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Evaluation of Heavy Metals in Vegetables from Two Origins Marketed in Northern Peru

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ABSTRACT

The objective of the study was to evaluate the concentration of arsenic, chromium, cadmium, and lead in onion (*Allium fistulosum* and *Allium cepa*), tomato (*Solanum lycopersicum*), and celery (*Apium graveolens*) from two origins (local - Chachapoyas province and from the coast-province of Chiclayo) that are sold in the model market of the city of Chachapoyas. Six samples were taken on three different dates in November 2020, which were collected by non-probabilistic sampling (by convenience), which allowed choosing the most appropriate sample (according to its origin). For the determination of heavy metals, the Agilent 4100 MP-AES spectrometer was used. The concentration of As, Cr, and Cd in the vegetables remained below the Maximum Allowable Limits of the international standards with which they were compared; however, the concentration of Pb exceeded the Maximum Allowable Limits in all the samples analyzed, obtaining the lowest value in the celery samples from the local origin (0.15 mg.kg^{-1}) and the highest value in the tomato samples from the coast (0.21 mg.kg^{-1}). Therefore, it is concluded that only Pb is higher than the Maximum Allowable Limits with which it was compared.

INTRODUCTION

Vegetables are the most important sector in agriculture, however, technological advances and innovations are still dependent on the climatological, environmental, and soil conditions for their development (Burbano-Orjuela 2016).

Vegetables occupy an important place in the daily diet because of their vitamin and mineral content. However, exposure to heavy metals through the consumption of contaminated vegetables and their toxicity is a concern (Manzoor et al. 2018).

The presence of heavy metals in foods of vegetable origin, such as vegetables, is generally due to the excessive use of agrochemicals and occasionally the use of wastewater for irrigation (Durán et al. 2017). It was determined that the absorption of agrochemicals in vegetables depends on the type of plant, especially in leafy vegetables, which are not eliminated through food preparation (Guzmán et al. 2016). Also, the presence of heavy metals in vegetables is related to mining, causing socio-environmental conflicts due to the generation of toxic substances. Heavy metals are concentrated in the soil, then they are impregnated in the plants (Madueño & García 2019).

Improper use of pesticides disturbs the components of the environment and can cause pesticide residues in vegetables (Guerrero 2003). In this sense, contamination by mercury (Hg), arsenic (As), cadmium (Cd), and lead (Pb) is closely related to the cultivation scenarios; due to this, the consumption of vegetables with heavy metals affects different parts of the organism (Buendia 2018, González et al. 2020). Vegetables containing cadmium can have harmful consequences on human health, including cancer if consumed for an extended period of time (Estupiñan 2016, Giuffré et al. 2005, Mirabent 2015).

Fiallos (2017)found that the heavy metal content and microbiological quality in fruits and vegetables sold in markets in the city of Ambato, Colombia, exceeded the permissible limits in food quality for Zn, Mn, Hg, Pb, Cd, and Cu. Also, Juan de Dios (2018) found concentrations of Cadmium and Arsenic in onion (*Allium cepa*) in Metropolitan Lima, which exceed the maximum limit specified by WHO/FAO. Similarly, Marín (2019) compared the concentration of two heavy metals in oregano (Oreganum vulgare) and olives (Olea europaea) in Tacna; based on this background, it can be inferred that there is a presence of heavy metals in vegetables.

However, in northern Peru, there is no study of this type, which leads to a vacuum of information that the authorities require for decision-making. This will benefit public health and the economic prosperity of Peru (Galagarza et al. 2021).

Based on the above, the objective of the study was to evaluate the concentration of heavy metals in vegetables from two sources sold at the Modelo market in Chachapoyas.

MATERIALS AND METHODS

Study Area

The city of Chachapoyas is located in northern Peru, in the region of Amazonas, at an altitude of 2483 meters above sea level, and has a population of 32,026 inhabitants (INEI 2017). Chachapoyas has six markets that sell both groceries and agricultural products: Modelo market (central), La Unión market, Yance market, Requejo market, Pedro Castro market and the wholesale market. The study was carried out with samples obtained from the Modelo market since this market is where vegetables of different origins are concentrated.

Sample Collection

Triplicate samples were taken in November 2020. The non-probabilistic sampling method (by convenience) was used, which allowed for choosing the appropriate sample (according to its origin) (Wang et al. 2019a).

Samples were collected during the morning (6:00 am) because local vegetables are brought to the market at that time to be sold and found fresh. The samples were composed of three vegetables (onion, tomato, and celery) both local and from the coast. To identify the origin of the samples, the traders were consulted about the place of origin. Hermetically sealed polyethylene bags were used and these were transported for analysis to the Water and Soil Laboratory of the Research Institute for Sustainable Development of Ceja de Selva (INDES-CES) of the National University Toribio Rodriguez de Mendoza (UNTRM).

Sample Preparation

Samples of tomato, onion, and celery were washed (Sharma et al. 2008). The edible part of each vegetable was cut into small pieces, the samples were left to dry in aluminum foil, the samples were placed in the oven at 105°C for approximately 24 h, the samples were crushed using the mortar, then 2 g of the samples were weighed in beakers. Finally, the samples were placed in the muffle at 450°C for 6 h.

Methodology for the Detection of Heavy Metals

The determination of heavy metals such as cadmium, lead, arsenic, and chromium in samples of tomato (*Solanum lycopersicum*), onion (*Allium fistulosum*, *Allium cepa*), and celery (*Apium graveolens*) was performed by the Atomic Emission Spectrometry method, using the principle of atomic emission spectrometry method 132 (Azcarate 2017). In the emission process in the spectrometer, the sample is transported by means of a pump to the nebulizer system where it is converted into an aerosol; the aerosol passes into the center of the hot plasma, dries, decomposes, and is then atomized. The plasma is generated by subjecting a flow of nitrogen gas to a zone where microwave radiation is applied. The atoms of the sample emit radiation at a wavelength that is characteristic of each element. The detector then measures the intensity of this radiation; this information is processed by a computer system (Fig. 1).

Statistical Analysis

Data was analyzed using Minitab statistical software version 19.1 (Fachelli 2018). Descriptive statistics was used to calculate the means and standard deviations of heavy metal concentrations by vegetable species and place of origin. An Excel spreadsheet was used to compare the maximum levels allowed by Codex and the EU.

RESULTS

Table 1 shows the results of the heavy metal concentration levels analyzed in the 18 samples of tomato, onion, and celery from two origins.

Fig. 2 shows graphically the concentration of heavy metals according to the origin of the vegetables, where the concentration of arsenic in local and coastal celery was 0.31 and 0.30 $mg.kg^{-1}$, respectively. Likewise, the concentration of chromium for celery from the coast had the highest value reaching 0.33. While the chromium concentration levels for tomatoes were not reported. With respect to the high values of lead, it belongs to the tomato from the coast, and the lowest value can be seen in celery. Lead concentration levels for locally sourced celery showed the lowest concentration (0.15 $mg.kg^{-1}$), while tomatoes from the coast showed the highest values (0.21 $mg.kg^{-1}$).

Table 2 shows that lead exceeds the maximum permissible limits of the Codex Alimentarius (FAO/WHO) and Europe-

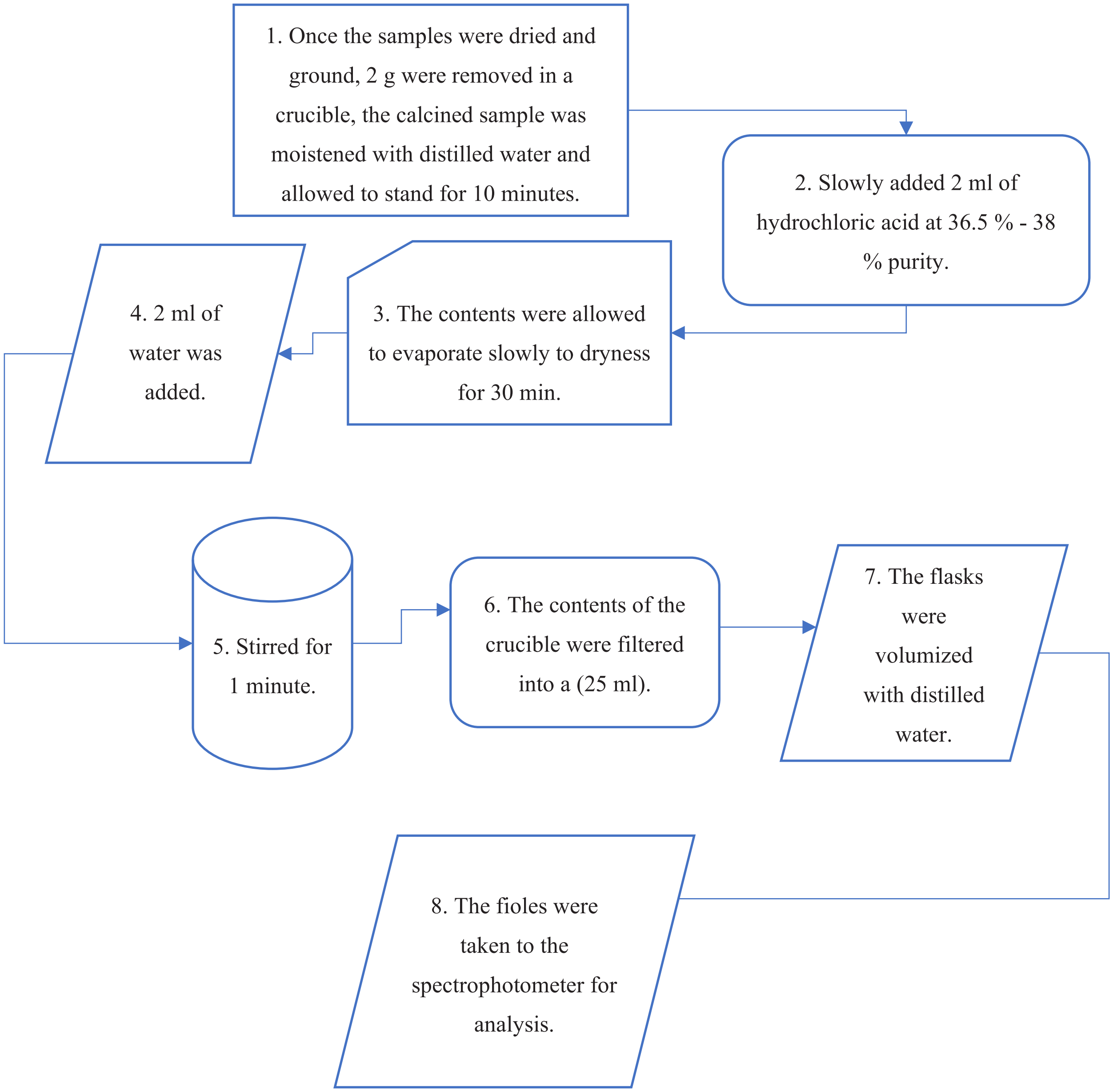

Fig.1: Flow chart of the heavy metal determination methodology.

Table 1: Heavy metal concentrations in vegetable species from two source locations (mean ± standard deviation in $mg.kg^{-1}$).

Cultivation	As	Cr	Cd	Pb
Local tomato	0.23 ± 0.08	0.00 ± 0.00	0.00 ± 0.00	0.18 ± 0.02
Tomato coast	0.25 ± 0.03	0.00 ± 0.00	0.00 ± 0.00	0.21 ± 0.04
Local onion	0.23 ± 0.08	0.01 ± 0.01	0.00 ± 0.00	0.20 ± 0.01
Onion Coast	0.22 ± 0.06	0.00 ± 0.00	0.00 ± 0.00	0.17 ± 0.01
Local celery	0.31 ± 0.05	0.03 ± 0.01	0.00 ± 0.00	0.15 ± 0.02
Celery coast	0.30 ± 0.02	0.03 ± 0.03	0.00 ± 0.00	0.17 ± 0.01

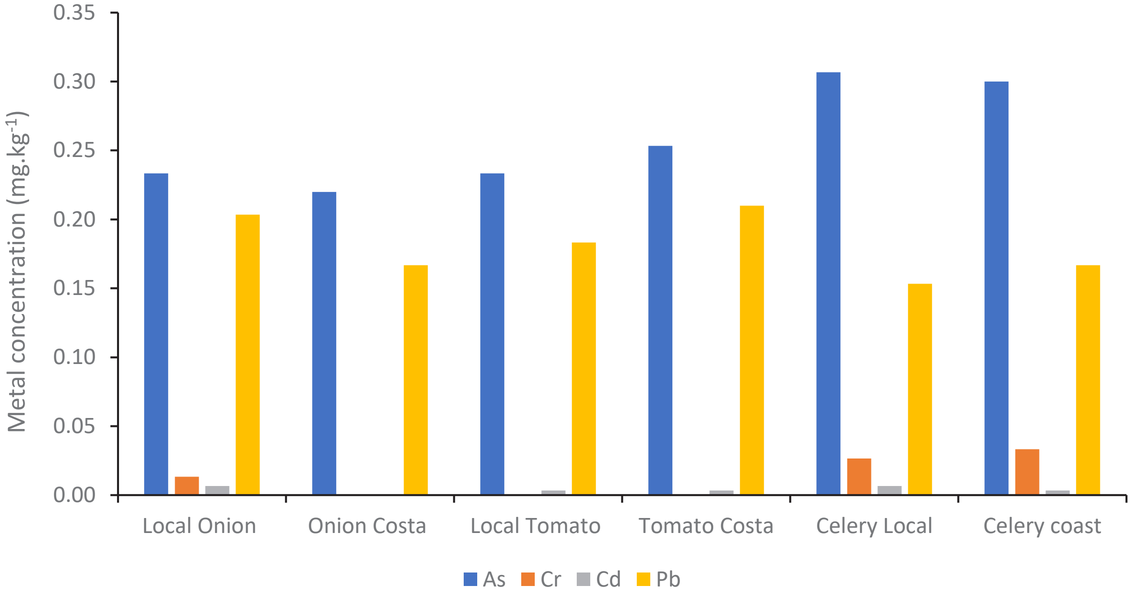

Fig. 2: Concentration of heavy metals for vegetables according to their origin.

Table 2. Concentration of heavy metals in vegetable species compared with the maximum permissible limits of international standards.

Parameters	Vegetables evaluated						Maximum allowable limit		
	Local Onion	Onion Costa	Local Tomato	Tomato Costa	Celery Local	Celery Coast	CODEX [mg.kg^{-1}]	UE [mg.kg^{-1}]	ECA SOILS [mg.kg^{-1}]
As	0.233	0.220	0.233	0.253	0.307	0.300	0.5	NC	50
Cr	0.013	0.000	0.000	0.000	0.027	0.033	NC	0.1	0.4
Cd	0.007	0.000	0.003	0.003	0.007	0.003	0.05	NC	1.4
Pb	0.203*	0.167*	0.183*	0.210*	0.153*	0.167*	0.1	0.1	70

ECA = Environmental Quality Standards for Soil; NC = Not covered by the standard; * = Values exceeding maximum permissible limits.

an Union (EU) food safety standards. The comparison with the Environmental Quality Standards (EQS) for soils is also shown.

DISCUSSION

High concentration of heavy metals is a risk to human health due to exposure during vegetable consumption (Birghila 2022). Arsenic in food can be acquired by the effects of volcanic ash, water, soil, and pesticides; it can also be due to the use of arsenic or phosphorus-based insecticides because they induce the accumulation of arsenic in plant tissues (Fiallos 2017). Another problem is the presence of arsenic, which may be due to the soils in which it is grown, the sediments, and the water used for irrigation (Chuan-Ping et al. 2012). However, due to crop permeation, the highest concentrations are directly related to mining regions and are becoming a global concern (Alonso et al. 2014, Tripathi et al. 2007).

The highest chromium concentration was 0.03 mg.kg^{-1} for local and coastal celery since celery can accumulate chromium in its edible and inedible parts (Wang et al. 2019b). Generally, the concentration of chromium is due to the natural components of the soil (Mihaileanu et al. 2019). Chromium in lower concentrations may help stabilize blood glucose levels; however, if these values were excessive, it would cause irregular heartbeat, and stomach upset (Järup 2003). Even worse if these vegetables are consumed without adequate washing (Nabulo et al. 2012).

Lead was the metal found in high concentrations in celery, onion, and tomato. Contamination is generally higher in plant foods, especially leafy vegetables, due to plant uptake and the existence of soil contaminated with this metal (Malavolti et al. 2020, Reyes et al. 2016). It may also be due to the use of agrochemicals such as pesticides and fertilizers, sewage sludge, and compost (Olivares 2013). It can also be attributed to other anthropogenic activities such as the dumping of paint and garbage dumps containing electronic parts (Ds et al. 2017). They may also be influenced by roadside crops (Nabulo et al. 2006).

Lead exposure occurs mostly through the food chain, and as long-term Pb intake through food can have negative health effects (even at relatively low levels), it is being researched for risk assessment of human health (Ćwieląg-Drabek et al. 2020). The irrigation of vegetables with wastewater should be monitored and controlled through some management plans, in order to avoid health risks for consumer groups (Atamaleki et al. 2019). To reduce contaminants such as heavy metals in crops, the transportation system and handling of agricultural products must be improved to reduce the introduction of heavy metals into crops (Onwuka et al. 2019).

With respect to lead concentrations, the highest level found was 0.21 ppm in tomatoes from the coast; this value is higher than the one obtained by Heshmati et al. (2020) (0.007 $mg.kg^{-1}$ for tomatoes). Likewise, Sharma et al. (2016), found elevated lead values (1.20 $mg.kg^{-1}$) in sites that were close to sewage drainage but irrigated with groundwater. In that regard, it is crucial to define corrective variables for future research, such as the principles of sound agricultural practices for consumer protection purposes (CODEX 1999).

It should be noted that the concentrations of heavy metals such as cadmium, chromium, and arsenic, compared to the limits established for vegetables (onion, tomato, and celery) both from the coast and from local sources, did not exceed the Maximum permissible limits established by the Codex Alimentarius (FAO/WHO) and European Union food safety standards. Donkor et al. (2017) also found that 18.99% of leafy vegetable samples had metal detections below the FAO/WHO reference values. However, studies show that the metal content varies greatly between samples (different origins), indicating that there is no standard composition (Çelik et al. 2018). The RCTs were significant for the comparison of the evaluated parameters because they served as a reference for the amount of heavy metals and other contaminants present in soils as a receiving body. They were also significant for the population's health because the levels of heavy metals in vegetables shouldn't pose a risk to human health or the environment (MINAM 2017).

CONCLUSIONS

The concentration of cadmium, chromium, and arsenic for tomato, onion, and celery vegetables sold in the Central Market of Chachapoyas from local and coastal sources did not exceed the maximum permissible limits established by the Codex Alimentarius (FAO/WHO) and European Union food safety standards. Lead concentrations in tomatoes, onions, and celery from local and coastal sources exceeded the maximum permissible limits established by Codex Alimentarius (FAO/WHO) and European Union food safety standards. Finally, future studies on vegetables are needed, with a larger number of samples, over longer periods of time, for the implementation of food safety measures.

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