Health risks assessment of heavy metals (Al, Cd, Cr, Cu, Fe, Ni, Pb) linked to the consumption of used fish frying oils used by “garba” traders : case of the city of Daloa

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Abstract

Palm oil remains the most used oil in Ivory Coast. However, its constant reuse, even used, by «garba» traders could present a health risk to the consumers. The objective of this study is to assess the carcinogenic and non-carcinogenic risks linked to metals, for consumers of «garba» in the city of Daloa. The methodology consisted of taking 15 samples of used oils in the city of Daloa between May and July 2024 in order to determine their heavy metal contents (Al, Cd, Cr, Cu, Fe, Ni, Pb) by Atomic Adsorption Spectroscopy (AAS). The results of the contents obtained were lower than the threshold values set by CODINORM, FAO and WHO for refined oils. The Hazard Index (HI) and Incremental Lifetime Cancer Risk (ILCR) values were all less than 1 and 10^{-6} respectively, indicating no significant risks to consumers. So, the used fish frying oils used by garba traders in Daloa are of satisfactory quality and they do not pose any significant risks to consumers.

Keywords: Palm oil; Carcinogenic and non-carcinogenic risks; cassava semolina; metals

1. Introduction

Vegetable oils are substances obtained from seeds, kernels, or fruits [1]. They are used in cooking for seasoning, cooking, or frying [2]. There are a variety of cooking oils, each bringing distinct characteristics to cooked dishes. The main vegetable oils, in terms of production, are peanut, rapeseed, corn germ, sunflower, soybean, olive, walnut, and grape seed oils [3]. Among these oils, the most widely used in our country and in the West African region remains palm oil due to its availability, low cost, and ease of use for everyday cooking needs [4]. This oil is widely used by traders in our country in general and those of "garba" in particular, because it is very widespread and less expensive. It is in this dynamic that traders of "garba", an emblematic dish of Côte d'Ivoire made from cassava semolina and fried fish, from the city of Daloa, located in the center of Côte d'Ivoire, use palm oil for their business. Indeed, the city of Daloa is distinguished by the richness of its culinary tradition, particularly through "garba". “Garba”, the region's flagship dish, derives its authenticity from the use of palm oil, sometimes used, for frying fish, giving this specialty a unique flavor and a particular taste identity. The reuse of used oils by "garba" traders allows them to save money and attract customers who are very fond of the unique flavor that these used oils give to fried fish. However, behind the delight provided by this dish, there is the question of the health risk for consumers. The objective of this study is to assess the carcinogenic and non-carcinogenic risks linked to the consumption of used fish frying oils used by "garba" traders by the population of Daloa. Thus, this risk assessment will focus on skin and ingestion risks for children and adults. The results of our research could shed light on heavy metal contamination in used fish frying oils and help consumers and government authorities take protective measures to better preserve their health.

2. Materials and methods

2.1. Study area

Daloa, the capital of the Haut-Sassandra region, is an integral part of the old administrative entities of Côte d'Ivoire. This town is made up of indigenous Bété people, a community of non-natives from all over Côte d'Ivoire, and non-natives, mostly from the West African region. Daloa is characterized by a dynamic economic activity, particularly in the street food sector, where traders of "garba" (a local culinary specialty) play an important role.

2.2. Material

15 samples of used oil were collected between May 25, 2024 and July 12, 2024 in sterile bottles from several traders in the city of Daloa. The GPS positions of the sampling locations are presented in Table I below. The

sampling sites were selected to represent various neighborhoods in Daloa. The selected sites include areas frequented by various populations, from residential neighborhoods to commercial areas, to ensure a diversity of sources of used cooking oil.

Table I. GPS position of sampling points

LOCATION	GPS COORDINATES
3ème Arrondissement	6.86758° N, 6.44315° W
Centre médical Béatitude	6.90515° N, 6.43655° W
Clinique sociale	6.86963° N, 6.44577° W
Collège Fadiga	6.87285° N, 6.43389°W
Garba center Tazibouo	6.89392° N, 6.43859° W
Garbadrome	6.88111° N, 6.45631° W
Gare UTB	6.88653° N, 6.44710° W
Garage moto Malicki	6.87718° N, 6.44518° W
Groupe Scolaire Dioulabougou	6.87099° N, 6.44767° W
Hôpital Islamique	6.85452° N, 6.44615° W
Hôtel Assemon	6.90338° N, 6.44278° W
Maquis Ramé plus	6.87555° N, 6.45552° W
Microky	6.87478° N, 6.45554° W
Rue du stade	6.88956° N, 6.45639° W
UJLOG	6.90559°N, 6.44045° W

2.3. Sample preparation and analysis

The heavy metal content (Al, Cd, Cr, Cu, Fe, Ni, Pb) of the waste oil samples was quantitatively determined by Graphite Furnace Atomic Absorption Spectroscopy (GFAS) according to the AOAC 999.10 method [5-6]. For heavy metal analysis, a 0.5 g aliquot of waste oil was digested in a microwave digester (Milestone Ethos), with 5 ml of nitric acid (65%) and 2 ml of hydrogen peroxide (30%). The extract was then transferred to a 25 ml volumetric flask, made up to the mark with ultrapure water and stored in a refrigerator until analysis by GFAS [5].

2.4. Health risk assessment

The health risk assessment was carried out according to the Codex Alimentarius methodology. This methodology includes the steps of identification, exposure assessment, dose-response relationship assessment and hazard characterization.

Hazard Identification and Characterization

The various potential hazards due to heavy metals present in used oils are presented in Table II.

Table II. Identification and characterization of hazards related to heavy metals

Heavy metals	Danger characterization	
	Acceptable daily intake/tolerance (ADI or TDI) in mg/kg/day	Diseases
Cuivre	0.01	Kidney failure
Fer	0.02	Risk of significant gastrointestinal bleeding if: ADI = 250 mg/kg/day
Aluminium	0.7	Brain disorders

Cadmium	0.001	Kidney failure, osteoporosis, prostate cancer [7]
Plomb	$3.6x10^{-3}$	Lead poisoning (anemia, low IQ and neurodevelopmental disorders)

Exposure assessment

The exposure assessment was carried out following the following scenario: frying oil is used on the one hand for frying fish directly consumed by the population and on the other hand is poured directly on the "garba" dish and is ingested by the consumers. The exposure assessment consisted of determining the Daily Intake (DI) of metals. The calculation of the DI was done by estimating the maximum load of heavy metals in the body system of a specified body weight of a consumer. The DI provides information on the relative phytoavailability of metals and indicates the possible ingestion rate of a particular metal. The DI in this study was calculated based on the following equation:

$$\mathbf{DI} = \frac{C m\acute{e}tal \times Q}{MC} \quad \mathbf{(1)} \quad [4]$$

With Cmetal, the concentration of heavy metal in used frying oil samples, Q the daily amount of oil ingested by populations and MC the average body mass of consumers. The value of Q is 1 g/day [4] while the Body Mass is 70 kg for adults and 28 kg for children on average from 0 to 15 years old US EPA [8].

Evaluation of the dose-response relationship

Evaluating the dose-response relationship is establishing a quantitative correlation between the absorbed dose and the impact of the effect. From this effect value, the Reference Doses (RFD) are determined. The RFD values for Aluminum, Cadmium, Chromium, Copper, Iron, Nickel and Lead are respectively 0.06; 0.001; 1.5; 2.5; 0.7; 0.02 and 0.004 mg/kg/day [4, 9-10].

Characterization of non-carcinogenic risk

The characterization of non-carcinogenic risk for Al, Cd, Cr, Cu, Fe, Ni and Pb due to the consumption of used oils is assessed by calculating the hazard quotient (HQ) and the hazard index (HI). The hazard quotient (HQ) is given by the formula:

$$\mathbf{HQ} = \frac{DI}{RFD} \quad \mathbf{(2)}$$

If HQ > 1, a non-carcinogenic risk is likely, while if HQ < 1, a non-carcinogenic risk is unlikely [11].

The hazard index (HI) is the non-carcinogenic effect due to a multitude of metals. HI is calculated as the sum of all hazard quotients for individual heavy metals [11-12]:

$$\mathbf{HI} = \mathbf{HQ_{Al}} + \mathbf{HQ_{Cd}} + \cdots + \mathbf{HQ_{Pb}} \quad \mathbf{(3)}$$

Characterization of carcinogenic risk (Cd and Pb)

The Incremental Lifetime Cancer Risk (ILCR), which is defined as the probability for an individual to develop any cancer following exposure to a specified daily quantity of a carcinogenic element over a period of years, is given by the following relationship:

$$\mathbf{ILCR} = \mathbf{DI} \times \mathbf{CSF} \ \mathbf{(4)}$$

With CSF, the cancer slope factor for a particular contaminant. For cadmium and lead, CSF are CSF(Pb) = 0.0085 and CSF(Cd) = 15 $mg.kg^{-1}.day^{-1}$, respectively [12].

If ILCR < 10^{-6}, the carcinogenic risk is negligible; if ILCR > 10^{-4}, there is a high risk of developing cancer. However, when 10^{-6} < ILCR < 10^{-4}, the risk is low and can be neglected [8].

The sum of the cancer risks associated with each of the carcinogenic heavy metals (Cd and Pb) is called the cumulative cancer risk [13]. In our study, this risk is calculated for Lead (Pb) and Cadmium (Cd), which are the only metals with proven carcinogenic risks in our study. The cumulative risk of cancer is given by the following formula:

$$ILCRtotal = ILCR_{Cd} + ILCR_{Pb} \quad (5)$$

3. Results and discussion

Metal content in used frying oils

The metal contents in our samples of used fish frying oils used by "garba" traders are given in Table III below. The concentrations of heavy metals obtained in the samples of used fish frying oils analyzed reveal variable concentrations for each metal. The aluminum concentrations in our samples varied between 0.0222 mg/kg (recorded in the 3rd district) and 0.9507 mg/kg (Ramé maquis). All aluminum contents were below 1 mg/kg, the threshold value set by the FAO and WHO as the admissible weekly value for aluminum [14]. Cadmium contents varied between 0.0004 mg/kg, at the Hôtel Assemon sampling point, and 0.0118 mg/kg at the Dioulabougou school group. These cadmium levels are far below the threshold value recommended by the FAO and WHO, set at 0.5 mg/kg [15]. In addition, the copper levels in our samples varied between 0.0037 mg/kg at the Social Clinic and 0.1474 mg/kg at the Béatitude Medical Center. These copper levels are lower than the tolerable threshold values set by the FAO and WHO at 3 mg/kg [16]. Iron levels were between 0.1872 mg/kg (Maquis Ramé) and 1.7502 mg/kg (UJLOG) and are generally lower than the threshold values set by CODINORM, except at the stations of the Islamic Hospital, Rue du Stade and Jean Lorougnon Guédé University (UJLOG). For nickel, the levels fluctuated between 0.0002 mg/kg at the Social Clinic and 0.0516 mg/kg at the sampling point called the garbadrome. Nickel levels are therefore lower than the threshold values set by the FAO and WHO at 0.2 mg/kg [17]. Finally, the lead levels obtained fluctuated between non-detected (ND) and 0.0056 mg/kg at the garbadrome sampling point. Lead levels were lower than the threshold values set by CORINORM for refined edible oils (0.1 mg/kg).

Thus, the metal levels (Al, Cd, Cr, Cu, Fe, Ni, and Pb) obtained in the samples of used garba oil are generally lower than the threshold values set by CODINORM, FAO, and WHO. The used oils are therefore of edible quality and are in accordance with the recommendations of CODINORM, FAO and WHO. The metal contents (Cr, Cu, Fe, Ni, Pb) obtained in our study are generally lower than the values found by Ibrahim & Hajo [18] in edible oils from Riyadh (Saudi Arabia) and lower than those found by Ogabiela et al. [19] in edible oils from Zaria (Nigeria).

Table III. Concentration of metals in used frying oils from the town of Daloa

	Heavy metal concentration (mg/kg)						
Sampling points	**Al**	**Cd**	**Cr**	**Cu**	**Fe**	**Ni**	**Pb**
3ème arrondissement	0.0222	0.0006	0.0117	0.0044	0.6876	0.0116	0.0009
Centre médical Béatitude	0.7009	0.0117	0.1027	0.1474	0.2067	0.0157	ND
Clinique sociale	0.9021	0.0012	0.0015	0.0037	0.9749	0.0002	ND
Collège Fadiga	0.8016	0.0047	0.0031	0.0096	1.2221	0.0217	0.0016
Garba center Tazibouo	0.8008	0.0075	0.0119	0.0157	0.3297	0.0082	ND
Garbadrome	0.9017	0.0024	0.0074	0.0167	0.9596	0.0516	0.0056
Garage UTB	0.8801	0.0048	0.0075	0.0087	0.7875	0.0298	ND
Garage moto Maliki	0.8016	0.0026	0.0059	0.0088	1.1446	0.0036	ND
Groupe scolaire Dioulabougou	0.7513	0.0118	0.0027	0.0319	0.4176	0.0117	ND
Hôpital	0.7076	0.0034	0.0109	0.0087	1.6708	0.0044	0.0016

Islamique							
Hôtel Assemon	0.7019	0.0004	0.0039	0.0109	0.4981	0.0095	0.0005
Maquis Ramé	0.9507	0.0048	0.0102	0.0085	0.1872	0.0013	ND
Microky	0.6972	0.0057	0.0027	0.0432	0.3320	0.0031	0.0010
Rue du stade	0.8752	0.0031	0.0041	0.0046	1.6281	0.0108	ND
UJLOG	0.9209	0.0102	0.0014	0.0467	1.7502	0.0070	0.0042

ND: Not Detected

Assessment of carcinogenic and non-carcinogenic risks of used frying oils

- Non-carcinogenic risks

The non-carcinogenic risk assessment by calculating the hazard index (HI) for each sampling point is presented in Figure 1 below. The HI values are between 9.88x10^{-5} (3rd district) and 1.05x10^{-3} (UJLOG) for children and between 3.95x10^{-5} (3rd district) and 4.21x10^{-4} (UJLOG) for adultS. Regardless of the site considered, the hazard index (HI) is less than 1 for both children and adults. Frequent consumption of the used oils studied therefore does not present significant risks for consumers. The HI values obtained through this study are far lower than the values obtained by Ramezani et al. [20] for lead and cadmium in sesame oils (1.08).

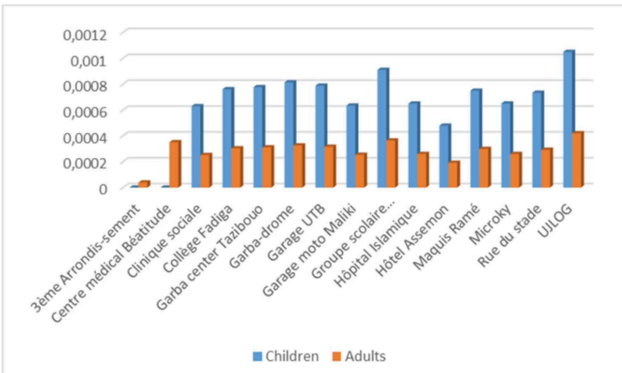

Figure 1. Hazard index for each sampling point

- Carcinogenic risks (ILCR) linked to cadmium and lead

Figure 2 below shows the results of carcinogenic risk assessment by ingestion for cadmium and lead. The cumulative cancer risk (ILCRtotal) values obtained apply to both children and adults. The values ranged from 2.73x10^{-10} (Assemon Hotel) to 4.37x10^{-9} (UJLOG) for children and from 1.09x10^{-10} (Assemon Hotel) to 1.75x10^{-9} (UJLOG) for adults. The ILCRtotal values for children and adults, which are well below 10^{-6}, indicate that there is no risk of developing cancer through frequent consumption of used frying oils used by the "garba" sellers of Daloa. The higher ILCR values in children than in adults reflect the greater risk of developing cancer in children than in adults from the consumption of used fish frying oils. In addition, the ILCRtotal values obtained in our study are significantly lower than those of Ramezani et al. [20] for lead and cadmium obtained in sesame oils.

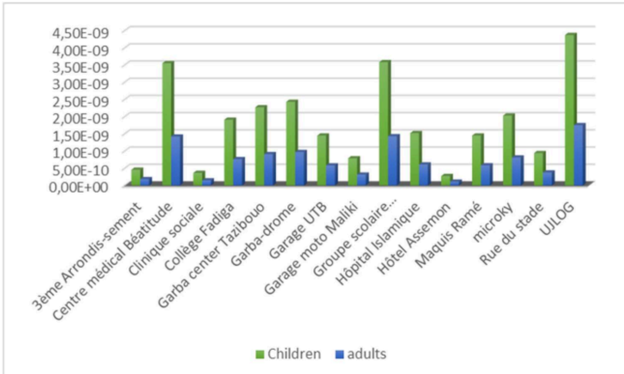

Figure 2. Cumulative cancer risk (ILCRtotal) for each sampling point

4. Conclusion

The assessment of health risks related to exposure to heavy metals (Al, Cd, Cr, Cu, Fe, Ni, Pb) through the consumption of used fish frying oils used by "garba" traders in the city of Daloa (Ivory Coast) revealed their presence in the analyzed samples. The metal levels in used "garba" oils were generally lower than the threshold values set by CODINORM, FAO and WHO, reflecting their edible quality. In addition, the hazard index lower than 1 and the cumulative cancer risk values (ILCRtotal) for children and adults well below 10^{-6} reflect that the used fish frying oils used by the "garba" traders of Daloa do not present obvious carcinogenic and non-carcinogenic risks by ingestion. However, the risk of developing cancer remains higher for children than for adults.

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