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Analytical Techniques for The Evaluation of Lead Concentrations in Food for Human Consumption

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Abstract: In the present work, a review was carried out on the studies carried out in different parts of the world, on the analysis techniques used to evaluate the concentrations of lead in various products for human consumption. A review was made of 25 arbitrary scientific articles from three databases SCOPUS, Science direct and Google academic, published from 2016 to February 2021, identifying 15 countries of origin, the country with the highest number of publications was the results with the Codex quality standard.

Keywords: Analysis Techniques, Concentrations in Food, Human Consumption

INTRODUCTION

It must define the problem and importance of the research carried out, it presents a (not very extensive) review of the literature on the subject of the article, including the authors' contributions to the state of the art. If you use abbreviations or acronyms, first write the words that identify them and then, in parentheses, the acronym. This set also establishes the research question, the objectives of the work and hypothesis, if necessary, the importance and limitations of the study. Establishes the method used at work. It is written in the present tense.

THEORETICAL REFERENCE

Globalization has brought very serious results, such as pollution due to various toxins that are emitted and produced, which affect the environment, but not only the environment is harmed, but also indirectly or directly harms man. The accumulation of these pollutants, among them heavy metals, lodged inside the human body due to the ingestion, inhalation or dermal route [1] of certain elements with certain concentrations is the cause of diseases and various disorders. Among them, lead is classified as highly carcinogenic and toxic [2].

Many diseases have increased significantly in recent decades in developed countries and to a greater extent in developing countries, particularly chronic diseases, which would be associated with environmental pollutants [3].

Therefore, considering the potential health hazards due to exposure to pollutants, it is necessary to be able to guarantee the protection to be considered, and this will be achieved by determining and reporting the degree of exposure of the population to pollutant determinants, analyzing the presence of certain pollutants in environmental compartments (water, food, air, soil, etc.) [4].

In this work we will focus on the contaminants that humans ingest through food, because many concurrent cases have been witnessed, due to the fact that food is considered to be the main route of entry of contaminants into the human body [5]. For example in the year 2019 in Spain, an analysis of a series of meat products of big game hunting species was carried out in order to detect the presence of traces of lead, and thus be able to quantify the concentration of lead in the food and thus be able to determine whether with the values obtained it is possible an influence on human health; this was determined by comparing these concentrations with the maximum limits allowed in this case by the European Union for this type of food products [6].

According to this case, it was observed that food safety and quality must be enhanced in all European countries and that foodborne diseases have increased considerably throughout Europe during the last 10 years. In particular those of microbiological origin such as salmonella, as well as cases of food contaminated by chemicals, dioxins, or metals such as lead and cadmium. The results are as follows: "One in three people in industrialized countries may be affected by such diseases every year". Therefore, it is important to address this issue; those most at risk are children, pregnant women, those with chronic diseases and the poor, i.e. the most vulnerable population [7].

To address this problem of food contamination, we must bear in mind that for a large part of the world's population, when talking about food security, it is not only a problem of quality but, above all, of "quantity" [8], due to population growth and changes in eating habits, which has resulted in the transformation of many forests into land for agricultural use, which originated and promulgated the development of intensive agriculture, with the use of pesticides and genetically modified foods. But also, as a consequence, these changes brought with them many counterproductive effects, because their intensification produced a direct increase in the risks of exposure to infectious agents or contaminants both to food and soil, producing a loss of biodiversity and soil fertility. In most cases, despite the fact that foods are modified, since foods do not change their general appearance or other characteristics when contaminated or exposed to contaminants, they cannot be recognized with the naked eye and their presence usually goes unnoticed [9]. These contaminants normally remain in the trophic chain and persist, causing bioaccumulation phenomena [5].

Although efforts have been made to try to improve or solve this problem, such as the "World Food Summit" in 1996, which focused international attention on the concept of food security, as well as on the access of all people to "nutritious food to maintain a healthy and active life", according to FAO [7]. In order to solve the problem of food distribution and generation on the planet, it is necessary to create programs that help increase agricultural production and improve food distribution, achieving a better management of resources and provision of family planning services. In spite of the good intentions, in June 2002, the FAO itself, meeting in Rome at the II International Food Summit, indicated that they would continue to study how to combat hunger, since what had been agreed in 1996 was a failure. This is reflected in the fact that one person dies every 4 seconds from malnutrition on our planet, most of them children [10]. The Codex Alimentarius Commission given by the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations [10], which consolidated the basis of risk analysis (RA) as a methodology to evaluate the impact of environmental contaminants on the health of the population [5], and to be able to do so, it is done through the development of analytical methodologies together with specialized equipment such as those based on liquid chromatography coupled to mass spectrometry developed in a meat experiment in Spain [4], or the use of atomic fluorescence spectrometry of electrothermal vaporization developed in a Chinese milk experiment [11], or research developed in Peru where they used ICP-MS in two investigations developed on the presence of lead in carrots and potatoes [12,13]. Based on this background, the objective of this research is to review the most recent articles regarding the determination of lead in food for human consumption, in order to determine the concentrations or traces of lead and to compare it with standard reference concentration measurements, identifying which foods meet the requirements for consumption.

MATERIALS AND METHODS

A literature review was conducted in the following databases: Scopus, Science Direct and Google Scholar, in which academic scientific articles on the topic of evaluation of lead concentrations in various products for human consumption were searched.

Once a strategic overview of the topic was obtained, an advanced search was performed in each of the databases:

English keywords such as "lead", "determination", "food" and "chemical analysis" were used in the Scopus database. Only the Boolean term AND was used for which it was entered by selecting the search engine field according to the article title, abstract and keywords as follows: "lead" AND "determination" AND "food" AND "chemical AND analysis". From this first search the result yielded 618 articles. After that it was filtered considering the choice of academic scientific articles published during the period of year from 2016 to February 2021; in addition the subject area chemestry (chemistry) was included, in the article access the option All open access was selected, after this filtering 20 academic scientific articles were obtained. [14]

In the Science Direct database, the following keywords were used: "determination", "lead", "heavy metals", "food" and "contamination". Boolean AND and OR terms were used for which were entered by selecting the search engine field according to the article title, abstract and keywords as follows: "determination" AND "lead" OR "heavy metals" AND "food" OR "contamination", in addition another search engine field was also entered according to the title as follows: "lead" OR "heavy metals".[15] From this first search the result yielded 6,109 articles. After that it was filtered considering the articles published during the year period from 2016 to February 2021, which provided a result of 1 994, subsequently it was filtered considering the type of article as the option research article was selected, in this way we only included research articles, obtaining now 1 678 articles, immediately after that in the subject area filter, chemestry (chemistry) was selected, resulting in 254 academic scientific articles, which is the final filtered amount of articles. [16]. In the Google Scholar database, the Spanish keywords used were: "determinación", "determinar", "plomo", "alimentos", "concentraciones" and "metales pesados". Two searches were performed in the Google Scholar database.

The first search used the following combination of keywords: "heavy metals", "food" and "determine". Only the Boolean term OR was used for which it was entered in the general search engine field as follows: "heavy metals food" OR "determine heavy metals". This resulted in 150 articles. Then the year was filtered from 2016 to February 2021, which resulted in 70 articles, then the language was filtered, since the option to search only in Spanish pages was selected, which resulted in 68 articles, also the order by relevance was selected and also resulted in 68 articles, which is the final number of articles filtered.

In the second search, the following combination of keywords was used: "food", "lead", "concentrations" and "determination". The advanced search tool was used in which in the boxes of all the words were placed: "food" and "lead"; in the exact phrase box was placed: "lead determination" and finally in at least one was placed: "determination", "lead" and "concentrations". The result was 737 articles. Then the year was filtered from 2016 to February 2021, which resulted in 350 articles, then the language was filtered, as the option to search only in Spanish pages was selected, which resulted in 339 articles, also the order by relevance was selected and also resulted in 339 articles, which is the final filtered number of articles. [17]

In summary, the advanced search retrieved 20 articles in Scopus, 252 articles in Science Direct and 404 articles from Google Scholar, as well as papers in English and Spanish. A review of titles and abstracts of each article that were available in full text was then carried out, and those that met the following inclusion criteria were selected: information on the analytical technique used, novel analytical methods, quantitative results, specification of the lead quality standard. [10] Articles that were not directly related to the subject of the study were excluded, as well as those that presented qualitative results, lacked graphs and tables of results, and review articles.

Finally, 25 academic scientific articles were obtained, 4 articles in Scopus, 17 articles in Science Direct and 4 articles in Google Scholar respectively, for which a cross-checking of information was carried out beforehand so that the academic scientific articles would not be repeated in other databases already used. [18]. We divided the search in general into three stages in our research method: identification, which consists of probing the topic in general using keywords and years of publication; the second stage was exclusion, in which we excluded articles from each of the search engines using parameters such as articles that were not directly related to the topic and qualitative articles; and the third stage was inclusion, which covers the articles that we will use in this systematic review. [19]

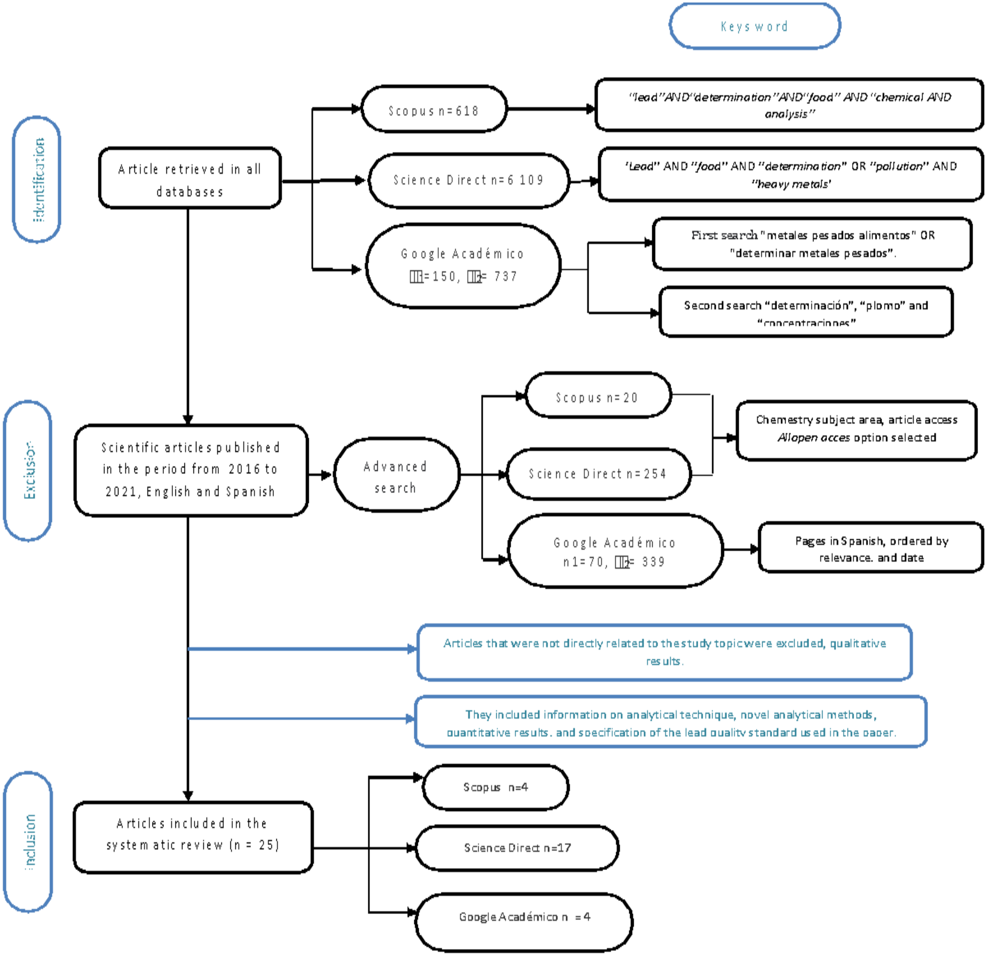

Fig.1: Search flow diagram

In the figure 1 shows the flow of the methodological process of the research elaboration

Table 1: List of 25 scientific articles evaluating the amount of lead in food for human consumption by author, year, country, keywords and journal.

N°	Article title	Author	Year	Country	keyword	magazine
1	Determination of cadmium and lead in tomato (Solanum lycopersicum) and lettuce Lactuca sativa) consumed in Quito, Ecuador.	David Romero-Estévez, Gabriela S. Yánez-Jácome, Karina Simbaña-Farinango, Pamela Y. Vélez-Terreros, Hugo Navarret	2020	Ecuador	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Toxicology Reports
2	Determination of lead in dietary supplements by high-resolution continuum-source graphite furnace atomic absorption spectrometry with direct solid sampling	Gabriela Camera Leal, Patricia Mattiazzi, Franciele Rovasi, Thaís Dal Molin, Denise Bohrer, Paulo Cícero do Nascimento, Leandro M. de Carvalho, Carine Viana	2020	Brazil	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Journal of Food Composition and Analysis
3	Determination of lead and cadmium in tilapia fish (Oreochromis niloticus) from selected areas in Kuala Lumpur	Ahmad Razali Ishaka, Mohd Shahrir Mahmud Zuhdi, Mohd YusmaidieAziz	2020	Malaysia	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Microchemical Journal
4	Lead and cadmium blood levels and transfer to milk in cattle reared in a mining area	Doris Maritza Chirinos-Peinado, Jorge Isaac Castro-Bedrinana	2020	Peru	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Heliyon
5	Determination of lead traces in honey using a fluorimetric method	María Carolina Talio, Vanesa Muñoz, Mariano Acosta, Liliana P. Fernández	2019	Argentina	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Food Chemistry
6	Lead (Pb) concentrations in lettuce (Lactuca sativa) crops in Azuay, Ecuador.	Jacinto Vázquez; Cecilia Sangurima; Manuel Alvarez-Vera	2019	Ecuador	"metales pesados en alimentos", "determinar metales pesados"	Scientia Agropecuaria
7	Centrifuge-less deep eutectic solvent based magnetic nanofluid-linked air-agitated liquid–liquid microextraction coupled with electrothermal atomic absorption spectrometry for simultaneous determination of cadmium, lead, copper, and arsenic in food samples and non-alcoholic beverages	Mahboube Shirani, Saeed Habibollahi, Ali Akbari	2019	Iran	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Food Chemistry
8	Content and the relationship between cadmium, nickel, and lead concentrations in Ecuadorian cocoa beans from nine provinces	David Romero-Estévez, Gabriela S. Yánez-Jácome, Karina Simbaña-Farinango, Hugo Navarrete	2019	Ecuador	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Food Control
9	Heavy metals in carrots (Daucus carota) traded at the Huacho Centennial Market - 2019	Yulisa Melisa Alejandro Santos, Cecilia Maura Mejía Domínguez, Nayla Nahomi García Gargatt, Víctor Joel Jaimes, Vilcherrez, Zareth Elicene Zafra	2019	Peru	“determinación", "plomo", "alimento”	Big Bang Faustiniano

		Cruzado, Mariluz Karolina Medina Oporto				
10	High-sensitivity determination of cadmium and lead in rice using laser-induced breakdown spectroscopy	PingYang, Ran Zhou, Wen Zhang, Rongxing Yi, Shisong Tang, Lianbo Guo, Zhongqi Hao, Xiangyou Li, Yongfeng Lu, Xiaoyan Zeng	2019	China	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Food Chemistry
11	Carcinogenic and non-carcinogenic risk assessment of heavy metals contamination in duck eggs and meat as a warning scenario in Thailand	P. Aendo, S. Thongyuan, T. Songserm, P. Tulayakul	2019	Thailand	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Science of the Total Environment
12	A closed inline system for sample digestion using 70% hydrogen peroxide and UV radiation. Determination of lead in wine employing ETAAS	Raineldes A. Cruz Junior, Adriano VB Chagas, Caio SA Felix, Rosemario C. Souza, Luciana A. Silva, Valfredo A. Lemos, Sergio LC Ferreira	2019	USA	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Talanta
13	Determination of heavy metal content of processed fruit products from Tehran's market using ICP- OES: A risk assessment study	Ayub Ebadi Fathabad, Nabi Shariatifar, Mojtaba Moazzen, Shahrokh Nazmara, Yadolah Fakhri, Mahmood Alimohammadi, Ali Azari, Amin Mousavi Khaneghah	2018	Brazil	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Food and Chemical Toxicology
14	Determination of cadmium, lead and ochratoxin in flour from the husks of two cocoa varieties in Ecuador.	Ahmed El Salous, Alina Pascual	2018	Ecuador	“determinación", "plomo", "alimento”	Revista de I+D Tecnológico
15	Determination of cadmium and lead in wine samples by means of dispersive liquid–liquid microextraction coupled to electrothermal atomic absorption spectrometry	DavidMartínez, GuillermoGrindlay, LuisGras y JuanMora	2018	Spain	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Journal of Food Composition and Analysis
16	A simple and green deep eutectic solvent based air assisted liquid phase microextraction for separation, preconcentration and determination of lead in water and food samples by graphite furnace atomic absorption spectrometry	Rizwan Ali Zounr, Mustafa Tuzen y Muhammad Yar Khuhawar	2018	Turkey	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Journal of Molecular Liquids
17	The effect of site- and landscape-scale factors on lead contamination of leafy vegetables grown in urban gardens	Chan Yong Sung, Cheon-Bo Park	2018	South Korea	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Landscape and Urban Planning
18	Fabric fiber sorbent extraction for on-line toxic metal determination by atomic absorption spectrometry: Determination of lead and cadmium in energy and soft	Luciane B. Paixão, Geovani C. Brandão, Rennan Geovanny O. Araujo, Maria Graças A. Korn	2018	Brasil	“determination”, “lead”, “heavy metals”, “food”, “contamination”	Food Chemistry

	drinks.					
19	Direct Determination of Lead in Foods by Solid Sampling Electrothermal Vaporization Atomic Fluorescence Spectrometry	Derong S. Hang , Yanfang Z. Hao , Yuxiu Z Hai ,Jinsong N Ing , Delin Duan ,Yongdong Z. Hou	2017	China	'food", "lead", "determination", "chemo analysis"	Food Chemistry
20	Levels of lead in foods from the first French total diet study on infants and toddlers	Thierry Guérin, Emilie Le Calvez, Julie Zinck, Nawel Bemrah, Véronique Sirot, Jean-Charles Leblanc, Rachida Chekri, Marion Hulin cLaurent Noël e	2017	France	"determination", "lead", "heavy metals", "food", "contamination"	Food Chemistry
21	Determination of lead at trace levels in mussel and sea water samples using vortex assisted dispersive liquid-liquid microextraction-slotted quartz tube-flame atomic absorption spectrometry	Sezin Erarpat; Gözde Özzeybek; Dotse Selali Chormey; SezginBakırdere	2017	Turkey	"determination", "lead", "heavy metals", "food", "contamination"	Chemosphere
22	Determination of Heavy Metals in Seafood Marketed at the Port of Huacho	Franklin Alexis Tejada Pacus, Analí Melissa Fernández Jaimes, Cecilia Maura Mejía Dominguez	2016	Perú	"metales pesados en alimentos", "determinar metales pesados"	Big Bang Faustiniano
23	Direct determination of Pb in raw milk by graphite furnace atomic absorption spectrometry (GF AAS) with electrothermal atomization sampling from slurries	Tatiane Milao de Oliveira, Jayme Augusto Peres, María Lurdes Felsner, Karin Cristiane Justi	2016	Brazil	'food", "lead", "determination", "chemo analysis"	Food Chemistry
24	Determination of macro, essential trace elements, toxic heavy metal concentrations, crude oil extracts and ash composition from Saudi Arabian fruits and vegetables having medicinal values	Hana R. Alzahrani a , Hope Kumakli a , Emmanuel Ampiah a , Tsdale Mehari a , Austin J. Thornton b , Carol M. Babyak b , Sayo O. Fakayode	2016	Saudi Arabia	'food", "lead", "determination", "chemo analysis"	Arabian Journal of Chemistry
25	Preparation of Pb(II) Ion Imprinted Polymer and Its Application as the Interface of an Electrochemical Sensor for Trace Lead Determination	Shanling Hu, Xiaodong Xioang, Shuiying Huang, Xiaoqi Lai	2016	China	'food", "lead", "determination", "chemo analysis"	Analytical Sciences

In the table 1 show the table shows the detail of the consumption of the investigations found

Table 2: List of 25 scientific articles evaluating the amount of lead in food for human consumption according to type of food, method of analysis, result and food quality standard.

N°	Article title	Type of food	Analysis technique	Result	Quality standard
1	Determination of cadmium and lead in tomato (Solanum lycopersicum) and lettuce Lactuca sativa) consumed in Quito, Ecuador.	Tomato (Solanum lycopersicum) and Lettuce (Lactuca sativa)	Atomic absorption spectrophotometry in a graphite furnace.	0.066 mg/kg of Pb detected in lettuce; 0.0100 mg/kg of Pb detected in tomato.	Threshold value CXS 193-1995, (0.100 mg/kg and 0.200 mg/kg) respectively.
2	Determination of lead in dietary supplements by high-resolution continuum-source	Dietary supplements	high-resolution continuous-source graphite furnace atomic	0.04 to 25.3 µg/day Pb detected in dietary supplements	The Permitted Daily Exposure (PDE) - Provisional Tolerable Weekly Intake (PTWI)

	graphite furnace atomic absorption spectrometry with direct solid sampling		absorption spectrometry		-> The PDE for lead was set at 10 µg/day for a body weight of 50 kg.
3	Determination of lead and cadmium in tilapia fish (Oreochromis niloticus) from selected areas in Kuala Lumpur	Tilapia Samples (Oreochromis niloticus)	Acid digestion method of dry ash and determination by atomic absorption spectrophotometry (AAS).	Muscle tissues 0.078 ± 0.05 mg/g of Pb; gills 0.151 ± 0.12 mg/g of Pb; bones 0.108 ± 0.09 mg/g of Pb.	Malaysian Food Regulations 1985 (2 mg / g) Permitted limit concentrations by FAO / WHO 2004 = 1.5 µg / g (Pb)
4	Lead and cadmium blood levels and transfer to milk in cattle reared in a mining area	Cow's milk sample	Flame atomic absorption spectrophotometry (NAMBEI AA320N)	0.58 mg/kg Pb detected in milk	Reference values for average Pb concentrations 0.5 mg/kg (Codex Standard, 2010; EEC, 2006)
5	Determination of lead traces in honey using a fluorimetric method	1: Ecological honey A (Multiflora: chañar, piquilin, white carob and palo amarillo). 2: Ecological honey B (Multiflora: melilotus, chilca, usillo and jarilla. 3: Multiflora I: not specified. 4: Multiflora II: not specified. 5: Monoflora: carob tree.	Fluorescence spectrometry	1: Organic honey A (0.122 ± 0.01 ug/L of Pb) 2: Ecological honey B (0.171 ± 0.03 ug/L of Pb). 3: Multiflora I:(0.213 ± 0.08 ug/L of Pb). 4: Multiflora II:(0.249 ± 0.04 ug/L of Pb). 5: Monoflora: carob (0.109 ±0.04 ug/L of Pb).	European authorities, maximum residue limit (MRL) for lead in honey (1 mg/kg). for lead in honey (1 mg/kg) - In Argentine legislation (Argentine Food Code) there are no maximum limits established for this metal.
6	Lead (Pb) concentrations in lettuce (Lactuca sativa) crops in Azuay, Ecuador.	Lettuce	Atomic Absorption Spectrometry	0.066 mg/kg Pb in lettuce grown under glass, 0.087 mg/kg Pb in lettuce grown in open field.	The General Standard for Contaminants and Toxins in Food and Feed of the Codex Alimentarius CXS 193-1995 of the UN Food and Agriculture Organization and the World Health Organization - (<0.3 mg/Kg)
7	Centrifuge-less deep eutectic solvent based magnetic nanofluid-linked air-agitated liquid–liquid microextraction coupled with electrothermal atomic absorption spectrometry for simultaneous determination of cadmium, lead, copper, and arsenic in food samples and non-alcoholic beverages	Nut, rice, tomato paste, spinach samples	Air-stirred liquid-liquid microextraction, air-stirred and deep magnetic nanofluid stirred without centrifuge and centrifuge (CL-DES-MNF-AALLME)	Rice (54.4 ± 1.5 ng/L of Pb) - Spinach (50.3 ± 2.5 ng/L of Pb) - Walnut (48.8 ± 2.5 ng/L of Pb) - Tomato paste (50.3 ± 2.5 ng/L of Pb)	EU regulated concentration limits - Vegetables 0.10-030 ug/Kg - Berries and small fruits 0.20 ug/Kg
8	Content and the	cocoa beans	Atomic	0.502mg/kg and 1.966	does not specify

	relationship between cadmium, nickel, and lead concentrations in Ecuadorian cocoa beans from nine provinces		absorption spectrophotometry with two different atomization techniques: flame (FAAS) and graphite furnace (GFAAS).	mg/kg of Pb detected in cocoa beans.	
9	Heavy metals in carrots (Daucus carota) traded at the Huacho Centennial Market - 2019	Daucus carota (zanahoria)	Inductively Coupled Plasma Mass Spectrometry (ICP-MS)	< 0.032 mg/kg of Pb detected in carrots.	Permissible limits (0.1 mg/kg) according to Codex Alimentarius and the European Union.
10	High-sensitivity determination of cadmium and lead in rice using laser-induced breakdown spectroscopy	Rice samples	Laser-induced degradation spectroscopy	Sample 1: 11.35 ± 0.52 mg/kg Pb; sample 2: 20.87 ± 1.84 mg/kg Pb; sample 3: 28.42 ± 0.14 mg/kg Pb.	Food quality standards for rice in China (based on food safety GB2762-2017)(0.1mg / kg).
11	Carcinogenic and non-carcinogenic risk assessment of heavy metals contamination in duck eggs and meat as a warning scenario in Thailand	Eggs and duck meat	Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES)	Duck eggs: 4.06 ± 2.70 mg/kg Pb Duck meat: 1.94 ± 1.75 mg/kg Pb	TAS = Thai agricultural standard for duck egg (0.1) NMPHT = Notification of the Ministry of Public Health of Thailand (57.77%). EC = (EC) COMMISSION REGULATION (66.66%). FAO/WHO = FAO/WHO 2002 and Codex Alimentarius. (66.66%)
12	A closed inline system for sample digestion using 70% hydrogen peroxide and UV radiation. Determination of lead in wine employing ETAAS	Wine	Atomic absorption spectrometry in a graphite furnace	2.19 - 43.48 µg/L Pb detected in wine	La Organization Internationale de la Vigne et du Vin (OIV) 150 µg/L
13	Determination of heavy metal content of processed fruit products from Tehran's market using ICP-OES: A risk assessment study	Fruit juice and canned fruit (peach, orange, cherry, cherry and pineapple)	Inductively Coupled Plasma Atomic Emission Spectrometry (ICP-OES)	Fruit juice 40.86 (27.87-66.1) µg/kg Pb Fruit canning 690.54 (470.56-910.14) µg/kg Pb	Codex (0.05 mg / kg) Codex (fruit juices 100 mg / kg and FC 250 mg / kg)
14	Determination of cadmium, lead and ochratoxin in flour from the husks of two cocoa varieties in Ecuador.	Flour from cocoa husks	Atomic absorption spectrophotometry	0.17 mg/Kg and 0.34 mg/Kg of Pb detected in cocoa husks.	INEN 616 (<0,2 mg/Kg) - INEN 621 (<1 mg/Kg)
15	Determination of cadmium and lead in wine samples by means of dispersive liquid–liquid	Sample of white, red, rosé, fortified and sparkling wines.	Dispersive liquid-liquid microextraction (DLLME) and determination	White: 2.0 ± 0.2 µg / L of Pb; Pink 2.17 ± 0.16 µg / L of Pb; Sparkling1.75 ± 0.15 µg / L of Pb;	La Organization Internationale de la Vigne et du Vin (OIV) 150 µg/L

	microextraction coupled to electrothermal atomic absorption spectrometry		by electrothermal atomic absorption spectrometry (ETAAS)	Fortified1.8 ± 0.3 µg / L of Pb; Red 2.7 ± 0.2 µg / L of Pb	
16	A simple and green deep eutectic solvent based air assisted liquid phase microextraction for separation, preconcentration and determination of lead in water and food samples by graphite furnace atomic absorption spectrometry	Food sample (black tea, green tea, cumin, beef, flaxseed, canned fish, chicken, potato)	Atomic absorption spectrometry in a graphite furnace	Black tea 0.72 ± 0.02 µg/g Pb; Green tea 0.23 ± 0.01 µg /g Pb; Cumin 0.29 ± 0.02µg/g Pb; Beef 0.56 ± 0.04µg /g Pb; Flaxseed 0.34 ± 0.01µg/g of Pb ; Canned fish 0.87 ± 0.05µg /g of Pb; Chicken meat 0.25 ± 0.02µg/g of Pb;Potato 0.18 ± 0.01µg/ g of Pb	SRM 1946 (0,7 mg/kg), CRM CS-M-3 (1.863 ± 0.108 µg/kg)
17	The effect of site- and landscape-scale factors on lead contamination of leafy vegetables grown in urban gardens	Sweet Potato, Cayenne Pepper, Perilla, Garlic, Lettuce, Cabbage, Welsh Onion, Pumpkin.	Plasma Mass Spectrometry (ICP-MS), using inductively coupled	Sweet potato 362 µg/kg Pb; Cayenne pepper 329 µg/kg Pb; Perilla 103 µg/kg Pb; Garlic 85 µg/kg Pb; Lettuce 258 µg/kg Pb; Cabbage 22 µg/kg Pb; Welsh onion 80 µg/kg Pb; Pumpkin 245 µg/kg Pb.	Korean standard for maximum Pb and found that 25% of the sampled vegetables exceeded the Korean standard for maximum Pb content in leafy vegetables of 300 µg / kg.
18	Fabric fiber sorbent extraction for on-line toxic metal determination by atomic absorption spectrometry: Determination of lead and cadmium in energy and soft drinks.	Natural coconut water samples, industrialized coconut water samples, coconut water milk, coconut water samples	High-resolution continuous source graphite furnace atomic absorption spectrometry (HR-CS GFAAS)	Natural coconut water samples 0.70 - 36.32 µg/L Pb; industrialized coconut water samples 6.57 - 29.02 µg/L Pb , coconut milk samples 0.85 - 22.41 ng/g Pb	Resolution No. 42/2013 of ANVISA , Maximum permissible limit for natural coconut water 50 µg L - 1 ,for industrialized coconut water 20 µg L - 1, for coconut milk samples 50 µg L - 1.
19	Direct Determination of Lead in Foods by Solid Sampling Electrothermal Vaporization Atomic Fluorescence Spectrometry	Rice and wheat flour ,fresh vegetables (celery, broccoli and cabbage)	Atomic absorption spectrometry in a graphite furnace	wheat flour 50.2 ± 2.2 µg/kg Pb; rice flour 32.5 ± 1.6 µg/kg Pb; celery 127.2 ± 5.2 µg/kg Pb ; broccoli 255.6 ± 10.1 µg/kg Pb; cabbage 223.8 ± 7.5 µg/kg Pb	Regulations 466/2001 and 221/2002 Vegetables and mushrooms 100 µg/kg, Flours 200µg/kg
20	Levels of lead in foods from the first French total diet study on infants and toddlers	Leche, arroz y trigo	Inductively coupled plasma mass spectrometry with a cyclonic sputtering chamber	0.8 -1.34 mg/kg Pb(milk); 0.27-7.7 mg/kg (wheat) Pb; 3.35-6.80 mg/kg Pb (rice)	EC Regulation 1881/2006 (<15mg/kg wheat and rice) (<10mg/kg milk)
21	Determination of lead at trace levels in mussel and sea water samples using vortex assisted dispersive liquid-liquid microextraction-slotted	Mussel samples	Dispersive liquid-liquid microextraction (DLLME) and slotted quartz tube (SQT) were coupled to flame	270 µ g/kg of Pb detected in mussel samples.	OMS: 0.015 y 0.010 mg/ L ,

	quartz tube-flame atomic absorption spectrometry		atomic absorption spectrometry (FAAS).		
22	Determination of Heavy Metals in Seafood Marketed at the Port of Huacho	mussel, limpet, snail and crab	Atomic Absorption Spectrometry	<0.034mg/kg Pb detected on average in mussel, limpet, snail and crab.	SANIPES (1.5mg/kg for mussel, limpet and snail mussel, limpet and snails; 0.5mg/kg for crab)
23	Direct determination of Pb in raw milk by graphite furnace atomic absorption spectrometry (GF AAS) with electrothermal atomization sampling from slurries	Raw milk	Electrothermal vaporization atomic fluorescence spectrometry	2.12 to 37.36 µg of Pb detected in raw milk	Limits of detection and quantification :0.64µg and 2.14 µg
24	Determination of macro, essential trace elements, toxic heavy metal concentrations, crude oil extracts and ash composition from Saudi Arabian fruits and vegetables having medicinal values	Two types of butters (Caralluma munbayana and Caralluma hes-peridum), Vigna (Vigna unguiculata), common fig (Ficus carica), Annona seeds (Annonaceae seeds), Annona fruits (Annonaceae fruits), fennel (Foeniculum vulgare) and fennel flowers (Nigella sativa)	Inductively coupled plasma optical emission spectrophotometry (ICP / OES)	Caralluma munbayana (0.27 ± 0.06µg / g of Pb) ; Caralluma hesperidum(0.47 ± 0.23 µg / g of Pb) : Vigna (0.29 ± 0. 25 µg / g of Pb); common fig (0.18 ± 0.05 µg / g of Pb); Annona seeds (0.21± 0.02 µg / g of Pb); fennel(0.24± 0.12 µg / g of Pb) and fennel flowers (0.36 ± 0.07 µg / g of Pb).	Limits of Detection (LOD) and Limits of Quantification (LOQ); 0.1-20 mg
25	Preparation of Pb(II) Ion Imprinted Polymer and Its Application as the Interface of an Electrochemical Sensor for Trace Lead Determination	Rice samples from supermarkets	Square wave voltammetry (VOC)	0.05 to 60 µm Pb detected in supermarket rice samples	Detection limit at 0.01 µm

Table 2 shows a description of the methods used in each scientific article together with their respective results, in addition, it was also considered to mention the maximum permissible limits in order to determine that the food products comply with the quality standards and do not harm human health. [22] The maximum permissible limits are determined according to the legislation of each country where the experimentation was carried out, in addition we consider what is established by world health organizations such as WHO or FAO for the proper quality standards according to the origin and type of food.

RESULTS

Figure 2 shows the number of scientific articles, by year of publication, where a downward trend is observed from 2016 to 2017, and then an upward trend from 2017 to 2019. The year in which more articles were published was in 2019 which represents 32%. 2017 was the year in which the least number of articles were published. [20,21]

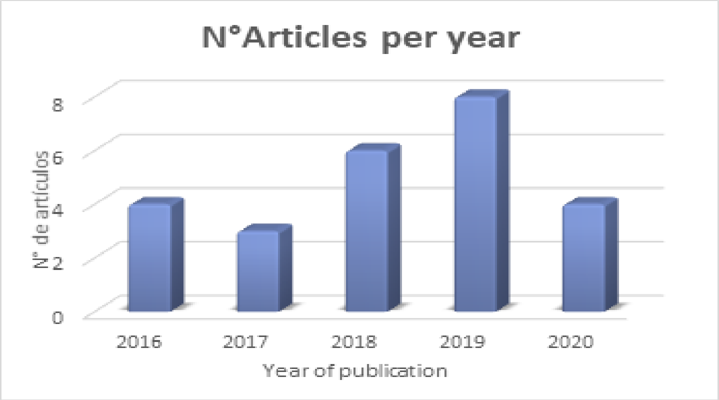

Fig.2: Number of scientific articles per year from 2016 to 2020 in the evaluation of lead determinations in food for human consumption.

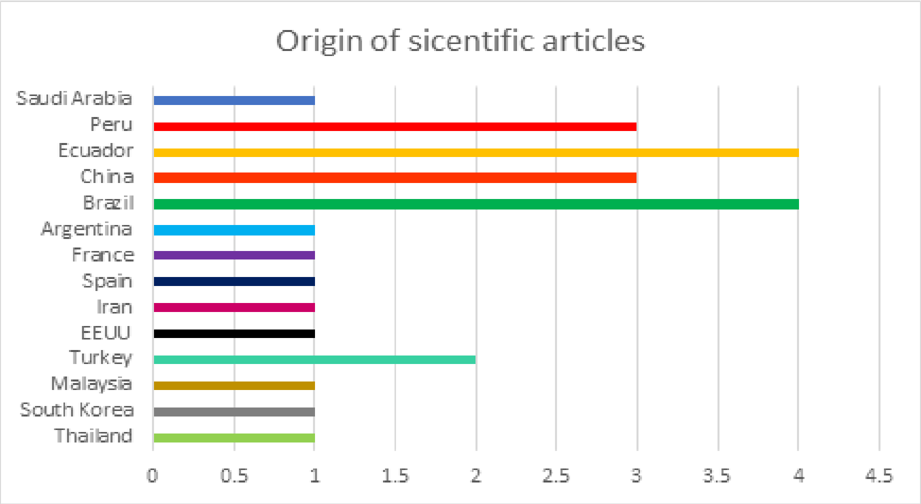

Fig.3: Origin of scientific articles around the world

Figure 3 shows the number of scientific articles according to their origin. It can also be seen that, of the 25 scientific articles with 15 places of origin, the country with the highest number of articles considered was Brazil with 5 articles respectively and those considered the least were Saudi Arabia, Argentina, France, Spain, Iran, United States, Malaysia, South Korea and Thailand with 1 article each, therefore, it can be said that there is an average of approximately 1,667 for each country considered. [23]

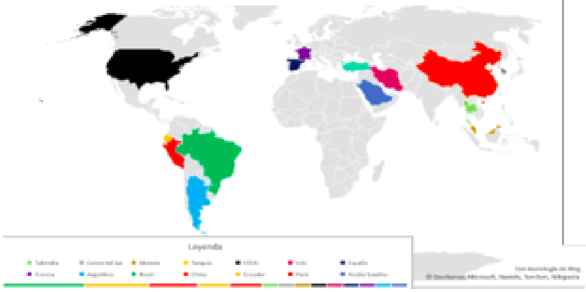

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Fig.4: World map of the provenance of scientific articles found between 2016 to 2020 on lead contamination in food.

Figure 4 show the ratio of percentages between foods and beverages of the total food samples studied in the articles and the drinkable and solid food for human consumption, where the percentage of items studied is identified.

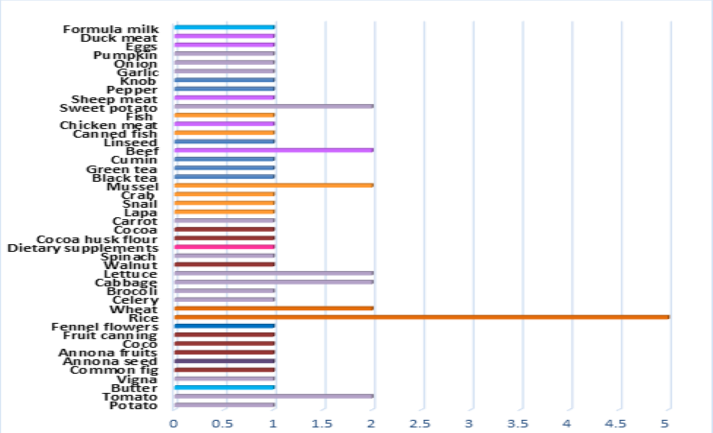

Fig.5: Solid foods with more studies within the classification of liquid and solid consumer products

Figure 5 identifies the solid foods with the most studies, among which rice stands out with 5 scientific articles. This is followed by solid foods with 2 articles on sweet potato, beef, mussels, lettuce, cabbage, wheat, tomato and potato. It should be noted that most of these foods come from crops, with the exception of beef. The remaining items have a total of only one item, including potatoes, onions, garlic, pepper, formula milk, crab, snail, limpet, broccoli, coconut, tomato, celery, walnuts, spinach, etc. [24]

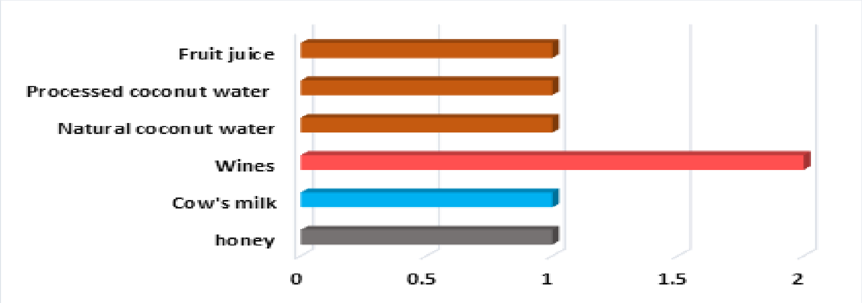

Fig.6: Solid foods with more studies within the classification of liquid and solid consumer foods.

Figure 6 shows the liquid foods with the most studies according to the number of articles found, in which wine stands out with 2 articles with respect to fruit juices, processed coconut water, natural coconut water, cow's milk and honey.

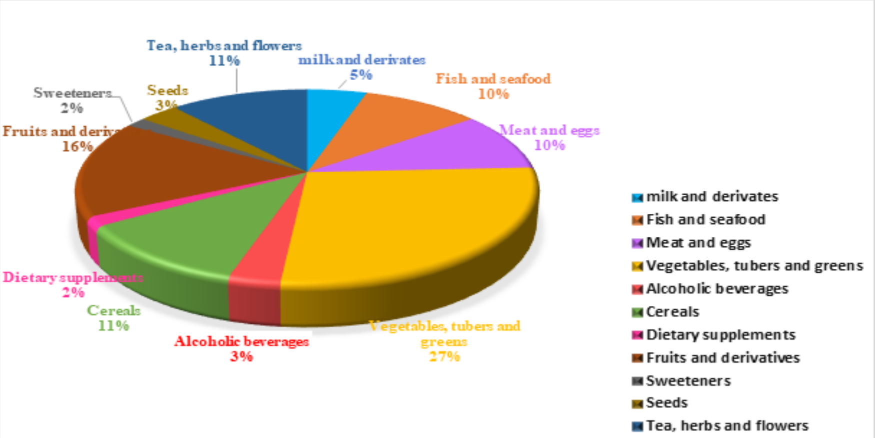

Fig.7: Classification of total foods for human consumption in scientific articles.

Figure 7 shows the 10 classes or groups into which the foods for human consumption were classified in this review work, the first group being dairy products and their derivatives, which include cow's milk and butter. [25] the second group is fish and seafood, including samples of canned fish, fish such as Tilapia and shellfish such as mussels; the third group is meat and eggs, including beef, sheep, chicken and duck meat, and duck eggs; the fourth group is vegetables, tubers and vegetables; the fifth group is sweets; the sixth group is cereals such as corn and rice; the seventh group is food supplements; the eighth group is fruits, tubers and vegetables; the fifth group includes sweets; the sixth group is cereals such as corn and rice; the eighth group includes fruits and vegetables; the fourth group belongs to vegetables, tubers and greens; the fifth group includes sweets; the sixth group consists of cereals such as corn and rice; the seventh group includes food supplements; the eighth group includes fruits and derivatives such as common figs, Annona fruits, cocoa and cocoa husk flour; the ninth group includes seeds such as flaxseed and Annona seeds. [26,27]

Table 3: Analysis of results (mg/kg) according to the analytical method used and the type of feed under the Codex quality standard

Nº of Research Article	Food	Analytical method used	Results (mg/Kg)	Codex Alimentarius quality standard (mg/Kg)	Defect (mg/Kg)	Excess (mg/kg)
1	Lettuce A	GFAA-SS	0.066	0.3	0.234	
	Tomato		0.01	0.1	0.09	
4	Muscle Fish (Tilapia)	Dry ash acid digestion method and AAS	78	0.2		77.8
5	Fruit juice	ICP - OES	0.04086	0.05	0.00914	
	Canned fruits		0.69054	0.1		0.59054
6	Milk A	FAAS	0.58	0.02		0.56
8	Greenhouse lettuce	AAS	0.066	0.3	0.234	
	Open lettuce		0.087	0.3	0.213	
10	Cocoa beans	GFAASS Y FAAS	2	2	0.034	
11	Daucus carota (carrot)	ICP-MS	0.032	0.1	0.068	
12	Rice A	LIBS	11.35	0.2		11.15
	Rice B		20.87	0.2		20.67
	Rice C		28.42	0.2		28.22
13	Duck eggs	ICP -OES	4.06	0.05		4.01
	Duck meat		1.94	0.05		1.89
14	Cocoa husks	AAS	0.34	0.2		0.14
16	Cumin	GFASS	0.29	0.1		0.19
	Beef		0.56	0.05		0.51
	Linseed		0.34	0.2		0.14
	Canned fish		0.84	0.2		0.64
	Chicken meat		0.25	0.05		0.2
	Potato		0.18	0.1		0.08
17	Milk B	ICP-MS	0.58	0.02		0.56
	Sweet potato		0.362	0.1		0.262
	Cayenne pepper		0.329	0.3		0.029
	Knob		0.103	0.3	0.197	
	Lettuce B		0.258	0.3	0.042	
	Cabbage A		0.022	0.3	0.278	
	Onion		0.8	0.3		0.5
18	Wheat A	GFAASS	0.0502	0.2	0.1498	
	Rice D		0.0325	0.2	0.1675	
	Celery		0.1272	0.3	0.1728	
	Broccoli		0.2556	0.3	0.0444	
	Cabbage B		0.2238	0.3	0.0762	
19	Milk C	ICP-MS	1.34	0.02		1.32
	Wheat B		7.7	0.2		7.5
	Rice E		6.8	0.2		6.6
20	Mussel	DLLME y FAAS	0.27	1.0	0.73	
23	Butter A	ICP-OES	0.27	0.05		0.22
	Butter B		0.47	0.05		0.42
	Vigna		0.29	0.2		0.09

	Common fig		0.18	0.1		0.08
	Annona seeds		0.21	0.2		0.01
	Hinojo		0.24	0.1		0.14
	Fennel Flowers		0.36	0.1		0.26

Table 3 shows the results obtained by applying the analysis technique for each type of food. The excess and defect columns show the subtraction between the Codex quality standard and the results. The results that were classified in the excess column are represented by those foods that exceed the Codex Alimentarius quality standards, while the results that were classified as defective are those that remain within the range of the quality standard. (From this last table, products such as green tea, black tea and Annona seeds were removed because their classification within the Codex Alimentarius was not found). [28]

Table 4: Abbreviation of each analytical technique used.

ANALYTIC TECHNIQUE	ABBREVIATION
Square Wave Voltimetry	SWV
Graphite Furnace Atomic Absorption Spectrometry	GFAAS
Electrothermal Vaporization Atomic Fluorescence Spectrometry	AFS
Inductively Coupled Plasma - Optical Emission Spectrometry	ICP -OES
Inductively Coupled Plasma - Mass Spectrometry	ICP-MS
Atomic Absorption Spectrometry	AAS
Dry Ash Acid Digestion Methodr	MDACS
Flame Atomic Absorption Spectrometry	FAAS
Laser - Induced Degradation Spectroscopy	LIBS
Microextraction Liquid-Liquid Agitated by Air and Agitated by Deep Magnetic Nanofluids without centrifuge and with centrifuge	CL-DES-MNF-AALLME
Dispersive Liquid-Liquid Microextraction	DLLME
Direct Solid Sampling	DSS

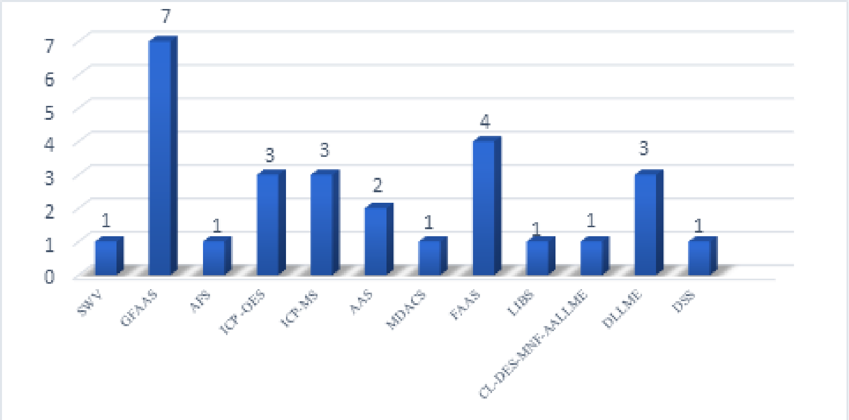

Fig.8: Analytical techniques most commonly used in scientific papers

Figure 8 shows the most used analytical techniques, where graphite furnace atomic absorption spectrophotometry stands out with 6 articles. The next two analytical techniques are inductively coupled plasma mass spectrometry and flame atomic absorption spectrometry with 4 articles. Plasma atomic emission spectrometry and dispersive liquid-liquid microextraction with 3 publications for each analytical technique.

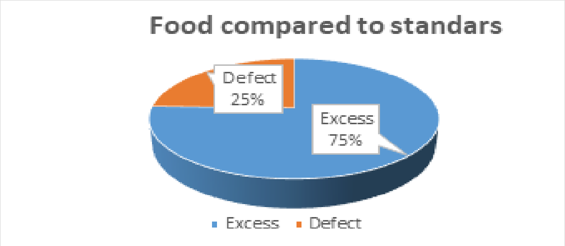

Fig.9: Percentage of food that exceeds quality standards.

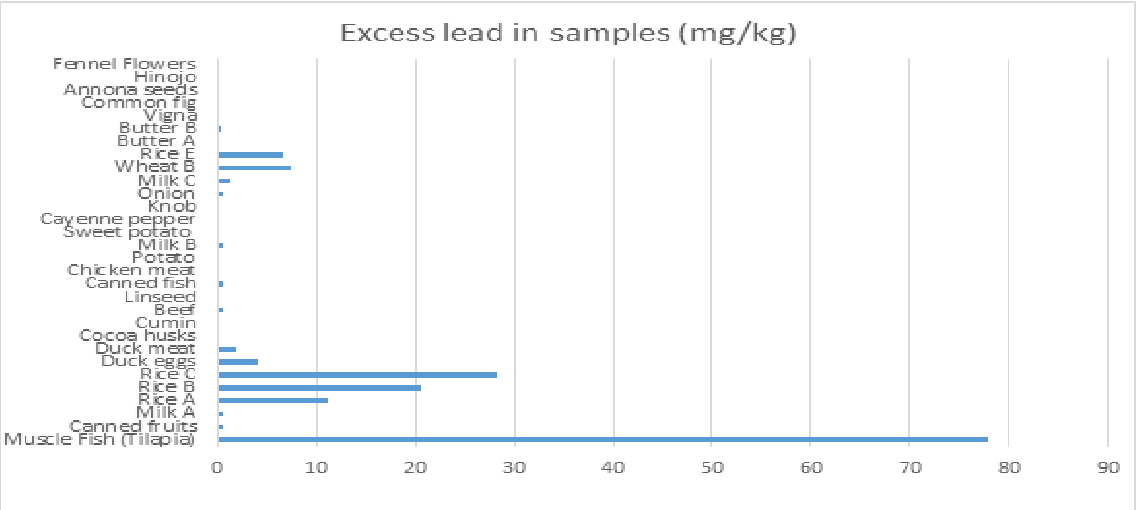

Fig.10: Foods that exceed quality standards

DISCUSSION

Place of origin

Brazil also has a high rate of food contamination investigations. This is due to the fact that it has a significant contamination of various heavy metals, among which lead stands out. The presence of heavy metals such as lead is mostly due to anthropogenic sources related to industrial activities, oil processing and the use of agrochemicals. [29]

Other studies highlight contamination through livestock, which is essentially transmitted in the highlands and the mid-Andean zone. Lead, caused by mining activity, is present in pastures and therefore goes to the animals' consumption through grazing. The products obtained from the animals were exposed to heavy metal contamination, especially cadmium and lead, which are dynamically transferred to the milk. That is why quantification studies are important to prevent their consumption from damaging the nervous, skeletal, circulatory, enzymatic and immunological systems. [30,31]

Type of food

Due to the fact that there are different types of food contaminants, which can be classified classically into biological and chemical contaminants, the need arises to classify foods according to certain criteria such as their origin, composition or the stages of production they go through, because these determine how often a type of food is exposed to certain contaminants, for example, contamination by nitrates in products of agricultural origin due to the use of nitrogen fertilizers to enrich the soil, or contamination by pesticides in foods because they are very commonly affected by pests.

In this research it is more directed to the contamination by metals and more specifically by lead which can constitute a serious risk for public health, in which it is observed that in foods with greater exposure to lead through the diet is carried out fundamentally through cereals, for this reason most of the researches are referred to this type of food, in addition it is also determined that it is necessary to carry out researches in foods with greater incidence in cities with greater atmospheric contamination. [33] In addition, according to what has been said, foods can be selected according to different criteria, among them the representativeness if we are working on a database of food consumption considering the evaluated results of the diet of the population to be investigated. [34]

The classification of foods is also related to the type of analysis to be performed, since, in order to determine the concentration of lead in liquid and solid foods, it is necessary to perform other preliminary procedures and even in some cases a different analytical method. In addition, also in the case of liquid and solid foods it is necessary their classification due to the fact that they provoke different appetitive and intake responses in the human being.

It is also possible to classify foods according to their nutritional level, which will help you to select which foods to work with due to their importance in human nutrition, among them milk or those with high percentages of consumption such as wines.

Analytical technique used

From the results obtained, according to Table 3 and 4, it can be deduced that the most used analytical technique is atomic absorption spectrophotometry in a graphite furnace. The analytical technique of graphite furnace atomic absorption spectrophotometry (GFAAS) allows reducing the detection limits to the parts per billion (ppb) range with a relatively simple instrumentation, without so much effort and loss of time that previous extraction techniques entail, however, one of its disadvantages is a lower precision, Another disadvantage is that graphite furnace atomic absorption spectrophotometry (GFAAS) incurs a greater number of interferences. [23]

The analytical technique of graphite furnace atomic absorption spectrophotometry (GFAAS) has a higher sensitivity compared to the analytical technique of flame atomic absorption spectrophotometry (FAAS), which is the second most used method, because levels of ng/L can be detected. Comparing both methods of analysis, it was observed that flame offers results in shorter times, allows working with larger sample volumes and interferences are lower. [14]

Likewise, the analytical technique of inductively coupled plasma mass spectrometry (ICP-MS) together with the analytical technique of flame atomic absorption spectrophotometry (FAAS) were the later most repetitive methods. Inductively coupled plasma mass spectrometry (ICP-MS) is an analytical technique that is generally established for food analysis, it features high precision, shorter analysis time, low detection limits, and less interference.

It was identified that the analytical technique of inductively coupled plasma mass spectrometry (ICP-MS) works better in liquid food, since a higher precision is obtained, however, it has a higher cost of the equipment and operation, reason why not all countries can have access to perform such analytical technique. Comparing the analytical technique of inductively coupled plasma mass spectrometry (ICP-MS) with graphite furnace atomic absorption spectrophotometry (GFAAS), inductively coupled plasma mass spectrometry (ICP-MS) analyzes even smaller samples than graphite furnace atomic absorption spectrophotometry (GFAAS), which is why it is less accurate than graphite furnace atomic absorption spectrophotometry (GFAAS).

Excess in samples (mg/kg)

From the results obtained, it can be deduced that the sample that exceeds the Codex Alimentarius quality standard to the least extent is the sample of Oreochromis niloticus or commonly called Tilapia and the sample that exceeds the Codex Alimentarius quality standard just by thousandths is the Capsicum annuum commonly called as cayenne pepper. Tilapia samples were extracted from Kepong Metropolitan Lake Garden Metropolitan Lake and Sri Murni Lake, Malaysia, both of which are former mining areas and today have been opened to the public for recreational activity in this case fishing recreational areas, Being the concentration of lead 78 mg/kg although in the country registered is not considered a hazard as the limit concentration allowed by the Malaysian Food Act, 1983 is 2 mg/g (Pb) ~ 2000 mg/Kg, but it is a high concentration for the quality standard of Codex Alimenarius which has as maximum permissible in its classification of heavy (fish muscle) is 0.2 mg/Kg having an excess of 77. 8mg/kg. [34]

The cayenne pepper samples were extracted from urban vegetable gardens near industrial complexes in Daejeon city, Korea, the participating gardens were in proportion of built-up areas within buffer zones of 100 m and the proportion of industrial areas within buffer zones of 200 m, the lead concentration being 0, 329 mg/kg, in the country registered is considered a hazard as the maximum concentration of Lead in leafy vegetables according to the Ministry of Food and Pharmaceutical Safety, 2015, is 300 µg/ kg ~ 0.3 mg/kg, coinciding with the quality standard of the Codex Alimenarius which has the same maximum permissible in its classification of green leafy vegetables, giving an excess of 0. 0289 mg/kg.

CONCLUSION

A review of recent research on the analysis techniques used in the determination of lead concentrations in food for human consumption was carried out. The search method for this work was explained in a detailed and specific way, using a recognized database applying advanced search methods, filtering criteria were considered according to years and topics.

The various foods intended for human consumption were classified, separating the 55 products into 10 groups established by their own criteria, using as reference some classifications that consider as variables their function (energetic, plastic, protective), origin (extracted from the sea, cultivated, produced and transformed by man) and composition (macro and micronutrients), among others.

According to international regulations given by the World Health Organization (WHO) or more specific standards such as the Codex Alimentarius Quality Standard with regulations very similar to those given by the European Union (EU), comparisons were made with the results obtained in the research articles in order to determine whether they met the requirements for sale and consumption, from which it was found that of the 14 countries considered in most cases exceed the maximum permissible limits (MPL) showing alarming results in some cases where they exceeded them up to ten times more.

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