpato, C., Só, B. B., Bruggemann, R., Kopper, P. M. P., & Pereira, J. R. (2015). Evaluation of the in vitro antimicrobial activity of alcoholic solution and aqueous extract of bee propolis against *Enterococcus faecalis*. *Journal of Research in Dentistry, 3*(1), 576–582.
Soares, R. R. A., Santos, T. A. R. B., Ferraz, V. P., & Moreira Santos, E. (2019). Nutritional composition of insects *Gryllus assimilis* and *Zophobas morio*, Potential foods harvested in Brazil. *Journal of Food Composition and Analysis, 76*(9), 22–26. https://doi.org/10.1016/j.jfca.2018.11.005
Sobral, F., Sampaio, A., Falcão, S., Queiroz, M. J. R. P., Calhelha, R. C., Vilas-Boas, M., & Ferreira, I. C. F. R. (2016). Chemical characterization, antioxidant, anti-inflammatory and cytotoxic properties of bee venom collected in Northeast Portugal. *Food and Chemical Toxicology, 94*, 172–177. https://doi.org/10.1016/j.fct.2016.06.008
Sprangers, T., Ottoboni, M., Klootwijk, C., Ovyn, A., Deboosere, S., Meulenaer, B., Michiels, J., Eeckhout, M., Clercq, P., & Smet, S. (2017). Nutritional composition of black soldier fly (*Hermetia illucens*) prepupae reared on

different organic waste substrates. *Journal of the Science of Food and Agriculture, 97*, 2594–2600. https://doi.org/10.1002/jsfa.8081

Suk, M., Park, S., Choi, T., Lee, G., Haam, K., Hong, M., Min, B., & Bae, H. (2013). Cytokine Bee venom ameliorates ovalbumin induced allergic asthma via modulating CD4 + CD25 + regulatory T cells in mice. *Cytokine, 61*(1), 256–265. https://doi.org/10.1016/j.cyto.2012.10.005

Tait, R. R., Rodrigues, S., Sinópolis, A. A., Ruvolo-Takasusuki, M., & Conte, H. (2018). Bioprospection of immature salivary glands of *Chrysomya megacephala* (Fabricius, 1794) (Diptera, Calliphoridae). *Micron, 112*(4), 55–62. https://doi.org/10.1016/j.micron.2018.06.007

Tamura, T., Cazander, G., Rooijakkers, S. H. M., Trouw, L. A., & Nibbering, P. H. (2017). Excretions/secretions from medicinal larvae (*Lucilia sericata*) inhibit complement activation by two mechanisms. *Wound Repair and Regeneration, 25*(1), 41–50. https://doi.org/10.1111/wrr.12504

Tang, T., Li, X., Yang, X., Yu, X., Wang, J., Liu, F., & Huang, D. (2014). Transcriptional response of *musca domestica* larvae to bacterial infection. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0104867

Tombulturk, F. K., Kasap, M., Tuncdemir, M., Polat, E., Sirekbasan, S., Kanli, A., & Kanigur-Sultuybek, G. (2018). Effects of *Lucilia sericata* on wound healing in streptozotocin-induced diabetic rats and analysis of its secretome at the proteome level. *Human and Experimental Toxicology, 37*(5), 508–520. https://doi.org/10.1177/0960327117714041

Torres, O. D., & Velho, L. (2009). La bioprospección como un mecanismo de cooperación internacional para fortalecimiento de capacidades en ciencia y tecnología en Colombia. *Ciencia Da Informacao, 38*(3), 96–110. https://doi.org/10.1590/S0100-19652009000300007

Touzani, S., Embaslat, W., Imtara, H., Kmail, A., Kadan, S., Zaid, H., Elarabi, I., Badiaa, L., & Saad, B. (2019). In vitro evaluation of the potential use of propolis as a multitarget therapeutic product, physicochemical properties, chemical composition, and immunomodulatory, antibacterial, and anticancer properties. *BioMed Research International (united States)*. https://doi.org/10.1155/2019/4836378

Valachova, I., Prochazka, E., Bohova, J., Novak, P., Takac, P., & Majtan, J. (2014). Antibacterial properties of lucifensin in *Lucilia sericata* maggots after septic injury. *Asian Pacific Journal of Tropical Biomedicine, 4*(5), 358–361. https://doi.org/10.12980/APJTB.4.2014C1134

Varelas. (2019). Food wastes as a potential new source for edible insect mass production for food and feed: A review. *Fermentation*, *5*(3), 81. https://doi.org/10.3390/fermentation5030081

Van Oers, M. M., Pijlman, G. P., & Vlak, J. M. (2015). Thirty years of baculovirus-insect cell protein expression, from dark horse to mainstream technology. *Journal of General Virology, 96*(1), 6–23. https://doi.org/10.1099/vir.0.067108-0

Velásquez, B. D., & Montenegro Gómez, S. P. (2017). Actividad antimicrobiana de extractos etanólicos de propóleos obtenidos de abejas *Apis mellifera*. *Revista de Investigación Agraria y Ambiental, 8*(1), 185–193. https://doi.org/10.22490/21456453.1848

Vit, P., Huq, F., Barth, O., Campo, M., Pérez-Pérez, E., Tomás-Barberán, F., & Santos, E. (2015). Use of propolis in cancer research. *British Journal of Medicine and Medical Research., 8*(2), 88–109. https://doi.org/10.9734/bjmmr/2015/16216

Volkoff, A. N., Rocher, J., D'alençon, E., Bouton, M., Landais, I., Quesada-Moraga, E., Vey, A., Fournier, P., Mita, K., & Devauchelle, G. (2003). Characterization and transcriptional profiles of three *Spodoptera frugiperda* genes encoding cysteine-rich peptides. A new class of defensin-like genes from lepidopteran insects? *Gene, 319*(1–2), 43–53. https://doi.org/10.1016/S0378-1119(03)00789-3

Wang, K., Hu, L., Jin, X. L., Ma, Q. X., Marcucci, M. C., Netto, A. A. L., Sawaya, A. C. H. F., Huang, S., Ren, W. K., Conlon, M. A., Topping, D. L., & Hu, F. L. (2015). Polyphenol-rich propolis extracts from China and Brazil exert anti-inflammatory effects by modulating ubiquitination of TRAF6 during the activation of NF-κB. *Journal of Functional Foods, 19*, 464–478. https://doi.org/10.1016/j.jff.2015.09.009

Wang, L., Li, J., Jin, J. N., Zhu, F., Roffeis, M., & Zhang, X. Z. (2017). A comprehensive evaluation of replacing fishmeal with housefly (*Musca domestica*) maggot meal in the diet of Nile tilapia (*Oreochromis niloticus*), growth performance, flesh quality, innate immunity and water environment. *Aquaculture Nutrition, 23*(5), 983–993. https://doi.org/10.1111/anu.12466

Wang, Z., Yu, Z., Zhao, J., Zhuang, X., Cao, P., Guo, X., Liu, C., & Xiang, W. (2020). Community composition, antifungal activity and chemical analyses of ant-derived actinobacteria. *Frontiers in Microbiology, 11*, 201. https://doi.org/10.3389/fmicb.2020.00201

Watanabe, K., Rahmasari, R., Matsunaga, A., Haruyama, T., & Kobayashi, N. (2014). Anti-influenza viral effects of honey in vitro, potent high activity of manuka honey. *Archives of Medical Research, 45*(5), 359–365. https://doi.org/10.1016/j.arcmed.2014.05.006

Watanabe, S., Kakudo, A., Ohta, M., Mita, K., Fujiyama, K., & Inumaru, S. (2013). Molecular cloning and characterization of the α-glucosidase II from *Bombyx mori* and *Spodoptera frugiperda*. *Insect Biochemistry and Molecular Biology, 43*(4), 319–327. https://doi.org/10.1016/j.ibmb.2013.01.005

Willette, D. A., Simmonds, S. E., Cheng, S. H., Esteves, S., Kane, T. L., Nuetzel, H., Pilaud, N., Rachmawati, R., & Barber, P. H. (2017). Using DNA barcoding to track seafood mislabeling in Los Angeles restaurants. *Conservation Biology, 31*(5), 1076–1085. https://doi.org/10.1111/cobi.12888

Wolff, M. I., Rivera, C., Herrera, S. E., Wolff, J. C., & Escobar, M. M. (2010). *Lucilia eximia* (Diptera, Calliphoridae), a new alternative for maggot therapy. Case series report. *Iatreia, 23*(2), 107–118.

Xia, J., Ge, C., & Yao, H. (2021). Antimicrobial peptides from black soldier fly (*Hermetia illucens*) as potential antimicrobial factors representing an alternative to antibiotics in livestock farming. *Animals*. https://doi.org/10.3390/ani11071937

Yapi Assoi Yapi, D., Gnakri, D., Lamine Niamke, S., & Kouame, L. P. (2009). Purification and biochemical characterization of a specific β-glucosidase from the digestive fluid of larvae of the palm weevil, *Rhynchophorus palmarum*. *Journal of Insect Science, 9*(4), 1–13. https://doi.org/10.1673/031.009.0401

Yun, J., Hwang, J. S., & Lee, D. G. (2017). The antifungal activity of the peptide, periplanetasin-2, derived from American cockroach *Periplaneta americana*. *Biochemical Journal, 474*(17), 3027–3043. https://doi.org/10.1042/BCJ20170461

Zdybicka-Barabas, A., Bulak, P., Polakowski, C., Bieganowski, A., Waśko, A., & Cytryńska, M. (2017). Immune response in the larvae of the black soldier fly *Hermetia illucens*. *Invertebrate Survival Journal, 14*, 9–17.

Zdybicka-Barabas, A., & Vilcinskas, A. (2016). Peptides the functional interaction between abaecin and pore-forming peptides indicates a general mechanism of antibacterial potentiation. *Peptides, 78*(2016), 17–23. https://doi.org/10.1016/j.peptides.2016.01.016

Zeng, C., Liao, Q., Hu, Y., Shen, Y., Geng, F., & Chen, L. (2019). The role of *Periplaneta americana* (Blattodea, Blattidae) in modern versus traditional Chinese medicine. *Journal of Medical Entomology, 56*(6), 1522–1526. https://doi.org/10.1093/jme/tjz081

Zhang, S. Q., Che, L. H., Li, Y., Dan, L., Pang, H., Ślipiński, A., & Zhang, P. (2018). Evolutionary history of Coleoptera revealed by extensive sampling of genes and species. *Nature Communications, 9*(1), 1–11. https://doi.org/10.1038/s41467-017-02644-4

Zhang, Z., Wang, J., Zhang, B., Liu, H., Song, W., He, J., Lv, D., Wang, S., & Xu, X. (2013). Activity of antibacterial protein from maggots against staphylococcus aureus in vitro and in vivo. *International Journal of Molecular Medicine, 31*(5), 1159–1165. https://doi.org/10.3892/ijmm.2013.1291

Zhao, Y., Yang, A., Tu, P., & Hu, Z. (2017). Anti-tumor effects of the American cockroach, *Periplaneta Americana*. *Chinese Medicine, 12*(1), 1–6. https://doi.org/10.1186/s13020-017-0149-6

Zhou, Y., Chen, H., Li, X., Wang, Y., Chen, K., Zhang, S., Meng, X., Lee, E. Y. C., & Lee, M. Y. W. T. (2011). Production of recombinant human DNA polymerase delta in a Bombyx mori bioreactor. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0022224

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