

## EVALUATION OF HEAVY METALS AND PESTICIDES CONTENTS IN MARKET-GARDENING PRODUCTS SOLD IN SOME PRINCIPAL MARKETS OF OUAGADOUGOU (BURKINA FASO)

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### ABSTRACT

Pesticides and heavy metals are persistent organic pollutants responsible for immune deficiency, certain types of cancer, and decreased length of pregnancy. In this study, 20 chemical pesticides and 4 heavy metals were detected from 120 samples of 4 types of vegetables and 40 samples of *babenda* collected from Ouagadougou principal markets. The "*babenda*" is a Burkinabe dish made mainly of leafy vegetables (*Hibiscus sabdariffa*, *Amaranthus hybridus*, and *Cleome gynandra*) coarsely chopped and millet or rice that was boiled together. A multi-residue method was developed to detect the pesticides in the samples collected by gas chromatography, with micro electron capture detector. The concentration of cadmium, lead, mercury and arsenic were obtained from the 120 vegetables samples by using an atomic absorption spectrometer. Residues of pesticides were detected in 87% of the samples, and among the positive samples, 58.40% contained concentrations higher than the limit of maximum residue (LMR). Thirteen active pesticide residues were detected in the vegetables. The contents of the majority of pesticides residues were higher than the LMR. Seven active ingredients were detected in the *babenda*. 50% of the samples had more than one pesticide residue. The heavy metal concentrations ranged from 0.0098 to 2.66 mg.kg<sup>-1</sup> for Hg; 0.01 to 1.146 mg.kg<sup>-1</sup> for Pb; 0.016 to 1.72 mg.kg<sup>-1</sup> for Cd and 0.012 to 1.885 mg.kg<sup>-1</sup> for As. The relative abundance of heavy metals in the vegetables followed the sequence Cd (0.018 mg.kg<sup>-1</sup>) > Pb (0.016 mg.kg<sup>-1</sup>) > As (0.012 mg.kg<sup>-1</sup>) > Hg (0.0098 mg.kg<sup>-1</sup>). In addition, the concentration of heavy metals in the samples collected from the different markets exceeded the threshold according to the lawful maximum concentration (CMR) established in France. The continuous follow-up and a strict regulation of these pollutants in the vegetables particularly, are necessary.

**Keywords:** Heavy metals; Vegetables; Pesticides; Markets; Pollutant, Ouagadougou

### INTRODUCTION

Truck farming is being developed in cities in developing countries to ensure food security. It is also an income generating activity for households. In Africa, truck farming is currently part of hidden hunger solution among large cities' neighbourhoods population (Touré *et al.*, 2015; Yao *et al.*, 2016). Insects attacks and plants pathologies are most of the obstacles to truck farming. Market-gardeners use available chemical pesticides to limit the damage to their crops. Unfortunately pesticides are used in anarchistic and abusive ways (Son *et al.*, 2017; Tarnagda *et al.*, 2017). The risk of this practice is also increased by the ignorance of the market-gardeners (Diop, 2013).

Urban origin market-garden products are nutritionally rich but are not always safe. The production sites of market-garden products around urban cities are subject to contamination by residues of medicine (Koffi-Nevry *et al.*, 2012; Touré *et al.*, 2015). Majority of the sites of production of market-garden products are located in places polluted with domestic and industrial wastes. Some sites of gardening in the urban cities are located in or close to household refuse dump sites or industrial waste disposal sites where there is frequent incinerations of wastes (Ahouangninou *et al.*, 2011; Kanda *et al.*, 2013). Pesticides are frequently used to increase vegetables production (Yao *et al.*, 2016; Son *et al.*, 2017; Tarnagda *et al.*, 2017). Pesticides and heavy metals have chronic effects on human health. Among the critical points for hazard analysis of market-garden products, the site of production and the utilization of pesticides are very important. Without an adequate mechanism of control, the use of pesticides present a medical and an environmental risk (Yao *et al.*, 2016; Tarnagda *et al.*, 2017). The effects on the environment in general, the ground and the cultivated plants in particular, are considerable, because these husbandries are likely to involve an accumulation of heavy metals and pesticides in the plants and the surface layers of the ground, rich in organic matter (Touré *et al.*, 2015).

The "*babenda*" is a Burkinabe dish made mainly of leafy vegetables (*Hibiscus sabdariffa*, *Amaranthus hybridus*, and *Cleome gynandra*) coarsely chopped and millet or rice that was boiled together. Vegetables play an important role in diversifying the diets of people in developing countries and are a major source of nutrients. Indeed, because of their richness in protein, fiber, minerals, vitamins, and antioxidants, vegetables help to improve the health of populations (Lock *et al.*, 2005). They are therefore of nutritional interest in the fight against micronutrient deficiencies (Devadas *et al.*, 1980). The iron content of amaranth (*Amaranthus cruentus*) and cornet (*Corchorus olitorius*) is 22 to 77 mg / 100 g dry matter (Ndlovu *et al.*, 2008). The  $\beta$ -carotene content of black nightshade (*Solanum scabrum*) is 3943.03  $\pm$  0.89  $\mu$ g / 100 g in relation to the crude product (Soro *et al.*, 2012). It is a sauce that is prepared in the villages during the lean season, when there was not enough millet or other grains to provide for the families until the harvest. In fact, at the base of this leaf sauce was mainly bean leaves and sorrel crushed and millet that were boiled together. This study was aimed at evaluating the contents of heavy metals and pesticides of market-gardening products (*Amaranthus hybridus*, *Hibiscus sabdariffa*, *Cleome gynandra* and *Ipomaea batatas*) and *babenda* sold in twenty principal markets of Ouagadougou.

### MATERIAL AND METHODS

#### Sampling and preparation of the vegetables

A total of 120 samples of four vegetables and 40 *babenda* samples commonly consumed by the local population were collected. The concerned vegetables were: *Amaranthus hybridus*: Borom-bouli, *Hibiscus sabdariffa*: Bito, *Cleome gynandra*: Kenebdo, and *Ipomaea batata*: Nagnui-noodo. Samples were taken randomly from 20 principal markets ( Zone1 year, Wemtenga year, : Zogona

yaar, : Nabi yaar, : Benogo yaar, : Katré yaar, : Kossodo yaar, : Dassassgho yaar, : Bonsé yaar, : City Year II, : Oscar yaar, : Gounghin yaar, : Boulmiougou yaar, : Tanghin yaar, : Pissy yaar, : Power station, : Larlé yaar, : Tampouy yaar, : Paagala yiri and : Sankaré yaar) of Ouagadougou. The markets are codified A to T. Ouagadougou, commonly known as Ouaga, is the capital and largest city of Burkina Faso, with a population of 2.5 million in 2015. It is the The market cultural, economic and administrative center of the country. Sampling was carried out in accordance with the directive of EU 2002/63/CE (EC, 2002). A composite sample of 1-2 kg of each vegetable were collected and sealed in sterile polyethylene bags. Samples were codified with a single identifier and placed in a refrigerator until analysis in National Laboratory of Public Health at Ouagadougou. The samples were stored at 4 °C until the analysis. Analyses were carried out within 24 h according to recommendation of Islam and Shamsad (2009). The analyses was focused on edible parts.

**Determination of heavy metals contents in the vegetables samples**

For the analysis of heavy metals, 0.3 g of each freeze-dried samples were digested using 6 ml of HNO<sub>3</sub> (69%) and 2 ml of H<sub>2</sub>O<sub>2</sub> 30% (Wako Chemical Co, Japan) in a digestion system by microwaves (Berghof Speedwave, Germany). The digested samples were then transferred into a Teflon Becher, and the volume was completed to 50 ml by Milli-Q water. The digested solution was then filtered using a syringe filter (Dismic®-25hp PTFE, size of the pores ¼ 0, 45 mm, Toyo Roshi Kaisha, Ltd, Japan, 1979) and stored in polypropylene tubes of 50 ml (Nalgene, New York, the USA). The method of Awofolu (2005) was adopted for the acid digestion of vegetables samples. The analyses were carried out by atomic absorption with a spectrometer (Baize et Paquereau, 1997). Tab 1 shows the thresholds used to diagnose the contamination of gardens grounds and the plants.

**Table 1** Thresholds used to diagnose the contamination of the plants

ETM	Content (mg/kg <sup>-1</sup> )	References
Cd	0,1	AQSIQ, (2001)
	0,2	FAO/WHO (2001); CMR (Mench & Baize, 2004)
	0,05	AQSIQ, (2001)
	1,5	Indian standards (Awashti, 2000)
Pb	0,1	(FAO/WHO, 2011)
	0,2	AQSIQ, (2001)
	0,3	CMR (Mench & Baize, 2004) ; Valeur maximale du règlement 1881/2006/CE (Tremel- Schaub & Feix, 2005)
AS	0,1	(FAO/WHO, 2011)
Hg	0,05	Based on the Chinese standard (GB 2762-2012)

**Table 2** Average values of heavy metals (mg.kg<sup>-1</sup>) in fresh vegetables sold in various markets of Ouagadougou town.

Heavy metals (mg.kg <sup>-1</sup> )					
Species	Site of study (codes of markets)	Hg	Pb	Cd	As
<i>Amaranthus hybridus</i>	A	3.842 ± 0.001	0.017 ± 0.015	3.939 ± 0.04	1.404 ± 0.04
<i>Cleome gynandra</i>	B	0.323 ± 0.02	0.129 ± 0.06	0.698 ± 0.09	0.002 ± 0.01
<i>Hibiscus sabdariffa</i>	C	ND	0.176 ± 0.01	0.734 ± 0.06	1.495 ± 0.03
<i>Ipomaea batatas</i>	D	ND	0.027 ± 0.08	0.017 ± 0.08	0.292 ± 0.02
<i>Cleome gynandra</i>	E	ND	0.012 ± 0.02	0.742 ± 0.012	1.691 ± 0.04
<i>Hibiscus sabdariffa</i>	F	0.256 ± 0.00	0.114 ± 0.05	2.799 ± 0.015	0.074 ± 0.02
<i>Amaranthus hybridus</i>	G	0.305 ± 0.00	0.119 ± 0.012	0.395 ± 0.015	0.176 ± 0.04
<i>Ipomaea batatas</i>	H	2.66 ± 0.05	0.013 ± 0.01	0.148 ± 0.05	ND
<i>Amaranthus hybridus</i>	I	0.103 ± 0.001	1.027 ± 0.06	0.292 ± 0.015	1.887 ± 0.013
<i>Hibiscus sabdariffa</i>	J	0.624 ± 0.001	1.014 ± 0.07	0.174 ± 0.008	ND
<i>Cleome gynandra</i>	K	ND	0.156 ± 0.02	0.252 ± 0.013	ND
<i>Ipomaea batatas</i>	L	ND	0.016 ± 0.035	0.119 ± 0.018	1.395 ± 0.005
<i>Hibiscus sabdariffa</i>	M	ND	0.127 ± 0.015	0.250 ± 0.055	0.001 ± 0.053
<i>Ipomaea batatas</i>	N	ND	0.155 ± 0.00	0.099 ± 0.07	ND
<i>Amaranthus hybridus</i>	O	ND	0.354 ± 0.05	2.714 ± 0.045	0.145 ± 0.040
<i>Cleome gynandra</i>	P	ND	0.018 ± 0.07	5.740 ± 0.05	ND
<i>Cleome gynandra</i>	Q	0.327 ± 0.028	0.043 ± 0.083	0.021 ± 0.006	0.016 ± 0.084
<i>Amaranthus hybridus</i>	R	0.098 ± 0.017	0.023 ± 0.005	0.276 ± 0.055	0.174 ± 0.05
<i>Hibiscus sabdariffa</i>	S	0.300 ± 0.052	1.145 ± 0.002	0.237 ± 0.08	0.190 ± 0.012
<i>Ipomaea batatas</i>	T	ND	0.035 ± 0.075	0.024 ± 0.02	0.026 ± 0.09
	CMR (WHO. 2004)	2	0.1	0.2	0.01
	Mench and Baize. 2004		3	2	

**Pesticides contents determination**

**Extraction and cleaning of the samples**

The QuECHERS method was used with some modifications (Ozowicka et al., 2012). A micro-extraction of the sample finely crushed with acetonitrile was carried out in centrifuge tubes. While taking as a starting point of the literature (Anastassiades, 2005), the purification of the extracts was carried out by centrifugation with salts (sulphate of anhydrous sodium) and carbon black graphitized (GCB) to mobilize the coloured substances (chlorophyll and carotene) that are non-active by precipitation. The supernatant obtained from the frozen extract after centrifugation was recovered in a vial using a Pasteur pipette. The analysis of the extracts was carried out using a chromatograph in gas phase (Agilent Technologies) that has a micro-detector that captures electron (GC-μECD/GC-FPD, Hewlett Packard). A capillary chromatographic column of type dB-17 MS. It had a length of 30 cm, an internal diameter of 250 μm and a thickness of 0.25 μm. Nitrogen of high purity was used as the carrier gas. The injection was carried out using Split/Splitless injection technique with an injection volume of 2 μl. The temperatures of the apparatus were as follows:

- Room of injector programmed at 275°C with a pressure of 20.72 psi;
- Column (75°C during 0.5 mn, 75-300°C with a flow of 10°C/mn and 300°C during 7mn);
- Detector (325°C).

**Statistical analysis**

Principal component analyses (PCA), were carried out, in order to determine the correlations between the various elements.

**RESULTS AND DISCUSSION**

**Evaluation of metals traces in the market-gardening products**

The results of the levels of heavy metals in the plants are presented in Tab 2. Heavy metals found in the vegetables sold in markets of Ouagadougou town are Cd, Pb, AS and Hg.

Cd is accumulated by both leaves of *Hibiscus sabdariffa*, and *Ipomeae batatas* and in *Cleome gynandra* (fig 2 and 5). Cd contents is low in the leaves of *Ipomeae batatas* sold in the market of Nabi yaar (0.017 mg.kg<sup>-1</sup>) and in the leaves of *Hibiscus sabdariffa* collected from the market of the City Year II (0.017 mg.kg<sup>-1</sup>). The Cd contents in the various plants largely exceed the thresholds recommended by FAO/OMS (0.1 mg.kg<sup>-1</sup>) and 65% of the plants have Cd contents higher than standards (0, 2 mg.kg<sup>-1</sup>). For Hg, 50% of vegetables sold in several markets showed values higher than the thresholds values compared to the Chinese standard (Tab 2). The values obtained in the other plants are relatively high and largely above the tolerable threshold range (0.05 to 2 mg.kg<sup>-1</sup>). The values of Pb in the analysed vegetables ranged between 0.013 and 1.145 mg.kg<sup>-1</sup>. And 55% of the samples collected from the 20 markets, largely exceeding the thresholds values indicated by FAO/OMS (0.1 mg.kg<sup>-1</sup>). Pb and Hg were more accumulated in the leaves of *Cleome gynandra*, *Hibiscus sabdariffa* and *Amaranthus hybridus* (Fig 2 and 5). The As were accumulated in the leaves of *Amaranthus hybridus*, *Cleome gynandra* and *Hibiscus sabdariffa*; and in 60% of the analyzed leaves. The amounts were relatively high in the leaves samples of *Amaranthus hybridus* from Bonsé yaar (1.887 mg.kg<sup>-1</sup>), *Cleome gynandra* (1.691 mg.kg<sup>-1</sup>) from the market of Benogo and in the leaves of *Hibiscus sabdariffa* taken from Zogona yaar (1.495 mg.kg<sup>-1</sup>). Thus, the analyses showed values of up to 1.887 mg.kg<sup>-1</sup>, which largely exceeded the tolerable threshold value (0.1 mg.kg<sup>-1</sup>).

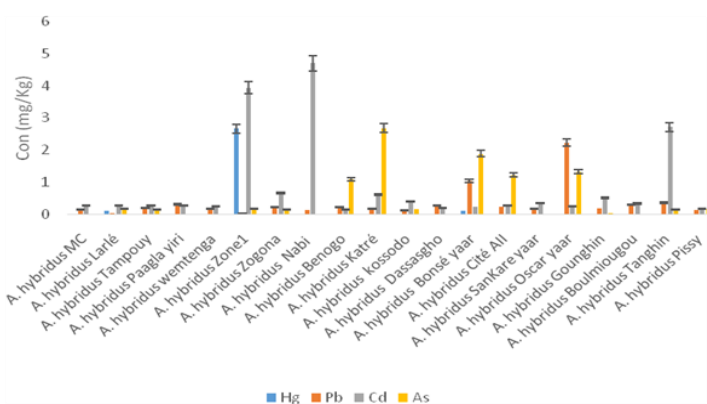


Figure 1 Heavy metal contents in *Amaranthus hybridus* leaves

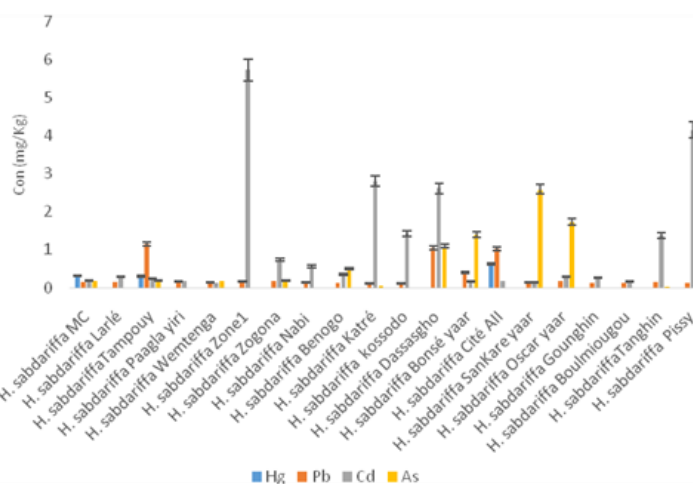






Figure 2 Heavy metal content in *Hibiscus sabdariffa* leaves

Various types of chemical pesticides found in the plants

The analysis of the pesticides content in plants (Tab 3) indicated that the 53,33% of the chemical elements found in the vegetables are pesticides of the family of pyrethrinoid (permethrin, tetramethrin, cypermethrin, deltamethrin and λ - cyhalothrine); 24% of the organochlorinated compounds (lindane, alachlore, heptachlore, dieldrine); 22,67% of the organophosphorus compounds and carbamates (chlorpyrifos-methyl, parathion-ethyl, diazinon and quintozène).

Table 3 Pesticide contaminated vegetables sold in Ouagadougou

Culture/family/species (number of sampling)	Name of the pesticides detected	Number of contaminated samples	Sample exceeding numbers of the MRL	Number of samples containing multiple residues of pesticides for each product	Range of pesticide/Residues (mg.kg <sup>-1</sup> )	of MRL (mg.kg <sup>-1</sup> )
 Amaranth / <i>Amaranthus hybridus</i> / (30)	Tetramethrine	3		1	0.097 - 0.365	0.05
	λ-cyhalothrine	3	1	1	0.099 - 0. 107	0.05 -0.02
	Permethrine	1		1	0.692 - 1.775	0.05 -0.25
	Cypermethrine	1		1	0.102 - 0.826	0.05
	Deltamethrine	3	2	1	0.294 - 0.86	0.05
	Lindane	1	1		0.014 - 0.65	0.5
	Quintozene	2		1	0.157 - 0.371	0.007
	Heptachlore	1	1		0.016 - 0.025	0.05
	Alachlore	1			0.082 - 0.198	0.05
	Dieldrine	1	1		0.028 - 0.092	0.02-0.05
	Diazinon	1	3	1	0.037 - 0.089	0.01-0.05
	Chlorpyrifos-methyl	4	2	1	0.046 - 0.54	0.01-0.05
	Parathion-ethyl	1			0.023 - 0.035	0.05
 Sorrel / <i>Hibiscus sabdariffa</i> / (30)	Lindane	2	1		0.019 - 0.52	0.5
	Cypermethrine	4	3	1	0.282 - 0.813	0.05
	Permethrine	1		1	0.689 - 0.853	0.05 -0.25
	Alachlore	1	1		0.016 - 0.085	0.05
	Dieldrine	1			0.024 - 0.047	0.02-0.05
	Deltamethrine	3	1	1	0.145 - 0. 324	0.05
	λ-cyhalothrine	3	4	1	0.018 -0.059	0.05 -0.02
	Diazinon	1	2	1	0.036 - 0.042	0.01-0.05

 Bastard mustard / <i>Cleome gynandra</i> / (30)	Chlorpyrifos-methyl	1	1	1	0.014 - 0.035	0.01-0.05
	Tetramethrine	4			0.021 - 0.043	0.05
	Δ-cyhalothrine	4	2	1	0.069 - 0.178	0.02 - 0.05
	Permethrine	3	1	1	0.169 - 0.355	0.05 - 0.25
	Cypermethrine	3	1	1	0.164 - 0.89 1	0.05
	Heptachlore	1	1		0.016 - 0.083	0.05
	Tetramethrine	4	3		0.096 - 0.132	0.05
 Sweet potato / <i>Ipomaea batatas</i> / (30)	Deltamethrine	2	4	1	0.059 - 0.288	0.05
	Permethrine	5	1	1	0.169 - 0.326	0.05 - 0.25
	Δ-Cyhalothrine	8	2		0.178 - 0.574	0.02 - 0.05
	Dieldrine	3	1	1	0.012 - 0.828	0.02-0.05
Total = 120	Deltamethrine	4	4	1	0.059 - 0.158	0.05
	Cypermethrine	1	3	1	0.155 - 0.925	0.05
		82	47	22		

MRL-Maximum Residue Level

The principal component analysis revealed the correlation between pesticides contents and plant species, between heavy metal contents and plants species.

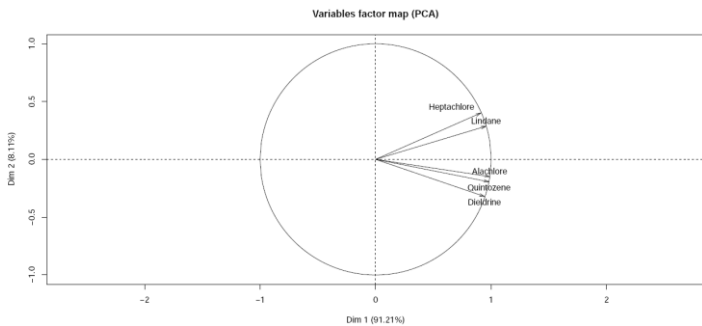


Figure 3 Principal component analysis of organochlorinated compounds and carbamates in the studied vegetable species - a: Organochlorinate and carbamate

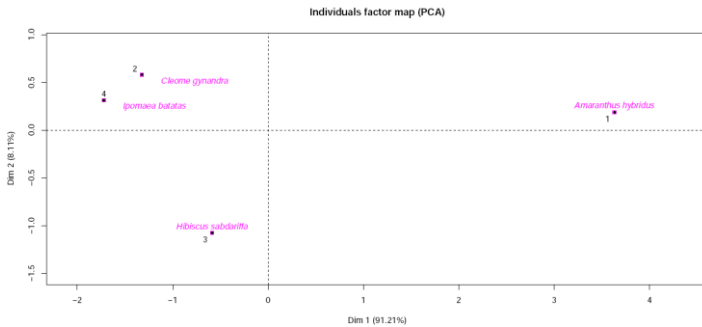


Figure 3 Principal component analysis of organochlorinated compounds and carbamates in the studied vegetable species - b: Vegetable species

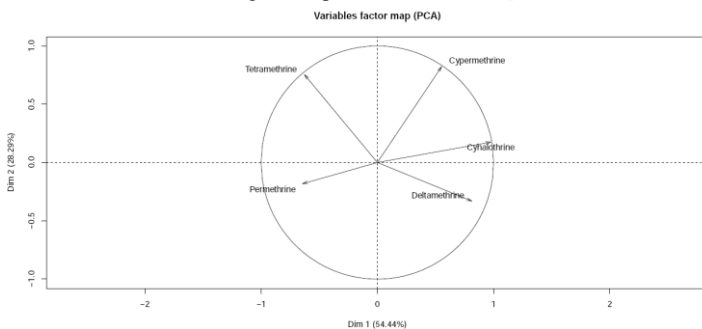


Figure 4 Principal Component Analysis of Pyrethrinoid of synthesis in the vegetables leaves - a: Pyrethrinoid synthesis in the vegetables

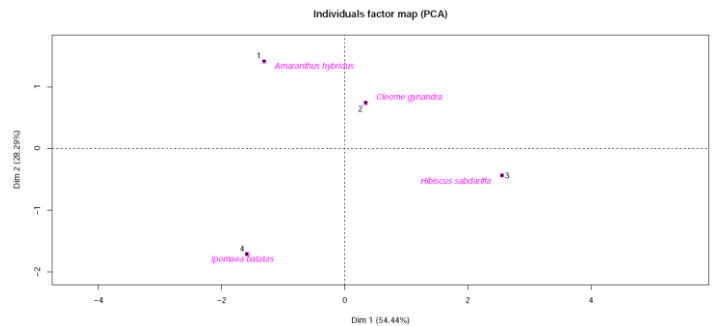


Figure 4 Principal Component Analysis of Pyrethrinoid of synthesis in the vegetables leaves - b: Vegetables species

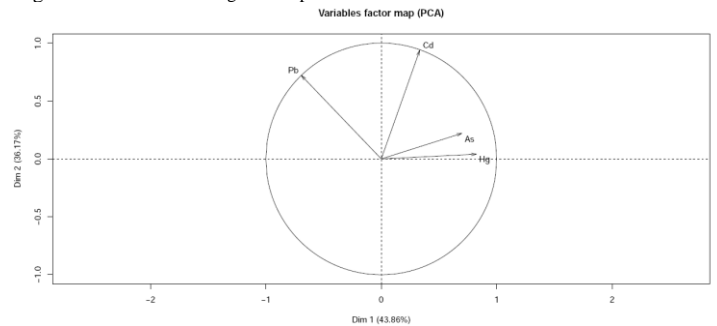


Figure 5 Principal component analysis of heavy metals in vegetables - a: Heavy metals analyses in vegetables leaves

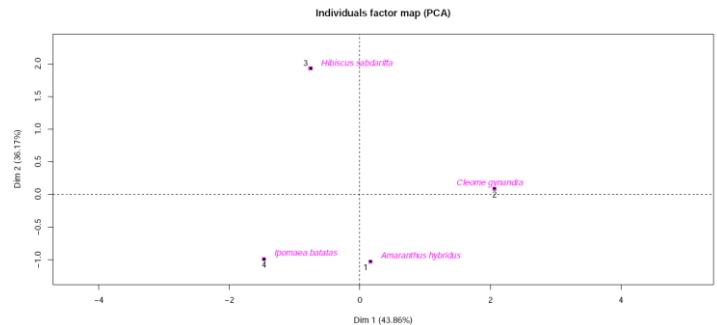


Figure 5 Principal component analysis of heavy metals in vegetables - b: Vegetables species



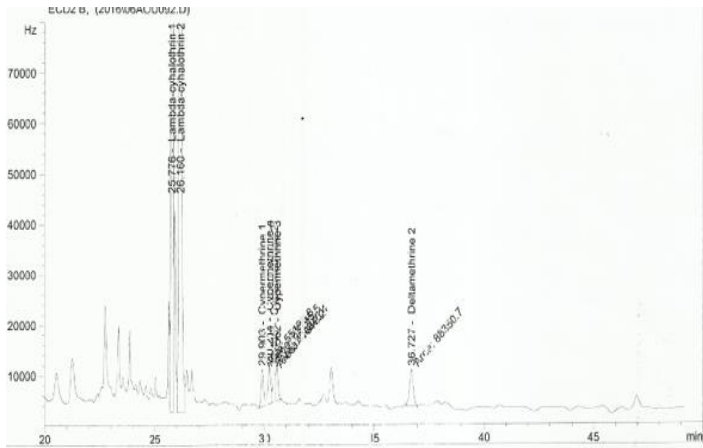


Figure 6 Chromatogram of the vegetable leaves samples containing of the residues of pesticides - a: Chromatogram of a sample of *Amaranthus hybridus* satisfying with pyrethrinoid synthesis.

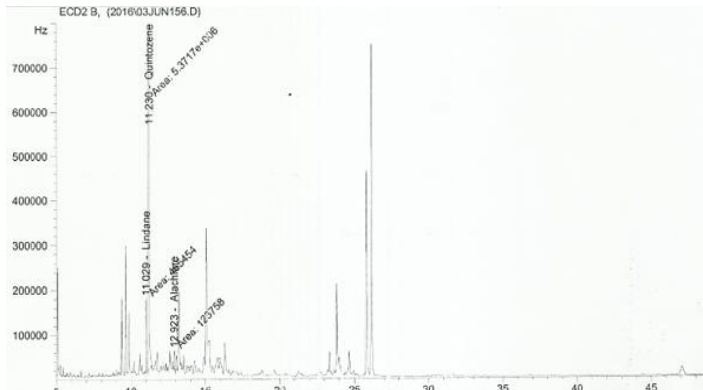


Figure 6 Chromatogram of the vegetable leaves samples containing of the residues of pesticides. – b: Chromatogram of a sample of *Hibiscus sabdariffa* containing the organochlorinated ones and carbamates.

Residues of pesticides in the *babenda*, local sauce.

In general, there was a decrease in the level of residues but it varied greatly, depending on:

- (i) washing, it depends on the nature of the molecule and its formulation, the plant structure and washing methods; it only concerns contact products;
- (ii) the degree of heating (cooking or bleaching), it is also effective and can supplement for the drops due to previous treatments.

The moist heat is a significant factor. Tetramethrin was detected in the samples with contents ranging from 0.0024 to 0.0085 mg.kg<sup>-1</sup>, respectively. Lambda-cyhalothrin concentrations ranged from 0.0049 to 0.0057 mg.kg<sup>-1</sup> in samples d and b, unlike cypermethrin, samples e - b recorded pesticide residue levels of 0.0072 to 0.0085 mg.kg<sup>-1</sup>. Samples a - d recorded deltamethrin levels of 0.0043 to 0.0072 mg.kg<sup>-1</sup>. An 80% reduction of lindane in the *babenda*, with a value of

0.0075 to 0.0081 mg.kg<sup>-1</sup> in samples b - c, while heptachlor recorded values of 0.0099 to 0.0012 mg.kg<sup>-1</sup> in level 1 sample a - d. 92.5% tetramethrin, 15% lambda-cyhalothrin, 87.5% cypermethrin and 60% deltamethrin were the percentages of synthetic pyrethroids removed during cooking. Compared with organochlorine insecticides, lindane had 95% and 52% heptachlor removal. About 75.65% of the analysed plants had heavy metal contents which exceeded the threshold fixed at 0.2; 0.3 and 0.1 mg.kg<sup>-1</sup>, respectively for Cd, Pb and As (FAO/WHO, 2001). Vegetables sold in several markets show Hg content below the thresholds values (Table 2). The Cd contents obtained (0.017 to 3.939 mg.kg<sup>-1</sup>) was higher than the contents obtained with the crop plants on the metallurgical grounds of Noyelles Godault and Auby in France, which reached up to 1.5 mg.kg<sup>-1</sup> (Douay and Sterckeman, 2002; Touré et al., 2015). But a study carried out on the sites of Cocody and Maccory in Côte d'Ivoire (Gupta et al., 2008) reported Cd contents in plants lower than those of this study (0.12 to 0.41 mg.kg<sup>-1</sup>).

In the leaves of *Amaranthus hybridus* and *Hibiscus sabdariffa* collected from the markets, Hg was detected (1,6,7, 9,10,18,19), whereas in the samples of *Ipomoea batatas* and of *Cleome gynandra*, Hg was detected only in samples from certain markets with average values of concentration varying from 0.098 to 3.842 mg.kg<sup>-1</sup>; lower than those reported from India (Gupta et al., 2008), (2.682 to 3.947 mg.kg<sup>-1</sup>) and then Cameroon (Noubissié, 2015). Among the four types of vegetables examined, *Cleome gynandra* and *Amaranthus hybridus* recorded the highest level of Cd concentration which were 5.74 mg.kg<sup>-1</sup> and 3.842 mg.kg<sup>-1</sup>, respectively. *Hibiscus sabdariffa* recorded the highest level of Pb concentration which was 1.145 mg.kg<sup>-1</sup> and *Hibiscus sabdariffa* recorded the highest concentration of As which was 1.691 mg.kg<sup>-1</sup>. The average contents of the heavy metals detected in *Hibiscus sabdariffa*, *Amaranthus hybridus*, *Hibiscus sabdariffa* and *Amaranthus hybridus* were in the order: Cd > Pb > As > Hg. *Cleome gynandra* and *Ipomoea batatas* had high holding capacity for Cd, Pb, As and Hg, respectively.

Hg acceptable limit value is 2 mg.kg<sup>-1</sup>, the results obtained show a high level when compared to the standards (*Amaranthus hybridus* 2.665 mg.kg<sup>-1</sup> *Ipomoea batatas* 3.842 mg.kg<sup>-1</sup>).

The result is similar to those obtained in Cameroon on plants samples (*Amaranthus hybridus* and *Hibiscus sabdariffa*) (Noubissié, 2015), 2.682 to 3.947 mg.kg<sup>-1</sup>.

The normal acceptable values of Pb according to the FAO/WHO (2001) is 0.3 mg.kg<sup>-1</sup>. The average values of Pb found (0.3535, 0.445, 0.548, 1.145 and 2.223 mg.kg<sup>-1</sup>) were higher than the standard set by the FAO/WHO (2011) which is only 0.1 mg.kg<sup>-1</sup>; but similar to those reported by Mpundu et al. (2013) (0.72 and 1.72 mg.kg<sup>-1</sup>). Whereas the toxic nature of Pb has been known for a long time, as well as the dangers related to the contamination of food by this metal (Mourato et al., 2015). But these values are lower than those reported in DR Congo with values of 3.67, 4.089; 5.21, 7.547 and 10.25 mg.kg<sup>-1</sup>. The results of this study corroborate with those obtained by Noubissié (2015) who reported values of 0.134, 0.283, 2.697 and 3.503 mg.kg<sup>-1</sup>. The high Pb values recorded in certain vegetables are probably as a result of pollutants in the water of irrigation, agricultural grounds or road traffic (Qui et al., 2000).

Wong et al. (1996) reported that the Chinese cabbage more easily collects Pb compared to other heavy metals such as Cd, Cu, Ni and Zn. The Pb rate in this study is higher in the leaves of *Hibiscus sabdariffa* (1.145 mg.kg<sup>-1</sup>) and weaker in the sheet of *Ipomoea batatas* (0.013 mg.kg<sup>-1</sup>). The Pb rates reported in this study are higher than that reported in lettuce leaves (0.01 mg.kg<sup>-1</sup>) by Adu et al. (2012).

Table 4 Total concentrations of pesticides (mg.kg<sup>-1</sup>) in the "*babenda*" leaf sauce collected from the markets of the city of Ouagadougou.

Market	Babenda	Pesticides detected in <i>babenda</i> ( mg.kg <sup>-1</sup> )						
		Tetraméthrine	Heptachlore	Lindane	λ-Cyhalothrine	Cyperméthrine	Perméthrine	Deltaméthrine
Market 1 (08)	a	< LQ	< LQ	< LQ	0,0020	< LQ	< LQ	< LQ
	b	< LQ	0,0010	0,0075	0,0042	< LQ	< LQ	< LQ
	c	< LQ	< LQ	0,0081	0,0093	< LQ	< LQ	< LQ
	d	< LQ	0,0012	< LQ	0,0051	0,0056	0,006	0,0059
	e	< LQ	< LQ	< LQ	0,0310	< LQ	< LQ	< LQ
	f	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	0,0019
Market 2 (08)	a	< LQ	0,0012	< LQ	0,0011	< LQ	< LQ	< LQ
	b	< LQ	< LQ	< LQ	0,0057	< LQ	< LQ	< LQ
	c	< LQ	0,0013	< LQ	< LQ	< LQ	< LQ	< LQ
	d	< LQ	0,0097	< LQ	0,0015	< LQ	< LQ	0,0076
	e	< LQ	< LQ	< LQ	0,0030	< LQ	< LQ	0,0072
	f	< LQ	< LQ	< LQ	0,007	< LQ	< LQ	< LQ
Market 3 (08)	a	< LQ	0,0010	< LQ	< LQ	0,0085	0,0086	< LQ
	b	0,0081	0,0011	< LQ	0,0049	< LQ	< LQ	0,00793
	c	< LQ	0,0010	< LQ	< LQ	< LQ	< LQ	< LQ
	d	< LQ	0,0017	< LQ	0,0049	< LQ	< LQ	0,0051
	e	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	0,0061

	f	< LQ	< LQ	< LQ	< LQ	< LQ	< LQ	0,0058
	a	< LQ	0,0099	< LQ	0,0069	< LQ	< LQ	0,0046
	b	< LQ	< LQ	< LQ	0,0035	< LQ	< LQ	0,0059
Market 4 (08)	c	< LQ	< LQ	< LQ	0,0054	< LQ	< LQ	0,0099
	d	< LQ	< LQ	< LQ	0,0083	< LQ	< LQ	0,0068
	e	< LQ	0,0013	< LQ	0,0041	< LQ	< LQ	< LQ
	f	< LQ	0,0016	< LQ	0,0052	< LQ	< LQ	< LQ
	a	0,0085	0,006	< LQ	0,0057	0,0038	0,001	0,0043
	b	0,0024	0,0016	< LQ	0,0017	< LQ	< LQ	< LQ
Market 5 (08)	c	< LQ	0,005	< LQ	0,0071	< LQ	< LQ	0,0052
	d	< LQ	< LQ	< LQ	0,0026	< LQ	< LQ	0,0042
	e	< LQ	< LQ	< LQ	0,0053	0,0072	0,0072	< LQ
	f	< LQ	< LQ	< LQ	0,00154	0,0011	0,001	< LQ
	Total	40						

a,b,c: Code samples of *babenda*; LO: Quantitation Limit

### Heavy metals

The acceptable value of Cadmium (Cd), defined by WHO (2004) is 0.2 mg.kg<sup>-1</sup>. The values obtained in this study (5.74, 4.702, 3.9395, 2.799, 1.425 and 0.742 mg.kg<sup>-1</sup>, respectively) showed higher contents than the standards of WHO (2004). Also, the results obtained in this study were higher than those reported by Kalonda et al. (2015) in DR Congo with values of 7.717, 1.981, 1.621, 1.245 and 0.782 mg.kg<sup>-1</sup>. Mpundu et al. (2013) reported Cd contents of 1.2 and 1.49 mg.kg<sup>-1</sup> in the vegetables sold in the markets of mining zones of Lubumbashi.

The results obtained reveal that Cd concentration in the leaves was higher when compared to those reported by Rehman et al. (2016) in the five areas of Pakistan which varied from 0.2 to 1.6 mg.kg<sup>-1</sup>. Cd concentration for all vegetables, except *Hibiscus sabdariffa*, *Cleome gynandra* and *Ipomaea batatas* were respectively 0.174 ± 0.008 mg.kg<sup>-1</sup>; 0.021 ± 0.006 and 0.024 ± 0.02 mg.kg<sup>-1</sup>, and exceeded the limits (0.1 to 0.2 mg.kg<sup>-1</sup>) established by SEPA (2005). Similar to the studies by shaheen et al. (2016); islam et al. (2015); rahman et al. (2013); ahmad and goni, 2010 was reported mean cd concentration of 0.013 – 0.056 mg.kg<sup>-1</sup>; 0.009 – 7.9 mg.kg<sup>-1</sup> respectively and 0.01 – 0,2 mg.kg<sup>-1</sup> and 0.6 mg.kg<sup>-1</sup>. Al-Rmalli et al. (2012) declared levels of Cd in not-light vegetables (0.008 ± 0.0008 mg.kg<sup>-1</sup>) and in some fruits (0.002 ± 0.001 mg.kg<sup>-1</sup>). These metals were in fossil fuels, oils and lubricants, and the smoke of engines of vehicles (Li et al., 2001; Imperato et al., 2003; Dao et al., 2010).

For Arsenic (As), the acceptable value is limited to 0.01 mg.kg<sup>-1</sup> (WHO, 2004); the results obtained show that for some samples, the values were higher (3.372, 2.928, 1.887 and 0.0106 mg.kg<sup>-1</sup>). These results are similar to those obtained by Alina et al. (2012) who reported values in As as 6.57, 2.13, 1.36 and 0.59 mg.kg<sup>-1</sup> in the samples of spinach sheet, *Amaranthus hybridus* and *Hibiscus sabdariffa*, respectively. Ubalua et al. (2007) reported some values of As (0.01, 0.02 and 0.2 mg.kg<sup>-1</sup>) lower than that found in this study. These differences in contents could be due to the different farming techniques and differences in the level of contamination of the ground, the atmosphere and the water of each site where samples were collected from (Adu et al., 2014).

### Pesticides

Thirteen active compounds were detected in the vegetable-leaves studied such as: the pyrethrinoid compounds (tetramethrine, permethrine, λ-cyhalothrine, cypermethrine and deltamethrine), organophosphorus compound and nitrogenized compounds (diazinon, chlorpyrifos-methyl and parathion-ethyl), organochlorinated compounds (lindane, heptachlore, alachlore and dieldrine) and the carbamates (quintozene) (Fig 3 and 4).

These results are similar to those obtained by Farag et al. (2011) who detected 16 residues of pesticides (chlorpyrifos, diazinon, malathion, profenofos, sulphur, chlorpyrifos-methyl, carbendazime, cypermethrine, ethion, propargite, perméthrine, λ-cyhalothrine, methomyl, phenpropathrin, quinalphos and pirimiphosméthyl) in the vegetables sold in the Egyptian market.

In general, the residual rates of pesticides of the 20 studied markets were either identical, below or above the hot lines of the LMR (Tab 3) authorized by FAO/WHO (2010) and the EU (2008). This may be as a result of inappropriate or abusive use of pesticides and lack of environmental education for farmers (Assogba et al., 2007). The organophosphorus pesticides were detected in almost all the vegetables analyzed with contents ranging from 0.029 to 0.089 mg.kg<sup>-1</sup> for the diazinon; chlorpyrifos-methyl with 0.039 mg.kg<sup>-1</sup> and 0.023 to 0.054 mg.kg<sup>-1</sup> for the parathion-ethyl; often higher than the standard (EU, 2008) (0.02 mg.kg<sup>-1</sup>). Similar studies carried out by Ngom et al. (2013) on the evaluation of pesticides residues in the horticultural products consumed in Senegal detected residues of pesticides that are from organophosphorus compounds, in onion leaves with 0.017 and 0.014 mg.kg<sup>-1</sup> in headed cabbage. The results of this study are largely higher than those recorded by Farag et al. (2011) who detected diazinon in the vegetables sold in the Egyptian markets, with values of 0.01 and 0.016 mg.kg<sup>-1</sup> for chlorpyrifos-methyl. But these results are lower than those obtained by Touré et al. (2015) who reported contents of chlorpyrifos-methyl as 0.338 mg.kg<sup>-1</sup> in *Amaranthus hybridus* during the analysis of pesticides

residues in the market-gardening products collected from the dam Loubila of Burkina Faso.

For lindane, the collection of different vegetables in the markets of Ouagadougou showed contents that largely exceeded the LMR (0.5 mg.kg<sup>-1</sup>) with respective average concentrations of 0.52 and 0.65 mg.kg<sup>-1</sup> (Tab 3). On the other hand, for the heptachlore, the highest content was recorded, varying from 0.016 to 0.025 mg.kg<sup>-1</sup>, and alachlore recorded contents such as 0.085, 0.092 and 0.198 mg.kg<sup>-1</sup> in the samples of vegetables analyzed (Tab 3). The values of dieldrine recorded in the vegetables were 0.92, 1.023 and 1.47 mg.kg<sup>-1</sup>. These results are similar to those obtained by Kanda et al. (2009). Congo (2013) reported residues of organochlorinated pesticides with variable concentrations (0.586, 1.095 and 3.913 mg.kg<sup>-1</sup>) in vegetables samples cultivated in the market-gardening perimeter of Lomé, Togo and Burkina Faso. These were collected from various markets of the countries. Compared to those obtained by Bempah et al. (2011), (0.04 and 0.1 mg.kg<sup>-1</sup>) in the samples of vegetables and spices collected from supermarkets and markets of Kumasi (Ghana). For the alachlore, the contents obtained in this study are higher (0.714 mg.kg<sup>-1</sup>) than those reported by Sène (2008) in lettuce and cabbage collected from Niayes Power Stations of Thiès with concentrations varying between 0.001 and 0.026 mg.kg<sup>-1</sup>.

The contamination of leaves by pyrethrinoid compound is also high even if its remanence is weaker compared to other active matters. The contents of these five active matters exceeded the LMR for the analyzed plants (0.096 mg.kg<sup>-1</sup> for tetramethrine, 0.018 mg.kg<sup>-1</sup> for λ-cyhalothrine, 0.0826 mg.kg<sup>-1</sup> for cypermethrine, 0.169 mg.kg<sup>-1</sup> for permethrine and 0.059 mg.kg<sup>-1</sup> for deltamethrine) (Tab 3). The results of pyrethrinoid obtained in this study are largely higher than those obtained by Touré et al. (2015) who, in a study on the evaluation of the metal-traces, pesticides and plasticizers in the market-gardening products (gombo, corète pot, spinach and aubergine) in the valley of the nieki, south-east of the Ivory Coast, obtained 0.007 mg.kg<sup>-1</sup> of λ-cyhalothrine in spinach against 0.022 mg.kg<sup>-1</sup> of λ-cyhalothrine in pot corète. Deltamethrine gave a concentration of 0.053 mg.kg<sup>-1</sup> for the pot corète and 0.009 mg.kg<sup>-1</sup> for spinach. The contents of pesticides residues obtained from the analyses in this study remained higher than those recommended by Codex alimentarius (2010) and the EU (2008) in the plants. The total concentrations of the pyrethrinoid residues recorded are higher than those obtained by Coly (2000). The total concentrations of pyrethrinoid residues are also higher than those obtained by Ngom et al. (2013); with contents ranging between 0.006 and 0.01 mg.kg<sup>-1</sup> for the deltamethrine in samples collected from the markets of Beavers and Large-Dakar. The results of this study are also higher than those published by Diop (2013) whose contents of deltamethrine lie between 0.087 mg.kg<sup>-1</sup> in cabbage and 0.002, 0.009 and 0.018 mg.kg<sup>-1</sup> for salad and λ-cyhalothrine with contents of 0.316 mg.kg<sup>-1</sup> in cabbage and 0.012, 0.061 and 0.222 mg.kg<sup>-1</sup> for salad; during a study that was related to the diagnosis of the practices of use and quantification of the pesticides in the zone of Niayes of Dakar (Senegal). For λ-cyhalothrine, the average contents observed are higher (2.035; 3.153 and 4.475 mg.kg<sup>-1</sup>) than those reported as standards in the United States and in Western Europe which lay between 0.01 and 0.67 mg.kg<sup>-1</sup> (Codex Alimentarius, 2010).

In Poland, Qozowicka et al. (2012) also reported that chlorpyrifos was 27.4% (100) in their analyzed samples. The range of chlorpyrifos-methyl in *Amaranthus hybridus* (0.046 to 0.54 mg.kg<sup>-1</sup>) obtained in this study are similar to those reported by Chowdhury et al. (2013), who detected chlorpyrifos-methyl in majority of the vegetable samples (0.04 to 0.70 mg.kg<sup>-1</sup>). The concentration of chlorpyrifos in the leaves of *Hibiscus sabdariffa* varied from 0.014 to 0.035 mg.kg<sup>-1</sup>, in five samples having the highest concentration less than the LMR (0.50 mg.kg<sup>-1</sup>) (Tab 3). In addition, the studies carried out in the United States, China and Venezuela reported alarming results. These authors reported high concentrations of chlorpyrifos in tomatoes samples collected from Florida (0.07 mg.kg<sup>-1</sup>) (Stevens and Kilmer, 2009), from Xiamen, China (3.8 mg.kg<sup>-1</sup>) (Chen et al., 2011) and in Venezuela (0.14 to 0.16 mg.kg<sup>-1</sup>) (Quintero et al., 2008). However, the results of this study recorded lower concentration in the leaves of *Hibiscus sabdariffa* (0.014 to 0.035 mg.kg<sup>-1</sup>) when compared to those found in tomatoes samples of Hyderabad, Pakistan (average concentration was 0.22 mg.kg<sup>-1</sup>) (Latif et al., 2011) and India (0.158 mg.kg<sup>-1</sup>) (Sinha et al., 2012). Chlorpyrifos contents in the analyzed plants also recorded lower concentrations

than those reported by Chowdhury *et al.* (2013) who reported contents of chlorpyrifos in cauliflower ranging from 0.062 to 0.080 mg.kg<sup>-1</sup>. These samples are higher than the standard recommended by the EU (2008) (0.05 mg.kg<sup>-1</sup>), and lower than those reported in cauliflower samples from China (0.018 mg.kg<sup>-1</sup>) (Sinha *et al.*, 2012) and India (2.85 mg.kg<sup>-1</sup>) (Mandal and Singh, 2010; Sinha *et al.*, 2012).

Similar studies carried out in Nigeria (Adeyeye and Osibanjo, 1999), in Ghana (Ntow, 2001), and in Gambia (Manirakiza *et al.*, 2003; Williamson, 2008) revealed contaminations of tubers, fruit and vegetables by various residues of pesticides; all higher than the LMR enacted by WHO (2004) and the European Union (EU, 2008).

A total of seven active ingredients (permethrin, tetramethrin, cypermethrin,  $\lambda$ -cyhalothrin, deltamethrin, heptachlor, and lindane) were detected in the *babenda* leaf sauce.

The results of this study are consistent with those reported by FAO (2004) with reference to the *Codex Alimentarius* (2010) who adopted these definitions and classifications of foods for the purpose of pesticide residue controls. The committee recorded a 50% decrease in organochlorine residues in carrots and a 10-25% removal of pyrethroids in cabbage after cooking. Other existing heat treatment results suggest that bleaching of vegetables results in a 20-40% decrease in organochlorine insecticides in spinach compared to 30-80% pyrethroids (FAO / WHO, 2004).

DGAL (2000) reported that identical meals or "duplicate meals" collected from 25 sites and 5 regions were containing six residues that are at least 1-times higher than the limit of quantification; and 4 of the residues have never been quantified. The analysis showed that the contamination is not significant. The results of this study are in line with those reported by the EFSA (2007), who found out that over 97% of the food tested contained pesticide residues within the allowed limits.

This constitutes a true problem of public health because the vegetables produced in these small farms located near the urban centres occupy a significant place in the daily food of the cities populations.

## CONCLUSION

The majority of vegetables tested present contamination by heavy metals and pesticides that are alarming. The pesticides and heavy metals contents present in vegetables in the various markets of Ouagadougou town were tested. The majority of the samples showed that the contents of pesticides are relatively higher than the contents of heavy metals; probably because of the excessive use of pesticide chemicals by industries, mining activities and animal husbandries. The risk of contamination of the food chain by the consumption of the vegetables sold on the markets of Ouagadougou town are not negligible. This contamination could be the cause of many diseases suffered by the consumers. It can also cause damage in agricultural production like breeding.

The results obtained in this study are significant in the sense that it shows that human health is directly affected by the consumption of the vegetables. The monitoring of pesticides and heavy metals contents in the vegetables intended for the preparation of "*babenda*" sauce must be continued; because this sauce is highly consumed during great ceremonies (marriages, baptisms, university canteens and households) in Burkina Faso.

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