

Analysis of pesticide residues: organophosphates and pyre-throids in *Solanum lycopersicum* and *Solanum tuberosum*, and their potential impact on Public Health

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Abstract

*In this study, the presence of pesticide residues in foods, specifically in tomatoes and potatoes, was investigated after harvesting in the Paute Canton-Ecuador. An information survey was carried out to determine the most relevant crops and pesticides in the study area. A qualitative analysis of organophosphates and pyrethroids was carried out in samples of *Solanum lycopersicum* and *Solanum tuberosum* using the thin layer chromatography technique. It was found that 80.00% of the tomato samples presented residues of organophosphate compounds and 30.00% pyrethroid residues, while 66.7% of the potato samples tested positive for pyrethroids and 50.00% for organophosphates. These results indicate that there is a public health risk for people who consume foods with pesticide residues, even after washing and peeling tomatoes and potatoes, since the complete removal of these chemicals from foods cannot be guaranteed. This study highlights the importance of taking measures to minimize exposure to pesticides in food production and promote safer eating.*

Keywords: *Organophosphates, Pyrethroids, *Solanum lycopersicum*, *Solanum tuberosum*, Health.*

Introduction

The Paute canton, located in the province of Azuay, Ecuador, stands out for its agricultural potential due to the presence of favorable microclimates. The most important agricultural crops in this area are corn associated with beans, potatoes, and kidney tomatoes [1]. Since agriculture is one of the main economic activities in this canton [1], farmers need to use pesticides to control pests and diseases that affect crops, which are occurring with increasing incidence due to climate change. [2].

Pesticides have numerous practical applications, but their consumption is especially high in the agricultural environment, where they are mainly used as herbicides, insecticides, and fungicides [3]. These substances help protect plants and their products from harmful organisms, but they can also have undesirable consequences due to their residual presence in food. This can generate health risks, both through direct consumption of vegetables and indirectly through animals intended for human consumption [4].

Given that there is a lack of studies on the use and management of pesticides in the Paute canton, it is necessary to carry out research to inform the community about these issues of social importance. To determine the most used pesticides and the most relevant crops in the study area, surveys were carried out with farmers in the canton. Based on this information, it was determined that the most important crops are the kidney tomato (*Solanum lycopersicum*) and the potato (*Solanum tuberosum*), while there is an incidence in the use of pesticides, with organophosphates and pyrethroids being some of the most used.

Organophosphate compounds can enter the body through inhalation, ingestion and absorption through the skin due to their high lipid solubility, which facilitates their passage through biological barriers, and their volatility, which facilitates their inhalation. Once absorbed and distributed in the body, these compounds are metabolized by liver enzymes, which causes a series of chemical transformations. The liver is the main organ affected by exposure to organophosphates [5].

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Regarding pyrethroid compounds, their mechanism of action is found in the nervous system, where an alteration occurs in the transmission of the nervous impulse. This alteration is due to changes in the structure and function of voltage-gated sodium channels of the nerve membrane, leading to a state of hyperarousal of the nervous system [6]. These compounds affect the nervous system, altering the balance of sodium and potassium ions in the axons of nerve cells. Initially, they stimulate nerve cells, generating repetitive discharges, followed by paralysis and death [7].

Thin layer chromatography, also known as TLC, is an analytical technique used to isolate mixtures with organic molecules, compare samples according to their chemical structure, lipid solubility and water solubility, and determine the degree of purity of a compound. This technique uses a stationary phase of silica gel (SiO₂), alumina (Al₂O₃), magnesium silicate or cellulose, bonded to a plastic layer or support with an approximate thickness of 0.1 mm. This phase interacts with the samples (solutes) through hydrogen bonds and other intermolecular interactions. In addition, a mobile phase is used, which consists of a solvent that drags the compounds from the mixture. Commonly used solvents are hexane, tetrachloromethane, chloroform, dichloromethane, ethyl acetate and acetone [8]. This technique was used because it is a quick and effective method that allows us to perform qualitative analyzes and toxicological determinations.

Materials and Methods

Information gathering

This step allowed us to collect relevant and reliable data that were subsequently analyzed and used to obtain meaningful conclusions.

Regarding the collection of information, surveys were carried out with farmers in the region. These surveys gave us an overview of the most used pesticides in local agriculture. Through this method, it was determined that Organophosphates and Pyrethroids are the pesticides most used by farmers in the study area.

In addition, a selection process was carried out for the crops that would be evaluated in this study. To do this, the economic impact and importance of each of them within the canton was considered. Taking these criteria into consideration, it was decided to evaluate the cultivation of Kidney Tomatoes, since it is one of the largest sources of economic income in the region.

On the other hand, the choice of potato cultivation was based on its prevalence in all the parishes participating in the information collection. Potato is one of the most common crops in the study area, which allowed us to obtain a broader and more representative perspective of the effects of pesticides on local agriculture.

In summary, the Data Collection methodology used in this study provided a solid foundation for the collection of reliable data. The analysis of the surveys carried out made it possible to identify the pesticides most used by farmers, while the selection of the crops evaluated guaranteed the representativeness of the results obtained. This rigorous and well-founded methodology ensures the quality and reliability of the results, which will contribute to the impact and relevance of the article in the scientific community.

Collection, transportation, and processing of samples.

A total of 60 samples were collected in the February 26 market in the Paute canton; of which 30 of potato (*Solanum tuberosum*) and 30 of kidney tomato (*Solanum lycopersicum*) were distributed for three consecutive weeks [9].

During sampling, 227 grams of each product were taken, which were packaged in polyethylene bags and subsequently labeled and transported to the Life Sciences laboratory of the Salesiana Polytechnic University, Cuenca Campus.

Once in the laboratory, the potato and kidney tomato samples were weighed individually, and their net weight was obtained. The samples were then washed with distilled water to remove any surface contaminants. Subsequently, the potato samples were peeled and cut into small pieces of approximately 1 cm in size. In the case of the kidney tomato, the peduncle was removed and cut into slices approximately 0.5 cm thick.

Extraction of Bioactive Compounds

For the extraction of the bioactive compounds present in the potato and kidney tomato samples, the solvent extraction technique was used. 20 ml of solvent (ethanol-water mixture) was added to each sample and homogenized for 5 minutes in a homogenizer. Then, it was centrifuged at 3000 rpm for 10 minutes and the supernatant was collected for further analysis. [13,14]

Analytical Techniques Used

The bioactive compounds present in the samples were analyzed using spectrophotometric and chromatographic techniques.

For the analysis of carotenoids, a UV-Vis spectrophotometer was used, taking readings at different wavelengths to determine the concentration of each carotenoid present in the samples. [11,12]

On the other hand, phenols and antioxidant compounds were analyzed using high-performance liquid chromatography (HPLC), using a reverse phase column and a UV detector. A previously established calibration curve was used to quantify the concentration of each compound.[12]

Analysis of Data.

The results obtained from the analytical techniques were analyzed statistically using specialized software. Student's t-tests and analysis of variance were performed to determine if there were significant differences between the potato and kidney tomato samples in terms of their content of bioactive compounds. In addition, the results obtained were correlated with other quality parameters such as the moisture content and acidity of the samples.

Methodology Validation

The validity of the methodology used was verified by repeating all the steps described above in three different replications. The precision and accuracy of the results obtained were evaluated, as well as the reproducibility of the methodology in different experimental conditions.

Results

The results obtained were interpreted based on the objectives set out in the study and compared with other previous studies carried out in the same research area. The importance of the bioactive compounds analyzed was discussed in relation to their possible benefits for human health and possible practical applications of the results obtained were proposed.

In summary, the collection and transportation of the samples was carried out, followed by their preparation and description. Bioactive compounds were extracted using solvent extraction techniques and analyzed by spectrophotometric and chromatographic techniques. The data obtained was statistically analyzed and the methodology used was validated. The results were interpreted according to the objectives of the study and their importance in relation to human health was discussed.

Gathering Information.

This section reflects the results obtained from the products grown in 5 different parishes, to determine which are the main crops in each area, and therefore determine which are the main pesticides used by farmers. With this data, you can carry out the laboratory analysis, and know whether there are actually residues in the food after it has been harvested and displayed for sale in the market for consumption by people in the community.

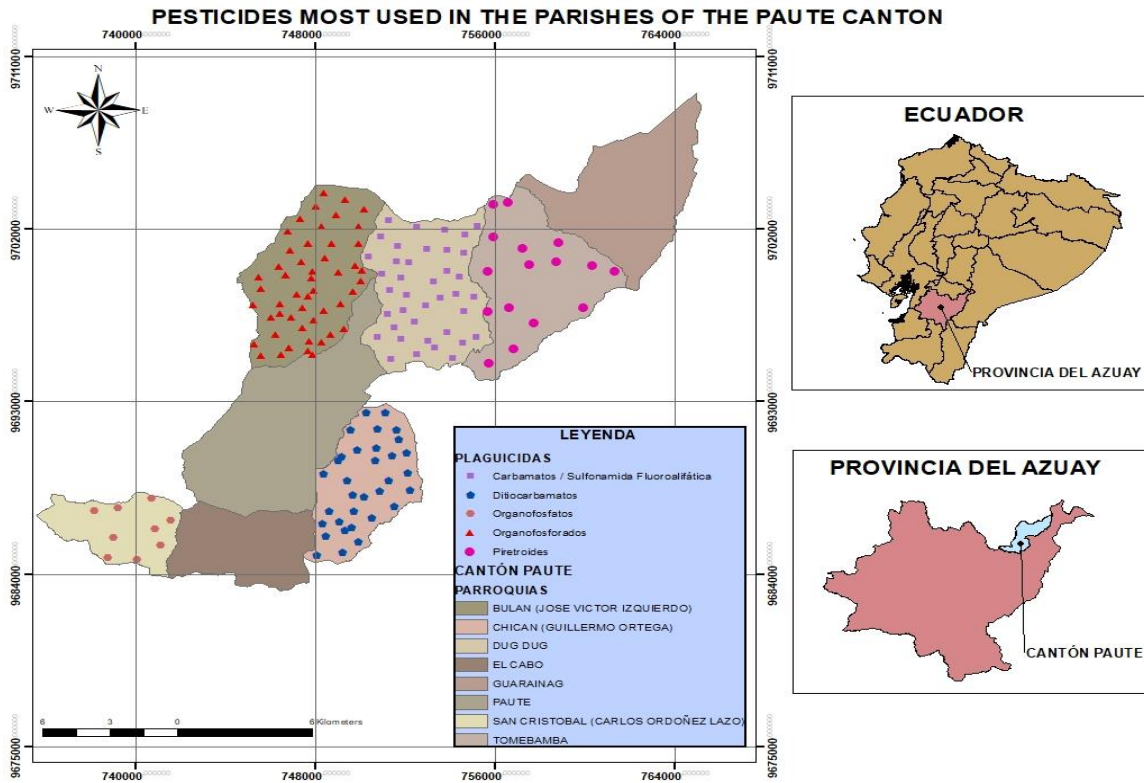


Figure 1. Pesticides identified as the most used in the 5 parishes of the Canton of Paute-Ecuador.

Table 1. This is a table. Tables should be placed in the main text near to the first time they are cited.

	Bulán	Dug Dug	Chicán	Tomebamba	San Cristobal
Food production					
	%	%	%	%	%
Potatoes	45,83	100	50	100	38,5
Carrot	45,83	0	22,22	0	37,5
Radish	4,17	0	16,67	0	12,5
Kidney tomato	78,79		80	9,09	100
Cabbage	6,06		0	15,91	0
Lettuce	3,03		20	20,45	0
Celery	3,03		0	15,91	0
Cauliflower	3,03		0	15,91	0
Broccoli	3,03		0	11,36	0
Parsley	3,03		0	6,82	0

Courgette	0		0	4,55	0
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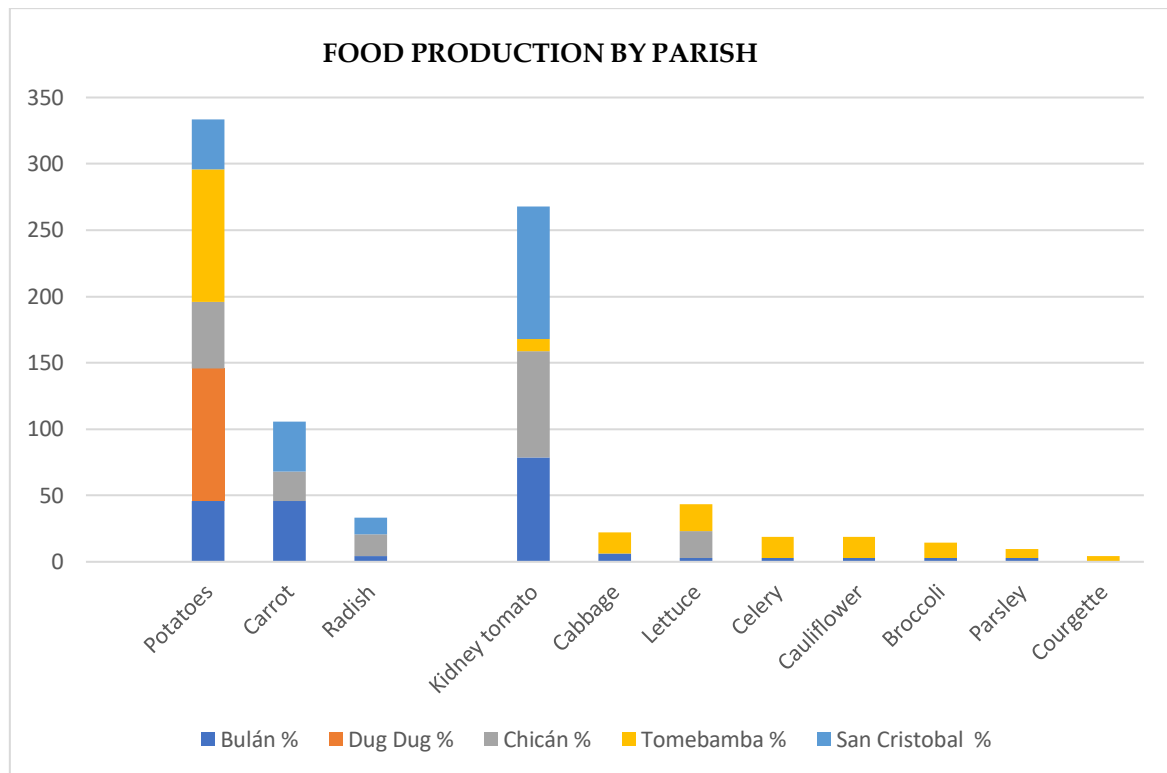


Figure 2. Main Food Crops by Parish of the Canton of Paute-Ecuador.

- Results of the Presence of Pesticides in Food Using Thin Layer Chromatography.
- Firstly, the predominant foods in the crops of Canton Paute were selected, which were potatoes and kidney tomatoes. In addition, information was collected on the types of pesticides used in these crops, finding organophosphates and pyrethroids as a result.
- Next, the necessary information was collected for subsequent laboratory analysis. The objective of this analysis was to determine the presence of pesticides in both kidney tomato and potato.
- It is important to note that, in the case of the potato samples, they were washed and peeled. In the case of the kidney tomato, the established protocol was followed, and washing was carried out.
- These steps were essential to obtain accurate results regarding the presence of pesticides in the mentioned foods, as seen in Table 3 and 4.

Table 2. Results of the presence of pesticides in Kidney Tomato using thin layer chromatography.

No. Samples	Week 1		Week 2		Week 3	
	Organophosphates	Pyrethroids	Organophosphates	Piretroides	Organophosphates	Pyrethroids
T1	+	-	-	-	+	-
T2	+	+	-	-	+	-
T3	+	+	+	-	+	+
T4	+	+	-	-	+	-
T5	+	-	-	-	+	+
T6	+	-	-	-	+	-
T7	+	-	+	-	+	+
T8	+	-	+	+	+	-
T9	+	-	-	-	+	+
T10	+	-	+	-	+	+
frequency	10	3	4	1	10	5
%	100	30	40	10	100	50

Table 3. Results of the presence of pesticides in Potato using thin layer chromatography.

No. Samples	Week 1		Week 2		Week 3	
	Organophosphates	Pyrethroids	Organophosphates	Piretroides	Organophosphates	Pyrethroids
T1	-	-	+	+	-	-
T2	+	+	+	+	-	+
T3	+	+	-	-	-	-
T4	-	+	+	+	+	+
T5	-	+	+	+	+	+
T6	+	+	+	+	-	-
T7	-	-	-	-	+	+
T8	+	+	-	+	-	+
T9	-	+	+	+	-	-
T10	+	+	-	-	+	-
Frequency	5	8	6	7	40	5
%	50	80	60	70	40	50

- 1.
- 2.
- 3.

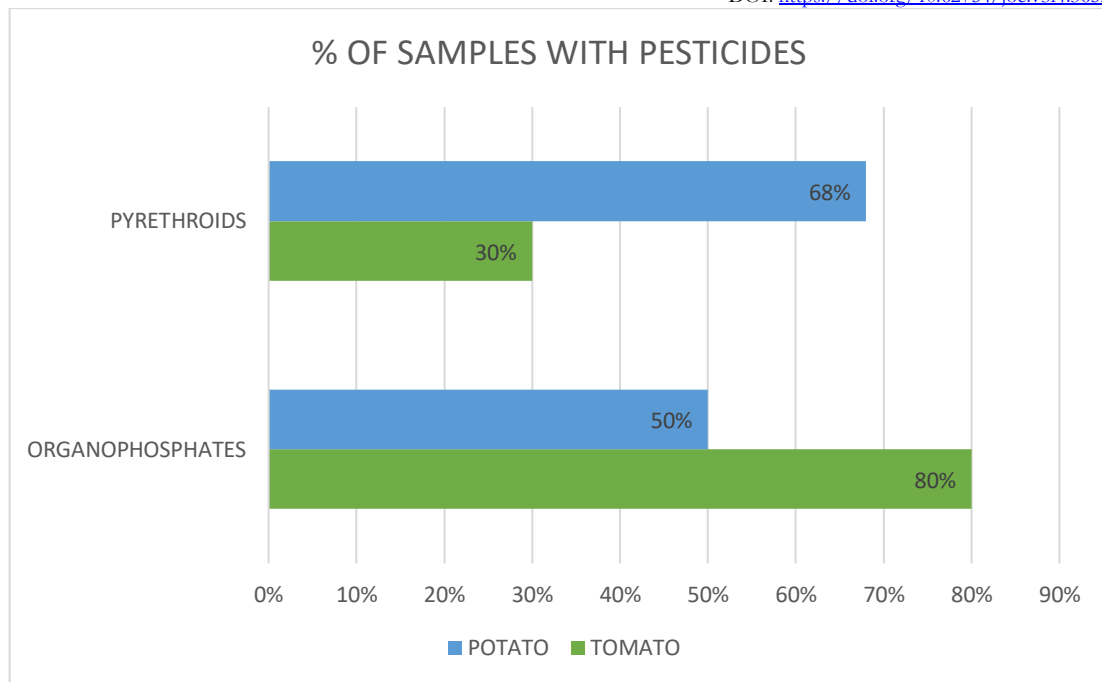


Figure 2. Main Food Crops by Parish of the Canton of Paute-Ecuador.

Discussion

In the present study, an investigation was carried out to determine the presence of pesticides in foods, specifically in kidney tomatoes and potatoes, which are the main foods of economic importance in the Paute canton, Ecuador. The technique used was thin layer chromatography, which is a method that allows us to perform a qualitative, rapid, and effective analysis for toxicological determinations.

Obtaining information on the use and management of pesticides in farmers was essential to select the chemical compounds to analyze in food. According to the chemical classification, there are different types of pesticides, so it is necessary to direct the chromatographic analysis towards the type of compound to be determined. The result obtained through thin layer chromatography is qualitative, which indicates the presence or absence of the pesticide that is sought to be identified.

Surveys were carried out to determine the types of crops produced in the study area, which allowed the kidney tomato and potato to be selected as the main foods of economic importance. These foods are present in most of the parishes of Paute, which facilitated the selection of the pesticides to be analyzed in them.

The results obtained in the chromatographic analysis revealed the presence of pesticides in the kidney tomato and potato samples. In the case of organophosphates, all kidney tomato samples were positive in the first and last week of sampling, while the percentage of positive samples in the second week was 40%. In the case of pyrethroid compounds, the percentage of positive samples varied between the three weeks.

Regarding the potato samples, the results indicated that both organophosphates and pyrethroid compounds were present in the analyzed samples. The percentages of positive samples varied each week, but in general significant percentages of positive samples were found in all sampling weeks.

These results are relevant, since they show the presence of pesticides in foods consumed daily in the homes of the population. This can generate serious health problems for consumers, so it is necessary to constantly analyze the presence of pesticides in food and disseminate these results in the community.

It is important to highlight that there are no studies carried out in the Paute canton on the presence of pesticides in food, so this study provides relevant information for the region. In addition, it seeks to train farmers in the proper management of pesticides as a disease prevention measure for both farmers and consumers.

Conclusions

In conclusion, this study demonstrated the presence of pesticides in kidney tomato and potato in the Paute canton, Ecuador. These results highlight the importance of conducting research in this area and socializing the data obtained to the community to promote safer agricultural practices and protect the health of consumers.

In this sense, it is important to note that the results obtained in this study refer only to the presence of pesticide residues in the foods analyzed. A quantitative analysis has not been performed to determine the exact concentration of these compounds in the samples. Therefore, it is not possible to determine whether the levels of residues found represent a risk to the health of consumers.

However, considering the known negative effects of pesticides on human health, it is essential to continue food quality control studies and promote training of farmers on the safe handling of pesticides. This includes following the indications and safety periods established for each type of pesticide, to minimize the presence of residues in food and protect the health of consumers.

In conclusion, this study has demonstrated the presence of pesticide residues in the foods analyzed in the Paute canton. These results highlight the importance of continuing research on the presence of pesticides in food, as well as implementing quality control and training strategies for farmers. Constant surveillance and dissemination of the results of these studies are essential to guarantee food security and protect the health of the population.

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Data Availability Statement: The present manuscript entitled " Analysis of pesticide residues: organophosphates and pyrethroids in *Solanum lycopersicum* and *Solanum tuberosum*, and their potential impact on Public Health" indicates the availability of data and materials for consultation and review. This study, directed to the journal "Research in environmental sciences and pollution", focuses on the contribution of the researcher to the environmental and health field. The data collected and analysed in this study provide important information on the presence and concentration of heavy metals in the water of rivers affected by mining activities. In addition, details are provided on the techniques and methodologies used in sampling and analysing the samples. This manuscript contributes to scientific knowledge in the identification of risks associated with exposure to heavy metals in water consumed by the population, offering solid evidence for decision making and the implementation of preventive and corrective measures that protect both the environment and public health.

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Conflicts of Interest: "The authors have no relevant financial or non-financial interests to disclose.

References

- GAD Municipal de Paute. (2015). Actualización Del Plan De Desarrollo Y Ordenamiento Territorial Del Cantón Paute. GAD Municipal de Paute, II.
- Quiroga, I. A. (n.d.). Impactos Del Cambio Climático En La Incidencia De Plagas Y Enfermedades De Los Cultivos. Retrieved February 8, 2022, from <https://www.croplifela.org/es/actualidad/articulos/impactos-del-cambio-climatico-en-la-incidencia-de-plagas-y-enfermedades-de-los-cultivos>
- Guitart, R. (n.d.). Residuos De Plaguicidas En Alimentos. Retrieved February 8, 2022, from https://www.adiveter.com/ftp_public/articulo1534.pdf
- Carretero, M. del M. (2009). Control De Residuos De Plaguicidas En Alimentos De La Comunidad De Madrid. <https://www.comunidad.madrid/servicios/salud/plaguicidas-alimentos-vegetales-debemos-preocuparnos#limites-maximos-residuos>
- Fernández, D., Mancipe, L., & Fernández, D. (2010). Intoxicación Por Orgafofosforados. <http://www.scielo.org.co/pdf/med/v18n1/v18n1a09.pdf>
- Castillo, G. I., & Barba, K. R. (2017). Nivel De Exposición A Piretroides Y Prevalencia De Síntomas En Trabajadores De Viveros Del Departamento De Estelí. <http://riul.unanleon.edu.ni:8080/jspui/bitstream/123456789/6931/1/240566.pdf>
- López, D. V. (2012). Determinación De Residuos De Plaguicidas En Tomate Riñón (*Lycopersicon esculentum*) Por Cromatografía De Gases Con Detector De Espectrometría De Masas (Gc-Msd). 19.
- Ruiz, M. L. (2020). Guía De Laboratorio Cromatografía En Capa Fina Y En Columna. Universidad Simón Bolívar, 3. <https://bonga.unisimon.edu.co/bitstream/handle/20.500.12442/7984/Gu%C3%ADa%20de%20Cromatograf%C3%ADa%20en%20capa%20fina%20y%20por%20columna.pdf?sequence=1&isAllowed=y>
- Milla, O. M., & Palomino, W. R. (2002). Niveles De Colinesterasa Sérica En Agricultores De La Localidad De Carapongo (Perú) Y Determinación De Residuos De Plaguicidas Inhibidores De La Acetilcolinesterasa En Frutas Y Hortalizas Cultivadas. https://cybertesis.unmsm.edu.pe/bitstream/handle/20.500.12672/1100/Palomino_hw.pdf?sequence=1&isAllowed=y
- Syngenta Crop Protection S.A. (n.d.-a). Curacron. Retrieved January 20, 2022, from https://www.syngenta.com.ec/sites/g/files/zhg486/f/ec_ficha_tecnica_curacron_mar_17.pdf?token=1535984678
- Syngenta Crop Protection S.A. (n.d.-b). Engeo. Retrieved January 20, 2022, from https://www.syngenta.com.ec/sites/g/files/zhg486/f/ec_ficha_tecnica_engeo_mar_17.pdf?token=1535984898
- Alcívar, E. H., & Coba, W. X. (2013). Determinación De Compuestos Piretroides En Muestras De Aspirado Gástrico Por El Método De Cromatografía En Capa Fina Que Ingresan Al Laboratorio De Química Forense Del Departamento De Criminología De La Policía Judicial De Chimborazo. <http://dspace.unach.edu.ec/bitstream/51000/1182/1/UNACH-EC-LAB.CLIN-2013-0039.pdf>
- Sarwat, N., Ali, R., & Khan, T. I. (2021). Challenging, hindering job demands and psychological well-being: The mediating role of stress-related presenteeism. *Research Journal of Social Sciences and Economics Review*, 2(1), 135-143.
- Khan, T. I., Kaewsang-On, R., & Saeed, I. (2019). Impact of workload on innovative performance: Moderating role of extrovert. *Humanities & Social Sciences Reviews*, 7 (5), 123-133.
- Jamil, R. A., Qayyum, U., ul Hassan, S. R., & Khan, T. I. (2023). Impact of social media influencers on consumers' well-being and purchase intention: a TikTok perspective. *European Journal of Management and Business Economics*, (ahead-of-print).
- Li, H. X., Hassan, K., Malik, H. A., Anuar, M. M., Khan, T. I., & Yaacob, M. R. (2022). Impulsive and compulsive buying tendencies and consumer resistance to digital innovations: the moderating role of perceived threat of COVID-19. *Frontiers in Psychology*, 13, 912051.
- Ahmed, I., Farooq, W., & Khan, T. I. (2021). Customers' Perceptions and their Responses to Objectives of Islamic Banks—A Three-Wave Investigation. *Asian Economic and Financial Review*, 11(1), 43.
- Khan, M. T., Khan, T. I., & Khan, S. (2020). Innovation & Its Diffusion in Business: Concept, Stages & Procedural Practices. *sjesr*, 3(4), 174-186.
- Khan, T. I., Khan, S., & Zia, M. H. (2019). Impact of personality traits on workplace deviance—a pakistani perspective. *Global Regional Review, Humanity only*, 4(2), 85-92.
- Campos, C., & Palacios, A. (2010). Determinación Por Hplc De Residuos De Insecticida Órganofosforado (Methamidophos) En Tomates Comercializados En Lima-Perú. https://cybertesis.unmsm.edu.pe/bitstream/handle/20.500.12672/1611/Campos_cc.pdf?sequence=1&isAllowed=y

- Aquino, M. S., & Castro, C. C. (2008). Análisis De Residuo De Plaguicida Organofosforado (Methamidophos) En Muestras De Papa De Mercados De Lima Metropolitana. https://cybertesis.unmsm.edu.pe/bitstream/handle/20.500.12672/1613/Aquino_am.pdf?sequence=1&isAllowed=y
- Velásquez, J. (2016). Determinación De Plaguicidas Organofosforados En Lechugas Comercializadas En Puestos Del Mercado Modelo De La Ciudad De Cajamarca. <http://repositorio.upagu.edu.pe/bitstream/handle/UPAGU/452/FYB-021-2016.pdf?sequence=1&isAllowed=y>