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A Review: Insect Gut Microbiota's Function in Decomposition of Pesticide

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Abstract: The intestines of insects offer unique conditions for the colonization of microbes, and these bacteria may offer their hosts a variety of advantageous functions. The insects' varying degrees of reliance on gut bacteria for essential processes are evident. Compared to the guts of mammals, most insect guts are home to a very small number of microbial species; nonetheless, many insects support sizable gut communities of specialized bacteria. Others are only sporadically and opportunistically colonized by common bacteria from different habitats. The physicochemical characteristics and shape of insect digestive systems differ widely, which has a significant impact on the composition of microbial communities. The absence of reliable pathways for transmission between hosts is one barrier preventing the emergence of close relationships with gut microbes. Social insects like termites, ants, and bees are an exception in this case. Social contacts present chances exist in species of social insects. However, it has also been demonstrated that the gut microbiota of other insects aids in communication, immune response regulation, feeding, and defense against parasites and infections. It is yet unknown how big these roles are and needs more research.

Key points: gut microbiota, bacteria, gut communities, symbiosis.

Introduction

According to Basset et al. (2012). In terms of biomass, ecological behaviors, and species count, insects are by far the most prevalent, diverse, and variable animal group in the world. The many interactions that insects have with beneficial microbes have been substantially responsible for their variety and evolutionary success.

, which have been shown to enhance nutrient-deficient diets, aid in the digestion of food ingredients that are resistant to processing, provide defense against pathogens, parasites, and predators, promote intraspecific and interspecific communication, affect how well insects transmit disease, and control mating and reproductive systems. Due to their short generation times and rapid evolutionary rates, insect gut bacteria can develop numerous metabolic pathways and can adapt to diverse ecological niches (Mondal et al., 2023). the insect gut microbiota tries to degrade toxic compounds by changing their toxicity (Jaffar.et.al,2022). Microbial communities are particularly prevalent in the digestive system of almost all animals, and they may play a significant role as mediators of the diverse lives of their insect hosts. Microorganisms, especially those found in the alimentary tract, have an essential function in the daily activities of insects (Mondal et al., 2023). This has implications for agriculture, medicine, and ecology. For investigations into microbial communities and their interactions with hosts, especially to better understand immunology and metabolic interactions, a few insect species are good laboratory models. symbionts that could influence the health and possibly impact human environments (Aziz FWA, Hussein RA, 2024) vectoring efficiency (Ricci et al., 2012) of insects that carry disease, providing targets for possible. The way that insects impact crop plants can be influenced by microbes linked to both herbivores and pollinators. Insects and the microbial communities that live in their stomachs play a crucial role as mediators of biogeochemical cycles in ecosystems that are influenced by both the natural and human worlds. For instance, the nitrogen cycle and rates of nitrogen fixation can be significantly impacted by insect-microorganism mediation. as well as the carbon cycle and the breakdown of plant biomass (Fox-Dobbs et al., 2010). the percentage of effectiveness of the pesticides Actara and Zenith after days of treatment (Abdulelah& Abdelrazaaq, 2023). Even though there are strong reasons to understand insect gut communities and the amount of study on the bacteria that colonize insect digestive tracts is now increasing, broad principles for their structure are still being developed.

Insect gut structure and functions

Despite a number of changes related to adaptation to various feeding habits and environmental circumstances, insects share a similar basic digestive system anatomy (Figure 1). The foregut, midgut, and hindgut are the three main sections of the digestive tract (Simpson, 2013). The embryonic epithelium gives rise to the foregut and hindgut, which are shielded from infections by an exoskeleton made of integument glycoproteins and chitin. The gastrointestinal lumen and the epithelia are separated by this exoskeleton, which is shed at each ecdysis. The foregut is often differentiated from other diverticula or crops for temporary food storage when separated into functionally distinct subgroups (Linser and Dinglasan, 2014). Figure (1) Describe the basic structure and divisions of the insect digestive system. The midgut, which lacks an exoskeletal coating and originates from endodermal cells rather than the rest of the body, is the principal location of absorption and metabolizing in many insects.Among other things, the hindgut has separate sections for fermentation and a separate rectum for keeping waste during an earlier evacuation (Engel and Moran, 2013, Gupta,2020).

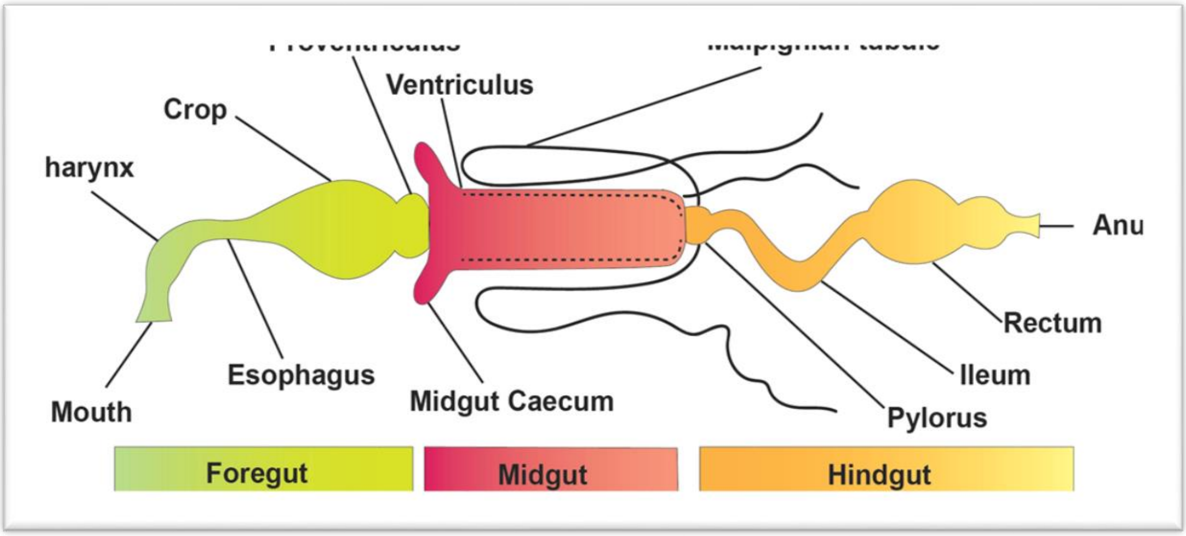

Figure (1) Basic structure and divisions of the insect digestive system (Siddiqui.et.al, 2022)

Living Conditions of Microorganisms in the Insect Gut

The cuticular glycoproteins of chitin (Adair et al., 2017) are the intestinal lining that surrounds the foregut and hindgut (both embryonic ectoderm derivatives) in insects. This exoskeleton is thus shed at each ecdysis and protects the intestinal lumen from the epidermal cells (Consuegra et al., 2020). The hindgut has many sections, including fermentation chambers and recta, for holding excrement prior to defecation, whereas the insect foregut typically contains real feeds or crop diverticula for short-term food storage. The normal alimentary tract with an enlarged hindgut portion is represented by Cyclocephalla signaticollis Burmeister (Coleoptera: Scarabaeidae).(Gasmi L et al., 2021). Microflora are commensal microorganisms from a wide range of phyla that live in the hindgut of scarab larvae and are concentrated in large numbers into a fermentation chamber where they play a key role in the digestion of plant material.

In the midgut of most insects, digestion and absorption take place; As an endodermal tissue without cuticle, the midgut is divided into an endoperitrophic area and an ectoperitrophic space by the peritrophic matrix secreted by the midgut epithelial cells (or, less technically, the peritrophic membrane or PM). and the microbes are compacted to the former to avoid contact with the midgut epithelium (Duplais C et al., 2021). Peritrophic matrix is classified into two classes: type I peritrophic matrix and type II peritrophinae. Type I peritrophic matrix is found in most hymenopterans, whereas it is seen in a small number of lepidopterans, coleopterans, dictyopterans, and orthopterans. Only a few dipteran and lepidopteran insects are known to contain type II PM. Perform a variety of tasks, including: Food particles are mechanically damaged, which leads to microbial invasion and food concentration and digestion (Klowden, 2012). Numerous detoxifying interactions that need considerable detoxification on the body's part are referred to as "gut symbioses," and they involve symbiotic microorganisms that are extraneously present in the digestive system lumens. Murgantia cribraria Fab bug species, Riptortus pedestris Fab. many sac-like structures appressed to the posterior gut in the midgut of two stinkbug species. This sac (Engel, 2013) includes these symbiotic bacteria. The bacteria of the plataspid stinkbug localize in midgut crypts (Hosokawa et al., 2012). Fig (2) shows the Role of gut microbiota in insect physiology**.** Several new research studies have begun to elucidate the functional roles and metabolic niches of the gut microbiota in insects, utilizing honey bees as a model (Bonilla-Rosso and Engel, 2018). The significant connections between microbiome dysbiosis and the decline of bee populations globally have drawn attention to the honey bee, an essential pollinator (Raymann and Moran, 2018).

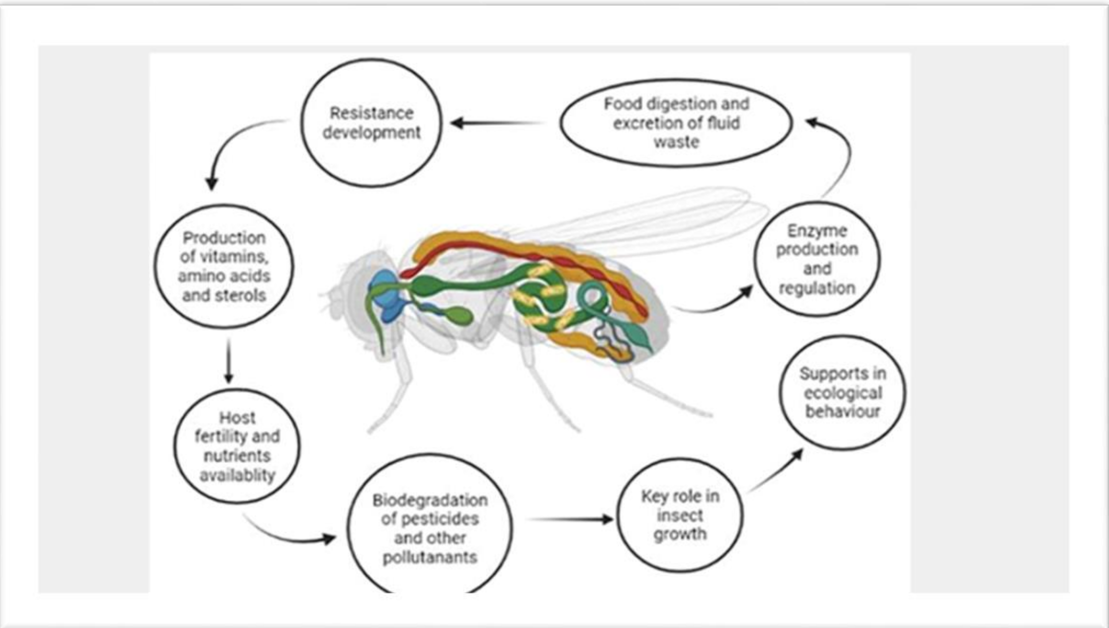

Fig (2) The gut microbiota's activity in insect physiology

Removal of toxins

Some symbionts able to detoxify diverse inorganic or organic compounds, such as insecticides and plant secondary metabolites (Raza MF et al., 2020). A feature of such dexterity can give some insects an important edge colonizing ecological niches devoid of other competitors. Hypothenemus hampei (Coleoptera: Bostrichidae) can complete its life cycle in coffee beans due to its microbiota (Bueno de Luna et al. 2015), which degrades caffeine a toxic alkaloid. More specifically, complete sets of N-demethylases that are responsible for the caffeine-to-theobromine (7-methylxanthine and so on) transformation have been identified in sequenced Pseudomonas genomes (Vega et al., 2021). Komagataibacter of the fruits of guava (image) is used to colonize fruits by three groups of the tisanía fly (Stratynerio or chubby), hymenoptera ferruginosa, pseudagranaa, and strente. Or possibly flies A. ludens are associated with this bacterium and cannot (Ochoa-Sánchez et al., 2022).

The tea saponin that is consumed by Camellia weevils, Curculio chinensis, qualifies as a toxic compound for them, but they develop on trees that are able to tolerate this because they harbor endosymbionts other than Acetobacter that can digest the poison. Zhang S et al. (2020). Taken together, provide evidence for a positive role of the gut microbiota for honey bee fitness upon viral infection (Dosch et al,. 2021).Other insects get a lot of support from microbial degradation of phytochemicals (Shukla SP, 2020). Finally, microorganisms are responsible for insecticide resistance in a wide range of insects (Brown JB 1982). Whilst previous results showed deltamethrin resistance in Aedes albopictus larvae and propoxur, naled to Ae. aegypti microbiota (Wang H et al., 2022). This was due to the up-regulation and inactivation ability of esterases, glutathione-S-transferases, P450 cytochromes, among others. In another example, P450 cytochrome from the microbiota of Apis mellifera honey bees protects bees with increased exposure to thiacloprid or fluvalinate (Dosch et al,. 2021 ; ,Scates et al., 2019). The aphid Susobion produces Hamiltonella defensa that detoxifies acetylcholinesterases, glutathione transferases, and carboxylesterases (Bhandari, G. et al., 2021).

Impacts of gut microbiota on the Activity of pesticides

According to Zhang et al. (2022). Insect microbiota is very dynamic and responds to many different forms of stress. The animal model of microbiota is under pressure by adaptations, similar to insects themselves, and its composition can be affected by changes in diet, food deprivation, and exposure to harmful substances (Akami et al., 2020; Kakumanu M et al,.2018). Microbes that live inside insect guts play critical roles in aspects of host nutrition, physiology, and behavior (Li, G., Sun et al,.2022). These chemicals can also be metabolized by the host-specific microbiota of pesticide-exposed hosts. It might be a source of variety, meaning that the host is less sensitive to pesticides. There are a large number of pesticide-degrading bacteria in nature that have been found across different insect orders, such as Insecta: Butterflies and moths (Lepidoptera), Hemiptera (Kikuchi et al., 2012), Diptera, , and Coleoptera (Akami et al., 2019b). As demonstrated by evidence from Xia et al. (2018) on resistant bacteria of the gut in Plutella xylostella Linnaeus (larvae) (FAO, 2010) & de Almeida et al. (2017) on reactions from many pesticides of resistant bacteria in the Spodoptera frugiperda, potentially by the breakdown of numerous agpesticides. Frugiperda strains resistant to normal pesticides guided the selection of pesticide-degrading bacteria not present in unselected L. vova's microbiome (Almeida et al., 2017). The utilization of pesticides as a carbon source by microorganisms depends on the expression of the suite of biochemical systems that can synthesize for handling the substrate (Lourthuraj et al., 2022). Temperature, pH, bacterial colony size, chemical concentration, and nutrient availability all affect the pesticide metabolism process (Domínguez-Santos R et al,.2020). The gut microbiota species and their roles in the biodegradation of environmental contaminants are depicted in Fig. (3). The speeds and efficiencies at which bacteria convert pesticides are changed by their chemical makeup and level of complexity. The rapid development of microbes can use a range of metabolic pathways to converge on the breakdown of xenobiotics (Bhatt et al., 2019, 2021; Gangola et al., 2022). for example, Pseudomonas spp. and Ensifer adhaerens could degrade the thiamethoxam pesticide. This most important metabolic pathway includes the (SNOH1) conversion of its N-nitroimino group oxide ($N\text{-}NO_2$) to N-nitrosimine or nitrosoguanidine (NO) and hydroxyurea (NH_4) (i.e., NH_4)., Another familiar case is that of the microbial symbiont genera Arsenophonus (Anderson et al,.2017). According to Hussain et al. (2016), Ensifer spp., Stenotrophomonas spp., and Variovorax spp. show that imidacloprid can be broken down by bulk mechanisms, and nitro-reduction and oxidation are two of the main ways that bacteria metabolize it. (Coyte, K et al,2015). Many pesticides, including pyrethroids, carbamates, and diamide organochlorines, can be broken down by the gut microbiota (Lin et al., 2022).

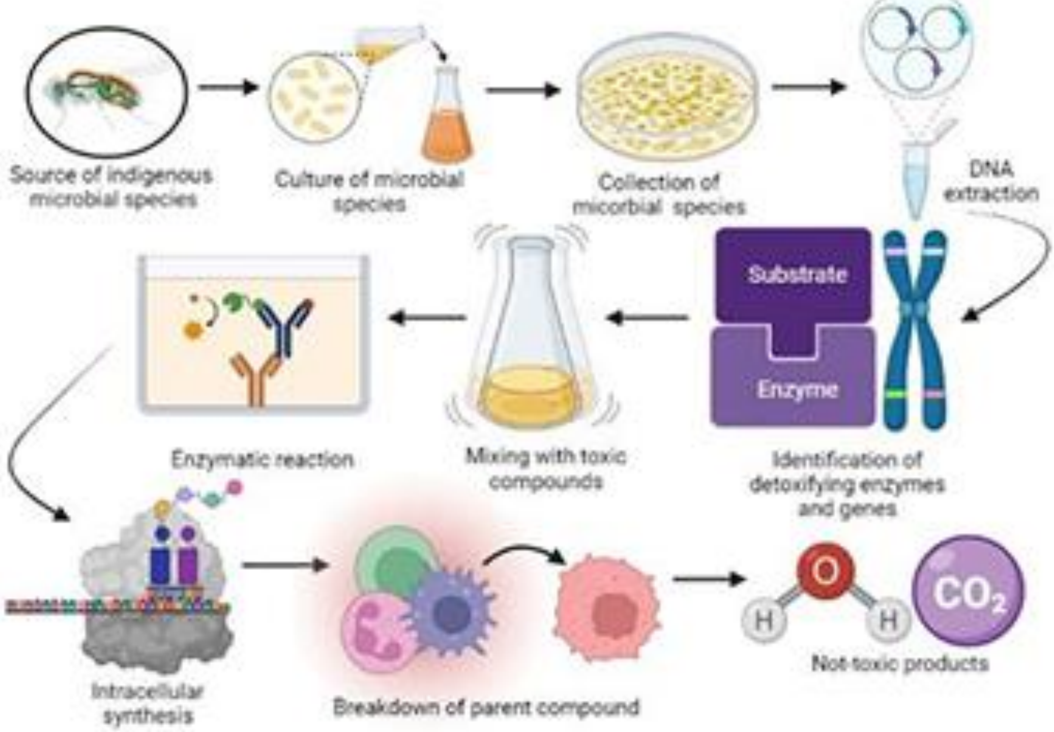

Fig (3) A picture of the distinct gut microbiota species of insects and how they contribute to the biodegradation of environmental contaminants (Jaffar et al., 2022).

Conclusion

The intricate relationship between intestinal microbiome of insects and pesticide decomposition underscores the significant role that microbial communities play in the ecology and physiology of insects. The diverse and specialized microorganisms residing within the insect digestive system contribute to essential functions such as detoxification of harmful compounds, nutrient absorption, and immune response modulation. As shown in various studies, these symbiotic bacteria not only enhance the insects' ability to thrive in challenging environments but also facilitate the degradation of pesticides, presenting a promising avenue for sustainable pest management strategies. Understanding the dynamics of these gut communities and their metabolic pathways offers potential applications in agricultural practices and ecological conservation. Future research should focus on elucidating the mechanisms of microbial interactions and their implications for insect health and pest resistance, paving the way for innovative approaches to addressing pesticide-related challenges in agriculture.

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