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BEES AS BIOSENSORS OF DRUGS AND EXPLOSIVE SUBSTANCES – A BIBLIOGRAPHIC REVIEW

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Abstract: Bees have been acquiring space as biological biosensors in prevention and repression activities in the location of explosives and narcotics in some International Security Institutions. Normally this attribution was only for canines, now a reality for insects and other mammals. Using bees as a biosensor is effective, with the right training and use of equipment to allocate bees when needed and when required. This article is a literature review study, with a descriptive and comparative procedure of scientific works that describes the sensory system of bees and the species used as biosensors, explaining the techniques used for training and the efficiency of economy, both in time as economic financing. In addition to being a low-cost project, similar to other technological innovations, it also has its downfall as in the progression of its training, where the training of bees is effective in hours, while other animals of different taxonomy would take at least months to train. detection and various stages to progress. For a good detection operation to occur, it is necessary to combine a deeper study of knowledge in different situations and use technology to provide operational ease regarding the precision and sensitivity of bees as a biosensor.
Keywords: Bees; biological biosensors; bee training.

INTRODUCTION

Insects are interesting animals, with coexistence and interaction in the life of other living organisms including humans. There is a diversity of insects with wide distribution in nature, also living symbiotically. (REECE et al., 2015). Currently, there are several studies on insects that are excellent detectors, especially bees, which detect and associate chemicals (RAINS et al., 2008). It is research on the smell of insects that can detect various types of chemical substances, due to the reactions of odor molecules with binding proteins, converting into electrical signals in the dendritic membrane, which is the distribution of information in the sensory areas of the antennae of insects. (SCHOTT et al., 2015). Insects of the order Hymenoptera have a well-developed olfactory system, dividing the neural zones of the anatomical periphery with the antennal, medial and lateral lobe regions (CARCAUD et al., 2018).

Before insects, there were other studies and research of various animal species as a biological biosensor to detect and locate various types of chemical substances helping to save lives in preventive-investigative work in the scope of public safety activity. According to the Associação Brasileira de Estudos das Abelhas, insects belonging to the order Hymenoptera and the superfamily of Apoidea (Apiforms group), are divided into approximately 20,000 species, with Apis mellifera (western bee) being the best known (BEES, 2021). “Bees occupy an important ecological role as pollinators of a variety of flowering plant species” (PATEL et al., 2021).

The bees Apis ssp. are insects with the function of transporting, pollinating using the sense of smell and their “dance” type of movement. (FRISCH, 1919), to locate food, identify sources of different odors at any time of year, flying long distances. There is also the transmission of learning and memory, with performance of their cognitive abilities. (AGUIAR et al., 2019). They learn to associate the scent and memorize the locations, discriminating between a flower and nectar, because when there is a need to return to the source, or find a similar flower, they know the way (HADAGALI; SUAN, 2017; MACDONALD; LOCKWOOD, 2019).

The use of bees as sniffers (biosensor) managed to conquer space and attract the attention of many scientists, carrying out several researches on their smell and other senses to contribute as a simple, sensitive, economical and easy to use alternative in certain activities (HADAGALI; SUAN), 2017). As biosensors, bees are not limited to locating only explosive and narcotic substances, they also collaborate in other types of applications, such as monitoring product smuggling and food quality control (HOO, 2012; HADAGALI; SUAN, 2017).

Given the context, this article aims to report information on research using bees as biological biosensors of explosive substances and narcotics at the national and international levels and their respective results to contribute to future research.

METHODOLOGY

This is a literature review with a descriptive and comparative procedure on projects using bees as biosensors in order to verify their effectiveness as detectors of explosive and narcotic substances in national and international productions. Platforms for storing articles available on the internet were used in which the keywords "bees", "biological biosensors", "bee training" were used: Scielo - Scientific Electronic Library Online, Lilacs - Centro Latino-Americano e do Caribbean Health Sciences Information, NIH-NCBI-Pubmed - National Center for Biotechnology Information - National Library of Medicine and Google Scholar.

Bibliographic materials from any year of publication were selected in Portuguese and English and that had in their content the subject addressed in this review.

LITERATURE REVIEW

To accelerate the removal of approximately 45-50 million landmines worldwide, there has been comparative research and bee performance in detecting antipersonnel mines in humanitarian demining operations (MACDONALD, LOCKWOOD, 2003). According to a research report, bees offer the potential to fly freely to large areas in the presence of explosives, unexploded ordnance (UXO) and land mines without any detonation. However, like all living beings, there are limitations, because the lack of knowledge due to some unobserved factors regarding the limitation of performance of bees in real landmine detection tests, also the different climatic conditions, environments and, for being an insect of diurnal habit, the use of bees is still limited (MACDONALD, LOCKWOOD, 2003).

LITERARY SYNTHESIS ON BIOLOGICAL BIOSENSORS

One of the important senses for animal survival is smell, which solves most of the hidden problems with odor detection and discrimination (ACHE; YOUNG, 2005). In the course of the need to improve resources and short-term results, there have been several biological biosensors to detect the chemical substances of explosives and narcotics. In a city in Tanzania at the APOPO Research Center, for years they have used rats to detect mines in places that for a long time were the scene of war (HERORAT ADOPTION PROGRAM, 2021).

Man's best friend, the dog, was the first mammal used as a biological biosensor. For many years, canines detect explosive and narcotic chemicals primarily in the area of public safety. Other mammals, arthropods and insects also participate as biological biosensors in research through their olfactory abilities (SCHOTT et al., 2015; HADAGALI; SUAN, 2017).

BEE ANATOMY AS A BIOSENSOR

The head of the *Apis mellifera* bee houses important organs, for example, the antennae, where the olfactory cavities are located, organs that have the important function of capturing odors. (BOMFIM et al., 2017). The antennae of bees are responsible for the sense of smell, due to this function they are commonly called "nose", consisting of a flagellum with 10 segments attached to the scapular and this to the pedicel (BOMFIM et al., 2017; HADAGALI; SUAN, 2017).

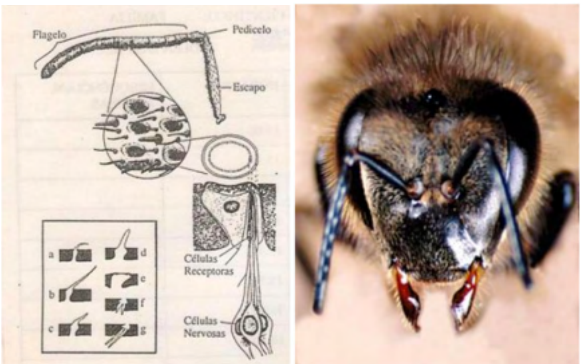

Figure 1. Anatomy of the organ responsible for the bee's sense of smell:*Apis mellifera.*

Source: Google Ebook

Bees have an olfactory capacity that is 10 to 100 times more sensitive than humans, and the main sense of smell is even that of vision, due to the hairs similar to hairs located on their antennae, responsible for capturing sounds, enabling the perception of movement of molecules in the air (HADAGALI; SUAN, 2017).

STUDIES OF BEES AS A BIOSENSOR

Apis mellifera bees are the best known species, being studied by many scientists, and it was in the early 1960s, with Frisch's research. It was proven that the olfactory system of bees can detect and discriminate various types of odors, according to research based on the method investigated by Von Frisch in 1919, to understand the behavior and movement of bees that used communication. (HADAGALI; SUAN, 2017). He performed some experiments in which he exposed various odors to naturally flying bees, being stimulated and rewarded with a solution of sugar (sucrose) (FRISCH, 1919; HADAGALI; SUAN, 2017; MACDONALD; LOCKWOOD, 2003).

The researcher Karl Von Frisch was the one who started the studies of the behavior of bees, where they used body language, as if they were performing some type of dance, where communication and signaling of the places where they flew and could return to collect food, nectar or other information for the survival of the comee. With this study he won the Nobel Prize in 1973, and demonstrated that bees could be trained and used for other means, such as identifying different odorants. (HADAGALI; SUAN, 2017). "The olfactory and learning ability was proven through the classical conditioning of bees, making it possible [...] as detectors of narcotic substances and explosive agents in police activity" (WOLFF; FILHO, 2013).

Bees are disciplined animals that have a hierarchical structure within the hive, dividing functions and each one of them has its olfactory capacity from 10 to 100 times more sensitive in relation to that of man, being the main sense of smell even than vision (BOMFIM et al. al, 2017; HADAGALI; SUAN, 2017).

TECHNIQUE USED WITH BEES AS A BIOSENSOR

Bees are animals well adaptable to training, whose technique was created in 1920 by Pavlov who used dogs to perform activities in associating a sound with a reward, a stimulus known as Pavlovian conditioning (SCHOTT et al., 2015; HADAGALI; SUAN, 2017). According to Hadagali and Suan (2017), with Apis mellifera bees, the stimulus to activate the olfactory and their processing, detection and learning capabilities can be studied and compared with regard to different reinforcement modalities. Comparing with Proboscis Extension Response (PER), which is also a conditioning method, but an aversion being tested in bees to verify their learning regarding their olfactory memory (SCHOTT et al., 2015; HADAGALI; SUAN, 2017).

Bees can be conditioned by offering sucrose to their proboscis (tongue) by associating the target odor substance, demonstrating a positive response to the stimulus (HOO, 2012; HADAGALI; SUAN, 2017). Several researchers started the practical application of bees as biosensors, which demonstrated the detection of TNT in different parts of explosive substances. "In early 2004, the Defense Advanced Research Projects Agency (DARPA) funded a project to use bees for explosive detection" (HOO, 2012). A series of experiments were carried out from 2001 to 2002, with positive results, with bees having the olfactory ability to detect different levels of explosive vapors or any other chemical substances (REPASKY et al., 2006).

In 2008, in the United Kingdom, bees were used as biosensors to screen bulk cargo, training them with explosive odors and placing them in a portable detector, the Vasor136. (HOO, 2012).

Figure 2 – Vase: 136.

Source: Inscentinel, Rothamsted Research.

FINAL CONSIDERATIONS

Bees have been used since ancient wars as weapons of dispersion and currently there are numerous researches for use in the areas of maintaining public order and saving lives in demining projects where several resources were used and the cost was the lives of many collaborators. In addition to being a low-cost project, similar to other technological innovations, it also has its downfall as in the progression of its training, where the training of bees is effective in hours, while other animals of different taxonomy would take at least months to train. detection and various stages to progress.

For a good detection operation to occur, it is necessary to combine a deeper study of knowledge in different situations and use technology to provide operational ease regarding the precision and sensitivity of bees as a biosensor.

REFERENCES

ABELHAS. Associação Brasileira de Estudos das Abelhas. **Espécies de abelhas.** Disponível em: https://abelha.org.br/especies/. Acesso em: 05 de abril de 2021.

ACHE, B.; YOUNG, J. Olfaction: Diverse Species, Conserved Principles. **Neuron**, v. 48, p. 417–430, 2005.

AGUIAR, J.; TELLES, F.; BERGAMO, P.*et al*. Como treinar sua abelha: métodos aplicados à biologia cognitiva da polinização. **Oecologia Australis**. v. 24, p. 45-60, 2020.

HERORAT ADOPTION PROGRAM. 2021. Disponível em: <https://www.apopo.org/en/herorats/training-and-research>. Acesso em: 12 ago. 2021.

BOMFIM, I.; OLIVERIA, O.; FREITAS, B. **Biologia das abelhas**. Agosto, 2017. Disponível em: <https://www.researchgate.net/publication/320907688_Biologia_das_abelhas>. Acesso em: 29 ago. 2021.

CARCAUD, J.; GIURFA, M.; SANDOZ, JC. Differential Processingby Two Olfactory Sub systems in the Honey bee Brain. Neuroscience. 374, p. 33-48, 2018.

HADAGALI, M.; SUAN, C. Advancement of sensitive sniffer bee technology. **TrAC Trends in Analytical Chemistry**, v. 97, p. 153–158, 2017.

HOO, Ivan. **Using sniffer bees for bulk screening of cargo**. **Port Technology International**. Reino Unido. ed. 54, p. 146-147, maio. 2012. Disponível em: https://www.porttechnology.org/technical-papers/using_sniffer_bees_for_bulk_screening_of_cargo/. Acesso em: 18 maio. 2021.

FRISCH, K. V. Über den Geruchsinn der Biene undseineblüten biologische Bedeutung, **Zool. Jahrb**. v. 37, p.1-238, 1919.

PATEL, V. PAULI, N. BIGGS, E. BARBOUR, L. BORUFF, B. Why bees are critical for achieving sustainable development. **Ambio**. v. 50, p. 49–59, 2021.

MACDONALD, J.; LOCKWOOD, J. Alternatives for Landmine Detection. Santa Monica, CA: **RAND Corporation**, 2003. Disponível em: https://www.rand.org/pubs/monograph_reports/MR1608.html. Acesso em 21 abril 2021.

RAINS, G.C.; TOMBERLIN, J.K.; KULASIRI, D. Using insect sniffing devices for detection. **Trends Biotechnol**. v. 26, p. 288-94, 2008.

REECE, J. B.; URRY, L. A.; CAIN, *et a*l. **Biologia de Campbell.**10. ed. – Porto Alegre: Artmed, 2015;

REPASKY, K.; SHAW J.; SCHEPPELE R.; *et al.* Optical detection of honey bees by use ofwing-beat modulation of scattered laser light for locating explosives and land mines. Appl Opt. 2006 Mar 10; v. 45. p. 1839-43.

SCHOTT, M.; KLEIN, B.; VILCINSKAS, A. Detection of Illicit Drugsby Trained Honey bees (*Apismellifera*). **PLoS ONE** HERORAT ADOPTION PROGRAM. v. 10, p. 1-12, 2015.

WOLFF, J.; FILHO, R. **O emprego de abelhas na detecção de substâncias entorpecentes e agentes explosivos.** 2013. 19 pag. Trabalho de Conclusão de Curso Ciências Militares. Universidade do Estado do Amazonas – IESP. 2013.