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Risk assessment of lead in wheat flour bread consumed in Benin

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ABSTRACT

Objective: Lead, like most other metallic trace elements, tends to accumulate along the food chain. For humans, studies have shown that the major toxic effect of lead (known as lead poisoning) during foetal development would be a lasting neurobehavioral deficit during childhood). The objective of the present study was to assess the health risks associated with the exposure to lead (Pb) by bread consumers in Benin.

Methodology and Results: Thus, three samples of the main breads (stick breads, sugared moderns, traditional sugared) identified in each of the three cities (Cotonou, Bohicon and Parakou) were purchased as replicates and transported to Laboratory in Cotonou to evaluate the Pb content. The study followed the protocol of the French standard NF-EN-14082 to perform the dosage of lead by atomic absorption spectrophotometry after dry incineration). The results indicated that bread from Cotonou and Parakou was very significantly ($p<0.001$) richer in lead compared to that from Bohicon. The average lead content obtained in Cotonou and Parakou was 5.84 ± 0.53mg/kg. Similarly, the weekly lead intake of bread consumers in the cities of Cotonou and Parakou (1.75mg) is higher than in Bohicon (0.62). The daily exposure dose varies between 1.4 µg/kg pc (Bohicon) and 4 µg/kg pc (Cotonou and Parakou) while the OMS Norm (2006) is 3.6 µg/kg pc. Since Lead can accumulate in various parts of the body through bioaccumulation, populations face major long-term health risks, particularly in Cotonou and Parakou.

Conclusion and application of results: These results show that the consumption of bread can expose to a risk of lead overdose and its long-term health consequences, especially in Cotonou and Parakou. This is a situation that involves the health control services and should lead them to review their standards and tighten their control mechanisms.

Keywords: Toxicity, Exposures, Risk, Lead, Bread, standards, Benin

RÉSUMÉ

Objectif : Les éléments métalliques, et donc le Plomb, même en traces ; peuvent s'accumuler à différents niveaux de la chaîne alimentaire pour devenir toxiques ; entraînant des perturbations neurocomportementales durables chez l'homme telle que la maladie du saturnisme. L'objectif de la présente étude est d'évaluer les risques d'exposition au Pb sur les consommateurs de pain au Bénin.

Méthodologie et Résultats : Ainsi, trois échantillons des principaux pains identifiés dans chacune des trois villes (Cotonou, Bohicon et Parakou) ont été achetés à titre de répétition et transportés au Laboratoire pour la détermination la teneur en Pb. Le protocole utilisé pour doser le Plomb est celui de la Spectrophotométrie d'Absorption Atomique après incinération sèche suivant la norme française NF-EN-14082. Les résultats indiquent que les pains provenant des villes de Cotonou et de Parakou sont très significativement ($p<0,001$) plus riches en plomb comparativement à ceux provenant de Bohicon. La teneur moyenne en plomb obtenue à Cotonou et Parakou est de 5,84 ± 0,53mg/kg. De même, les quantités de plomb consommées hebdomadairement par les consommateurs de pains dans les villes de Cotonou et Parakou (1,75mg) sont plus importantes que celles de la ville de Bohicon (0,62). La dose journalière d'exposition varie entre 1,4 µg/kg pc (Bohicon) et 4 µg/kg pc (Cotonou et Parakou) pendant que la norme OMS est de 3,6 µg/kg pc.

Conclusion et application des résultats : Ces résultats montrent que la consommation du pain peut exposer à un risque de surdosage en Plomb et de ses manifestations sanitaires à long terme, notamment à Cotonou et Parakou. Une situation qui interpelle les services de contrôles sanitaires et qui devrait les amener à revoir leurs normes et à durcir leurs dispositifs de contrôle.

Mots-clés : Toxicité, Expositions, Risque, Plomb, Pain, normes, Bénin.

INTRODUCTION

Bread is a universal staple in the human diet (Sahu *et al.,* 2016). In Africa, life standard is changing and the emergence of a new middle class is significantly changing the consumption habits of the population (Adou *et al.,* 2013) to impose ready-to-eat foods such as bread. However, a study conducted over the past four years by the French Food Safety Agency has measured the long-term risk of exposure to the chemicals that foods contain as well as their nutritional value. This study reveals that for a dozen substances or families of substances, the risk of exceeding the toxicological reference values "cannot be excluded". It may be foods "not necessarily highly contaminated but widely consumed", such as bread, containing lead, cadmium, and mycotoxins. Cadmium (Cd) and lead (Pb) are toxic heavy metals that can accumulate in the food chain through industrial production systems (Devasena *et al.,* 2012; El Sayed *et al.,* 2011). Due to their toxicity and non-biodegradable nature, these widespread heavy metals are an environmental and ecological problem (Chopra *et al.,* 2009; Miri *et al.,* 2017)). Concerning lead (Pb) essentially, it is one of the constituents of the earth's crust, so it is naturally present in the soil and subsoil. It can also come from certain industrial activities. Pollution linked to automobile traffic has dropped considerably in recent years due to the ban on the use of leaded gasoline. Lead, like most other trace metals, tends to accumulate along the food chain (Baba-Moussa *et al.,* 2006). According to Li *et al.* (2019), raw vegetable materials are likely to be contaminated by airborne releases or by lead in soil. For humans, studies have shown that the major toxic effect of lead during foetal development would lead to lasting neurobehavioral deficits during childhood (lead poisoning). For adults, lead has effects on the kidneys (increased prevalence of chronic kidney diseases) and the cardiovascular system

(increased systolic blood pressure). This metal causes the highest rate of poisoning among all metals (Li *et al.,* 2019). Common symptoms include abdominal pain, hyper blood pressure, tiredness, autism, muscle weakness, and more. The same study revealed that "bâtard" bread consumed in Cotonou and sweet bread consumed in Parakou, contain high Pb content (5.80±0.23 mg/kg and 5.88±0.54 mg/kg respectively) compared to those consumed in Bohicon in central Benin (2.07±0.36 mg/kg). Regarding the source of contamination, we found a non-negligible lead content of 4.03±0.4 mg/kg in several wheat flour samples, but lead contamination of bread can also come from the water used in bakeries and from dust around major traffic areas on bread exposed for sale (Baba-Moussa *et al.,* 2006; Kohzadi *et al.,* 2019; Ismail *et al.,* 2019)). Thus, the objective of the present study was to assess the risks of Pb exposure on bread consumers in Benin.

MATERIAL AND METHOD

Study Framework*:* The study was conducted in three cities (Cotonou, Bohicon, and Parakou) in Benin, located in the south, centre, and north of the country, respectively (Figure 1). The choice of these three cities is justified by (1) the number of bakeries registered in each of these cities based on the directory of the Ministry of Industry and Trade of Benin and according to the statistics of the National Association of Pastry and Bakery Chefs of Benin; (2) their geographical spread in the South, Center, and North of the country; and (3) the cultural differences that may influence bread-making processes due to geographical differences.

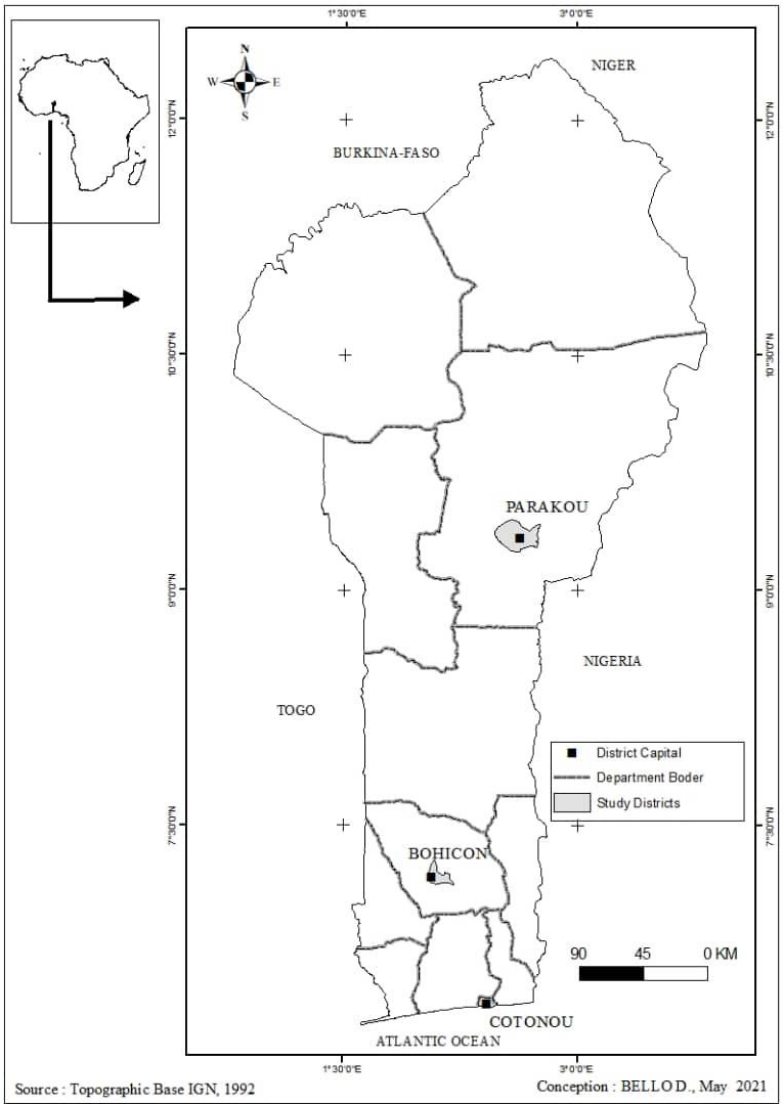

Figure 1: Map showing the study area

Method for sampling, determination of Pb content in bread samples, and assessment of lead risks

Method for sampling *and* determination of Pb content: The study on the typology of bread sold and consumed in Benin revealed that in the cities of Cotonou and Bohicon, "batard" bread is the most consumed, while sweet bread is the most consumed in Parakou. Thus, the study material is made of a set of nine bread samples, namely three samples of "batard" bread in the cities of Cotonou and Bohicon and three samples of sweet bread in the city of Parakou. The three samples were retained as a repetition. The places of purchase of the sample bread were chosen according to a zonal distribution to cover each city as well as possible. The batches of bread purchased in each locality were transported in sterile polyethylene bags to the "Laboratoire central du Contrôle de la Sécurité Sanitaire des Aliments" in Cotonou for the determination of Pb content. The determination of lead ; heavy metals which can cause serious physiological disorders on the nervous system, on the kidneys and on the bone marrow, was carried out by Atomic Absorption Spectrophotometry after dry incineration following the French

standard NF-EN-14082. The legally authorized maximum limit for Cadmium and Lead in wheat products is 0.2mg / Kg of product, according to CODEX STAN 193-1995. Once absorbed, these metals are often difficult to remove and the half-life of most of them in the human body is around 30 years (Feillet *et al.*, 2002). In the same way, the study carried out on the bread consumers and sellers in Benin allowed us to appreciate the quantities as well as the weight of bread sold in Benin.

Lead Risk Assessment: The lead risk assessment was conducted by comparing the amounts of Pb ingested by consumers to the recommended standards. The ingested amounts of lead were obtained using the following formula (Muhib *et al.*, 2016):

$Q_{Pb} = Q_P \times T$ where Q_{Pb} **(mg)** is the amount of lead ingested **per day;**

Q_P: **the amount of bread consumed per week (kg) and** T (mg/kg) is the lead content obtained in different types of bread.

Processing and statistical analysis of laboratory results: We used Microsoft Excel software to do the data entry and processing. We then used the Statistical Analysis System version 9.2 (SAS v. 9.2) to perform the one-factor analysis of variance (type of bread). Finally, we used the Student Newman-Keuls test with a threshold of 5% (probability level) to compare the average values between them.

RESULTS

Lead content in bread samples: Figure 2 presents the average lead (Pb) content determined in the different pieces of bread sampled. Analysis of this figure reveals that bread from the cities of Cotonou and Parakou is very significantly ($p<0.001$) richer in lead than those from Bohicon. The average lead content obtained in Cotonou and Parakou is 5.84 ± 0.53mg/kg.

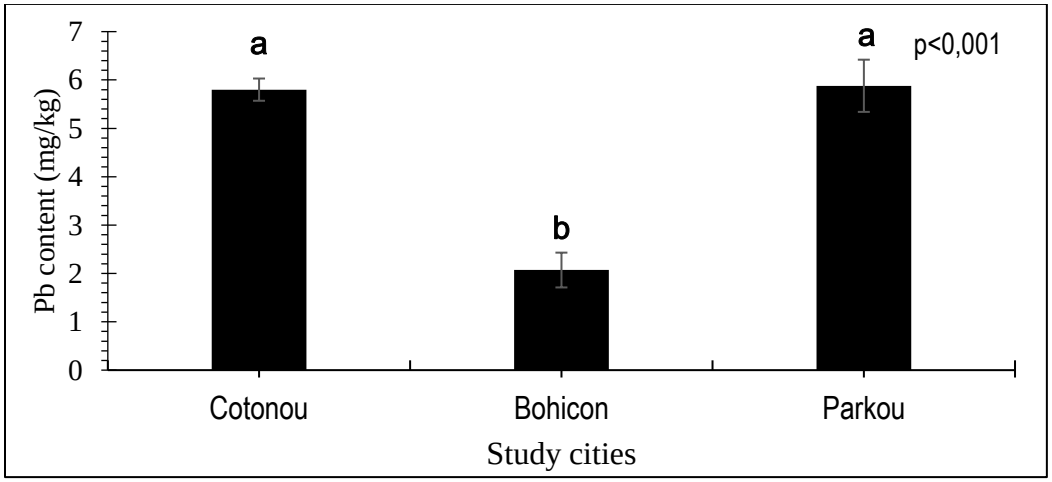

Figure 2: Pb and Cd content of analysed bread samples

Consumers' weight and bread quantity consumed in Benin: Table 1 presents the weight of consumers and the quantities of bread consumed in the three study cities. The analysis of the table reveals that on average, consumers weighing between 60 kg and 80 kg for the majority consume two pieces of bread (45%) per week. However, a significant number of people consume only one piece of "batard" bread (25%) on average per week. This bread consumption exposes these people to lead-related risks.

Table 1: Consumers' weight and quantities of bread consumed in the three study cities

Variables	Modalities	Bohicon (n= 86)[1]	Cotonou (n= 151)[1]	Parakou (n= 109)[1]	Total (n= 346)[1]
Average amount of bread consumed per week	One traditional sweet bread	1.20	15.80	26.60	15.60
	One baguette	26.70	22.50	31.20	26.30
	Two « batard »	48.80	53.00	41.30	48.30
	One bag of modern sweet bread	21.90	3.90	0.90	7.30
	One bag of modern salted bread	1.20	4.60	-	2.60
Weight of surveyed consumers	40 Kg ≤Weight ≤ 60 Kg	23.30	35.80	46.80	36.10
	60 Kg < Weight ≤ 80 Kg	53.40	53.60	45.90	51.50
	80 Kg < Weight ≤ 100 Kg	15.20	8.00	6.40	8.90
	Weight >100 Kg	8.10	2.60	0.0	3.50

[1]Number of surveyed consumers

Estimated lead-related risks in bread consumed in the three cities: The risk assessment of lead in bread consumed in the three cities was conducted by comparing the amounts of lead-containing bread consumed by consumers. The quantities of lead consumed weekly and the daily exposure dose are presented in table 2**.** The analysis of this table shows that the quantities of lead consumed weekly by bread consumers in the cities of Cotonou and Parakou are higher than those in the city of Bohicon. It follows that the risks related to lead in Cotonou and Parakou are greater than those in Bohicon.

Table 2: Amount of lead consumed weekly and daily exposure dose

	Amount of lead ingested per week (mg)		
Modalities	**Bohicon (n= 86)[1]**	**Cotonou (n= 151)[1]**	**Parakou (n= 109)[1]**
40 Kg ≤Weight ≤ 60 Kg 60 Kg < Weight ≤ 80 Kg 80 Kg < Weight ≤ 100 Kg Weight >100 Kg	0.62	1.74	1.76
Daily exposure dose (µg/kg pc)	1.4	4	4
OMS Norm (2006) (µg/kg pc)	3.6		

[1]Number of surveyed consumers

DISCUSSION

Throughout the study, it was found that the average Pb content in Cotonou and Parakou is 5.84 ± 0.53mg/kg while in Bohicon it is 2.07±0.36 mg/kg. These values obtained in bread consumed in the three cities are much higher than the Pb content (0.37 mg/L) obtained by Fuerst *et al.* (2006) in the wheat grains raised around some industrial areas. According to the authors, in industrialized countries, the quantity of Pb consumed by each person is around 200 to 300 µg per person and per day. The same numbers had been saved in many studies since 30 -40 years ago. This metal is distributed in all categories of food.

Muhib *et al.* (2016) found through their studies that the maximum lead concentration in the studied milk samples (0.37 mg/L) is almost twice the value reported in dairy cow milk in Bangladesh (0.20 mg/L). In their work on cow milk in India at several industrial units, Patra found a higher concentration of lead of 0.85 mg/l (Patra *et al.,* 2008. Lead (Pb) is one of the constituents of the earth's crust, so it is naturally present in the soil and subsoil but it can also originate from certain industrial activities. Nevertheless, pollution linked to automobile traffic has decreased significantly in recent years due to the ban on the use of leaded gasoline. According to Wild *et al* (2005), contaminated soils are the main process by which heavy metals, especially Pb, enter the food chain, particularly in bread, and then in humans and animals. For plants, work by Ramamurthy and Kannan (2009) showed that plants would seem to absorb Pb from the atmosphere during pro-photosynthesis. Human heavy metal exposure can occur through several channels, such as consumption of food plants grown on soil contaminated with heavy metals, consumption of contaminated drinking water, and inhalation of dust (Baba-Moussa *et al.,* 2006; Kohzadi *et al.,* 2019; Ismail *et al.,* 2019). Excessive ingestion of heavy metals such as Pb, Cr, and Cd in food can lead to serious health problems for humans in the short or long run (Ismail *et al.,* 2019. To better address the relatively high toxicity of heavy metals in the human body, there are allowable limits for the concentration of lead in milk set by regulatory agencies (Ismail & al., 2019. In India, for example, the standard limit for lead in milk is 0.02 mg/kg (FSSAI, 2011). The same value is recommended by the European Union (EU, 2006). In humans, the major toxic effect of lead during foetal development would result in a long-lasting neurobehavioral deficit during childhood (lead poisoning). For adults, lead has effects on the kidneys (increased prevalence of chronic kidney disease) and the cardiovascular system (increased systolic blood pressure). Lead, like most other trace metals, tends to accumulate along the food chain. For humans, exposure comes primarily from drinking water pipes as well as from old paint containing lead. According to the French Total Diet Study (2011), beverages contribute to 14% of human exposure, bread and bakery products to 13%, and water to 11%. For children, milk appears to be the major contributor (11%) with water (11%) and soft drinks (10%) (Maton, 2012). Based on the results of the present study, daily lead exposure ranges from 1.4 µg/kg bw and 4 µg/kg bw for bread consumers. These values are significantly higher than those obtained elsewhere. In their work on the assessment of the Ivorian population's exposure to trace metals (cadmium, mercury, lead) through the consumption of imported beef and pork meats and offal, Akesse (2014) found lead amounts in bread samples ranging from 0.0875 to 0.7840 µg/g, values above the acceptable limit. In France, the average population exposure is estimated to be 0.20 µg/kg body weight/day in adults and 0.27 µg/kg bw/day in children. The values obtained at Bohicon (1.4) are lower than those recommended by the WHO in 2006, while those from Parakou and Cotonou are higher. Bakers must ensure that bread production facilities and their surroundings are well maintained and properly treated. This study also highlights the importance of routine checks by regulatory authorities to ensure that bakers are always complying with rules and regulations to protect people's life. Similarly, lead levels found in the bread samples analysed are above the maximum limit of 0.2 mg/kg in cereals prescribed by CODEX STAN 193-1995. The lead could come from the soil of the wheat cultivation, from the moulding equipment, or even from the exposure of the bread to intense traffic. Knowing that lead can accumulate in various parts of the body through bioaccumulation, the population of Cotonou and Parakou, is at great risk of long-term health problems.

CONCLUSION AND APPLICATION OF RESULTS

In the end, it appears that the bread sampled in the three municipalities of study contain a certain quantity of Pb. These Pb contents largely exceed the standard recommended by the European Union (EU, 2006). However, the risks associated with Pb exposure are greater in the communes of Parakou and Cotonou than in Bohicon. As, lead can accumulate in various parts of the body through bioaccumulation, the population faces significant long-term health risks, particularly in Cotonou and Parakou. These results are warnings for the health control services who should be inspired to review their standards and tighten their control mechanisms.

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