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Evaluation of metals distribution in *Solanum lycopersicum* plants located in a coastal environment using micro-energy dispersive X-ray fluorescence imaging

Josu Trebolazabala [a], Maite Maguregui [b], Héctor Morillas [a,*], Alberto de Diego [a], Juan Manuel Madariaga [a]

[a] Department of Analytical Chemistry, Faculty of Science and Technology, University of the Basque Country UPV/EHU, P.O. Box 644, 48080 Bilbao, Basque Country, Spain
[b] Department of Analytical Chemistry, Faculty of Pharmacy, University of the Basque Country UPV/EHU, P.O. Box 450, 01080 Vitoria-Gasteiz, Basque Country, Spain

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ABSTRACT

The metal accumulation in edible parts of the plants is an important issue to provide a healthy food for the population. Some plants have the ability to take up certain trace elements from metal-polluted soils. Depending on the characteristics of the area and the environment where these plants have been grown, a different metal distribution can be observed on them. The aims of this work were to determine which are the general trends of metals distribution (e.g. K, Ca, Mn, Fe, Zn, Cu, Sr, etc.) in the different parts (roots, stems, leaves and fruits) of *Solanum lycopersicum* plants located in a seaside village (Barrika, Basque Country, North of Spain) and to asses if there is any potential dangerous accumulation in the edible part, the tomato fruit. Moreover, it was also evaluated if halogen elements (e.g. Cl, Br) emitted by the marine aerosol to the atmosphere are also highly distributed on these parts of *Solanum lycopersicum* plants. To perform this study a portable micro energy dispersive X-ray fluorescence spectrometer (μ-EDXRF) was used, which allows performing a mapping of each section of the plant in order to obtain the distribution of each element. The results obtained showed that a portable μ-EDXRF is a good analytical technique in order to know the distributions of these elements. Most of the elements identified in the roots, stem and leaves were not detectable in the fruit using this elemental technique. Moreover, it was detected the possible influence of the marine aerosol taking in to account the high distribution in all the parts of the plants of Cl and Br, except in the fruits.

1. Introduction

Metal homeostasis, is an emerging topic in the analysis of metal-l(oid)s accumulation and distribution in plants [1]. The location of different metals in specific parts of the plant provides information about its mobilization and transport inside it [2,3]. The interest of metal distribution in plants has gradually increased since it was established that hyperaccumulation in edible plants could be dangerous for human health [4]. Since polluting actions of the industry and human activities are well known, many studies have been carried out in order to evaluate which is the real condition of metallic pollution in soils [5,6]. Generally, these studies are useful in the analysis of the agricultural soils [7]. Apart from the soil pollution, a wide variety of fungi, vegetables and fruit trees are affected by these pollutant activities [8].

One important way of metal entrance or uptake in the plant is through the leaves stoma following air depositions [9]. However, metals mainly enter the plant through the roots [10]. After the absorption process, metals can migrate and be distributed throughout the plant [1]. Metal mobilization inside the plant can end up in two different ways. Firstly, metals can be accumulated or established in roots, stems or branches of the plant. Secondly, some plants have the ability to get rid of metals by accumulating these metals in their leaves. Occasionally, this could cause the subsequent senescence of the leaves. Specifically, the mechanism of tolerance or accumulation in some plants, apparently, is based on binding potentially toxic metals at cell walls of roots and leaves, away from sensitive parts inside the cell or storing them in vacuole compartment [11].

All this information can be used to improve the nutritional value of crops, to prevent the cultivation in soils with high content of toxic elements or to implement phytorremediation processes, for example [11, 12].

Tomato, one of the most consumed vegetables worldwide, has a high nutritional value. It is full of healthy benefits in prevention of many human diseases and tumours [13]. Nowadays, the distribution and speciation of metals in tomato plants is not completely understood [4].

Different authors have investigated metal distributions in tomato plants. R. Terzano et al. showed that Fe mainly accumulates in the external part of the root, but considerable amounts of this element can be

* Corresponding author.
E-mail address: hector.morillas@ehu.es (H. Morillas).

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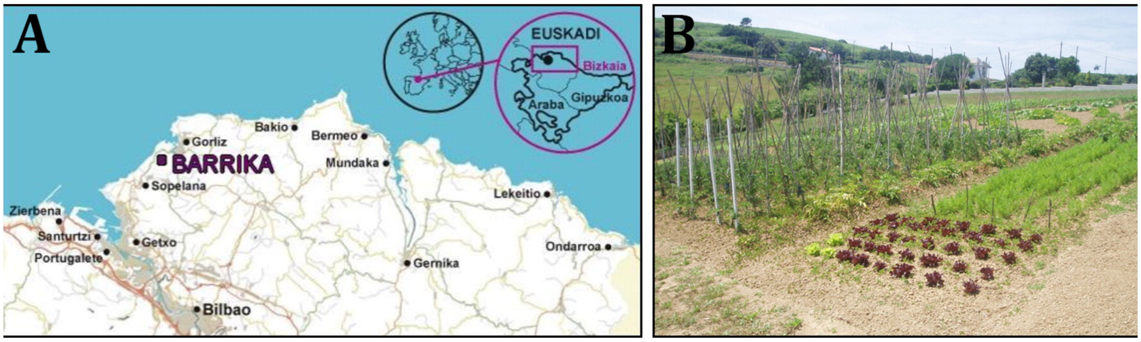

Fig. 1. (A) and (B) Location of the orchard in Barrika (Basque Country, North of Spain) where the tomato plants were collected.

found also in other parts inside the root (cortex, stele, vascular cylinders) [14]. Furthermore, N. Tomasi et al. evaluated the distribution of some metals in leaves of tomato plants. They observed that the concentration of Fe was significantly higher in the primary veins of the leaf. A similar behaviour was seen for K, Zn and Br. Moreover, while Cu and Ni were present mainly in the primary and secondary veins, Mn was homogeneously distributed over the leaf area [15].

The localization and distribution of elements inside the plant can be traced using many techniques, but spectroscopic methods are the most suitable ones. Some of them are non-destructive techniques that do not damage the sample and allow us to perform more than one measure on it if required [1]. Moreover, some spectroscopic techniques can be used to map a selected area of the sample, providing us an image that illustrates the distribution of a given element in the considered area [16]. The μ-EDXRF spectrometry is one of the most suitable and popular techniques within this category.

The aim of this study was to investigate the distribution of several elements in different sections or surfaces of different parts of *Solanum lycopersicum* plant (roots, stems, leaves and fruits). An easy-to-handle and relatively low-cost portable μ-EDXRF spectrometer was used to

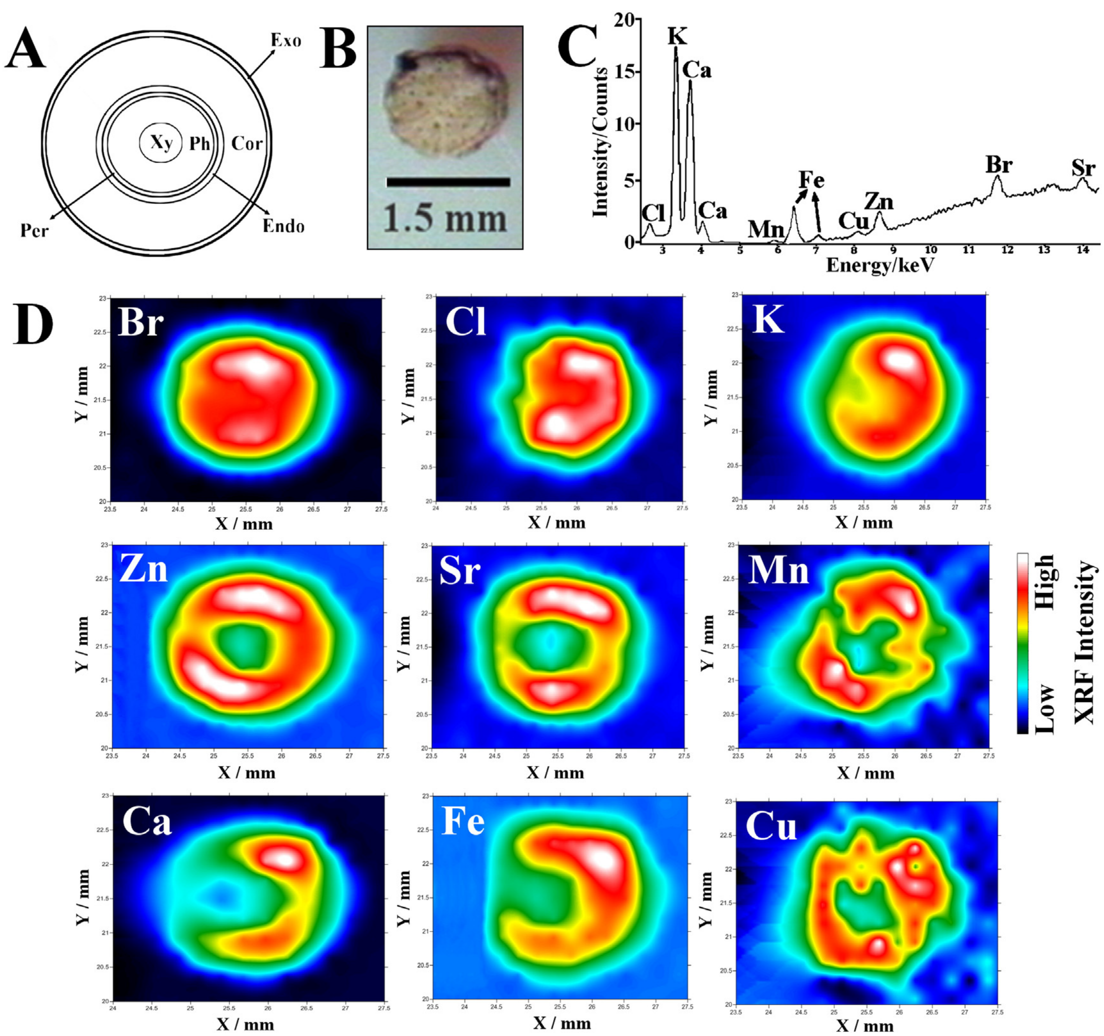

Fig. 2. (A) Different parts in a root section of a *Solanum lycopersicum* plant, (B) the mapped root section (2.25 mm^2, 220 μm step size), (C) the accumulated spectrum of the mapped area and (D) μ-EDXRF images showing the distribution of the different elements detected in the mapped area.