v. 5, n. 3, 2025

International Journal of Health Science

Acceptance date: 13/01/2025

NEW FEAR UNLOCKED: URBAN ANTS AS MECHANICAL VECTORS OF HUMAN DISEASE

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Abstract: ants are commonly found in domestic environments, mainly associated with sugary foods. In urbanized areas, these insects move around in search of refuge, food or spaces to form new nests, thus reaching our homes; Thus, the interaction between ants and humans can result in the occurrence of diseases of varying degrees of pathogenicity, from allergic processes to the transmission of multi-drug resistant bacteria. By means of a research review, we address and discuss the potential of ants in the transmission of human diseases, as well as we highlight prophylactic measures, and control, to avoid these arthropods in homes and their surroundings.
Keywords: Synanthropic insects. Formicidae. Urban ants. Multidrug-resistant bacteria.

INTRODUCTION

Cockroaches and flies are often the first "villains" associated with the process of transmitting diseases to humans; however, few people often reflect on the potential of ants in this process (Simothy et al., 2018; Nascimento 2022). It is possible that most readers have heard, at some point in their lives, the expression: it's good for your eyesight! An allusion to the fact that eating ants found in food would not be harmful, and that seeing such a small animal was proof that the person's eyesight was in perfect working order. But was such a statement really correct?

Formicidae is a large cosmopolitan family of insects, belonging to the order Hymenoptera, found in practically all terrestrial habitats; these arthropods are mostly eusocial, although there are also a few parasitic species (Triplehorn, Johnson, 2011; Baccaro et al. 2016; Gordon, 2019). Ants play important economic and ecological roles, such as: i. they participate in various food chains, ii. they are used in human food (Atta), iii. they carry out biological control by preying on various herbivores, iv. some species are pollinators and/or seed dispersers (mimercoria), v. they can also present themselves as agricultural pests - destroying roots, seedlings and flowers and vi. they act as transmitters of pathogens (Offenberg, 2015; Santos, 2016; Bueno et al., 2017; Gullan Cranston, Fernandes et al., 2019; Xu et al., 2022).

Urbanization has allowed these insects to arrive in our homes, mainly attracted by the garbage we produce (which is often packaged irregularly), in search of food, thermal stability or suitable places to set up new nests, such as furniture and gardens (Soares et al., 2001; Oliveira, Campos-Farinha, 2005). Tanaka et al. (2007) and Alves et al. (2011) state that ants are a public health problem in hospital environments, since multi-drug resistant bacteria, such as *Klebsiella pneumoniae* and coagulase--negative *Staphylococcus*, have already been identified as being carried on the skin of ants collected in hospitals.

The contact of ants with the soil, in itself, is already an aggravation of disease transmission since many parasites and pathogenic microorganisms inhabit the soil (Neves, 2016); in addition, ants inhabit highly polluted environments such as sewage and waste, move over dead animals and can feed on secretions such as phlegm, urine, pus and blood (Rodovalho et al., 2007; Rodrigues et al., 2010; Oliveira-Costa, 2011). Due to their great mobility and ability to adapt to various environments, ants can spread pathogens to domestic and peridomestic environments, such as *Yersinia pseudotuberculosis* (Lopes et al., 2020), *Serratia marcescens* (Fontana et al., 2010) and *Mycobacterium tuberculosis* (Roxo et al., 2010). Thus, the aim of this study is to address and discuss the main human diseases associated with transmission by ants, as well as ways of controlling these insects in domestic environments and their surroundings.

METHODS

The present research was structured by means of a literature review focused on identifying publications relating to descriptions of interactions between ants of different species associated with pathogens that cause human diseases in domestic and commercial environments. The systematization for the survey of bibliographic material in the online databases Scielo, Medline, Google Scholar, Science Direct and PubMed was carried out using the following descriptors: urban ants, synanthropic insects, ant vectors, multidrug resistant bacteria and bacteria associated with ants. No exclusion criteria were applied due to the time of publication of the references obtained, nor language restrictions, since few studies deal with ants as transmitters of pathogens in residential and/or commercial environments, with the majority describing ant-pathogen interactions in hospital environments.

The results were structured as follows: i. Morphological and behavioral structure of pathogen-transmitting ants; ii. Main diseases transmitted by ants and; iii. Ant control in the home and peridomestic environment

RESULTS AND DISCUSSION

MORPHOLOGY, SOCIAL STRUCTURE AND ALIMENTARY BEHAVIOR CONDUCIVE TO DISEASE TRANSMISSION

Among the main ants identified as carrying disease-causing microorganisms to humans, the following species stand out: *Tapinoma melanocephalum*, *Paratrechina longicornis*, *Monomorium pharaonis* and *Monomorium floricola*; these are commonly found in residential and industrial kitchens, as well as hospital environments (Roxo et al., 2010; Baccaro et al. 2016; Silva et al., 2016; Lopes et al., 2020). According to Baccaro et al. (2016) these species have the following characteristics:

T. melanocephalum: a cosmopolitan species with hospital and residential pest status all over the world. The "ghost ant" has a greatly reduced or even absent petiole node, and in addition, the petiolar region is concealed by the gaster when viewed dorsally.

P. longicornis: commonly known as the "crazy ant", it is a species that occurs worldwide and has very long antennal scapes and no erect hairs. This species is extremely well adapted to urban areas and has opportunistic foraging behavior, with polygynous colonies of up to 40 queens at a time.

Monomorium (pharaonis and floricola): a genus with a worldwide distribution with omnivorous species found from forests to urban environments. Morphologically they are characterized by having mandibles with 3 to 4 teeth, antennae with a 3-segmented apical clava and propodeum, generally without projections or carinae.

According to Silva et al. (2016), the external morphology and social organization of ants can contribute to these insects being used as mechanical vectors for microorganisms. The integument of ants can have structures such as spines and hairs, as well as projections and contours that presumably favor the attachment of spores, strains and parasite eggs (Mankowski et al., 2004). The antennae, present in pairs, can become contaminated when they are used to touch or taste some environment, material or food; the mandibles, can cut organic material or objects contaminated by pathogens; ambulatory legs - adapted for walking, have sensory structures in the form of hairs that can adhere to pathogenic life forms and transmit them (Oliveira-Costa, 2011; Triplehorn, Johnson, 2011; Pereira, Ueno, 2013). Siedlecki et al. (2021) report that spores of the fungus *Penicillium* were often found growing in a concentrated form on the head of the ant *Formica polyctena*, in the infrabuccal pouches of this insect; exemplifying how the morphology of ants can favor the transport of microorganisms.

The great dietary diversity found in Formicidae is apparently one of the factors that contributes to the transmission of pathogens by these insects, which can feed on fungi, dead animals, corpses, plants, honeydew and even secretions such as urine, blood and feces (Triplehorn, Johnson, 2011; Simothy et al., 2018; Queiroz et al., 2021). When foraging (moving in search of food), ants can become contaminated with strains, cysts and other pathogenic forms present in the soil; moreover, since the vast majority of species are omnivorous, the diversity of food can directly contribute to the contamination of ants with agents that cause human diseases, found in the most diverse environments while the ants are foraging; subsequently, the habit of foraging can lead them to kitchens, restaurants, bakeries and factories; contaminating food, surfaces and utensils (Zarzuela et al. (2004; Zarzuela et al. 2007).

Still on the subject of foraging habits and their contribution to the spread of pathogens, Rodovalho et al (2007) warn that multi-drug resistant bacteria belonging to the genera *Acinetobacter*, *Streptococcus*, *Gemella* and *Klebsiella* have been isolated from ants found in homes around hospital areas, warning of the need not to neglect these influential vectors in the domestic environment.

MAIN DISEASES THAT ARE TRANSMITTED BY ANTS

Mechanical vectors are organisms that carry pathogenic forms in their body (Neves 2016); ants are potent mechanical vectors of a large group of pathogens, ranging from bacteria, fungi to nematodes; they can result in mild and moderate infections to death (Santos et al., 2016; Alves et al., 2017; Simothy et al., 2018; Moura et al., 2020).

Foodborne infections

Human foodborne infections occur when microorganisms are ingested and begin to multiply in the digestive tract, causing, among other symptoms, fever, nausea, diarrhea and vomiting; among the species most commonly causing the problem are *Escheria coli*, *Listeria monocytogenes* and bacteria of the genus *Salmonella*, *Campylobacter* and *Singella* (Andrade et al., 2010; Lustosa et al., 2021; Bispo et al., 2022).

After collecting ants in different residential kitchens, Simothy et al. (2018) found that several insects were associated with pathogenic microorganisms capable of triggering foodborne infections and gastrointestinal disorders, such as strains of *E. coli* and *L. monocytogenes*; as well as yeasts and molds. Most of the publications related to ants as mechanical vectors of human disease describe samples collected in hospital environments (Moreira et al., 2005; Rodovalho et al., 2007; Tanaka et al., 2007; Pesquero et al., 2008; Fontana et al., 2010; Roxo et al., 2010; Alves et al., 2011; Gonçalves et al., 2011; Pereira, Ueno 2013; Lopes et al., 2020; Moura et al..., 2020) above all, because it is an environment where there are immunosuppressed people who would be more prone to damage from pathogens associated with ants, although, as Simothy et al. (2018) state, these animals should not be neglected in domestic environments, since the pathogenicity of microbial agents associated with ants collected in places where bread, sinks and utensils are stored, have been verified.

Yersinia pseudotuberculosis is a gram-negative bacterium that causes *Yersiniosis*, a gastroenteritis characterized by fever, acute diarrhea and abdominal pain; Lopes et al. (2020) isolated strains of this microorganism in the integument of the ants *P. longicornis* and *T. melanocephalum*; in addition to other pathogens such as *E. coli, Klebsiella ozaenae* and *K. rhinoscleromatis*.

Bacteriosis

Undoubtedly, among the pathogenic microorganisms associated with transmission by ants, bacteria (especially those belonging to the Enterobacteriaceae family) stand out in a major way, so that the vast majority of research related to synanthropic ants describes these insects carrying pathogenic bacteria (Tanaka et al., 2007; Pesquero et al., 2008; Roxo et al., 2010; Alves et al., 2011; Pereira, Ueno 2013; Lopes et al., 2020; Moura et al., 2020). Fontana et al. (2010) point out that ants collected in a hospital environment resulted in the capture of more than 20 bacterial species, among them: *Pseudomonas aeruginosa, P. fluorescens, Streptococcus viridans, Enterobacter aerogene* and *Serratia marcescens*; the latter is generally associated with a variety of human infections, mainly pneumonia, septicemia and urinary infections; the authors also isolated samples of *Stenotrophomonas altophilia* (associated with lung infections), *Shigella sonnei* (which causes bloody diarrhea) and *Staphylococcus aureus*, a bacterium capable of causing pneumonia, endocarditis and osteomyelitis. It is worth noting that the foraging habits of ants, as mentioned above, could spread these contaminants to kitchens and other residential areas in hospitals, for example.

Zarzuela et al. (2004) state that few studies have dealt with ants as pathogen transmitters in residential and/or commercial environments, with the majority describing ant-pathogen interactions in hospital environments; the authors therefore collected ants in the kitchens and bathrooms of homes, bakeries, cafeterias and pizzerias in order to assess the microbial load associated with this vector. In all, 132 bacterial strains were collected, with *K. pneumonae* being bacteria that deserve to be highlighted for the degree of pathogenicity they express; they can trigger pneumonia, bloodstream infections and meningitis.

In their study, Zarzuela and colleagues (2004) isolated bacterial strains resistant to several commonly prescribed antibiotics, such as Ampicillin, Ceftazidime, Erythomycin, Amoxalaxin, Ceftrianxone, Penicillin and Vancocillin. This situation raises concern, as the bacteria found in households are not expected to be resistant to antibiotics. Some of the households sampled were occupied by medical students, who attended hospitals on a daily basis. These people may bring resistant bacteria home with them, contributing to the spread of multi-drug resistant strains in households; however, the same bacterial resistance profile was also observed in households of people who did not frequent hospitals, suggesting that bacterial resistance may be evolving into a worrying situation in food premises.

Strains of *Mycobacterium tuberculosis* (Koch's bacillus) have already been isolated from the ant *P. longicornis*; in addition to it, *M. fortuitum peregrinum* and *M. smegmatis* have also been collected (Roxo et al., 2010). The authors warn about the pathogenicity of the *Mycobacterium* complex and the negligence that exists between the association of this pathogen with ants. Tuberculosis is a serious bacterial disease that preferentially affects the lungs, but can spread to other areas of the body, causing resistant cough, fever, night sweats and weight loss, for example (WHO 2013; Khawbung et al., 2021).

In view of the above, it can therefore be concluded that ants are important vectors of bacteria, with a high level of contamination and transmission. In addition, some bacteria carried by ants showed high levels of resistance, indicating that ants are mechanical disseminators of bacterial resistance

Helminths, protozoans and fungi

Vilani et al. (2008) proved through laboratory experiments that the urban ants *Camponotus rufipes*, *Solenopsis saevissima* and *Acromyrmrex nigere* were capable of carrying *Ascaris lumbricoides* eggs in their bodies. This nematode is the cause of Ascariasis, an intestinal parasitosis, characterized by affecting individuals, especially in childhood, and causing early weight loss, abdominal pain and diarrhea; when in high infestations it can lead to complications such as organ obstruction and perforation, hemorrhage and death (Brasil, 2010; Neves, 2016). The authors also reported that cysts of protozoans of the genus *Entamoeba* were carried by worker ants of *C. rufipes*.

Fungi can also pose health risks, since some species are capable of causing diseases in humans (mycoses); Moura et al. (2020), identified fungal strains associated with the integument of urban ants of the species *P. longicornis* and *T. melanocephalum*, among the fungi identified were *Mucor* spp, *Cladosporium* spp and yeasts.

When evaluating ants collected in industrial and residential kitchens, Zarzuela et al. (2007) observed that these insects were capable of carrying pathogenic fungi, so that the ant *T. melanocephalum* had, for example, 4 fungal strains per worker. The authors warn about the pathogenicity of these fungi, which are capable of triggering allergies and infections due to the production of mycotoxins. Industrial kitchens had the highest rates of ants contaminated by fungi, and the ant isolates included *Aspergillus*, *Cladosporium*, *Penicillium*, *Fusarium*, *Nigrospora*, *Rhizopus*, *Epicoccum* and *Neurospora*. The genera *Aspergillus*, *Fusarium* and *Penicillium* constitute three important groups of fungi in terms of toxigenicity, capable of producing, for example, potent hepatotoxins and being used as carcinogens (Dias 2018; Arruda, Beretta 2019).

Siedlecki et al. (2021) identified spores of *Akanthomyces* on the integument of *Formica polyctena*, which is an entomopathogenic fungus, i.e. harmful to ants; with this, the authors propose an interesting reflection on the association of ants with fungi to defend them from their natural enemies. This interaction, however, could be harmful to human health, for example, the ant could associate with *Penicilium* to inhibit *Aspergillus* sp, and this could result in food contamination due to the insect's foraging habits.

Allergic reactions

As well as acting as mechanical vectors for pathogenic organisms, ants can also cause direct damage through stings, as several of these insects have toxins (Alves et al., 2017). The stings of ants of the genus *Solenopsis* (foot washer), for example, can cause anything from mild discomfort and itching to triggering anaphylactic shock in allergic individuals (Oliveira, Campos-Farinha; 2005). Kipper et al (1998) described an incident with *S. invicta*, where multiple bites on a 2-year-old child triggered a hypersensitivity reaction generating perioral and peripheral cyanosis, weak respiratory movements, and later worsening to mild to moderate cerebral edema. The authors also point out that, in some cases, the lesions resulting from the bites can also become infected and lead to sepsis, with a greater risk for patients whose immunity is compromised.

CONTROLLING ANTS IN THE HOME AND PERIDOMESTIC ENVIRONMENT

In general, ants are found in low quantities in the home environment, so in order to control these insects it is necessary to adopt simple measures involving cleaning, hygiene and the use of household cleaning products, which are easily found in markets; some suggestions for management and control mea-

sures were presented by Campos-Farinha et al. (2002), Zarzuela et al. (2004); Zarzuela et al. (2007); Josens et al. (2017); Davis, Taylor (2019); Sousa et al. (2019); Fernandes et al. (2019); Pereira (2021) and Silva et al. (2021); Dhang et al. (2022), such as:

- Keep the house clean and free of leftover food, especially sweets, which attract ants. Wash the dishes thoroughly, clean the worktops, stove, floor and tables after meals. Keep food in closed jars and dispose of garbage daily;
- Plug up gaps, cracks and holes that could provide entry or shelter for ants. Use silicone, putty or other materials to seal these places;
- Use repellent substances such as vinegar to keep ants away from plants and surfaces. The product interferes with the ants' chemical communication, causing them to disperse from the environment;
- Apply a specific insecticide gel at strategic points where the ants travel. The product has a transfer effect and eliminates the other insects in the anthill, making it a product with a broad spectrum of action and low toxicity for the environment.
- Application of a specific insecticide gel at strategic points where ants travel. The product has a transfer effect and eliminates the other insects in the anthill, being a product with a broad spectrum of action and low toxicity for domestic environments;
- Use toxic baits, which in this case are slowly absorbed formulated products produced by companies specializing in chemical pest control. These are designed to enter the food cycle of these insects and interfere with their nutritional absorption, leading to their death;
- Use alternative control methods through the use of products such as sesame, detergent, petroleum jelly, cloves and cinnamon, which have proven deterrent and/or repellent effects.

By adopting some of these measures, it is possible to control and/or prevent ants from remaining in the home, avoiding problems such as bites, stings and pathogens carried by them. It is necessary to check the origin and extent of the infestation so that products can be used properly and safely.

FINAL CONSIDERATIONS

Although they have several more benefits than harms in the natural environment, ants should not be welcome in homes, since in addition to the diseases mentioned above, ants can cause allergies, food poisoning and damage to household appliances and furniture, so these synanthropic insects should be avoided in and around the home. The choice of control measures for these arthropods must take into account the ant population, its degree of infestation and the place of occurrence. Ant control measures can (and should) be used preventatively, such as insecticide baits and household cleaning products, in order to avoid interaction with these potential mechanical vectors of disease in our homes. It is also worth pointing out that the change in ants to the status of a synanthropic insect is a result of man's degrading action on natural environments and that although they should not be accepted inside homes, they should not be "demonized", as they are victims of the process of urbanization of natural landscapes.

ACKNOWLEDGEMENTS

We would like to thank Dr. Clovis José Cavalcanti Lapa Neto for evaluating and revising our manuscript, as well as Professor Marcia Modesto for her help with translation and proofreading.

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