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Coronavirus Disease Pandemic and Insects: A Historical Overview

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ABSTRACT

Coronaviruses have significantly changed 21st century medicine, healthcare systems, education and the global economy by driving the ongoing coronavirus disease (COVID-19) pandemic. COVID-19 in humans is characterized by a wide range of symptoms, from asymptomatic to mild or severe illnesses, including death. The existing literature shows the roles of insect vectors in aiding the transmission of viral pathogens and the possible roles of some insects in severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) transmission. In this study, we briefly review the possibility of biological or mechanical transmission of SARS-CoV-2 by insects in the environment.

Key words: Biological transmission, Coronaviruses, COVID-19.

Known as Coronavirus disease (COVID-19), this infectious disease is caused by a virus called severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which was discovered in December 2019 in Wuhan, China and could be the cause of Coronavirus disease (COVID-19). The disease is highly contagious and it has spread rapidly around the world since it was first discovered in 2019. When it invades other parts of the body, it can cause respiratory symptoms such as a cold, flu, or pneumonia, as well as other symptoms when it invades other parts of the body. The Coronavirus, like many other respiratory viruses, spreads rapidly through the production of droplets released from the mouth or nose when a person breathes, coughs, mechanical transmission, sneezes, or talks. It can also spread quickly *via* contact with surfaces. Regarding SARS-CoV-2's spread and its transmission route, many questions still remain as to how it spreads and how it spreads. There may be additional concerns regarding SARS-CoV-2 transmission from insects, especially as warmer weather approaches, thereby posing a further threat, particularly in connection with the approaching warm weather. Among the most prolific and successful organisms on earth, insects play a powerful role in transmitting many of the most critical diseases across the globe and are considered to be among the most prolific. As one of the most important vectors of disease transmission, mosquitoes have been known to be among the most significant for decades now (Sharawi, 2021). The fact that insects are involved in both mechanical transmission as well as biological transmission during the transmission of many viruses is without a doubt one of the most significant factors involved in the spread of these viruses (Chamberlain, 1968). As a rule of thumb, mosquitoes are considered one of the most effective vectors for transmitting diseases to humans around the world. In addition to that, they cause diseases such as malaria, Zika fever, West Nile fever, Eastern Equine Encephalitis, chikungunya, yellow fever and numerous other diseases to spread throughout the world. The biological transmission process occurs when a vector is infected with the virus and replicates it onto the surface of its body during its feeding cycle, after which the virus can be passed on to susceptible hosts through the feeding cycle (Balaraman *et al*., 2021). In mechanical transmission, the virus is passively acquired by a vector, which then harbors the virus for a brief period on its internal or external surfaces for a short period of time before it is subsequently transmitted to another vector (Balaraman *et al*., 2021). Viruses can be believed to remain viable on smooth surfaces for up to 72 hours in the environment if they are kept away from abrasive surfaces (Kwon *et al*., 2021) and for days in feces (Wu *et al*., 2020) and urine (Liu *et al*., 2021). There are many pathogens around the world that are capable of surviving for a long time and when combined with the behavior and eating habits of insects, this can lead to them spreading and they fall into four main groups: viruses, bacteria, fungi and protozoa (Brian, 2009). As a rule of thumb, these pathogens live most readily in the external cuticle and in the gut, which are their most accessible habitats (Douglas, 2015). The external exoskeleton of an insect can be brittle and pathogens that can breach it may gain access to the internal hemocoel, as well as a second layer of habitat provided by the insect cells

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themselves. While the insect exoskeleton enjoys a well-deserved reputation as the physical barrier between an insect and microbial infections, it also has some significant disadvantages that need to be taken into consideration (Vallet-Gely *et al*., 2008). Microorganisms can colonize in the substrate and in addition to this, it can be the source of food for the microorganisms that colonize the substrate. On the body surface of Drosophila melanogaster, there are an estimated 1,000 culturable bacteria, two orders of magnitude fewer than the number of bacteria carried internally by the same age group of flies and this level of bacteria is believed to precede the level of bacteria carried on their surfaces (Ren *et al*., 2007). Physical factors such as ecdysis and grooming behavior, as well as antimicrobial secretions in the insect's cuticle, limit the microbial population in the cuticle of insects, which includes physical factors such as ecdysis and grooming behavior (Yek and Mueller, 2011). This measurement enables us to assess whether the bacteria associated with the cuticle, such as those found on our skin, are able to reproduce and form stable communities on a given surface (Findley *et al*., 2013), which is largely unknown. Cuticular structures have evolved over evolutionary years in many insects, making them an ideal host for microorganisms that are trying to colonize them (Douglas, 2015). Basically, a mycangium, which is a cuticular formation within which fungi reside, can be characterized as a type of culture vessel within which mycangia have the ability to remain protected against both abiotic factors and contamination from other microorganisms (Huang *et al*., 2010). The concept that mycangia are defining characteristics of houses for fungi is, perhaps, artificial, as some of them also contain bacteria alongside the fungi that they house (Hulcr *et al*., 2012). The fact is that some cuticular modifications of the body have been exclusively found to house bacteria. The solitary digger wasps of the tribe Philanthini, for instance, retain Streptomyces species that have the ability to reproduce. Each segment of the antennal body is composed of 5-6 glandular reservoirs that are surrounded by cuticles that provide protection for the glands (Kaltenpoth *et al*., 2012). There are several different types of actinobacteria that belong to the genus *Pseudonocardia*. These actinobacteria are stored in glandular invaginations on the bodies of ants, called crypts or foveae, which are located on their thorax, legs, or other areas depending on which species they are (Currie *et al*., 2006).

For the gut, insect guts have several characteristics that make them highly suitable for colonization by microorganisms. These characteristics include the ability to colonize food-associated microbial cells, the availability of nutrients and the ability to cope with external stresses (Douglas, 2015). It is important to note that the insect gut presents a wide range of challenges to the microbes ingested with our food and there are several factors to consider when analyzing the gut of an insect. There are numerous factors that contribute to the undesirable conditions in the gut lumen, including a very unfavorable physico-chemical environment, secreted digestive enzymes and immune components, physical disturbances caused by peristalsis, as well as habitat loss resulting from insect moltings and metamorphoses (Douglas, 2015). As a result of the great variations in insect gut anatomy and physiology, a range of conditions, resources and hazards exist in the gut habitats of each insect group, depending on their life stage and the region within the gut where they live. This reflects the diversity in habitat requirements for different insect groups. A large part of an insect's digestive tract located between its proximal pylorus and distal rectum, called the hindgut, holds the largest concentration of microbes. One of these regions is known as the ileum, which is found between the two (Douglas, 2015). A terrestrial insect's distal hindgut is typically considered a relatively benign environment, as it lacks the digestive enzymes of the midgut, which is why it is a relatively benign environment. For many species, the distal hindgut's desiccation stress is one of the most common stress factors because it actively resorbs water into the insect's tissues. It is also possible that the hindgut filtrate contains a large number of ions and metabolites which may be conducive to the growth of microbes in the hindgut when they are transferred from Malpighian tubules to the filtrate. In spite of the fact that the ileum does not appear clearly morphologically or physiologically to be able to maintain microorganisms in many insects, termites and scarab beetles have an anoxic fermentation chamber formed by the expansion of the ileum, in which microbes degrade complex plant polysaccharides into products that insects can utilize aerobically (Brune, 2006; Noda and Koizumi, 2003). In many species of insects, it is common for their cuticles to be thrown into their hindgut spines or plates, which are the preferred attachment points of microorganisms through which they move from one place to another (Brune, 2006).

For example, within the *D. melanogaster* midgut, there are a number of antimicrobial peptides that help in the production of digestive enzymes, including lysozymes, which are secreted by the midgut epithelium in response to invading bacteria (Shanbhag and Tripathi, 2009), There is an enzyme that produces reactive oxygen species which are microbicidal as well as a dual oxidase enzyme which is responsible for oxidizing (Ha *et al*., 2005). *D. melanogaster* and other cyclorraphous dipterans have a part of their midguts that is highly acidic, indicating that they have evolved in a specific way to adapt to activities, such as utilizing ingested bacteria as a source of energy (Lemaitre and Miguel-Aliaga, 2013). A number of insects can have a pH that is between mildly acidic and neutral, suitable for quite a number of microorganisms; on the other hand, there are some insects, such as larval lepidopterans, which have a pH that is alkaline, which may be harmful to quite a few of these organisms (Hansen and Moran, 2014). During the colonization of the midgut of insects, peritrophic matrix contributes to the chemical barriers that eradicate microbial colonization by separating the food bolus from the midgut epithelium, which adds to the physical barriers to microbial colonization (Douglas, 2015). Several studies have demonstrated that many of the ingested microorganisms are not able to cross the PM and pass passively through the midgut along with the bulk flow of food. A number of microbes and insects are capable of passing through PM without being hindered by the enzymes known as chitinases, which originate from microbes or insects (Dostálová and Volf, 2012; Tsai *et al*., 2001). Additionally, some insects have communities of bacteria that live in an ectoperitrophic environment (Brune, 2006).

The crop may provide an important habitat for microorganisms in some insects and they may have microorganism counts that can even surpass those in distant parts of the gut that are found in more distant parts of the gut if the crop is the dominant foregut habitat for them (Köhler *et al*., 2012; Schauer *et al*., 2012). There is, however, the likelihood that the crop will be able to stay in this location for only a relatively short time, considering that it is often used for storage and is evacuated regularly, raising the possibility that microorganisms may live here for a relatively short period of time (Capuzz *et al*., 2005). It has been demonstrated that the prebarium of the leafhopper *Graphocephala atropunctata* is capable of supporting microbial adhesion. A good example of this would be the prebarium of the leafhopper *Griphocephala atropunctata*, which contains the plant pathogen Xylella fastidiosa in its prebarium (Newman *et al*., 2004).

A certain group of insect species has been found to be commonly infected with intracellular pathogens, such as the gill worms, but these pathogens are only present within cells whose sole purpose appears to be maintaining and housing microbes (Douglas, 1989). Currently, it is known that these insects are able to contain bacteria in their bacteriocytes, as well as yeast in their mycetocytes. It is unclear where the developmental origins of insect cells lie, but *Acyrthosiphon pisum* bacteriocytes have a morphological uniformity, but they are also capable of diverging at different stages of embryonic development in order to form two populations (Braendle *et al*., 2003). In order to establish and maintain a relationship between bacteria and bacteriophages, which are secondary symbionts of bacteria, phages must have no access to the external environment and they are transmitted vertically, typically via the ovaries of females and then into the cytoplasm of eggs (Douglas, 2015). This allows the host to maintain precise control over the distribution of microorganisms in transit from the bacteriocyte to the offspring, as well as their abundance, throughout the process. Several insects with primary symbionts also carry secondary symbionts that are associated with their bacteriocytes and which are transmitted vertically. The secondary symbionts differ in several ways from the primary symbionts that they carry, for example, they are associated with their bacteriocytes and transmit vertically. In this paper, we present a brief overview of how SARS-CoV-2 can be transmitted by way of biological and mechanical routes by insects that live in the environment.

Mechanical Transmission

As well as passive transmission, mechanical transmission occurs when contaminated mouthparts, legs, setae, or any other part of an insect's body is contaminated with pathogens and the pathogen is transmitted in a manner without any change in the development of the pathogen or the growth of the pathogen within or on the surface of the insect without any development or multiplication. Thus, it is found that insects are only used as a medium through which to transmit viruses to other insects (Barclay and Esther, 2020). As a member of this order, cockroaches are among the most common carriers of diseases, so they should be considered completely pest-free. Additionally, they are considered one of the oldest insect groups on the planet and have been around for 300 million years, making them one of the oldest in the world. In the past few years, approximately 5000 species of cockroaches have been identified and classified, according to current estimates. Generally, these plants can be found in tropical and subtropical forests, where they feed on dead and decaying organic matter and are considered decomposers, since they digest dead organic matter (Appel, 1995).

Several factors make cockroaches well suited for living with humans, the most important being that they live in shaded areas. As they go from one house to another searching for food and shelter, they enter houses looking for food and shelter (Gondhalekar *et al*., 2021). As with any insect pest, they can either be classified as domestic or peridomestic, depending on where they are found and whether they are a domestic or peridomestic pest. There are two kinds of species found predominantly inside buildings: domestic species, which are found mostly in indoor environments and peridomestic species, which are found mostly outdoors (Douglas, 2015). There are a number of reasons why cockroaches should not only be treated as nuisance pests, but also as serious medical problems that can result from infestations. Some people come into contact with pathogenic microorganisms on their bodies that are harmful to humans and they are capable of physically or mechanically transmitting those pathogens to surfaces that are used for serving or handling food (Pai *et al*., 2003).

It has been noted in recent years that the prevalence of several new viruses which threaten human health has increased. They include the severe acute respiratory syndrome coronavirus (SARS-CoV), Middle East respiratory syndrome–related coronavirus (MERS-CoV), Nipah, Epstein-Barr, Lassa fever, Marburg, Zika, Rift Valley fever, Chikungunya, Dengue, Ross River and SARS-CoV-2 viruses (Dehghani and Kassiri, 2019). Insects such as cockroaches are capable of transmitting these viruses to humans through the bite of their legs (Mayer *et al*., 2017). Most cockroaches spend a large amount of time in sewers, drains, or sewer pipes that contain an abnormally high concentration of pathogens and sewage in which they live. This leads to high levels of disease and infection (Basseri *et al*., 2016). Also, they feed on garbage regularly, so they have access to large quantities of human pathogens given that they spend a lot of time eating garbage (Pai *et al*., 2003). It must also be added that their habitual actions and dirty behavior, such as their filthy eating habits, make them perfect hosts for a variety of pathogens due to their habitual actions and dirty behavior (Allen, 1987). It was found that two different studies have found that cockroaches carry dangerous pathogens in their feces and their feces can also carry pathogens in their saliva (Allotey *et al*., 2009).

A coronavirus, if left in the environment for a period of time, will be able to survive quite well. This means that they can be transmitted by all organisms that have contact with or eat human feces, including cockroaches and snakes, this seems clear enough (Douglas, 2015). There have been a number of studies conducted on the effects of direct contact between infected cockroaches and humans or animals, but none of these have been able to assess the result of that direct contact (Reuben *et al*., 2020). Several researchers have reported that, at least in the wild, cockroaches are capable of interacting with contaminated human waste and transmitting Coronaviruses from one individual to anotherAccording to a study conducted by scientists from the University of Arizona, non-blood-sucking insects can be capable of transmitting pathogenic bacteria directly to human mucous membranes or conjunctival tissues by interacting with them directly (Heller *et al*., 2020). Meanwhile, another study reported that sewage and wastewater-based epidemiology is one of the main causes of COVID-19 in communities across the country, in comparison with sewage and wastewater-based epidemiology (Randazzo *et al*., 2020). A lot of cockroaches prefer to live in sewers since they are a good breeding ground for them. So, in terms of the spread of disease, the cockroaches that eat or interact with human secretions or excretions that are contaminated with a virus can easily spread these viruses, similar to the way that cockroaches can spread viruses through direct contact with the body surfaces of infected people (Dehghani and Kassiri, 2020). The study also found that the mechanical transmission of SARS-CoV and other Coronaviruses by cockroaches played a significant role in the transmission of SARS-CoV and other Coronaviruses in 2020 (Reuben *et al*., 2020).

As a result of its gregarious nature and synanthropic preference, *Musca domestica* (Diptera: Muscidae) is the most common fly in the world and is found almost everywhere within or surrounding human habitations due to its gregarious nature and synanthropic predilection. There are a number of factoids about this species, including that it is indiscriminate feeder and contaminates foods that it consumes with microbial agents transported from waste-contaminated breeding habitats. It is then the microbial agents that serve as breeding habitats for these organisms, while the unknown humans who consume these foods act as reservoirs in which these microbes can grow and thrive. It is common knowledge that household flies are attracted to excrement and exudates of humans and animals, as well as food products. There is a potential way for pathogens to be acquired or transferred through this means, since they are capable of carrying more than 250 pathogens, including bacteria, viruses, protozoa, helminths and fungi, through their mouths (Nayduch and Burrus, 2017). This is due to the fact that as bacteria move easily from one contaminated environment to another, they can spread the disease to nearby environments as they move between contaminated environments.

According to a number of studies, houseflies carry pathogens both inside their alimentary canals and on their external surfaces, which explains why they carry so many pathogens (Onwugamba *et al*., 2018). There are a number of studies that have shown that house flies can transmit Turkey Coronavirus which has been demonstrated in numerous studies (Calibeo-Hayes *et al*., 2003), Newcastle disease (Watson *et al*., 2007), porcine respiratory syndrome (Pitkin *et al*., 2009) and porcine transmissible gastroenteritis (Gough and Jorgenson, 1983). There is, however, no information regarding whether houseflies can be used to transmit SARS-CoV-2, they may acquire, harbor and transmit the virus and therefore the answer to the question remains unclear. It has been found that all flies exposed to SARS-CoV-2 on medium or milk substrates can acquire the illness within some four or twenty-four hours of being exposed to the virus, respectively, according to a study published in 2021 (Balaraman *et al*., 2021). A virus-spiked medium control group was not exposed to viral RNA while the virus-spiked milk group ingested more viral RNA than the virus-spiked medium control group, despite the fact the virus-spiked medium control group was not exposed to viral RNA either. An earlier study found that house flies do not carry enough Newcastle disease virus for them to transmit it to humans, but not enough to transmit the pathogen to other animals (Watson *et al*., 2007).

It should be noted that there has been only one experimental study looking into the mechanical transmission of SARS-CoV-2 to date. After exposure to the virus, according to the study, flies are capable of acquiring the virus as well as retaining viral RNA and the infective virus for up to 24 hours after the exposure. As well as spreading viral RNA, they were also capable of spreading infective viruses to virus-free surfaces, while not transferring the viroid itself (Balaraman *et al*., 2021). It was discovered in another study in which researchers were working with flies harvested from a hospital with active COVID-19 cases that the flies were carrying SARS-CoV-2 RNA on their bodies (Soltani *et al*., 2021). According to a previous review we conducted regarding houseflies, non-biting flies can transmit SARS-CoV-2 mechanically from one individual to another by transferring pathogens from their contaminated mouthparts or bodies to another person.

Biological Transmission

It is widely accepted that biological or passive transmission is the most important method by which diseases are transmitted by vectors (Ismail *et al*., 2020). During this transmission process, pathogens are undergoing biological development and as a result, must complete their life cycle in the body of the vector before they can spread. A number of recent studies have explored the possibility of blood-sucking insects acting as vectors for SARS-CoV-2 in recent years (Fortuna *et al*., 2021); many studies have investigated mosquitoes' potential for biological transmission (Huang *et al*., 2020). One study detected SARS-CoV-2 in mosquitoes <24 houres after virus exposure, but no biological transmission occurred (Balaraman *et al*., 2021). Another study also examined the susceptibility of three mosquito species to the virus by inoculating them intrathecally with SARS-CoV-2 in 2020 before they were exposed to the virus (Huang *et al*., 2020). Two hundred and seventy-seven mosquitoes were collected and then analyzed following inoculation to verify that no virus had been found. *Culex pipiens* could spread SARS-CoV-2 mechanically, while *Aedes albopictus* could not spread the virus mechanically. However, both *Culex pipiens* and *Aedes albopictus* were ineffective biological vectors (Fortuna *et al*., 2021). While the World Health Organization apparently believed that mosquitoes were not able to transmit SARS-CoV-2 during the initial outbreak of the epidemic, they subsequently changed their minds (World Health Organization, 2020). It has been determined in experimental studies that SARS-CoV-2 cannot replicate in the cells of *Aedes* mosquitoes in vitro and this was subsequently confirmed in subsequent studies (Xia *et al*., 2020).

To date, no information is available on the vector competency of *Culex pipiens* for SARS-CoV-2, the virus that transmits West Nile and Usutu (Riccardo *et al*., 2020). Similarly to how mosquitoes are capable of transmitting many viruses, it is possible to make a presumption that Coronaviruses are able to transmit other viruses based on observations and facts gained from other Coronaviruses that have been observed and extrapolated. In addition to being close relatives and related to SARS-CoV-2, MERS-CoV is also closely related to SARS-CoV-2; however, neither produces blood levels considered to be high enough to infect mosquitoes. Contrary to insect-borne viruses such as dengue fever and yellow fever, which, for example, are carried by insects. People who had been infected with SARS-CoV-2 did not have any signs of the virus in their peripheral blood or in the blood of monkeys. Biological vectors are created by the epithelial cells inside the mosquito's midgut absorbing enough viral load to become infectious for the virus to disseminate and, at the same time, cause the salivary glands to become infected with the virus. There are many barriers that mosquitoes must overcome to be able to transmit viruses if they are to get past a midgut infection and escape. These barriers are bypassed by mosquitoes that are resistant to viruses by inoculating them directly into their hemocoel before transmitting the virus. The mosquitoes that are carrying this family of viruses have not been found to carry any strains of this family of viruses so far. There has only been one study reported on the correlation between Coronavirus and mosquitoes in relation to the epidemic (Fauver *et al*., 2017). In a study published in the year 2020, mosquitoes were reported to be capable of being used for surveillance (Huang *et al*., 2020). During the study, the MERS-CoV virus was fed to *Anopheles gambiae* mosquitoes which still retained viral RNA in their midguts after being injected with MERS. This was similar to if the virus had been fed to humans earlier in the study. Similarly, positive polymerase chain reaction detection of *Bacillus anthracis*, *Trypanosoma brucei gambiense* and Zika virus was observed, none of which were infective or transmitted by *Anopheles gambiae*. Moreover, the levels of RNA in both samples were equal to or below the level of RNA in the input samples, which meant that the organism did not replicate. As a result of the study's results, it has been found that SARS-CoV-2 cannot replicate in either Aedes cells that are cultured in vitro or field strains that are used as a biological control, because it cannot replicate in insects that feed on blood, such as mosquitoes (Xia *et al*., 2020). It should also be noted that even if the virus runs in their blood, a mosquito feeding on a native species cannot be considered a disease vector.

CONCLUSION

As of December 2019, Chinese researchers have discovered that a virus called SARS-CoV-2 has been discovered in Wuhan. There is a possibility that this virus can cause COVID-19, a highly contagious disease that has rapidly spread worldwide and is highly contagious. Among the most common and effective organisms known to man, insects are among the most common and effective. Hence, for decades, they have been widely believed to be responsible for the transmission of many critical diseases, both mechanically and biologically and their potential for devastating consequences has been well established. According to our review and a number of research papers, cockroaches and houseflies have been reportedly found to be capable of mechanically transmitting the SARS-CoV-2 virus from one part of their bodies to another, such as their legs, wings and mouths. It has been shown in the past that the SARS-CoV-2 virus has difficulty replicating when transmitted biologically from blood-sucking insects. As a result, this suggests that there could be a mechanical transmission mechanism by insects that may come into contact with humans.

Conflict of interest: None.

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