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Presence of pesticides in edible insects: Risk to human health. The case of Mexico

Hernández-León, Karla P.[1]**; Aguilar-Toalá, José E.**[2]**; Díaz-Ramírez, Mayra**[2]**, Cruz-Monterrosa, Rosy G.**[2*]

[1] Universidad Autónoma Metropolitana, Unidad Lerma Licenciatura en Ciencia y Tecnología de Alimentos. División de Ciencias Biológicas y de la Salud.
[2] Universidad Autónoma Metropolitana, Unidad Lerma Departamento de Ciencias de la Alimentación. División de Ciencias Biológicas y de la Salud.
* Correspondence: r.cruz@correo.ler.uam.mx

ABSTRACT

Objective: To perform a literature review of the presence of pesticides in edible insects, main pesticides used in Mexico and to discuss the potential risk of contaminated edible insects for human consumption.

Design/methodology/approach: Concise analysis of the main research topics related with the impact of pesticides on insects, through a wide review of specialized journals on insects' field.

Results: The majority of edible insects are considered as a common plague in some crop varieties, causing a decrease in their production yield. As a result, farmers use mainly chemical insecticides to control this plague. Besides, farmers use also chemical herbicides and fungicides to control weeds and fungi. However, those pesticides have a negative impact on edible insects because they can be contaminated. These contaminated edible insects can be collected from different crop varieties for their use as food.

Limitations on study/implications: To conduct further research to identify and determine the pesticide levels in edible insects consumed in Mexico.

Findings/conclusions: Edible insects may represent a potential risk to human health, especially when insects are wild harvested because can be contaminated with pesticides, particularly insecticides, herbicides, and fungicides.

Keywords: Edible insects, pesticides, hazardous, health risk.

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INTRODUCTION

Mexico is one of the countries with the highest reported number and variety of edible insects (Baiano, 2020). The majority of edible insects are considered as a common plague in diverse crops because ravaging leaves, flowers, and fruits, and even can destroy a whole plant when they come in massive numbers (Gross, 2021; McLaughlin & Dearden, 2019). However, it is also recognized that some insect species have important roles in the agro-ecosystem such as pollination service, nutrient cycling, soil formation, decomposition, and water purification (van der Sluijs, 2020). In Mexico, it has been reported that insects can affect to staple food crops such as maize (*Zea mays* L.), alfalfa (*Medicago sativa* L.), coffee (*Coffea arabica* L.), wheat (*Triticum aestivum* L.), tomato (*Lycopersicon esculentum* Mill.), potato (*Solanum tuberosum* L.), and bean (*Phaseolus vulgaris* L.), to name a few (Zelaya-Molina *et al.*, 2022). In addition, other problems such as weeds and fungi damage crops (Anamika Sharma, Jha, & Reddy, 2018) harming agricultural activity, which lowers crop yield that impact the economy of farmers.

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Thus, pesticides are widely used in agriculture for helping in the control of those pests, and increases food production (McLaughlin & Dearden, 2019; Ndakidemi, Mtei, & Ndakidemi, 2016). It is known that pesticides impact non-target species, which is why not only insecticides have a direct impact on insects but also herbicides and fungicides might have a direct or indirect effect on them (Sánchez-Bayo, 2021). The effect of pesticides on edible insects includes the affectation on their survival of a range of different life cycle stages, reductions in their reproductive capacity, and cause direct mortality (Ndakidemi *et al.*, 2016). Besides, it has been reported that some insects are resistant/development resistant or are not affected by some pesticides because they are not the target; therefore, they survive and result in contaminated insects because carry pesticide residues (Calvo-Agudo, Tooker, Dicke, & Tena, 2022). Also, edible insects can be contaminated because fed on plants that accumulate pesticides (Houbraken *et al.*, 2016). Thus, the consumption of contaminated edible insects collected from crops can represent a potential risk to human health. Various types of health problems have been associated with the exposition to pesticide residues present in some food stuffs, including cancer, diabetes mellitus, respiratory disorders, neurological disorders, reproductive syndromes, and oxidative stress (Rani *et al.*, 2021). The exposure to pesticides through the consumption of contaminated edible insects can be considered accidental or non-occupational, generally low-level and long-term exposure, even though it is difficult to directly relate the exposure to pesticides and their hazardous effects (Sabarwal, Kumar, & Singh, 2018). Thus, the severity of those health problems is related to the pesticide bioaccumulation in human tissues, damage occasioned, detoxifying system activity, as well as antioxidant and immune responses of the consumers (Lushchak, Matviishyn, Husak, Storey, & Storey, 2018; Sabarwal *et al.*, 2018).

The above is relevant because in Mexico the insect consumption dates from pre-Hispanic times being an important component of current culture, gastronomy, and staple diet (Baiano, 2020; Imathiu, 2020). Accordingly, the consumption of edible insects in Mexico could represent a risk to human health due to the presence of pesticides. To the best of our knowledge, there are only a few reports summarizing findings on the presence of pesticides in edible insects. Hence, this review contributes with new and novel information regarding the presence of insecticides, herbicides, and fungicides in edible insects, the potential risk to human health of the consumption of contaminated insects, and the situation of Mexico related to the contamination of edible insects by pesticides.

Presence of pesticides in edible insects

Few studies have identified the pesticides in edible insects consumed in different regions of the world. The majority of the studies were screening-type and do not determine the pesticide levels. In a recent study, De Paepe *et al.* (2019) identified the herbicide isoproturon (<1 μg kg^{-1}) in grasshopper (*Locusta migratoria*), whereas house cricket (*Acheta domesticus*), yellow mealworm (*Tenebrio molitor*), and black soldier fly (*Hermetia illucens*) do not showed residues of this herbicide. Likewise, Poma *et al.* (2017) found that some edible insects and insect-based foods commercialized in Belgium showed presence of some insecticides (*e.g.*, affinine class, empenthrine, methoprene, pirimiphos-methyl), herbicides (*e.g.*, class of chlorbufam, difenzoquate, class morfamquate, tributylphosphate), and fungicides (*e.g.*, azoxystrobine, cycloheximide, tributylphosphate). However, the main limitation of this study was the screening method used with a qualitative approach. Thus, farmed insects could potentially accumulate chemicals from their substrate. Similarly, Brühl *et al.* (2021) investigated the direct pesticide exposure of flying insects in different areas in Germany. While the authors do not identify taxonomically the wild insect species that were collected, they detected 47 pesticide residues and insect samples were on average contaminated with ca. 17 pesticides. Residues of the herbicides metolachlor-S, prosulfocarb, and terbuthylazine, and the fungicides azoxystrobin and fuopyram were recorded in all insect samples. Besides, the insecticide thiacloprid was identified in most samples.

Likewise, it has been reported that edible Locust, short-horned grasshoppers in the family Acrididae, captured in Kuwait showed pesticides residues such as sumithion (740.6 μg kg^{-1}) and malathion (49.2 μg kg^{-1}), which are organophosphorus type, as well as chlorinated type such as benzene hexachloride (3 μg kg^{-1}), lindane (2.2 μg kg^{-1}), and aldrin (6.2 μg kg^{-1}). Likewise, Calatayud-Vernich, Calatayud, Simó, and Picó (2018) reported that honey bees (*Apis mellifera*) and their bee-derived products (*e.g.*, fresh stored pollen and beeswax) showed the presence of some pesticides including miticides (*e.g.*, coumaphos, fluvalinate, 2,4-dimethylphenylformamide) and insecticides (*e.g.*, chlorpyrifos, chlorfenvinphos). Also, in few samples of pollen and bees showed the presence of prohibited pesticides in the European Union such as dichlofenthion, carbendazim, and fenitrothion. On the other hand, also has been demonstrated that insects used as animal feed showed pesticides residues. Charlton *et al.* (2015) reported residues of the insecticide chlorpyrifos (800 μg kg^{-1}) in house fly (*Musca domestica*) and piperonyl butoxide (200 μg kg^{-1}) in blue bottle (*Calliphora vomitoria*).

While some authors mentioned that the chemical safety of insects in relation to pesticide contamination can be considered high (De Paepe *et al.*, 2019). The toxicological significance of the presence of pesticides in diverse edible insect should not be overlooked. For example, excessive residues of pesticides type organophosphates were found in grasshoppers/locusts in Kuwait and Arabia representing a human risk to consumers (Saeed, Dagga, & Saraf, 1993; van der Spiegel, Noordam, & van der Fels-Klerx, 2013).

The case of Mexico

To the best of our knowledge, there are no reports about the presence of pesticides in edible insects consumed in Mexico. However, in Mexico the application of pesticides is excessive, even are applied some products that are prohibited or not allowed in other countries. For example, according to the Food and Agriculture Organization of the United Nations (FAO), during 2013-2017 the average use of pesticides was estimates in 2 kg/ha (Calderon *et al.*, 2022), peaking in 2014 at 3.85 kg ha^{-1} (López-Gálvez, Wagoner, Beamer, de Zapien, & Rosales, 2018). Besides, although Mexico participates in different international agreements dealing with pesticides, continues to be using pesticides prohibited in other countries such as paraquat, endosulfan, lindane, methyl bromide, parathion, and malathion (Anket Sharma *et al.*, 2019).

In Mexico, the Secretariat of Agriculture and Rural Development (SADER, for its acronym in Spanish) regulates and establishes the maximum residue limit (MRL) for pesticides in foods through the Official Mexican Standard NOM-082-SAG-FITO/SSA1-2017. Additionally, the Federal Commission for Protection against Health Risks (COFEPRIS, for its acronym in Spanish) and the Secretariat of Environment and Natural Resources (SEMARNAT, for its acronym in Spanish) regulate the use of pesticides in Mexico. However, for edible insects and insect-derived products there are no regulations and no specific limits on their pesticide residue content, because edible insects are not considered as food in Mexican legislation (van der Spiegel *et al.*, 2013). Besides, among Latin American countries, Mexico has been placed among the countries with the highest rates of diseases related to pesticide exposure among farmworkers (Payán-Rentería *et al.*, 2012).

On the other hand, Table 1 described the most used pesticides in Mexico, which have been classified as dangerous at different levels (Bejarano González, 2017).

According to their degree of toxicity, pesticides with toxicity categories I and II are classified as extremely and highly hazardous, respectively, which can cause death in the case of ingestion, either if they are inhaled or if they come into contact with skin (Bejarano González, 2017; Githinji, Mwaura, & Wamalwa, 2019). On the other hand, the categories III and IV are considered as moderately and slightly hazardous, which are considered toxics in the case of ingestion (Bejarano González, 2017; Githinji *et al.*, 2019). Thus, it is very likely that edible insect wild harvested from crops in Mexico to be contaminated with the pesticides described in Table 1. Consequently, the consumption of edible insects could represent a risk to human health. However, to the best of our knowledge, there are no studies addressing the impact of pesticides on edible insects consumed in Mexico. Nevertheless, the scientific evidence about the presence of pesticides in edible insects consumed in other countries around the world, supporting the fact that the consumption of edible insects in Mexico may have a negative impact on consumers.

Table 1. Most commonly used pesticides in Mexico.

Active ingredient	Type	Classification	Toxicity category
Parathion	Insecticide	Organophosphates	II
Chlorpyrifos	Insecticide	Organophosphates	III
Cypermethrin	Insecticide	Pyrethroid	III
Malathion	Insecticide	Organophosphates	IV
Permethrin	Insecticide	Pyrethroid	IV
Mancozeb	Fungicide	Carbamate	IV
Chlorothalonil	Fungicide	Chloronitriles	IV
Glyphosate	Herbicide	Phosphonomethyl-glycine	IV
Atrazine	Herbicide	Triazine	IV
Deltamethrin	Insecticide	Pyrethroid	III

Bejarano González (2017). The list was ordered from more to less used.

CONCLUSIONS

Edible insects may represent a potential risk to human health, especially when insects are wild harvested because can be contaminated with pesticides, particularly insecticides, herbicides, and fungicides. It is too necessary to estimate the dietary risk of pesticides through the consumption of contaminated edible insects, mainly in regions of Mexico where the consumption of edible insects is greatest. Therefore, it is evident the need to pursue more studies aimed to reveal pesticide levels in edible insects consumed in different regions of Mexico, as well as to determine the possible health effects on the consumers due to exposure to pesticides through edible insects' consumption.

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