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ORIGINAL ARTICLE

Food Microbiology, Safety and Toxicology

Chemical risk assessment of conventionally and organically grown tomatoes in Côte d'Ivoire

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ABSTRACT

Background: The use of fertilizers in agriculture can be a source of contamination of fruits and vegetables. **Aims:** This study was to assess the level of contamination of tomatoes by heavy metals (Pb, Cd, Hg, and As), in order to assess the risks of exposure of consumers of tomatoes in Côte d'Ivoire. **Material and Methods:** More specifically, the assessment focused on the contamination by heavy metals used intensively by producers for the fertilization of vegetable crops. Four heavy metals (mercury, lead, cadmium and arsenic) were tested in tomato samples from both types of agriculture. **Results:** The average level of mercury in organic tomatoes (0.08290 ± 0.03 mg/kg) and in conventional tomatoes (0.1564 ± 0.1 mg/kg) exceeded the maximum limit (EC N 1881/2006). However, in organic tomatoes, only mercury level exceeded the required standard, the other heavy metals being present in trace amounts. The content of these other metals in the organic tomatoes exceeded the standard. However, the ratio (hazard quotient) of the weekly heavy metal intake to the provisional tolerable weekly intake for all heavy metals was less than one (1). **Conclusion:** Consumption of tomatoes from the areas in this study did not pose a health risk to the consumer.

Keywords: Organic agriculture, conventional agriculture, heavy metals, dietary exposure.

ARTICLE INFORMATION

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1 Introduction

Market gardening contributes to more than 33% of the world's agricultural production and employs 800 million people [1], which helps to reduce unemployment. Among the vegetables grown, the tomato (*Solanum lycopersicum* L.) occupies a prime position both nutritionally and economically. Tomato is the most consumed vegetable in the world [1]. According to the FAO [2], tomatoes are produced in more than 170 countries, with an estimated annual production of 163,963,770 tonnes, i.e., an average yield of 34.69 t/ha. This fruit-vegetable is the second most consumed fresh or processed food after the potato [3]. Furthermore, it is considered a "health" food because it is low in calories, rich in minerals and contains a variety of antioxidants. Tomato is a predominant source of antioxidants that are beneficial to health, such as carotenoids (lycopene and ß-carotene) and vitamins (ascorbic acid and α-tocopherol). Tomato production has been steadily increasing in recent decades worldwide. It has been reported that it increased from 48 million tonnes in 1978 to 177.042 million in 2016 [4,5].

In Côte d'Ivoire, as in the rest part of the world, the tomato is the most consumed vegetable because of its presence in all sauces and salads [2]. Tomato (*Lycopersicum esculentum*) cultivation is a lucrative activity for many producers [6], because

of its richness in minerals and its food uses. Annual production in Cote d'Ivoire fluctuates between 22,000 and 35,000 tonnes, coupled with a very high level of imports to meet demand. Imports of vegetables and fruit result in an outflow of foreign currency estimated at around 10 billion [7]. Tomato production in Côte d'Ivoire involves two types of agriculture, conventional and organic.

Organic and conventional vegetable crops play a key role in most nutrition programs. In addition, conventional agriculture is characterized by the use of high- yielding varieties and breeds, inputs to optimize production (fertilizers and pesticides) highly specialized and mechanized farms [8]. It is supposed to produce food with the longest possible shelf life. However, the development of tomato cultivation, such as other vegetable crops in our tropical regions, is beset by enormous difficulties [9]. The pesticides used influence environmental and climatic factors and on the other hand, the lack of high yielding varieties, supported by the persistence of rudimentary agricultural practices, which greatly reduce productions [9]. Thus, in order to improve yields and meet the ever-increasing market demand, the use of synthetic pesticides by producers is almost systematic [1,10], which could have harmful effects on humans and the environment.

The resistance of bio-aggressors to insecticides has been reported [11]. The consumption of these foods containing high levels of heavy metals can generate significant health risks for the population. To remedy the harmful effects on human health and the environment, some farmers have opted for organic market gardening in order to provide healthy products.

Organic gardening is defined as a production method that uses no or few synthetic inputs, such as synthetic fertilizers and pesticides or veterinary antibiotics [12] and respects the principles and logic of a living organism, in which all elements (soils, plants, livestock, insects, the farmer and local conditions) are closely related to each other [13]. It is supposed to produce food of higher nutritional quality, rich in protein, balanced in fatty acids and natural food (without traces of pesticides, or antibiotics) [13].

However, the products of this organic agriculture can be contaminated by heavy metals in the environment and in the soil. According to Amri et al. [14], heavy metals are serious environmental pollutants, especially in areas with high anthropogenic pressure. Their presence in the atmosphere, soil and water, even in trace amounts, can cause serious issues for all organisms. The accumulation of heavy metals in the soil is a concern in agricultural production because of their adverse effects on crop growth, food quality, consumer health and the environment [15]. Certain plant contamination occurs through root uptake or deposition of heavy metal-laden dust [16], followed by accumulation in the plant and transfer into the food chain [17].

The aim of this study was to assess the level of contamination of tomatoes by heavy metals (Pb, Cd, Hg, As) in order to assess the risks of exposure of tomato consumers in Côte d'Ivoire.

2 Material and Methods

2.1 Materials

The plant material consisted of two batches of ripe tomatoes. The first batch consisted of organically grown ripe tomatoes (*Solanum lycopersicum*) purchased from a greenhouse production site at Bounahouin in the Adzopé production zone (Côte d'Ivoire). The second batch consisted of conventionally grown ripe tomatoes purchased from a production site in the Abengourou production zone (Côte d'Ivoire). These two production zones are areas that supply most of the tomatoes that are consumed in Abidjan, the economic capital of Côte d'Ivoire. These two batches of tomatoes consisted of tomatoes of the Eva variety.

2.2 Methods

Sampling

The samples vegetables were purchased, and each batch of vegetable of the *Solanum lycopersicum* variety Eva was harvested in January 2022 at the orange ripening stage. The orange ripening stage is the stage most used by the population of Côte d'Ivoire. Immediately after harvesting, the fruits were arranged in batches in airtight boxes and transported to the Food Biochemistry Laboratory of the Swiss Centre for Scientific Research in Côte d'Ivoire (CSRS-Ci) where they were selected (fruits of the same size and free of mechanical damage and all kinds of stains), washed carefully with drinking water containing sodium hypochlorite (1%). After selection, one thousand (1000) tomatoes from each lot were selected for analysis. The triplet samples were collected each batch for this study making a total of six thousand samples.

Determination of the trace heavy metals

Atomic Absorption Spectrometry (AAS) was used for the determination of lead, cadmium, mercury and arsenic in tomatoes [18]. The samples were mineralized in the PTFE bomb by microwave radiation with addition of 2 cm^3 of nitric acid (3 min) and analyzed using a Pn 9100 Philips atomic absorption spectrometer.

Characterization of the hazard

The quantifiable hazard considered is the maximum tolerated human consumption limit per week and per kg body weight. The provisional Tolerable Weekly Intake

(DHTP) is 5 ug/kg bw/w, 25 ug/kg bw/w, 2.5 ug/kg bw/w and 0.15 ug/kg bw/w respectively for mercury, lead, cadmium, arsenic (EC Standard N° 1881/2006), where bw/w: body weight per week.

Estimation of exposure

The aim was to assess consumer exposure to heavy metals, and the intake of metal was calculated according to formula (1).

$$AHM = C*Q/ P \ldots\ldots\ldots (1)$$

AHM: Average weekly intake of metallic elements (ug/kg bw/w)
C: Concentration for each of the metal elements in the tomato
Q: Amount of tomatoes consumed per week per person
Q: 0.027 kg [19]
P: body weight of an adult = 70Kg

Determination of hazard quotient (QD)

The hazard quotient was obtained using the following formula (2):

$$QD = AHM /DHTP \ldots\ldots\ldots (2)$$

AHM: Average weekly intake of metallic elements
DHTP: Provisional Tolerable Weekly Intake
The result of the hazard quotient allows conclusions to be drawn about the potential occurrence of effects, but also about their significance. DQ< 1 means that the exposed population is not likely to develop the health effects under study.
DQ> 1 means that toxic effects are likely to occur in populations [20]

Statistical analysis

Descriptive statistics for chemical data were calculated with Excel (Microsoft, Redmond, WA). All statistical analyses were implemented in STATISTICA for Windows ver. 10 (Statsoft Iberica, Lisbon, Portugal). Parametric tests (one-way variance analysis with Duncan's test) at 5% significance level were performed to determine whether there were significant differences between agriculture type regarding chemical data collected.

3 Results

Heavy metal content of tomatoes

Table 1 summarizes the average heavy metal content of each type of tomato. The heavy metal content (mercury, lead, arsenic and cadmium) of organic tomatoes is below the EC N 1881/2006 standard. The arsenic content of organic and conventional tomatoes is below the standard. However, the mercury and lead content of conventionally grown tomatoes is higher than the standard. Of all the metals studied, mercury was more abundant in both types of tomato, with a predominance in conventionally grown tomatoes. The mercury content was 0.08290 ± 0.03 mg/kg in organic tomatoes compared with 0.1564 ± 0.1 mg/kg in conventional tomatoes.

Table 1. Heavy metal content of organic and conventional tomatoes

Agriculture type			
Heavy metals (mg/kg)	Organic tomatoes	Conventional tomatoes	Threshold limit (mg/kg)
Hg	0.0829 ± 0.03[a]	0.1564 ± 0.1[b]	0.1
Pb	0.045 ± 0.01[a]	0.0678 ± 0.03[b]	0.05
Cd	0.0123 ± 0.002[a]	0.01576 ± 0.07[a]	0.05
As	0.0378 ± 0.005[a]	0.04789 ± 0.02[a]	0.1

Organic tomatoes, tomatoes from organic farming; conventional tomatoes, tomatoes from conventional agriculture. In a line, the mean values followed by a different alphabetical letter are statistically different (p ≤ 005) (DUNCAN multiple t-test).

Heavy metal contamination levels in both types of tomatoes

The three (3) thousand organic tomatoes analyzed, 48% were contaminated with mercury, 27% with arsenic, 23% with lead and 2% with cadmium (Figure 1). As for the (3) thousand conventionally grown tomatoes, 58% were contaminated by mercury, 30% by lead, 28% by arsenic and 6% by cadmium (Figure 2). In both samples, mercury was the most abundant metal, and the conventionally farmed tomato samples were the most contaminated with all the metals studied. Mercury was the metal that contaminated the most tomatoes, regardless of the type of farming.

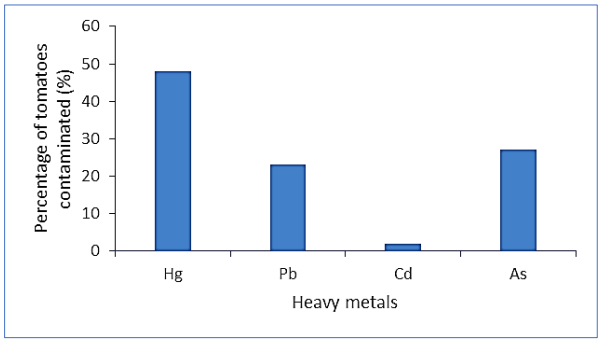

Figure 1. Heavy metal contamination rates in organic tomatoes
Nb: organic tomatoes, tomatoes from organic farming

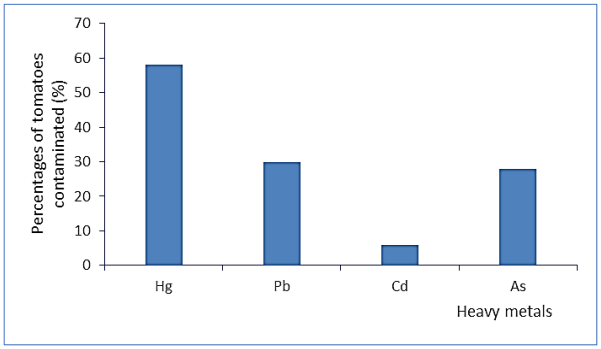

Figure 2. Heavy metal contamination levels in conventionally grown tomatoes

Nb; conventional tomatoes, tomatoes from conventional agriculture;

Estimation of inputs of Pb, Hg, Cd, As

The exposure of an individual consumption was estimated for organically grown tomatoes in Côte d'Ivoire per week to heavy metals revealed that the weekly heavy metal intake (AHM) value is 0.033 ug/kg bw/w; 0.01852 ug/kg bw/w; 0.0047 ug/kg bw/w; and 0.01458 ug/kg bw/w for mercury, lead, cadmium and arsenic, respectively. Taking into consideration the hazard quotient AHM/DHTP which is less than one (1) for all heavy metals in this study, the provisional tolerable weekly intake of organically grown tomato does not represent any health risk to the consumer. (Table 2). As for the calculation of the exposure of an individual consuming tomatoes from conventional agriculture in Côte d'Ivoire per week by heavy metals revealed that the value of the weekly heavy metal intake (AHM) is respectively 0.062 ug/kg bw/w, 0.026 ug/kg bw/w 0.006 ug/kg bw/w, 0.018 ug/kg bw/w for mercury, lead, cadmium and arsenic. Taking into consideration the hazard quotient AHM/DHTP which is less than one (1) for all heavy metals in this study, the provisional tolerable weekly intake of tomato from the conventional crop does not represent any health risk to the consumer (Table 3).

Table 2. Estimated heavy metal inputs in organic tomatoes

Elements	AHM (ug/kg bw/w)	DHTP (ug/kg bw/w)	AHM/DHTP
Mercury	0.033	5	0.0066
Lead	0.01852	25	0.00074
Cadmium	0.0047	2.5	0.00188
Arsenic	0.01458	0.15	0.0972

AHM: Average weekly intake of metallic elements; DHTP: Provisional Tolerable Weekly Intake; w: week; bw: body weight.

Table 3. Estimated heavy metal inputs in tomatoes from conventional agriculture

Elements	AHM (ug/kg bw/w)	DHTP (ug/kg bw/w)	AHM/DHTP
Mercury	0.062	5	0.0125
Lead	0.026	25	0.00104
Cadmium	0.006	2.5	0.0024
Arsenic	0.018	0.15	0.12

AHM: Average weekly intake of metallic elements; DHTP: Provisional Tolerable Weekly Intake; w: week; bw: body weight.

4 Discussion

The tomato is eaten in Côte d'Ivoire as a salad or cooked in a sauce. This tomato comes from either organic or conventional farming. These tomatoes may contain metals and pose a health hazard to the consumer. The primary objective of this study was to assess the level of contamination of tomatoes by traces of heavy metals (Pb, Cd, Hg, and As) in order to assess the risks of exposure of consumers of tomatoes in Côte d'Ivoire.

The results revealed the presence of residues of mercury, lead, cadmium and arsenic in both organically and conventionally grown tomatoes. In a study conducted in Algeria by Bounar et al. [16] heavy metals were found in tomatoes sold in that city. Similar results have been found in bananas, tomatoes, cucumbers, potatoes for human consumption by authors such as Dogheim et al, Parveen et al, Karavoltsos et al, Bahemuka and Mubofu, Pennington et al, Rahlenbeck et al. [21-26] in Tanzania, Pakistan and Egypt. This presence of heavy metals could come from the soils, the immediate environment in which production takes place. In addition, soils are places that naturally harbor heavy metals [27]. Mining, industrial and agricultural activities enrich water, air and soil with heavy metals [28]. Tomato crops grown on the soil will promote the accumulation of heavy metals in cassava roots. The use of chemical fertilizers for soil fertilization and sewage sludge are also sources of heavy metal contamination [29]. The presence of heavy metals in tomatoes could also be associated with various human transports, especially land transport [16].

Tomatoes from conventional agriculture were the most contaminated, in Côte d'Ivoire, most roads in the countryside are not paved, and this situation can expose tomato plants to dust and exhaust fumes from cars and motorbikes, which contain high amounts of heavy metals (lead, etc.). In addition, plant contamination occurs through root absorption, or deposition of dust loaded with heavy metals [16], followed by their accumulation in the plant [17]. In our study, tomatoes from conventional agriculture were more contaminated than those from organic agriculture. This could be explained by several reasons. Conventional agriculture uses chemical

fertilizers and the tomatoes are exposed to the air, which can carry heavy metals. These tomatoes are exposed to rain, while some authors have shown that due to human activities, rainwater can contain traces of heavy metals [29]. In all samples, the mercury content was high. Mercury is used in gold mining. In Côte d'Ivoire the phenomenon of illegal gold diggers has increased, especially in the central, eastern and northern parts of the country, and the tomato samples analyzed in this study are originated from these areas. These gold panners use mercury and therefore contaminate the soil and water. Once tomato plants are grown on these soils or watered with these waters, they will be contaminated [17]. As for the contamination of organically grown tomatoes, this could come from the water used to water the plants. Farmers use water from nearby wells or river to water their plants. This water could be contaminated with heavy metals from the environment.

The estimation of heavy metal intake, only the ratio of the weekly heavy metal intake and the provisional tolerable weekly intake for all heavy metals was less than one (1). Consumption of tomatoes from the areas in this study did not pose a risk to the consumer.

5 Conclusion

The primary objective of the current study was to evaluate the level of contamination of tomatoes by heavy metals (Pb, Cd, Hg, and As), and assess the risks of exposure of tomato consumers in Côte d'Ivoire. The study showed that tomatoes from organic and conventional farming contained heavy metals. The content of these heavy metals (mercury, lead, and cadmium) exceeded the EC standard N 1881/2006. Mercury was the most abundant metal in the tomatoes. The ratio of the weekly heavy metal intake to the provisional tolerable weekly intake for all heavy metals was less than one (1). Consumption of tomatoes from the areas in this study did not pose a health risk to the consumer. However, given the increase in illegal gold mining in the study areas, tomatoes in the future could present a health risk to the consumer.

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Authors' Contribution: The work was carried out in collaboration among all authors. C.N. and G.A.K. designed the study. K.K.A. performed the statistical analysis, drafted the protocol, and wrote the first draft of the manuscript. K.M J-P B. managed the analyses of the study, and M.K. managed the literature searches.

Conflicts of Interest: The authors hereby declare that there is no conflict of interest.

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