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FOOD RISKS RELATED TO THE PRESENCE OF HEAVY METALS (LEAD AND CADMIUM) IN THE MEAT AND EGGS OF HENS COLLECTED FROM FARMS IN CÔTE D'IVOIRE (ABIDJAN AND AGNIBILÉKROU)

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ABSTRACT

Contamination of foodstuffs by heavy metals is a major public health concern due to their persistence in the environment, their ability to accumulate in living organisms, and their toxic effect on humans. This study aims to assess the food risks related to the presence of heavy metals (lead and cadmium) in the meat and eggs of hens collected from farms in Côte d'Ivoire (Abidjan and Agnibilékrou). A survey based on food frequency was conducted. Twelve (12) composite samples of hen meat and thirty-six (36) eggs were collected across the two zones (Abidjan and Agnibilékrou). The analysis was performed using a VIARIAN brand atomic absorption spectrophotometer (AAS) series SPECTRAA 110 equipped with a graphite furnace and a sample feeder at different characteristic wavelengths of the studied heavy metals: 217 nm for lead and 228.8 nm for cadmium. The results show that the average daily exposure dose to cadmium (0.47 µg/kg bw) through consumption of hen meat and eggs is higher than that of lead (0.16 µg/kg bw). The hazard ratios (HR) of the surveyed populations are below the value of 1. Therefore, individuals exposed to the toxins (lead and cadmium) through consumption of hen meat and eggs are not at risk.

Keywords: Food Risks; Heavy Metals; Abidjan; Agnibilékrou; Eggs; Chicken Meat

1 INTRODUCTION

Pollution, whether of natural or anthropogenic origin, constitutes a major problem worldwide [1]. Among the different forms of pollution, chemical pollution caused by the presence of chemical substances in the environment is found. Their presence in the environment is responsible for the contamination of environmental matrices, and their transfer to humans occurs through food consumption [2].

In Côte d'Ivoire, chicken meat and eggs represent important sources of animal protein and are widely consumed by the population [3]. However, these foodstuffs can be exposed to various chemical contaminants such as trace metal elements (lead and cadmium). Lead and cadmium can originate from the environment, raw materials used in the manufacture of poultry feed, or certain anthropogenic activities [4]. These chemical pollutants can be transferred and accumulate in animal organisms, then enter the human food chain. Studies conducted by Acho et al [5] in Côte d'Ivoire showed the presence of lead and cadmium in eggs marketed in Abidjan. In this context, Abidjan, a major poultry production and consumption area, and Agnibilékrou, an important breeding area located in the east of Côte d'Ivoire, constitute sites of interest for the assessment of contamination of poultry products.

This study is part of an approach to food safety and consumer health protection. It aims to assess the food risks related to the consumption of chicken meat and eggs contaminated by trace metal elements (lead and cadmium).

2 MATERIALS

2.1 Presentation of the study areas

The study was conducted in areas located in the east-central and southern parts of Côte d'Ivoire, specifically in the Agnibilékrou department (7°7'49.012'' North, 3°12'11.074'' West) and in the Abidjan district (kilometre 17 point) (5°19'0.001'' North, 4°1'59.999'' West). The choice of these two cities is justified by the fact that they are the largest poultry production cities in Côte d'Ivoire.

2.2 Study materials and quality of products used

The study materials consist of chicken meat (Gallus gallus) and hen eggs collected from farms in Agnibilékrou and Abidjan, specifically in Yopougon (kilometre 17). The reagents used in this study include 69% pure nitric acid, 30-33% hydrogen peroxide, and distilled water, which were respectively used to digest the test samples, oxidize traces of oils and fats, and dilute the solutions after mineralization.

3 METHODS

3.1 Food survey

The food survey provides a more precise understanding of dietary habits. It was conducted in the municipalities of Yopougon, Macory, and Cocody. The choice of these municipalities was motivated by the fact that the chickens sold in the markets of these municipalities come from Abidjan (kilometre 17 point) and Agnibilékrou. The objective of the survey is to know the quantity of chicken made available to the populations in order to have an idea of the quantities consumed daily per person. Consumption per person was obtained by dividing the total quantity of chicken meat purchased by the number of consumers. This ratio is given by the following formula: Y =

- Y: Quantities of chicken or eggs consumed per person (g)
- n: Number of chickens or eggs purchased
- P: Weight of the chicken after cooking (g)
- N: Number of people consuming the chicken meat.

3.2 Sampling of chicken meat

Sampling of chicken meat was carried out on three (03) farms in Agnibilékrou and two (02) farms in the Abidjan district near kilometre point 17. In Agnibilékrou, the sampling consisted of randomly collecting thirty (30) chickens per poultry farm, divided into batches of five (05) chickens, i.e., six (06) batches per farm. A composite sample of chicken meat was taken from each batch of slaughtered chickens, corresponding to six (06) composite samples per farm. Thus, eighteen (18) chicken meat samples were collected from the three (03) farms in total. The same sampling was carried out in Abidjan. In total, twelve (12) composite chicken meat samples were collected from the two farms in the Yopougon municipality. All samples were placed in food-grade bags, then kept in a cooler with ice packs and transported to the laboratory.

3.3 Egg sampling

Eggs were randomly collected from three (03) farms in Agnibilékrou and two (02) farms in Abidjan. In Agnibilékrou, three (03) trays of eggs (one (01) tray per farm) and two (02) trays of eggs in Abidjan were assembled. Egg samples were formed by randomly selecting eggs from each tray. Thus, eighteen (18) eggs were collected in the Agnibilékrou region due to six (06) eggs per tray and eighteen (18) eggs in Abidjan due to nine (09) eggs per tray. In total, thirty-six (36) eggs were collected from the two sites for metal analysis.

3.4 Analysis methods

3.4.1 Experimental protocol

The treatment of chicken flesh was carried out by taking a mass of 0.5 g of ground chicken flesh and then homogenized using a turbo grinder. 5 mL of nitric acid (HNO3) at 65% and 2 mL of hydrogen peroxide (H2O2) at 30% were added to the grind. The mixture was then placed in an ETHOS Milestone microwave oven at 200°C for 45 minutes. After cooling, the mineralizate was recovered in a 25 mL flask with 10 mL of hydrochloric acid solution at 37% and filled to the mark with bidistilled water and stored until analysis. As for the egg samples, the liquid contained in the shells (the egg white and yolk) is homogenized in a 200 mL beaker. 0.5 g of this mixture is weighed in a crucible and calcined at 500°C for 2 hours in an ETHOS Milestone microwave oven. To the obtained ashes, 10 drops of bidistilled water and 4 mL of nitric acid solution (HNO3) at 65% were added. The resulting solution is evaporated to dryness on a hot plate at 100°C then calcined again at 500°C for 1 hour. After cooling, the ashes are moistened with 10 mL of hydrochloric acid solution at 37%. The mixture is filtered into a 50 mL volumetric flask and filled with bidistilled water up to the mark.

3.4.2 Instrumental analysis

For the dosage of lead and cadmium, a blank and two (02) series of standard solutions with known concentrations were prepared in order to plot the calibration curve for each studied heavy metal. The solutions obtained after acid digestion of chicken meat and egg samples were measured using a VIARIAN brand atomic absorption spectrophotometer (AAS) model SPECTRAA 110 equipped with a graphite furnace and an autosampler at different wavelengths: 217 nm for lead and 228.8 nm for cadmium. Each sample was analysed three (3) times with a measurement time of five (5) seconds. The retained value is the average of the three measurements. Concentrations are calculated using the following formula: C= with:

$$\frac{[\varphi - C_{blanc}] \times V}{M}$$

- C= Metal concentration (mg/kg)
- φ= Concentration measured by AAS (mg/L)
- Cblank= Concentration of the blank (mg/L)
- V= Final volume of the solution (L)
- M= Mass of the sampled specimen (kg)

3.4.3 Evaluation of food risks

The considered risk arises solely from exposure through ingestion of the food, which is chicken meat and eggs. The method used is the internationally recognized assessment model [6]. This method is divided into four (04) main steps: identification of potential hazards, hazard characterization, exposure assessment, and food risk characterization. To assess the population's exposure to heavy metals, two (02) data sources provided by the food questionnaire were taken into account. These are the average amount of chicken meat and eggs consumed daily per person and the average mass of the surveyed individuals. The assessment of the population's exposure to heavy metals was carried out by calculating the theoretical exposures (maximum theoretical daily intake: AJMT) and estimated exposures (estimated daily intake: AJE) according to the following formulas: AJMT=Σ (MRL × Qi) with MRL being the maximum residue limit of a given pollutant and Qi the mass of a food i. AJE= Σ (Cp × Qi) with Cp being the actual concentration of a given pollutant and Qi the mass of a food i. To obtain the theoretical or estimated daily intake, simply calculate the quotient of the AJMT or AJE by the body mass.

To characterize the food risk, a hazard ratio (HR) is calculated for substances with a threshold effect, that is, substances for which an effect occurs beyond an administered dose. If the HR < 1, the population is theoretically at no risk. However, if the HR > 1, toxic effects are likely to occur in the exposed population.

To characterize the food risk due to substances without a toxicity threshold, an individual risk excess (ERI) is calculated according to the formula ERI = DJE × ERU. The calculated ERI is compared to an acceptable risk value of 10-5. If ERI < 10-5, the risk is acceptable. If ERI > 10-5, there is occurrence of carcinogenic or mutagenic effect [9]. In the expression of ERI, T and Tp denote respectively the exposure duration and the weighting time. ERU is the unit risk excess.$\frac{T}{Tp}$

4 RESULTS AND DISCUSSION

4.1 Average weight of surveyed individuals and daily consumption of chicken meat and eggs

The average weight of surveyed individuals is 64.19 kg. The quantity of chicken meat and eggs consumed daily per person was determined. It is 160.49 g and 77.48 g respectively for chicken meat and eggs across the three (03) zones (Yopougon, Cocody, and Marcory).

4.2 Contamination level

The contents of chicken meat and eggs obtained by ACHO et al (2019) [5] are recorded in tables 1 and 2

Table 1: Contamination level of chicken meat by metals

Locality	**Abidjan**		**Agnibilékrou**	
Sought elements	Lead	Cadmium	Lead	Cadmium
% contaminated sample.	100	100	100	100
Detected levels (mg/kg)	0.067 ± 20	0.302 ± 30	0.060 ± 30	0.089 ± 70
MRL (EU) mg/kg	0.10	0.05	0.10	0.05

Table 2: Contamination level of eggs by metals

Locality	**Abidjan**		**Agnibilékrou**	
Elements searched for	Lead	Cadmium	Lead	Cadmium
% of contaminated sample.	100	100	100	100
Detected levels (µg/kg)	0.067 ± 0.02	25.96 ± 15.24	0.35 ± 0.09	35.46 ± 14.04

The results show that all the guinea fowl meat samples analyzed in the Abidjan locality contain lead and cadmium with respective contents of 0.067 mg/kg and 0.302 mg/kg. The same applies to samples from Agnibilékrou with concentrations of 0.060 mg/kg for lead and 0.089 mg/kg for cadmium. This contamination of guinea fowl meat by metals could be justified by the contaminated food ingested by the birds. Indeed, shellfish and crustaceans that are part of the formulation of poultry feed are natural accumulators of cadmium (Francklin, 2007). Regarding the level of contamination of eggs by metals, lead and cadmium were detected in all egg samples collected from the two areas (Abidjan and Agnibilékrou) with respective concentrations of 0.067 µg/kg and 25.96 µg/kg in Abidjan and 0.35 µg/kg and 35.46 µg/kg in Agnibilékrou. These high concentrations of cadmium found in egg samples from Abidjan and Agnibilékrou could be justified by the high concentrations of cadmium found in guinea fowl meat. The exceedance of the MRL for cadmium in guinea fowl meat in both areas (Abidjan and Agnibilékrou) and the cumulative nature of lead led to an assessment of the risks related to the consumption of guinea fowl meat and eggs.

4.3 Food risk assessment

4.3.1 Hazard identification and characterization

Lead and cadmium found in guinea fowl meat and egg samples are likely to present threshold effects as well as non-threshold effects. Among the threshold effects are abdominal pain, vomiting, and neurological disorders [7], [8]. In the case of non-threshold effects, the hazard may manifest through the occurrence of genetic mutation [9], [10].

4.4 Exposure assessment

4.4.1 Theoretical maximum daily intake (TMDI) and percentage of the ADI

The calculation of the theoretical maximum daily intake was done only at the cadmium level because the lead concentration found in chicken meat is below the maximum residue limit (MRL). Since the MRL is not set for eggs, the TMDI cannot be calculated for this food. The TMDI and the percentage of the PTDI for cadmium are mentioned in Table 3.

Table 3: Theoretical maximum daily intake and percentage of the PTDI

Food	**Amount of food consumed/day (g)**	**MRL (mg/kg)**	**PTWI (µg/person/day)**	**Theoretical TDI = PTWI/BW**	**% DJA**
Chicken flesh	160.49	0.05	8.02	0.125	12.5

According to these results, the ratio found is 12.5%. Since this ratio is below 100% of the PTDI, the calculation of the EDI is not necessary. However, given the abnormal presence of cadmium observed in chicken meat, we deemed it necessary to calculate the EDI, which is a much closer estimate of actual exposure.

4.4.2 Estimated daily intake (EDI) and calculation of the ADI

The EDI and ADI related to the consumption of chicken meat and eggs were calculated based on the estimated average quantities of chicken meat and eggs consumed as part of the most complete dietary ration, the residue concentrations found in chicken meat and eggs, and body weight (64.19 kg), a value derived from the dietary survey. The results of the estimated daily intake (EDI) and the calculation of the ADI are recorded in Table 4.

Table 4: Estimated daily intake (EDI) and calculation of the ADI

		Lead	**Cadmium**	**Lead**	**Cadmium**
Food	Amount of food consumed/day (g)	Conc (µg/kg)		AJE (µg/pers/j)	
Chicken meat	160.49	63	174.6	10.11	28.02
Eggs	77.48	0.16	29.13	0.012	2.26
Total AJE (µg/pers/day)				10.122	30.28
DJE = AJE/PC (µg/kg bw)				0.16	0.47
% DJA = $\times$100				4.44	47

It appears in this table that from the daily adsorption of 10.122 µg of lead and 30.28 µg of cadmium, there results an exposure of 0.16 µg to lead and 0.47 µg to cadmium for an adult weighing 64.19 kg. The average daily exposure dose to cadmium (0.47 µg/kg bw) through the consumption of chicken meat and eggs is higher than that of lead (0.16 µg/kg bw). These values are below the ADIs, which are 3.6 µg/kg bw and 1 µg/kg bw respectively for lead and cadmium. These results indicate that the risk is very low when consuming chicken meat and eggs [11]. The levels of lead and cadmium detected in chicken meat and eggs could change and have harmful effects on human health; therefore, the consumption of these products could represent a food risk for populations.

4.5 Characterization of food risk

In the case of threshold effects, the hazard ratios are shown in Table 5

Table 5: Hazard ratios for lead and cadmium

	Lead DJA = 3.6 µg/kg bw/day	**Cadmium DJA = 1 µg/kg bw/day**
RD = DJE/DJA	0.04	0.47

The hazard ratios (HR) of the surveyed populations are below the value of 1. Individuals exposed to toxins (lead and cadmium) through the consumption of chicken meat and eggs are not at risk. They are unlikely to develop health effects such as abdominal pain and neurological disorders [12]. However, it should be kept in mind that lead and cadmium have repeated toxic effects without a threshold (carcinogenic and mutagenic effects) [13]; therefore, it is necessary to calculate the individual excess risk (IER). Table 6 presents the calculation of the individual excess risk.

Table 6: Individual excess risk due to lead and cadmium.

Metals	ERU (µg/kg bw/day) (INERIS, 2011)	DJE (µg/kg pc/j)	ERI (μg^2 /kg^2)
Lead	8.5	0.16	$7.29.10^{-7}$
Cadmium	0.2	0.47	$5.04.10^{-8}$

The individual excess risk for each pollutant (lead and cadmium) calculated is below 10-5 (guideline value set by WHO), so there is no risk of cancer occurrence in the surveyed population.

5 CONCLUSION

This work allowed us to assess the food risks related to the presence of heavy metals (lead and cadmium) in the meat and eggs of chickens sampled from farms in Côte d'Ivoire (Abidjan and Agnibilékrou). The results of the dietary survey showed that the average weight of the surveyed individuals is 64.19 kg and the amount of chicken meat and eggs consumed daily per person is 160.49 g and 77.48 g respectively for chicken meat and eggs across the three (03) zones (Yopougon, Cocody, and Marcory). The samples of chicken meat and eggs taken from farms in Abidjan and Agnibilékrou were contaminated by metals (lead and cadmium). Cadmium shows the highest levels in chicken meat in both zones (Abidjan and Agnibilékrou) with concentrations exceeding the Maximum Residue Limit (MRL). The results of the population exposure assessment showed that from the daily intake of 10.122 µg of lead and 30.28 µg of cadmium, there results an exposure of 0.16 µg to lead and 0.47 µg to cadmium for an adult weighing 64.19 kg. The food risk assessment revealed no food risk for populations consuming chicken meat and eggs sampled from farms in Abidjan and Agnibilékrou.

Looking ahead, repeated awareness campaigns will be conducted to educate the population on the dangers of certain culinary practices.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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