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Monitoring of Heavy Metals in Leaves and Stalks of *Cleome gynandra* L. Grown around Landfills in Three Districts in Lomé City and Health Risk Implication

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Abstract
Cleome gynandra is an herbal plant available growing around solid waste landfills in Lomé city and suburbs. Its leaves and tender young stalks were highly used in various traditional culinary in Togo and other parts of Sub-Saharan Africa. The aim of this study is to assess the potential health risk of heavy metals content in fresh, dried and cooked leaves and stalks of Cleome gynandra collected around waste solid landfill. The heavy metals concentration in edible parts of C. gynandra were measured by atomic absorption spectrophotometer. The results indicate that the fresh leaves contained higher heavy metal concentration than the fresh stalks. The sun drying and cooking process reduced sensitively the heavy metal contents. The recorded values of mercury (<0.001 - 0.029 µg g^{-1}), arsenic (<0.001 - 0.055 µg g^{-1}) and nickel (0.02 – 0.19 µg g^{-1}) in analyzed samples were lower than the permissible limit values set by FAO/WHO. However, the concentration of cadmium (0.11 - 0.45 µg g^{-1}) and lead (0.22 – 0.65 µg g^{-1}) in leaves were higher than limit references. As plant leaves accumulate more heavy metal, it is recommended to don't consume the leaves of Cleome gynandra grow around solid waste landfills.

Key words*: Cleome gynandra, leaves, stalks, heavy metal content, landfill.*

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I. Introduction

Cleome gynandra L. is an available specie plant growing as a weed in rural and urban areas in Togo and others African countries. It is one of the African indigenous and traditional leafy vegetables in Burkina Faso, Côte d'Ivoire, Ghana, Kenya, Nigeria, South Africa, Tanzania, Uganda, and Zimbabwe etc. (Mishra et al., 2011; Ouédraogo et al., 2013; Agbo et al., 2014). Regular consumption of the leaves of *Cleome gynandra* by pregnant women is almost mandatory in some communities because it eases childbirth (Mishra et al., 2011).

The consumption of leaves and tender young stalks of *Cleome gynandra* L. in Togo especially in Lomé city and suburbs contributes to the diversification of people's diets with undeniable nutritive value. The fresh or sun-dried leaves are used directedly as an ingredient of sauces. In other cases, the fresh or sun-dried edible parts of *Cleome gynandra* are cooked by boiling water and mixed with other foods after discarding the boiling water. It has been shown that *C. gynandra* possess antioxidant, antibacterial, antifungal, antineoplastic, antiarthritic and antioxidant properties in addition to his minerals and vitamins contents (Anbazhagi et al., 2009). Due to its richness in essential micronutrients as vitamin A and iron, *Cleome gynandra* can serve to combat debilitating nutrient deficiencies (Ouédraogo et al., 2013).

Unfortunately, *Cleome gynandra* grows naturally around solid waste landfill in Lomé city and suburbs on soil with high contamination risk by heavy metals. Landfills have been shown to be one of the sources of heavy metal in soil (Kanmani and Gandhimathi, 2013; Olafisoye et al., 2013; Makuleke and Ngole-Jeme, 2020; Akanchise et al., 2020). The heavy metals are extremely persistent in the environment even at low concentrations and have been reported to produce damaging effects on human and animals because there is no good mechanism for their elimination from the body (Adah et al., 2013). The heavy metals in soils may be absorbed and accumulated by crops (Chang et al., 2014). Ingesting heavy metals through the soil and crops system is a major way to damage human health (Aeliona et al., 2008; Kanda et al., 2017). This has become health public concern because of the deleterious effects associated to heavy metals exposure. The main threats to human health from heavy metals are commonly associated with exposure to lead, cadmium, mercury, nickel and arsenic (Järup, 2003). However, little attention has been paid to the monitoring of heavy metal in leafy vegetables grown around landfills in local conditions at Lomé city scale.

The objective of this study was to determine the heavy metal concentration level in edible parts of *Cleome gynandra* grown around landfills before and after sun drying and boiling water processes in order to establish the advice regarding their consumption.

II. Material and Methods

2.1 Study area

The study was carried out in the districts of Gbadago, Kégué and Akodesséwa in Lomé city. The fresh edible parts (leaves and tender young stalks) of *Cleome gynandra* were collected around three landfills. The geographic position of the landfills were determined using a geographic positioning system GPS as recorded: Gbadago landfill (N 06°.08'32.0" E 001°13'08.9"), Kégué landfill (N 06°12'01.9" E 001°.14.18.4") and Akodesséwa landfill (N 06°.09'17.6" and E 001°15'40.8").

2.2 Laboratory material

These are chemical reagents, HNO_3 and H_2O_2 used for the samples digestion and the standard solutions were purchased from Laboratory SOPHYC SOCOLAB (France). All chemicals reagents used were analytical grade. Deionized water was used to prepare samples and standards for analysis. An atomic absorption spectrophotometer has been used for heavy metal analysis.

2.3 Collection and handling of edible parts of Cleome gynandra

To avoid any uncontrolled environmental stress, all samples were collected in the morning between 6 and 7 o'clock. There were three replicate collections by site. The edible parts of vegetable collected represent the stage of development that would normally be harvested for consumption. The leaves and stalks of *Cleome gynandra* were separated and washed with clean tap water to remove the dusts and other adhered particles on their surface. They were then washed and rinsed with deionized water and divided into different parts. One part was kept fresh under air-conditioned room for 5 days until complete desiccation and another part was sun-dried 3 days until constant weight. One part of each sample was directly crushed and reduced to powder using a mortar and sieved to obtain the fine fraction with a diameter less than 63 µm which was stored in clean and dry polyethylene bags. Another part of fresh each sample was boiled in deionized water. Boiling: 200 g of leaves and stalks were added to 1 L of boiling water and cooked for 90 minutes. The boiled samples were removed from the boiling water and cooled. They were successively dried first at room temperature (24 hours) and later in an oven at 40°C (overnight). They were then crushed and sieved to obtain also the fine fraction with a diameter less than 63 µm which was stored in clean and dry polyethylene bags.

2.4 Digestion of the vegetable samples and heavy metal content determination

An aliquot of 250 mg of each powdered sample were placed in Teflon beakers and mineralized with Hydrogen peroxide and Nitric acid HNO_3/H_2O_2 in a ratio of 2:1 on a hot plate. After digestion, the samples were cooled and filtered. The filtrate was then transferred to a clean propylene sample bottle with a leak-proof lid. The same quantities of reagents were used for samples and blank. The 1000 ppm stock solution of each heavy metal were prepared and required dilutions were made for the purpose of calibration curves. Both sample and blank solutions were analyzed using atomic absorption spectrophotometer - Thermo Orion Solaar S2 type and concentrations of heavy metals were determined. Mercury and arsenic were analyzed by atomic absorption spectrometry coupled to the branded cold vapor generator (VP100).

2.5 Statistical analysis

All the data were subjected to statistical analysis. The averages and standards deviations were performed using STATISTICA software (2005, 7.1 Version). The results were expressed as means ± standard error (SE).

III. Results

The leaves and stalks of *Cleome gynandra* analyzed contain arsenic, cadmium, lead, mercury and nickel at various concentrations as presented in Tables 1, 2 and 3. Each value is the mean (± standard deviation) for triplicate determinations. Globally, the samples collected from Kégué site presented the higher contents of heavy metal than those collected from Gbadago and Akodesséwa sites. According to the results, it has been revealed that *Cleome gynandra* plant accumulated, relatively some amounts of heavy metal in his leaves and stalks. The leaves contained higher heavy metal concentration than the stalks.

The concentration of nickel (0.02 – 0.19 µg g^{-1}) were below the limit values 0.2 - 2.70 set by WHO (1996). The recorded values of mercury (<0.001 - 0.029 µg g^{-1}) and arsenic (<0.001 - 0.055 µg g^{-1}) in leaves and stalks of *Cleome gynandra* analyzed were respectively lowers than the permissible limit values 0.03 µg g^{-1} and 0.19 µg g^{-1} reported by FAO/WHO (1999). Based on the permissible limit values of WHO (1996) and

FAO/WHO (1999), there are no health risks with respect to the concentrations of mercury, arsenic and nickel in the edible parts of *Cleome gynandra* analyzed in this study (Tables 1, 2 and 3). The concentration of cadmium in leaves (0.11 - 0.45 µg g^{-1}) exceeded the threshold value of 0.1 µg g^{-1} as reported by FAO/WHO (1999) and thus might be a great threat for the consumers. The level of lead (0.22 – 0.65 µg g^{-1}) in leaves is higher than FAO/WHO safe limit (0.2 µg g^{-1}) (FAO/WHO, 1999).

Table 1: Concentrations of heavy metals (µg g^{-1} of material) in leaves and stalks of *Cleome gynandra* collected around Gbadago landfill

Treatments	Cadmium (Cd)	Lead (Pb)	Mercury (Hg)	Arsenic (As)	Nickel (Ni)
Fresh leaves	0.32±0.02	0.51±0.05	0.022±0.004	0.049±0.002	0.12±0.04
Sun-dried leaves	0.27±0.01	0.39±0.03	0.012±0.002	0.023±0.003	0.09±0.003
Fresh leaves boiled	0.19±0.02	0.28±0.02	<0.001	0.016±0.004	0.06±0.003
Sun-dried leaves boiled	0.11±0.02	0.23±0.01	<0.001	0.002±0.002	0.04±0.002
Fresh stalks	0.18±0.02	0.09±0.005	0.008±0.002	0.017±0.004	0.05±0.003
Sun-dried stalks	0.11±0.02	0.06±0.003	<0.002	0.015±0.004	0.04±0.002
Fresh stalks boiled	0.09±0.002	0.05±0.002	<0.001	0.009±0.002	0.03±0.002
Sun-dried stalks boiled	0.04±0.002	0.03±0.002	<0.001	<0.001	0.02±0.002
FAO/WHO Limit values (1999)	**0.1**	**0.2**	**0.03**	**0.1**	-
WHO Limit values (1996)	-	-	-	-	**0.2 – 2.70**

Table 2: Concentrations of heavy metals (µg g^{-1} of material) in leaves and stalks of *Cleome gynandra* collected around Kégué landfill

Treatments	Cadmium (Cd)	Lead (Pb)	Mercury (Hg)	Arsenic (As)	Nickel (Ni)
Fresh leaves	0.45±0.04	0.65±0.05	0.029±0.03	0.055±0.04	0.19±0.04
Sun-dried leaves	0.39±0.03	0.58±0.04	0.015±0.02	0.041±0.04	0.15±0.02
Fresh leaves boiled	0.25±0.02	0.39±0.03	<0.001	0.022±0.02	0.11±0.02
Sun-dried leaves boiled	0.18±0.02	0.29±0.02	<0.001	0.008±0.002	0.09±0.003
Fresh stalks	0.22±0.03	0.15±0.01	0.010±0.01	0.023±0.01	0.10±0.02
Sun-dried stalks	0.16±0.01	0.11±0.01	<0.001	0.018±0.01	0.08±0.002
Fresh stalks boiled	0.12±0.01	0.08±0.03	<0.001	0.010±0.01	0.05±0.002
Sun-dried stalks boiled	0.09±0.004	0.05±0.02	<0.001	<0.001	0.04±0.002
FAO/WHO Limit values (1999)	**0.1**	**0.2**	**0.03**	**0.1**	-
WHO Limit values (1996)	-	-	-	-	**0.2 – 2.70**

Table 3: Concentrations of heavy metals (µg g^{-1} of material) in leaves and stalks of *Cleome gynandra* collected around Akodesséwa landfill

Treatments	Cadmium (Cd)	Lead (Pb)	Mercury (Hg)	Arsenic (As)	Nickel (Ni)
Fresh leaves	0.35±0.04	0.48±0.04	0.026±0.03	0.034±0.002	0.16±0.03
Sun-dried leaves	0.27±0.02	0.38±0.02	0.016±0.02	0.023±0.002	0.11±0.02
Fresh leaves boiled	0.16±0.03	0.29±0.02	<0.001	0.014±0.002	0.09±0.01
Sun-dried leaves boiled	0.11±0.01	0.22±0.03	<0.001	0.006±0.002	0.05±0.002
Fresh stalks	0.15±0.01	0.13±0.01	0.011±0.002	0.018±0.002	0.10±0.01
Sun-dried stalks	0.10±0.04	0.09±0.003	<0.001	0.011±0.002	0.06±0.002
Fresh stalks boiled	0.07±0.002	0.05±0.002	<0.001	0.008±0.002	0.04±0.002
Sun-dried stalks boiled	0.03±0.002	0.02±0.002	<0.001	<0.001	0.02±0.002
FAO/WHO Limit values (1999)	**0.1**	**0.2**	**0.03**	**0.1**	-
WHO Limit values (1996)	-	-	-	-	**0.2 – 2.70**

IV. Discussion

It can be noticed that there is significant tendency decrease of heavy metal concentration in samples subjected to sun-drying and boiling processes compared to their level concentration in fresh samples. The highest level of heavy metal concentration was observed in the fresh samples. The lowest level of heavy metal concentration was found in sun-dried cooked leaves and stalks. The drop in concentration of heavy metal in the cooked samples may be attributed to heat effect and a possibility of the heavy metal to be converted to other compounds (Ziarati et al., 2013; Kananke et al., 2015; Sadeghi et al., 2017).

The results of this study are in agreement with those found in previous studies which have indicated that the application of heat during thermal processes may affect the levels of toxic elements in food. Kananke et al. (2015) showed that cooking and stir-frying method have a minimal effect in reducing the heavy metal contents of green leafy vegetable samples. Sadeghi et al. (2017) reported that Pb, Zn and Cd have been reduced by cooking in parsley, basil and mint in Downtown of Tehran. Diaz e t al. (2004) investigated effect of four different cooking methods such as baking, stewing, boiling and pureeing on heavy metals in vegetables and cereals. They noticed that boiling method helps in reducing the arsenic content and concluded that their findings may be attributed to the bond breaking process acceleration due to the heat treatment as well as other processes such as solubilization in the water. Perello et al. (2008) reported that boiling brings about a significant reduction of arsenic content in vegetables. Lee et al. (2019) concluded that the heavy metals present in food substances may be soluble in water hence will decreased during cooking in watery medium. They attributed the heavy metal content decrease to water loss at high temperature.

On the contrary, some studies reported the heavy metals contents increased with cooking process. Bassey et al. (2014) studied the effects of processing on the proximate and metal contents in three fish species from Nigerian coastal waters. They concluded that the cooking methods caused significant increase in the concentrations of most metals compared to those of the raw samples. Ersoy et al. (2006) reported that frying caused an increase arsenic concentration in sea bass. Gheisari et al. (2016) investigated effect of steaming, boiling and frying on lead and cadmium content in lobster and shrimp and observed the highest content in the fried samples. The contradictory results reported in the literature compared to the findings of this study may be attributed to the nature of material (vegetable and fish), cooking conditions (time, temperature, and medium of cooking) as well as heavy metal evaporation during cooking processes.

V. Conclusion

The monitoring of heavy metals in leaves and stalks of *Cleome gynandra* grown around solid waste landfills was carried out. It was investigated the heavy metal reduction in leaves and stalks by sun drying and cooking, the processes commonly used by the population. Based on the permissible limit values of FAO/WHO, there are no health risks with respect to the concentrations of mercury, arsenic and nickel in the edible parts of *Cleome gynandra* analyzed. However, the concentration of cadmium and lead in leaves exceeded the threshold values set by FAO/WHO. It can be drawn from this study that as plant leaves accumulate more heavy metal, it is recommended to don't consume the leaves of *Cleome gynandra* grow around solid waste landfills.

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