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Original

Trace elements and toxic metals in intensively produced tomatoes *(lycopersicom esculentum)*

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Abstract

Introduction: **Tomato is considered a healthy food due to its high content in lycopene and other health-promoting natural compounds. Tomatoes have, undoubtedly, assumed the status of a food with functional properties, considering the epidemiological evidence of reducing the risk of certain types of cancers.**

Objective: **Samples of tomatoes from Morocco were analyzed for the mineral composition.**

Methods: **94 tomato samples from Morocco were analyzed. Flame Atomic Absorption Spectrophotometry (FAAS) was used to determine essential elements (Copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn)) and Atomic Absorption Spectrophotometry with Graphite Furnace (GAAS) was used to analyzed cadmium (Cd) and lead (Pb).**

Results: **The mean concentrations were 0.17 mg/kg, 0.73 mg/kg, 0.20 mg/kg, 0.44 mg/kg, 7.58 μg/kg and 15.8 μg/kg for Cu, Fe, Mn, Zn, Cd and Pb, respectively. The highest contribution to the intakes was observed for Cu (0.67% for adults) while that Zn showed the lowest contribution (0.14% for adult males and 0.20% for adult females).**

Conclusions: **Tomatoes are a good source of essential elements for the diet, mainly iron and zinc. Tomatoes consumption does not significantly affect the intake of heavy metals.**

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Key words: *Morocco. Tomatoes. Essential elements. Toxic metals. Intake.*

METALES TRAZA Y METALES TÓXICOS EN TOMATES PRODUCIDOS INTENSIVAMENTE *(LYCOPERSICON ESCULENTUM)*

Resumen

Introducción: **El tomate es considerado un alimento saludable debido a su alto contenido en licopeno y otros componentes naturales promotores de salud. Indudablemente, los tomates han asumido el estatus de un alimento con propiedades funcionales, considerando desde un punto de vista epidemiológico reducir ciertos tipos de cánceres.**

Objetivo: **Analizar la composición mineral de muestras de tomates de Marruecos.**

Métodos: **94 muestras de tomates de Marruecos fueron analizadas. Espectrofotometría de Absorción Atómica por llama (FAAS) se usó para determinar elementos esenciales (Cobre (Cu), hierro (Fe), manganeso (Mn) y zinc (Zn) y Espectrofotometría de Absorción Atómica con cámara de grafito (GAAS) se usó para analizar cadmio (Cd) y plomo (Pb).**

Resultados: **Las concentraciones medias fueron 0,17 mg/kg, 0,73 mg/kg, 0,20 mg/kg, 0,44 mg/kg, 7,58 μg/kg and 15,8 μg/kg para Cu, Fe, Mn, Zn, Cd y Pb, respectivamente. La contribución a la ingesta más alta fue observada para el Cu (0,67% para adultos) mientras que el Zn presentó la contribución más baja (0,14% para hombres adultos y 0,20% para mujeres adultas).**

Conclusión: **Los tomates son una buena fuente de elementos esenciales para la dieta, principalmente hierro y zinc. El consumo de tomates no afecta significativamente a la ingesta de metales pesados.**

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Palabras clave: *Marruecos. Tomates. Elementos esenciales. Metales tóxicos. Ingesta.*

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Abbreviations

AESAN: Spanish Food Safety Agency.
FAAS: Flame Atomic Absorption Spectrophotometry.
GAAS: Graphite Furnace Absorption Spectrophotometry.
HNO_3: Nitric Acid.
NIST: National Institute of Standard and Technology.
PTMI: Provisional Tolerable Monthly Intake.
$PTWI_S$: Provisional Tolerable Weekly Intakes.
RDA_S: Recommended Daily Allowances.
SRM: Standard Reference Material.
TWI: Tolerable Weekly Intake.
b.w.: Body weight.

Introduction

Tomatoes *(Lycopersicon esculentum)* are one of the world´s major vegetables with an annual production of 121 million tons in 2005. Souss-Massa is the leading tomato producing region in Morocco and between 85-90% of its total production is exported to Europe.[1] the quality of the tomatoes they buy.[2] Therefore, producers have tried to improve the quality of the tomatoes they produce by introducing new agricultural practices, growing more productive varieties of tomatoes, and reducing their use of pesticides.[3]

The tomato is considered a healthy food due to its high content in lycopene and other health-promoting natural compounds.[4,5] Tomatoes have, undoubtedly, assumed the status of a food with functional properties, considering the epidemiological evidence of reducing the risk of certain types of cancers.[3,5]

Mineral element content analysis allows the evaluation of nutritional quality and helps to analyze if the bodily needs are covered.[5,6] RDAs (Recommended Dietary Allowances) are the daily levels of intake of essential nutrients judged to be adequate to meet the known nutrient needs of practically all healthy persons.[7] The actual daily requirements (RDAs) of an adult are as follows: 900 µg Cu/day for men and women; 8 mg Fe/day for men and 18 mg Fe/day for women; 2.3 mg Mn/day for men and 1.8 mg Mn/day for women; 11 mg Zn/day for men and 8 mg Zn/day for women.[8]

The determination of heavy metals in foods allows for the evaluation of risk, and this is part of every food safety program. Regulation (EC) 1881/2006 of the European Commission has set maximum levels for certain contaminants in vegetables establishing a maximum level of 0.05 mg/kg for Cd and 0.10 mg/kg for Pb.[9]

The EFSA's Panel on Contaminants in the Food Chain (CONTAM Panel) concluded that for cadmium the current Tolerable Weekly Intake (TWI) of 2.5 µg/kg body weight (b.w.) established in 2009 should be maintained in order to ensure a high level of consumer protection, including subgroups of the population such as children, vegetarians or people living in highly contaminated areas.[10]

Provisional Tolerable Weekly Intakes (PTWI) are set for substances, such as heavy metals, that are contaminants in food and are known to accumulate in animals and humans. PTWIs have been set for cadmium, lead, mercury and tin. The PTWI recommended by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) was previously 7 µg Cd/kg b.w.[11,12] In 2010 the JECFA reviewed the evaluation on cadmium and established a new provisional tolerable monthly intake (PTMI) of 25 µg/kg b.w. which corresponds to a weekly intake of 5.8 µg/kg b.w.[11]. For Pb, the PTWI set by JECFA is 25 µg Pb/kg b.w.[12,13]

Combining data on metal levels with information on food consumption allows for the estimation of metal intakes from a food group in population groups.[14] The dietary intake of each element was calculated by multiplying the concentration of the element in tomatoes by the mean consumption for this food group established in the most recent Spanish diet survey.[15]

Some studies highlight the fact that vegetables are an important route of metal transfer from the soil to the human consumer.[16-18] Others factors such as climate, agricultural practices (for example the addition of fertilizers and metal-based pesticides), transportation, harvesting processes, and storage and commercialization conditions could explain differences in the concentrations of trace and heavy elements in vegetables.[19]

The objectives of this study were: (1) to determine the levels of four essential metal elements (Cu, Fe, Mn and Zn) and two toxic heavy metals (Cd and Pb) in samples of tomatoes from Morocco, and (2) to estimate the contribution of the tomato consumption to the RDAs and PTWIs set for essential and toxic metals, respectively.

Materials and methods

Sampling collection

A total of 94 samples of tomatoes were studied. All samples were harvested between May 2008 and June 2009 and acquired from 20 farmer plots. Samples were collected in a proportional and representative way in accordance with quantities cultivated of the region.

Sample treatment and analytical procedure

Each tomato sample was washed in de-ionised water for 15-20 s to remove dirt and soil particles. 20 g of each sample was placed in a porcelain crucible and then oven-dried at 80º C for 48 h. Dried samples were subjected to pyrolysis in a muffle-oven at 450º C for 50 h. White ashes were dissolved in 5 % nitric acid (HNO_3) solution to a volume of 50 mL.[20]

Table I
Copper, iron, manganese, zinc, cadmium and lead recovery study

Element	*Material*	*Certified value (mg/kg)*	*Obtained value (mg/kg)*	*Recovery (%)*
Cu	SRM 1573a Tomato Leaves	4.70 ± 0.14	4.38 ± 0.21	93.2
Fe	SRM 1573a Tomato Leaves	358 ± 7.00	359.5 ± 4.30	97.7
Mn	SRM 1573a Tomato Leaves	246 ± 8.00	241.8 ± 6.90	98.3
Zn	SRM 1573a Tomato Leaves	30.9 ± 0.70	30.1 ± 1.20	97.4
Cd	SRM 1573a Tomato Leaves	1.52 ± 0.04	1.40 ± 0.10	92.1
Pb	SRM 1515 Apple Leaves	0.47 ± 0.024	0.44 ± 0.09	93.4

Essential elements (Cu, Fe, Mn and Zn) were then analyzed by Flame Atomic Absorption Spectrophotometry (FAAS) using a Perkin-Elmer 2100 spectrophotometer with air-acetylene (Wellesley, MA, USA). All analyses were performed in duplicate. Quantitation was performed using external standards (Merck IV, multielement standard solution) and all the standard curves were obtained at five different concentrations presenting a correlation coefficient ≥ 0.998.

Cd and Pb determinations were done by a Perkin-Elmer spectrophotometer model 4100 ZL Zeeman, equipped with a graphite furnace tube with an automatic sampler. A mixture of $NH_4H_2PO_4$ and $Mg(NO_3)_2$ was used as matrix modifier.

Quality control

Quality control of the analytical measurements was performed using blank samples and the following certified reference materials SRM 1573a (Tomato Leaves) and SRM 1515 (Apple Leaves) from the National Institute of Standard and Technology (NIST) (table I). No significant differences were observed between the levels measured and the certified values. The obtained recovery percentages with the reference materials were all above 92 %.

All glassware was washed with acid and rinsed with purified water.

Statistical analysis

All results were tested for normality with Kolmogorov-Smirnov and Shapiro-Wilk tests. Levene test was used to check the homogeneity of the variance. P values of < 0.05 were considered statistically significant.

Results and discussion

Essential elements and heavy metal contents detected in tomatoes from Souss-Massa are detailed in table II. Among all analyzed elements Fe was the most important trace element, with levels between 0.28 and 1.89 mg/kg, followed by Zn, Mn and Cu. Positive correlations among Fe, Cu and Mn at the 0.01 level and between Mn and Zn at the 0.05 level were detected.

Table III shows a comparison of the obtained element contents with results published in existing literature.[21-32] Tomatoes' trace element contents vary widely among different countries.

In general, the mean concentrations of the trace elements considered in this study were most similar to those obtained for tomatoes in Spain by Bakkali et al. (2009). Bangladesh and Turkey presented the highest tomatoes contents in micro-minerals compared with those found for other countries.

As for heavy metals, mean levels of Pb were higher than Cd contents. None of the samples in this study

Table II
*Mean levels of trace elements in tomatoes samples (mg/kg fresh weight or *µg/kg fresh weight)*

Element	*N.º*	*Concentration*			*Standard deviation*
		Minimum	*Maximum*	*Mean*	
Cu	94	0.02	0.56	0.17	0.12
Fe	94	0.28	1.89	0.73	0.37
Mn	94	0.06	1.11	0.20	0.15
Zn	94	0.08	1.16	0.44	0.34
Cd*	94	0.72	50.4	7.58	8.60
Pb*	94	5.00	85.8	15.8	12.2

Table III
Comparison of essential element in tomatoes from different countries (mean and/or range expressed in mg/100 g fresh weight)

Origin	*Ca*	*Fe*	*Mn*	*Zn*	*Reference*
Australia	–	–	2.00	–	[21]
Mexico	0.70	2.00	0.50	0.70	[22]
Arabia Saudi	0.45	6.02	0.74	1.44	[23]
Pakistan	0.23	–	–	0.25	[24]
Brazil	0.60	–	–	–	[25]
Egypt	0.18	–	–	0.77	[26]
Finland	0.40	2.90	1.80	1.20	[27]
Spain	0.24-0.32	1.80-2.19	0.54-0.63	0.69-0.86	[28]
Spain	0.27-1.39	0.62-1.38	0.24-0.60	0.97-3.60	[29]
Bangladesh	2.79	35.0	–	2.90	[30]
Spain	0.08	–	0.032	–	[31]
Turkey	12.9-18.7	1.98-2.41	-	64.8-78.4	[32]

Table IV
Comparison of toxic metals in fresh tomatoes from different countries (mean and/or range expressed in µg/kg)

Origin	*Pb*	*Cd*	*Reference*
Kuwait	23.3-32.1	13.8-31.1	[33]
Pakistan	1560	330	[24]
Brazil	0.02	2.50	[34]
Egyptian	0.26	0.01	[26]
Greece	90.0-119	1.00-8.00	[35]
Bangladesh	14150	2390	[30]
Spain	30.3-67.7	14.2-19.9	[32]

contained Pb or Cd levels that exceeded the limits established for vegetable products by European legislation.[9]

Table IV shows a comparison of the obtained heavy metal contents with results published in existing literature.[24,26,30,32-35] Heavy metals contents vary widely among different countries. Levels of heavy metals found in this study were lower than those obtained in several countries with exception of Brazil and Egypt. Bangladesh presents the highest lead (14,150 µgPb/kg) and cadmium (2,390 µgCd/kg) concentrations in tomatoes, perhaps due to low standards of environmental protection and contaminated soils and water.

In order to know the contribution of tomato consumption to the Recommended Daily Intakes and to evaluate the risk of dietary heavy metal exposure through tomato consumption, the daily consumption of tomatoes set by the Spanish Food Safety Agency (AESAN) has been used. According to this agency the estimated average consumption of tomatoes for the Spanish population aged between 17 and 60 years is 35.3 g/person/day.[16]

The estimated intakes of trace elements were compared to the Recommended Daily Allowances (RDAs) while the estimated intakes of lead and cadmium were compared to the Provisional Tolerable Weekly Intakes (PTWIs).

Table V presents the average daily trace element and heavy metal intakes based on a 35.3 g/person/day tomato consumption and their contributions to the RDAs and PTWIs. Within the micro-minerals, the highest contribution to the intakes was observed for Cu (0.67% for adults) while that Zn showed the lowest contribution (0.14 % for adult males and 0.20% for adult females). Due to the differences in Fe requirements among men and women, tomato consumption

Table V
Mean daily intake of tomatoes and contribution to the daily requirements of minor and heavy elements for men and women

	Intake (g/day)	*Contribution to the RDA (%)*		*Contribution to the PTWI[1]/TWI[2] (%)*	
		Males	*Females*		
Trace elements					
Cu	0.006	0.670	0.670	–	–
Fe	0.026	0.330	0.140	–	–
Mn	0.007	0.310	0.390	–	–
Zn	0.016	0.140	0.200	–	–
Heavy metals					
Cd*	0.270	–	–	1.080	0.466
Pb*	0.560	–	–	0.262	0.262

*Expressed in µg/day. [1]Referred to the FAO/WHO. [2]Referred to the EFSA.

contributions to the recommended Fe intakes are significantly different among sexes (0.33% for males and 0.14% for females, respectively). The estimated daily intakes of Pb and Cd due to the consumption of tomatoes are very low and contribute very little to the PTWI (0.45% for Cd and 0.26% for Pb, respectively).

Conclusions

This study can provide a better knowledge about macroelements, microelements and toxic metal contents in crops. Tomatoes are a good source of essential elements for the diet, mainly iron and zinc. A daily tomato consumption pattern contributes to the recommended dietary intakes of trace elements, mostly Cu. Tomatoes consumption does not significantly affect the intake of heavy metals. There is no toxicological risk caused by the daily consumption of tomatoes.

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