



BIOCHEMICAL COMPOSITION AND CONSUMPTION RISK OF LEAFY VEGETABLES PUTS AND "BABENDA" CEREALS PRODUCED IN FIVE CITIES IN BURKINA FASO

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ABSTRACT

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Babenda is a national dish that has become famous in food habits and production without adequate knowledge of its nutritional and energy potential. It is made with leafy vegetables and cereals. This study aimed to determine the risk assessment of some heavy metals and physico-chemical characteristics of leafy vegetables and Babenda consumed in five cities in Burkina. The samples of 120 leafy vegetables and 60 Babenda were collected. The analyzes focused on the total levels of lead (Pb), cadmium (Cd), arsenic (As) and mercury (Hg) and were carried out using standard methods. The moisture content varied between 86.82 ± 2.51 and 88.57 ± 1.19 . The lipid content varied from 13.89 ± 0.22 g/100g to 19.91 ± 0.41 g/100g; the carbohydrate content ranged from 60.91 ± 0.22 g/100g to 77.35 ± 0.22 g/100g; the protein content between 9.76 ± 0.09 g / 100g and 23.56 ± 0.02 g / 100g. The energy potential was between 469.45 kcal and 499.57kcal with an average value of 480.766 Kcal 100g of dry matter. Babenda is a source of calcium (129.52 ± 2.38 mg / 100g), sodium (12.92 ± 0.29 mg / 100g). Babenda has a good nutritional value and its consumption can help fight against food insecurity and malnutrition.

Contribution/Originality: This study assesses the contamination risk and the Babenda composition. These are necessary valorization steps this local resource and fight malnutrition and improve food security. Besides, its consumption should be recommended, especially among the low-income population with little access to products with high nutritional value and the human health benefits.

1. INTRODUCTION

Cultivation of leafy vegetables is practiced throughout the year. Their production area is great, thus occupying more space compared to other vegetables. However, according to their soil requirements, they can be produced in

the dry season and covers only a small area. Nevertheless, the geographical location of these soils leads to an accumulation of various heavy metals enriched wastes such as effluents from factories located around cities, waters from artisanal washing of ores in the plots of the houses, chemical fertilizers used (Bakary et al., 2019). Contamination of plants by root absorption, or by depositing dust loaded with heavy metals on higher parts of plants is possible and should be evaluated. In some developed countries, cases of respiratory disease have been observed in an age group of women (aged 35 to 75) residing around copper electrical smelters (Ponka et al., 2006).

The leafy vegetables taken from the different markets of Ouagadougou city also had high levels of heavy metals (Bakary et al., 2019; Ponka et al., 2006). Different sources (factories, traffic) of emission are combined and thus the results of proximity are more important in the urban and peri-urban zones (Adjatin et al., 2013; Michel et al., 2013).

Local products and traditional home-made dishes have brought important socio-economic changes and reduced the time they have for cooking meals for household (Diarra et al., 2016; Soro, Atchibri, Kouadio, & Kouamé, 2012). At the same time, technological advances in production, processing and distribution, structural change, and the growth of large-scale retail trade are contributing to rapid market reorganization (Addis et al., 2013; Hama-Ba, Parkouda, Kamga, Tenkouano, & Diawara, 2017; Tarnagda et al., 2019).

"Babenda" is a typical dish of the "land of men of integrity" very much consumed by many people of Burkina Faso. In the past, "Babenda" was eaten as a food during periods of famine and consisted mainly of bean leaves and sorrel crushed and millet that was boiled together until cooked (Hama-Ba et al., 2017; Sawadogo, 2018). Nowadays this local dish is a sauce made from selected leaves such as leaves of *Hibiscus sabdariffa*, *Amarantus hybridus*, peanut seeds and cereal such as rice (Hama-Ba et al., 2017; Tarnagda et al., 2019). It is increasingly consumed by people in urban areas during ceremonies and for daily consumption.

The analysis of the national food balance sheet by the Ministry of Agriculture for the 2016-2017 crop year showed that, except for tubers and eggs, the needs of plant products and other products (fruits, cereals, legumes, oleaginous, etc.) are covered (General Direction of Studies and Sectoral Statistics (DGESS), 2018). Based on that Decree No. 2017-002 / PM / CAB / on the purchase of local food products by state structures has been adopted by the Burkina Faso government (Sawadogo, 2018). The adoption of this text helps to promote valorization and processing of local dishes including "Babenda" for meeting the nutritional needs of the people of Burkina Faso.

Therefore, the quality of the leafy vegetables used and the improvement of the nutritional value of this local dish could mitigate food insecurity in Burkina Faso and some aspects of hunger in the world (Diarra et al., 2016; Randrianatoandro, Avallone, Picq, Ralison, & Trèche, 2010; Tarnagda et al., 2019). During ancient days, Babenda was an adequate solution to household food security during times of food shortage in some regions of Burkina Faso, but nowadays it is a national dish. Babenda's production technology varies from one producer to another and from one Region to another (Tarnagda et al., 2019).

But the added value of this local dish is an adequate response to food insecurity as a whole and requires standardized technology. And this technology demands varieties of leafy vegetables and adapted cereals with a high nutritional and energy value. Several varieties of leafy vegetables and cereals are now being used and adapted to national agro-ecological conditions and production technology.

The most logical approach to this heavy metal problem is to prevent contamination from the production site of leafy vegetables and Babenda. The objective of the present study is to assess the risk associated with the contamination of vegetables by heavy metals, the biochemical and nutritional composition of a local dish made from leafy vegetables and "Babenda" cereals produced and consumed in five cities of Burkina Faso.

2. MATERIAL AND METHODS

2.1. Sampling of Leafy Vegetables and Babenda

Leafy vegetables (*Amaranthus hybridus*, *Hibiscus hybridus*, *Cleome gynandra* and *Ipomea batatas*) and Babenda were bought in five cities of Burkina Faso (Ouagadougou, Bobo-Dioulasso, Koudougou, Ouahigouya and Kaya). A total of

180 samples, including 120 vegetables (6 kg of each species) and 60 samples of Babenda were purchased per city and per vendor. Vegetables from two vendors in the same city were mixed to form a sample.

One part of each sample (1 kg) was rinsed three times with tap water, according to the practice of cleaning leafy vegetables. Babenda samples (60 samples) were collected at random from the same cities. Composite samples of 500 g to 1 kg of Babenda were collected, stored in sterile polyethylene bags, coded with a unique login and placed in a refrigerator (4 °C) before analysis.

2.2. Heavy Metals Analysis in Leafy Vegetables

Total Cd, Pb, Hg and As contents of plants were analyzed. Dry plants were ground in a tungsten carbide ring mill. The extract is a mixture of HNO₃ - HClO₄ (1/1 V/V). Five (05) grams of a powdered sample were mixed with 50 ml of extractant and heated until complete evaporation. Ten milliliters of HCl (10% V/V) were then added to the residue which is decanted and transferred in a 50 ml flask.

The method described by Awofolu (2005) was adopted for the acid digestion of vegetables samples. The determination of heavy metals was carried out by atomic absorption spectrometer (VARIAN 220).

2.3. Estimated Ingested Daily Intake of Heavy Metals

The average intakes obtained by the individual consumption of 400 g of leafy vegetables are calculated following the equation (FAO/WHO, 2008):

$ADI = Q \times CM / 10$, where ADI is the Average Daily Intake, CM is the Average Concentration of Heavy Metals and Q the Amount of leafy vegetables.

2.4. Determination of Babenda Physico-Chemical Composition

2.4.1. Determination of Ph and Acidity

Ten grams (10 g) of each sample was dissolved in 50 ml of distilled water and mixed. The pH was directly measured with a digital pH meter. For total acidity, 10 g of each sample was mixed with 50 ml of distilled water in rotating cones. The cones were then centrifuged for 15 minutes at 3900 rpm and the supernatant was collected. Titration was performed using 0.1 N KOH and phenolphthalein as an indicator. All measurements were repeated triplicata.

2.4.2. Biochemical Composition of Babenda

The proximal potential of the Babenda samples was performed using the following standard procedures described by the Association of Official Analytical Chemists (Firestone, 2008). Dry matter was determined by drying the samples at 105 ± 2 °C overnight; the ash content by incineration at 550 °C for 12 hours. The crude protein content ($N \times 6.25$) was carried out by the Kjeldahl method after acid digestion and the crude fat content by Soxhlet extraction using n-hexane as the solvent.

The total carbohydrates content was calculated by the differential method after the determination of protein, lipid, ash and water content according to Tollier and Robin (1979). The values were expressed in g/100 g fresh Babenda. The energy value was calculated using the method described by Rerat (1956) taking into account the carbohydrate, lipid and protein content.

2.4.3. Minerals Content of Babenda

The mineral content (Fe, Zn, Ca, Na) was determined after digestion of 0.5 g of the sample using the technique of atomic absorption spectrophotometry described in the Association of Official Analytical Chemists approved method (Firestone, 2008).

2.5. Statistical Analysis

The dendrogram and Analyses of variance (ANOVA) were realized using XLSTAT-Pro 7.5. Means, standard deviation and the least significant difference between the means were determined ($p < 0.05$). Newman-Keuls correlations among nutritional and physicochemical values were estimated for all the investigated factors. Software R 3.1.2 was used for the principal component analysis.

3. RESULTS AND DISCUSSION

3.1. Heavy Metals Profile

3.1.1. Principal Component Analysis of Heavy Metals

The main component analysis of leafy vegetable samples was conducted using a two-axis biplot (F1 and F2) that accounted for 78.91% of the variability of the study samples. The main F1 axis explained 46.74% of this variability and the secondary axis F2 32.17%. The two axes identified four (04) heavy metals: a first group consisting of Pb and Hg and which is linked to the main axis F1; a second group that includes As and Cd which is linked to the secondary axis F2. Observations made on the main axis showed that the samples of *Amaranthus hybridus*, *Cleome gynandra*, *Hibiscus sabdariffa* and *Ipomea batatas* were contaminated with Pb and Hg. whereas those on the secondary axis made it possible to distinguish between a contamination of the four species of leafy vegetables in As and in Cd. In the cities of Ouagadougou, leaves of *Amaranthus hybridus* recorded the level of contamination in Hg, Pb, Cd and As at concentrations of 2.665 ± 0.01 mg / kg; 0.228 ± 0.04 mg / kg; 3.939 ± 0.05 and 2.928 ± 0.03 mg / kg respectively. In Bobo Dioulasso, the leaves of *Hibiscus sabdariffa* recorded Pb and Cd contaminations 1.041 ± 0.02 mg / kg and 2.799 ± 0.01 mg / kg, respectively. In Koudougou, leaves of *Hibiscus sabdariffa* recorded levels of Pb and Cd contamination at values of 0.345 ± 0.01 mg / kg and 3.372 ± 0.01 mg / kg.

Cleome gynandra leaves recorded a level of Hg contamination (0.327 ± 0.03 mg / kg) compared to *Hibiscus sabdariffa* leaves, which recorded levels of Pb, Cd and As contamination at respective concentrations of 1.145 ± 0.00 mg / kg; 0.288 ± 0.03 mg / kg; 0.190 ± 0.01 mg / kg. Of the four (04) types of leafy vegetables examined, *Cleome gynandra* and *Amaranthus hybridus* recorded the highest level of Cd and Hg respectively at 5.74 mg/kg and 3.842 mg/kg.

Table-1. Mean values of heavy metals (mg / kg) in leafy vegetable samples sold in five cities of Burkina Faso.

Cities/ heavy metals	Ouagadougou	Bobo- Dioulasso	Koudougou	Ouahigouya	Kaya	Standard FAO/WHO. (2004)
Hg (mg/kg)	$2,665 \pm 0,01^a$ (<i>Amaranthus hybridus</i>)	$3,842 \pm 0,05^a$ (<i>Ipomea batatas</i>)	$0,624 \pm 0,01^b$ (<i>Hibiscus sabdariffa</i>)	< LQ	$0,327 \pm 0,03^c$ (<i>Cleome gynandra</i>)	2
Pb (mg/kg)	$0,228 \pm 0,04^{de}$ (<i>Amaranthus hybridus</i>)	$1,041 \pm0,02^{ab}$ (<i>Hibiscus sabdariffa</i>)	$2,223 \pm 0,00^a$ (<i>Amaranthus hybridus</i>)	$0,354 \pm0,01^{bc}$ (<i>Amaranthus hybridus</i>)	$1,145 \pm0,00^{ab}$ (<i>Hibiscus sabdariffa</i>)	0,1
Cd (mg/kg)	$3,939 \pm 0,05^b$ (<i>Amaranthus hybridus</i>)	$2,799 \pm 0,01^b$ (<i>Hibiscus sabdariffa</i>)	$0,345 \pm 0,01^c$ (<i>Amaranthus hybridus</i>)	$5,740 \pm0,05^a$ (<i>Cleome gynandra</i>)	$0,288 \pm 0,03^c$ (<i>Hibiscus sabdariffa</i>)	0,2
As (mg/kg)	$2,928 \pm 0,03^a$ (<i>Amaranthus hybridus</i>)	$2,691 \pm 0,01^a$ (<i>Amaranthus hybridus</i>)	$0,372 \pm 0,01^a$ (<i>Ipomea batatas</i>)	$0,177 \pm0,02^{de}$ (<i>Amaranthus hybridus</i>)	$0,190 \pm0,01^{cde}$ (<i>Hibiscus sabdariffa</i>)	0,01

Note: Means values followed by the same letter in the same line are not significantly different ($P > 0.05$), according to Tukey's multiple comparison test (the Newman-Keuls).

LQ: quantification of limit.

Amaranthus hybridus recorded the highest level of Pb concentration at 2.223 ± 0.00 mg / kg and *Hibiscus sabdariffa* recorded the highest level of As concentration of 3.372 ± 0.01 mg / kg. Similarly, leafy vegetables of *Ipomoea batatas* recorded mean levels of As concentration of 3.842 ± 0.05 mg / kg and 3.372 ± 0.01 mg / kg respectively for the city of Bobo Dioulasso and Koudougou. These trends show that samples of *Cleome gynandra* and *Ipomoea batatas* have a high retention capacity for Cd followed by Pb after As and Hg. However, average levels of heavy metal in the leaves of *Hibiscus sabdariffa* and *Amaranthus hybridus* are in order: Cd > Pb > As > Hg. This trend indicates that *Hibiscus sabdariffa* and *Amaranthus hybridus* have a high Cd retention capacity followed by Pb, As and Hg.

However, it can be seen that all leafy vegetables have a higher retention capacity for toxic metals (Cd, Pb, Hg and As). Considering the levels of mercury (Hg), the normal value is fixed at 2 mg/kg, the results found show an increase in the samples of *Amaranthus hybridus* (2.665 mg / kg) and *Ipomoea batatas* (3.842 mg / kg). Comparing the average values of heavy metals content found in the two species, analysis of variance showed that total heavy metals levels were significantly different in leafy vegetables collected in different cities. The levels of metal trace elements (mg / kg) in leafy vegetable samples are shown in Table 1.

The results of this study are superior to those obtained in Benin by Adanloknonon et al. (2019) which found a Hg content of 0.25 mg / kg. For Hg, leafy vegetables sold in several cities show values above threshold values Table 1. Li et al. (2012) (0.67mg /kg) reported lower Hg levels than ours. For Arsenic (As), the results show that in some samples the values were higher, respectively from 0.177 ± 0.02 mg / kg to 3.372 ± 0.01 mg / kg. These results are similar to those obtained by Mihali et al. (2012) who reported values in As respectively, of 0.001 to 0.479 µg/g fresh weight (As).

Bakary et al. (2019) reported in Burkina Faso values of As (0.001 ± 0.053 to 1.887 ± 0.013 mg / kg) lower than that found in our study in the five cities of Burkina Faso. These differences in levels may be due to products intended to improve the physicochemical properties of the soil are often richer in heavy metals than the soil itself, for example, fertilizers, composts and sewage sludge (Bakary et al., 2019). Relative to Cadmium (Cd), the limit value is 0.2 mg / kg; our results showed levels above the normal limit set by FAO/WHO. (2004) in some samples : 5.74 mg / kg, 3.939 mg / kg, 2.799 mg / kg, 0.345 mg/kg et 0.288 mg / kg.

Our results are greater than those reported by Li et al. (2012) which is 0.73 mg / kg and in Benin by Adanloknonon et al. (2019) (0.0261 mg / kg). The Cd contents obtained (0.017 - 3.939 mg / kg) are higher than those obtained by Mihali et al. (2012) (0.001 to 0.101 mg / kg). In the leaves of *Amaranthus hybridus* and *Hibiscus sabdariffa* and *Ipomoea batatas* Hg was detected in the markets of the other cities except for Kaya City with average concentration values ranging from 0.327 ± 0.03 to $3.842 \pm 0, 05$ mg / kg lower than those reported by Cui, Zhu, and Zhai (2004) (2.682 mg / kg) and in Benin by Adanloknonon et al. (2019) (0.001 mg / kg). For Lead (Pb), the normal values set by FAO/WHO. (2004) are 0.3 mg / kg.

Mean Pb values found range from 0.228 ± 0.04 mg / kg to 2.223 ± 0.00 mg / kg, which are higher than the level set by FAO/WHO. (2011) which is 0.1 mg / kg; but similar to those reported by Mubemba, Michel, Yannick, and François (2013) (1.72 mg / kg) and by Adanloknonon et al. (2019) (0.1727 mg / kg), whereas the toxic nature of lead has been known for a long time, as well as the dangers related to the contamination of food with this metal (Bakary et al., 2019).

Our results corroborate those obtained by Nakamoto, Simmons, William, and Falster (1999) whose obtained values of 2.94 mg / kg to 13.73 mg / kg and 5.22 to 37.15 mg / kg. Pb is a toxic element that can be harmful to plants, although plants generally show the ability to accumulate a quantity of lead without any visible change in appearance or yield. High levels of Pb in some leafy vegetables are probably attributed to pollutants from irrigation water, agricultural soils or road traffic (Bakary et al., 2019).

Pb levels in this study are higher in *Amaranthus hybridus* leaves (2.223 ± 0.00 mg / kg). The Pb levels reported in this study are higher than those reported in lettuce leaves (0.001 to 0.655 µg / g fw (Pb) by Mihali et al. (2012).

However, 90% of the vegetable samples examined in this study are therefore within the safety limit, but regular monitoring is required over a long period of time.

3.1.2. Estimation of Average Daily Intake (ADI) in Heavy Metals

Leafy vegetables were purchased in five cities in Burkina Faso to estimate the risks of contamination of the food chain through the consumption of these leaves. These results are shown in Table 2.

Table-2. Average daily dose (ADI) of heavy metals of 400g leafy vegetables sold in five cities of Burkina Faso.

Cities	Ouagadougou	Bobo-Dioulasso	Koudougou	Ouahigouya	Kaya	DJT ($\mu\text{g}/\text{kg}$)
Hg (μg)	106.6 (<i>Amaranthus hybridus</i>)	153.6 (<i>Ipomaea batatas</i>)	nd	nd	13.08 (<i>Cleome gynandra</i>)	109
Pb (μg)	9.12 (<i>Amaranthus hybridus</i>)	41.64 (<i>Hibiscus sabdariffa</i>)	88.92 (<i>Amaranthus hybridus</i>)	14.16 (<i>Amaranthus hybridus</i>)	45.8 (<i>Hibiscus sabdariffa</i>)	252
Cd (μg)	188.08 (<i>Amaranthus hybridus</i>)	111.96 (<i>Hibiscus sabdariffa</i>)	11.68 (<i>Ipomaea batatas</i>)	229.6 (<i>Cleome gynandra</i>)	11.04 (<i>Amaranthus hybridus</i>)	70
As (μg)	117.12 (<i>Amaranthus hybridus</i>)	107.64 (<i>Amaranthus hybridus</i>)	134.88 (<i>Ipomaea batatas</i>)	7.08 (<i>Amaranthus hybridus</i>)	7.6 (<i>Hibiscus sabdariffa</i>)	3000

Note: Values in bold are above the threshold.
nd: not detected.

An average value of 106.6 μg Hg was found in *A. hybridus*, whereas 188.08 μg Cd was detected in *A. hybridus* leaves purchased from the large market. The Tanghin market recorded an average value of 9.12 μg in Pb in *A. hybridus*. For Arsenic, the *A. hybridus* recorded an average value of 117.12 μg in the same market (Ouagadougou). In Bobo-Dioulasso, the average ADI reached 153.6 μg in *I. batatas* and 41.64 μg in *H. sabdariffa* at the level of the market respectively for Hg and Pb. The market of Accart-Ville recorded an average value of 111.96 μg in Cd in *H. sabdariffa*. For Arsenic, the *A. hybridus* recorded an average value of 107.64 μg in the fruit and vegetable market.

In *A. hybridus*, an average Pb value of 88.92 μg at the sector 5 market level. For Arsenic, the central market recorded an average value of 134.88 in *I. batatas* and the Cd recorded an average value of 11.68 μg of *I. batatas* in *H. sabdariffa* (Koudougou). In Ouahigouya, it is noted that Hg and As were not detected, unlike Pb, which recorded an average value of 14.16 μg in *A. hybridus* at the large market level. The vegetable market recorded an average value of 229.60 μg of Cd in *C. gynandra* and 7.08 μg of As was recorded at the large market level.

In Kaya, the average ADI reached 12.52 μg in *H. sabdariffa* and 13.08 μg in *C. gynandra* in the large market for Hg. The vegetable market recorded an average value of 12.00 μg in Hg in *H. sabdariffa*. For Pb *H. sabdariffa* recorded an average value of 45.8 μg in the central market while *I. batatas* recorded an average value of 4.52 μg in the large market. The central market recorded an average value of 10.88 μg of Cd at the level of *I. batatas*. Comparatively, Arsenic recorded a value of 7.60 μg in the fruit and vegetable market. These results are similar to those reported by Mench and Baize (2004) which showed that cereals do not accumulate much of the metals in the seeds compared to leafy vegetables.

These results are different from those found by Mench and Baize (2004) for leaves. These authors found levels of 17 to 20 μg and 52 - 68 μg respectively for Cd and Pb. Similar work was carried out by Mubemba et al. (2013) (ADI contents of 73.2 to 152 μg and 79.3 - 230 μg respectively for Cd and Pb) on the evaluation of metal trace elements in leafy vegetables sold in the markets in the Lubumbashi mining area. These results are different from those found by Mench and Baize (2004) for leaves. These authors found levels of ADI of 17 to 20 μg and 52 - 68 μg respectively for Cd and Pb on the trace elements contamination of soils and our foods of plant origin. Dietary exposure is reduced for Pb (-60%) and Cd (-40%) and increased for Hg (+ 50%) in parallel with fish consumption.

The Tolerated Daily Dose (DHT) of Hg is fixed at 300 µg per week, of which at most 200 µg of methylated mercury. The total Arsenic ADI is estimated at 4% of the DHT (3000 µg per day), but the speciation of ingested arsenic remains to be established. However, for lead, cadmium and arsenic, leaf vegetable ADI purchased in the markets studied had an overall contribution of more than 50% of the DHT. Mench and Baize (2004), had pointed out that foods with more than 50% contribution to the ADI present health risks to consumers.

The ADI provided by maize consumed as paste (tô) and fish, the daily meal of some Burkinabe, should be taken into account in the estimation of the weekly intake. Overall, market-grown vegetable meal prices are lower than those provided by vegetables grown on vegetable gardens studied in the city of Lubumbashi (Mubemba et al., 2013). The origin of these vegetables purchased in these markets could explain these low values. Bakary et al. (2019) have shown that the production of vegetables in sites remote from sources of contamination, remains one of the measures in the reduction of the risks of impregnation in heavy metals. The most contaminated plants with Pb, Cd, Hg and As are leafy vegetables (*H. sabdariffa*, *A. hybridus*, *C. gynandra* and *I. batatas*) Table 2. For the concentration of heavy metals, plant products are classified in this order:

Hg : *I. batatas* > *A. hybridus* > *C. gynandra* > *H. sabdariffa*

Pb : *A. hybridus* > *H. sabdariffa* > *C. gynandra* > *I. batatas*.

Cd : *C. gynandra* > *H. sabdariffa* > *A. hybridus* > *I. batatas*

As : *I. batatas* > *A. hybridus* > *H. sabdariffa* > *C. gynandra*

Many people consume less than 400g of vegetables a day (FAO/WHO, 2008). This is the case for many Burkinabe families who consume small amounts of vegetables per day. This low consumption could be a means to reduce the impregnation of heavy metals. In this case, the risk of contamination of the food chain via vegetables, is increasingly lower.

3.2. Physicochemical Characteristics of the Babenda

The physicochemical properties of babenda collected in the five cities are shown in Table 3.

Table-3. Physicochemical properties of babenda sampled in the five cities.

Sampling site	pH	Total acidity	% Water content	% Dry matter
Ouagadougou	4.99 ± 0.03 ^b	0.062 ± 0.01 ^a	87.6 ± 1.59 ^{ab}	12.40 ± 1.59 ^{ab}
Bobo-Dioulasso	5.33 ± 0.06 ^a	0.065 ± 0.01 ^a	87.61 ± 1.22 ^{ab}	12.39 ± 1.22 ^{ab}
Koudougou	5.31 ± 0.03 ^{ab}	0.075 ± 0.01 ^a	88.57 ± 1.19 ^a	11.43 ± 1.19 ^b
Ouahigouya	4.87 ± 0.04 ^b	0.077 ± 0.04 ^a	86.82 ± 2.51 ^b	13.18 ± 2.51 ^a
Kaya	5.09 ± 0.02 ^{ab}	0.060 ± 0.02 ^a	87.18 ± 1.46 ^b	12.82 ± 1.46 ^a
Average	5.12 ± 0.04	0.07 ± 0.02	87.56 ± 1.59	12.44 ± 1.59

Note: The same letters in a column are not significantly different at the 5% threshold according to the Newman-Keuls test.

The moisture content of babenda is between 86.82 ± 2.51 and 88.57 ± 1.19 g/100g with an average value of 87.56 ± 1.59g/100g. Babenda is slightly acidic with a pH between 4.87 ± 0.04 and 5.33 ± 0.06 with an average value of 5.12 ± 0.04. Their acidity ranges from 0.060 ± 0.02 to 0.077 ± 0.04 g lactic acid/100 g with an average of 0.07 ± 0.02 g. The lipid content of Babenda ranges from 13.89 ± 0.22 (Kaya / Babenda) to 19.91 ± 0.41 g/100g (Koudougou/ Babenda) with an average value of 16.12 ± 0.19.

The total carbohydrate content is between 60.91 ± 0.2 (Ouagadougou / Babenda) and 77.35 ± 0.22 (Kaya / Babenda) with an average value of 67.76 ± 0.28. The proteins content of Babenda ranged from 9.76 ± 0.09 g / 100g (Kaya / Babenda) to 23.56 ± 0.02 g / 100g (Ouagadougou / Babenda) with an average value of 16.32 ± 0.13. Total ash ranged from 4.14 ± 0.04 (Ouahigouya / Babenda) to 4.65 ± 0.09 (Koudougou / Babenda). Babenda is rich in minerals. The content of the main minerals of Babenda are: iron (8.38 ± 0.15 mg 100g), zinc (2.67 ± 0.12 mg 100g), calcium (129.52 ± 2.38 mg / 100g), and sodium (12.92 ± 0.29 mg 100g).

The total energy intake of the various Babenda samples analyzed is between 469.45 Kcal and 499.57 Kcal with an average of 480.77 Kcal / 100g of Babenda. The results show a variation in the total energy intake of the different

samples analyzed. These different variations would be due to the different constituents used in the process of preparation of the Babenda. These values are recorded in Table 4.

Table-4. Biochemical composition and mineral content of Babenda samples (g / 100g).

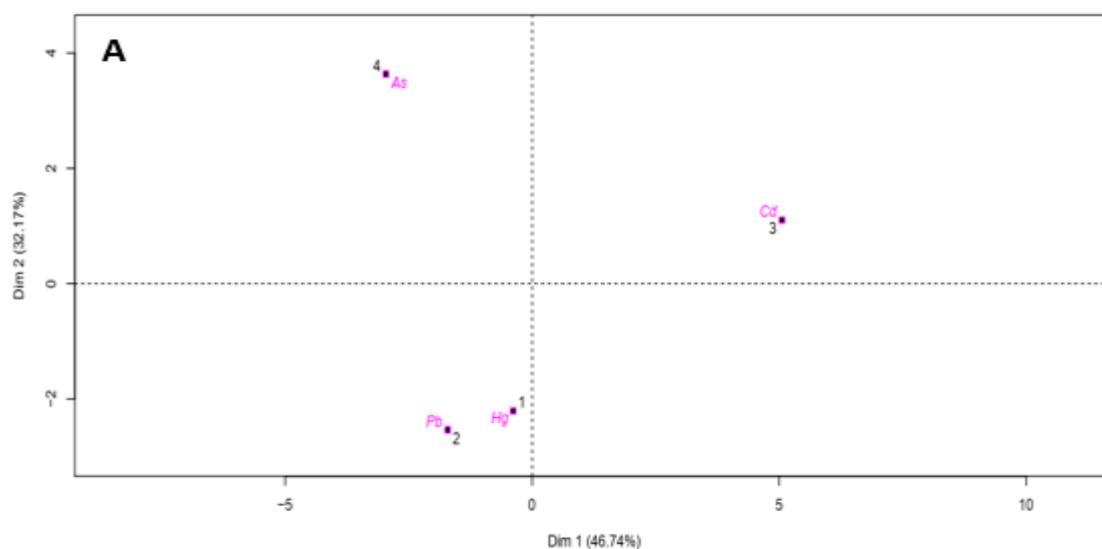
Sampling site	Lipids	Proteins	Carbohydrates	Iron	Zn	Ca	Na	Total Energy Contribution (Kcal)
Ouagadougou	15.53±0.04 ^{bc}	23.56±0.02 ^a	60.91±0.20 ^c	11.43±0.15 ^a	2.62±0.04 ^a	147.18±6.36 ^a	17.78±0.28 ^a	477.65
Bobo-Dioulasso	14.26±0.13 ^{bc}	16.92±0.18 ^b	69.15±0.23 ^b	7.97±0.14 ^b	2.86±0.01 ^a	142.05±0.6 ^a	10.76±0.18 ^{ab}	471.29
Koudougou	19.91±0.4 ^a	17.5±0.25 ^b	62.59±0.57 ^{bc}	7.78±0.15 ^b	1.59±0.16 ^a	127.02±2.47 ^b	15.06±0.15 ^{ab}	499.57
Ouahigouya	17.01±0.17 ^{ab}	14.2±0.12 ^{bc}	68.79±0.20 ^b	6.70±0.18 ^{bc}	2.69±0.11 ^a	109.62±1.41 ^c	5.99±0.14 ^b	485.87
Kaya	13.89±0.22 ^c	8.76±0.09 ^c	77.35±0.22 ^a	5.23±0.10 ^c	2.78±0.75 ^a	108.77±0.71 ^c	12.24±0.11 ^{ab}	469.45
Average	16.12 ± 0.19	16.32 ± 0.13	67.76 ± 0.28	7.82±0.14	2.68±0.21	120.10±2.31	8.93±0.17	480.766

Note: The same letters in a column are not significantly different at the 5% threshold according to the Newman-Keuls test Fer : Iron ; Zn : Zinc; Ca : Calcium; Na : Sodium.

The physical and chemical properties of Babenda are consistent with previous studies (Sawadogo, 2018) during a study on the evaluation of the nutritional quality of local food « Babenda» Consumed in the city of Ouagadougou. However, other authors have found similar moisture values between 85% and 87.39% (Mouquet-Rivier, Ouattara, Vallone, Amoussa, & Ba, 2010). The water content of the Babenda is lower than that of Bulvaka leaves which is 87.3% or 12.7% of dry matter. But our results are greater than the values of 8.99% and 87.39% with an average value of 85.74% obtained by Sawadogo (2018).

There is a significant difference in dry matter content, pH and humidity according to the Newman-Keuls test in a proportion of 5% Table 4. There is a correlation between the moisture content and the dry matter. The difference is then dependent on the varietal effect. This could also be explained by the method of preparation of this dish as well as the composition of raw material, consisting mainly of leafy vegetables which contain an average of 90% water. In fact, the type of cereal and the quantity added significantly influences the water content. The values of the acidity of the Babenda are in agreement with those found by Houndji et al. (2013) on leaves of *Moringa oleifera* (Lam.) with an average value of 0.07%.

The PCA of the sixty Babenda samples according to the biochemical composition and nutritional value are shown in Figure 1.



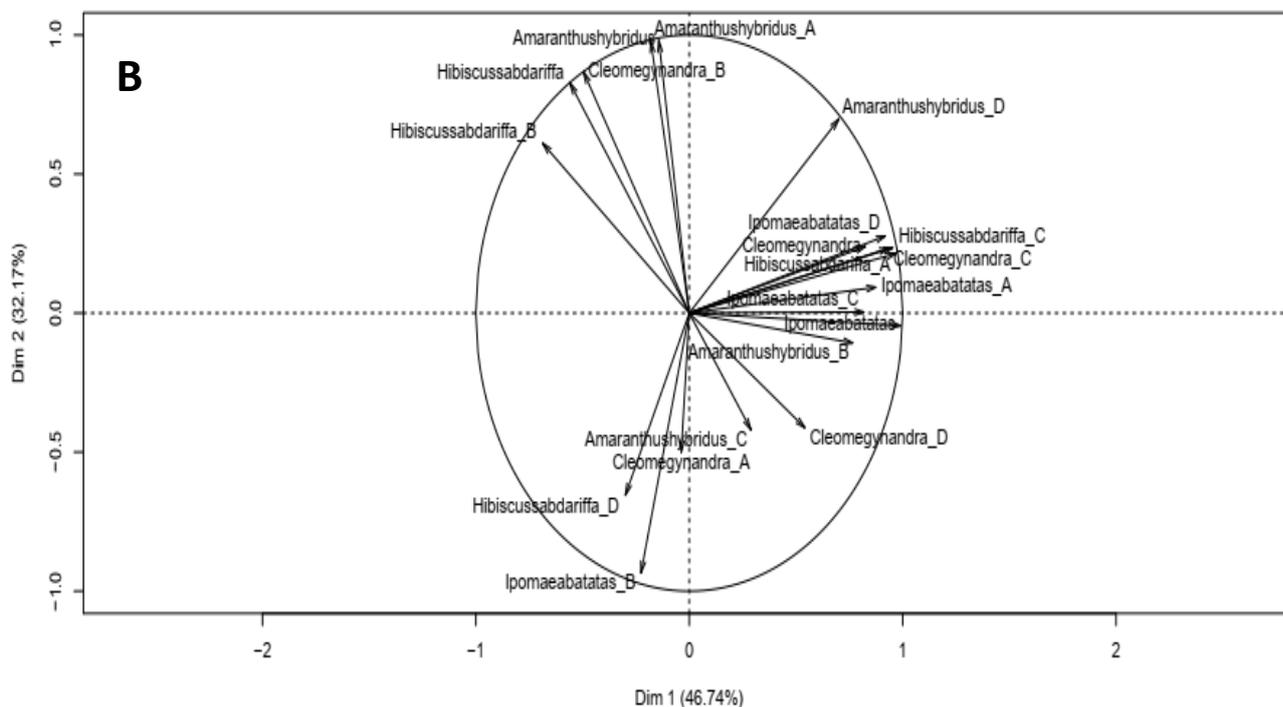


Figure-1. Analysis of the principal constituents of heavy metals in leaf vegetables studied (A). Variables of heavy metals and variable leafy vegetables (B)

The dry matter content is higher in the Ouagadougou samples (O1, O6), Bobo Dioulasso (B2, B3, B6, B10) and Kaya (KA4, KA7, KA8, KA10) respectively with mean values of 12.40 ± 1.59 ; 12.39 ± 1.22 and 12.82 ± 1.46 . The values of titrable acidity in lactic acid also correlate with the pH values determined. There is a significant difference in dry matter content, pH and acidity between Babenda at the 5% threshold according to the Newman-Keuls test. A correlation was observed between moisture and acidity. As for the average values obtained for the pH, they vary from 4.87 ± 0.04 and 5.33 ± 0.06 with an average value of 5.12 ± 0.04 .

Our results are lower than those obtained in Benin by Houndji et al. (2013) who found pH values between 7.3 and 8.7. These differences in values could be explained by the alkaline nature of the leaves of *Hibiscus sabdariffa* having a tendency to give the Babenda its alkaline character. The difference found would then depend on the varietal effect, production technology, transportation and preservation conditions of Babenda. In fact, the quantities and composition of the Babenda (rice, peanuts, leaf vegetables, meat, fish) could influence the ash content.

Also, for economic reasons, producers of "Babenda" get enough leafy vegetables at a lower cost than cereals and peanuts that are more expensive on the market. Rice is the main constituent of the total carbohydrates of the Babenda. It is an energetic food that needs to be balanced with other foods (Sawadogo, 2018; Tarnagda et al., 2019). Figure 2 shows the principal component analysis (PCA) of the different Babenda samples according to the five cities.

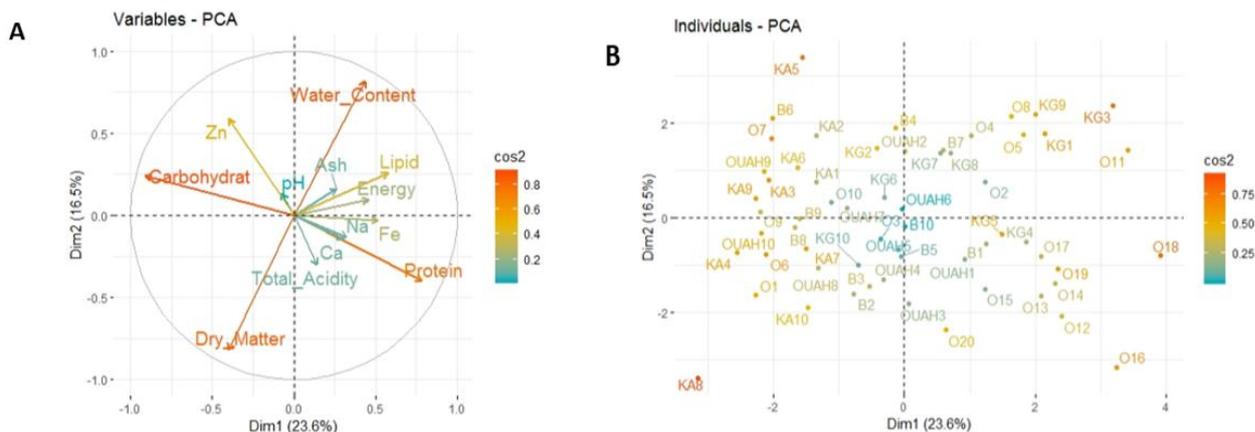


Figure-2. Principal component analysis (PCA) of the different Babenda samples (A). variables - PCA of physicochemical parameters and (B) variables of individuals - PCA samples from Babenda.

The protein content varies from 9.76 ± 0.09 g / 100g to 23.56 ± 0.02 g / 100g. Our results from our research corroborate with previous studies in Burkina Faso by [Sawadogo \(2018\)](#) that found in Babenda a protein content of 6.95% and 24.24% with an average value of 12.97%. But these values are lower than those reported by [Traoré, Parkouda, Guissou, Kamga, and Savadogo \(2018\)](#) in Burkina Faso and [Atchibri, Soro, Kouame, Agbo, and Kouadio \(2012\)](#) in Côte d'Ivoire which found values of 33.32 and 33.52% respectively.

These values were lower than those previously published for sauces consumed in Madagascar by [Randrianatoandro et al. \(2010\)](#), which reported an average protein content in laoka, a meal made from leafy vegetables and rice and other ingredients that ranged from 8.8 to 27.6 g / 100 g. But similar to the works of [\(Mariko, 2018\)](#) in Mali and Benin by [Adjatin et al. \(2013\)](#), that reported protein levels in leaf-based dishes respectively 26.87 g and 20 g. Thus, several factors would explain this Babenda protein content: the varietal effect, the use of the ingredients in the cooking as well as the processing ([Hama-Ba et al., 2017; Tarnagda et al., 2019](#)).

Indeed the addition of Soumbala, peanut, meat or dry fish which respectively have 36.5%, 23.2% and 47.3% of proteins, considerably increases the protein content ([Sawadogo, 2018](#)). The increase in Babenda protein content is dependent on the abundant sources of protein used in the diet. The statistical analysis of the protein contents shows that they are significantly different at the 5% level. Rates are higher in the Ouagadougou city samples (O12, O13, O14, O16, O17, O18, O19 and O20) than in other cities. The cities of Bobo-Dioulasso (B1, B5, B10) ($16.59 \pm 0.18\%$), Koudougou ($17.5 \pm 0.25\%$); Ouahigouya ($14.2 \pm 0.12\%$) and Kaya ($9.76 \pm 0.09\%$) have lower concentrations [Figure 2](#).

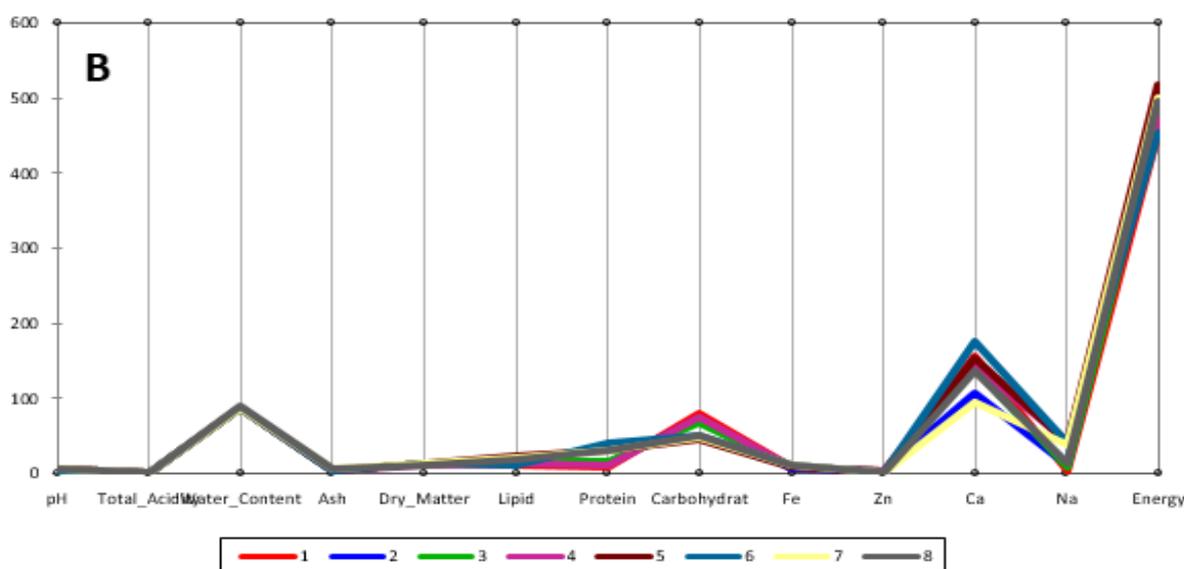
The data obtained also indicate that Babenda samples are good sources of protein. Indeed, [Atchibri et al. \(2012\)](#), showed that tropical leafy vegetables are high in protein and can help ensure food security for the poor. Our data are in agreement with those obtained by [Maundu, Ngugi, and Kabuye \(1999\)](#) which reported values of 28.3% and 16.6% of proteins respectively in the leaves *Amaranthus hybridus* L., *Cleome gynandra*. Variable component analysis data indicate that total carbohydrate levels are higher in Babenda samples produced in the cities of Ouagadougou (O3, O9, O10), Bobo Dioulasso (B4, B6, B8, B9) and Kaya (KA3, KA5, KA9) compared to Babenda samples produced in the other three cities of Burkina Faso. There is a significant difference between the total carbohydrate content of the Babenda at the threshold $\alpha = 0.05$. Ouagadougou (60.91 ± 0.2 g / 100 g), Bobo Dioulasso (69.15 ± 0.23 g / 100 g), Koudougou (62.59 ± 0.57 g / 100 g), Ouahigouya (68.79 ± 0.2 g / 100g), Kaya (77.35 ± 0.22 g / 100g) in the Babenda samples. Regarding the lipid content, the Koudougou samples have the highest and significantly different levels [Table 4](#).

Lipid contents range from 13.89 ± 0.22 g / 100 g DM to 19.91 ± 0.41 g / 100 g. The PCA of the sixty Babenda samples showed that the samples O5, O8, O11, KG1, KG3 and KG8 are higher in fat due to the incorporation of

large amounts of edible oil or shea butter during preparation. These values are lower than those found by [Randrianatoandro et al. \(2010\)](#) (38.6 and 52.2 g / 100 g), but higher than those reported by [Mariko \(2018\)](#) and [Adjatin et al. \(2013\)](#) respectively at 7.06g and 6.55g per 100 g/ kg. The total energy intake of the different Babenda samples (towns) ranged from 469.45 to 499.57 Kcal per 100g of dry matter. This value is not enough for a complete meal. The results show a variation in the total energy intake of the different samples analyzed. In addition, these analyzes show that Babenda samples produced in Koudougou are richer in potential energy. The average energy intake of the Babenda is higher than that of the cereal-legume porridge 40 Kcal per 100 ml of porridge. Differences in the total carbohydrate content of Babenda could be related to the nature of leafy vegetables, cereals and other ingredients (meat, fish and eggs) used. These different variations would be due to the different ingredients used in the process of preparation of Babenda. The ash extraction procedure yielded an average grade of 5.09 ± 0.4 g / kg, lower than the certified concentration value (9.7 ± 0.5 g / kg) of standard reference material (spinach in suspension). The average ash content of the dishes ranged from 4.64 to 5.09 g / 100 g. Iron, calcium and sodium levels of Babenda samples from Ouagadougou (7.82 ± 0.14 , 120 , 10 ± 2.31 and 8.93 ± 0.17 mg / 100 g) of Babenda MS are higher than other cities and are significantly different [Table 2](#). Compared with those of Bobo-Dioulasso and Kaya, higher levels of zinc (4.15 ± 0.01 and 3.02 ± 0.75 mg / 100 g of Babenda Dry matter) are found. Calcium samples analyzed in the five cities (120.10 ± 2.31 mg / 100 g) is lower than that found by [Atchibri et al. \(2012\)](#) (22.60 mg / 100 g) and that found by [Odhav, Beekrum, Akul, and Bajjnath \(2008\)](#) (23.63 mg and 2067 mg) respectively, the Babenda samples produced in the cities of Ouagadougou (O12, O13, O14, O16, O17, O18, O19, O20) have the highest levels of calcium, iron and sodium [Figure 2](#).

There is no significant difference in the mineral content of the Babenda samples with the exception of the zinc content in the Newman-Keuls 5% test. Ca content and Zn content Iron levels of Babenda samples are higher than those found by [Randrianatoandro et al. \(2010\)](#) (4 to 28.6 mg / 100 g) Babenda samples had an iron content comparable to that of green leafy sauces in Nigeria (sorrel, baobab, spinach) or Cameroon (cassava, amaranth) ([Ponka et al., 2006](#)). Average zinc levels ranged from 1.1 to 5.1 mg / 100 g as in other African leaf sauces (sorrel, baobab, spinach, amaranth, beans) ([Ponka et al., 2006](#)).

These concentrations could be related to the various origins (fields, other vegetable and garden sites) of leafy vegetables. The Hierarchical Ascending Classification (CAH) indicates on the basis of the overall biochemical composition that Babenda samples taken in the five cities were divided into eight groups according to origin [Figure 3](#).



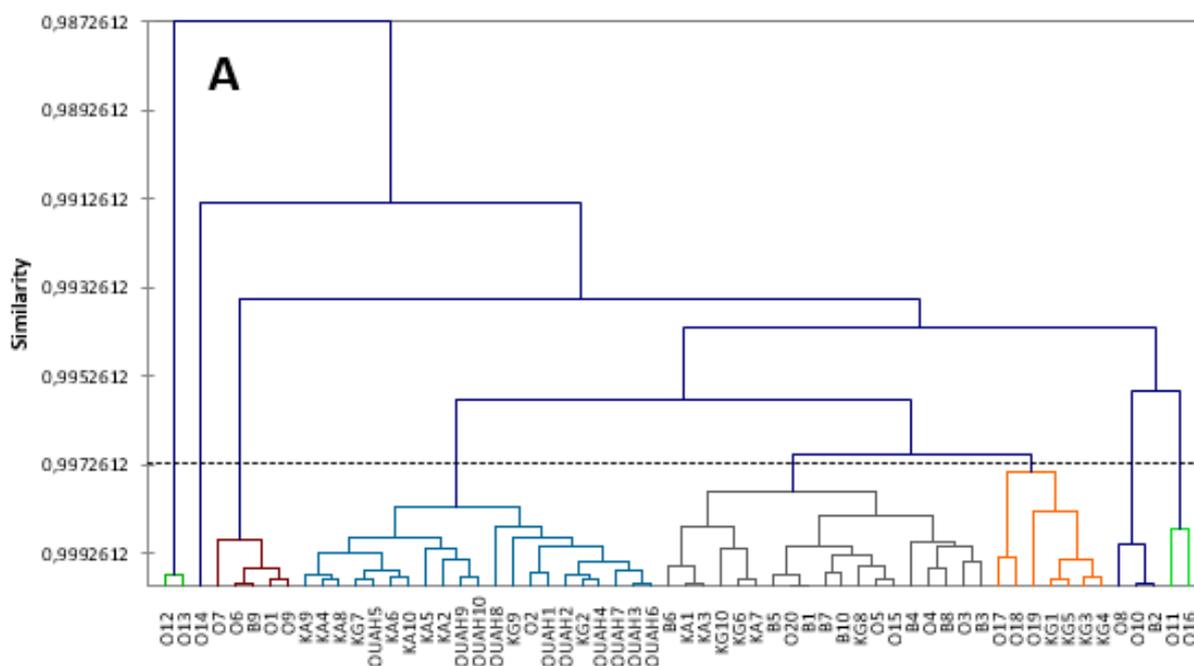


Figure-3. Dendrogram of similarity and class profile of samples according to their biochemical composition (A). Similarity diendogram of Babenda samples and Class Profile (B).

Classes 7 and 8 are formed by samples from two cities that differ in mineral and energy content from all samples [Figure 3](#). The Babenda studied has an interesting value of calcium content. This is essential because calcium is a major element in bone ossification. Differences in mineral contents are related to various origins of leafy vegetables ([Sawadogo, 2018](#); [Tarnagda et al., 2019](#)). The iron values mentioned in comparison with those obtained by [Siemonsma and Hamon \(2004\)](#) (Cortex = 7.2 mg and Celosia = 7.8 mg) show a lot of differences. However, Babenda is a good source of iron that could help recover a nutritional problem such as anemia and other micronutrient deficiencies ([Atchibri et al., 2012](#)).

Leafy vegetables present on the markets could come from other sites, allotments and fields. The calcium content is related to the iron and sodium content. The calcium content correlates with zinc. These differences are influenced by cropping techniques for leafy vegetables and cereals ([Tarnagda. et al., 2017](#)). At the market gardening site, the producers make much use of the NPK type chemical fertilizer, as for the markets leafy vegetables could come from allotments, other sites and fields.

4. CONCLUSION

The risks of contamination of the food chain by the consumption of leafy vegetables sold on the markets of the five cities of Burkina Faso are not negligible following the ADI obtained for certain vegetables. Vegetables sold on the market show levels of Pb and Cd that exceed the standards. The dishes of the Burkinabè population should be monitored to minimize the risk of impregnation in heavy metals. These results show that adequate soil-plant transfer reduction techniques for heavy metals must be put in place to avoid the risk of contamination of the food chain by Pb, Cd, Hg and As.

The sixty samples of Babenda have appreciable nutritional content. The biochemical and nutritional potential has proven that Babenda is a source of macronutrients and micronutrients. Babenda's energy intake varies according to the content of water, dry matter, fat, proteins and carbohydrates. Babenda is a dish very rich in water and for this purpose, its consumption contributes more to the hydration of the body. The lipid, protein, carbohydrate content is average but the addition of other ingredients such as meat, eggs, fish, vegetable oil and

cereal products help to increase the nutritional intake of these nutrients. Also, the Babenda cannot be considered as a high energy dish but its considerable content of mineral elements (iron, zinc, calcium and sodium), gives it a place of nutritional importance.

This study shows that some "Babenda" dishes contain very few leafy vegetables as evidenced by the color of the dishes and the differences in nutritional elements between the different samples analyzed. The Babenda produced and consumed in the five cities of Burkina Faso can be an alternative source in the fight against hunger and malnutrition. Their effect needs to be appreciated for a suitable formulation for the preparation of "Babenda" as part of the nutritional recovery of malnourished children, pregnant women and the elderly.

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