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## Phytochemical Study and Assessment of the Nutritional Potential Of Fifteen Wild Leafy Vegetables Consumed in the City Of Lubumbashi And Its Surroundings (Dr Congo)

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### Abstract

This study was conducted to assess the nutritional potential and identify groups of bioactive substances with therapeutic potential in fifteen wild leafy vegetables used in traditional medicine in Lubumbashi. Bromatological analyses of aqueous and methanolic extracts revealed the presence of water-soluble vitamins (vitamin C) and fat-soluble vitamins (vitamins A, E, and K). Furthermore, the determination of the energy density of the said vegetables showed that thirteen of them, or 87%, belonged to the very low energy density class ( $X=40.69\pm 0.47$ ) KJ. On the other hand, the analysis of trace elements revealed in particular the presence of Cd ( $0.16\pm 0.01$  mg/Kg DM), Fe ( $2.52\pm 0.52$  mg/Kg DM), Mg ( $2843.2\pm 0.20$  mg/Kg DM) and Se ( $0.02\pm 0.01$  mg/Kg DM). Phytochemical screening of their leaves, performed using standard solution reactions, qualitatively revealed the presence of saponins (100%), tannins (93%), terpenoids (87%), flavonoids and steroids (73%), quinones (47%), and alkaloids (40%).

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**Keywords:** Leafy Vegetable, Wild Plant, Food, Lubumbashi

### 1. Introduction

Among the many benefits that plants provide to humans are undoubtedly their use as food and medicine (Muleka *et al.*, 2024) <sup>[38]</sup>. Whether in the form of leaves, roots, stems, seeds, or flowers, vegetables contain substances necessary for the growth of the human body. For example, leaves are comparable to chemical laboratories in which simple inorganic substances, in the presence of sunlight, are converted into organic substances that are essential for human life on earth (Charles, 2008; Kabore, 2014). Several wild species related to cultivated plants in natural and semi-natural ecosystems play an important role in the diets of populations and are key to maintaining nutritional balance, helping to meet the needs of an ever-growing global population, which is one of the major challenges of our time. As we can see, the days when vegetables were only used for food are long gone. As for the therapeutic action of plants with medicinal properties, it is linked to their use in their entirety as a totum, and not reduced to active ingredient molecules (Clay, 2002; Akpavi *et al.*, 2011; Mirhonyi, 2023). In other words, consuming them as functional foods could help prevent and treat many diseases (Jain *et al.*, 2011). However, despite their importance, several threats currently weigh on these resources, including climate change, deforestation and forest degradation, demographic pressures, and the disappearance of rare individuals, generally elderly people who know these vegetables in local languages (Maxted and Kell, 2009; Ozer *et al.*, 2010; Muleka *et al.*, 2023) <sup>[39]</sup>.

Indeed, the city of Lubumbashi, an atypical environment characterized by tree and shrub vegetation, is currently undergoing unprecedented degradation and is under serious threat of disappearing as a result of rapid urbanization (Diallo *et al.*, 2009) <sup>[15]</sup>. Knowledge of these species remains essential for conservation and promotion strategies. Apart from the phytochemical study of a few wild vegetables consumed in Haut-Katanga by Mbayo in 2015, the phytochemical screening and antimicrobial activity of six edible rhizomes used in traditional medicine in Lubumbashi by Bashige in 2020, and the ethnobotanical study on *Bidens pilosa* conducted by Muleka in 2024, wild species have been the subject of very few scientific studies. It is in this context that we approached this study with a view to expanding the list of recent data on the diversity of edible wild plant species, but also to determine their composition in groups of bioactive substances responsible for their therapeutic potential. This is why we are attempting to explore other, more natural

therapeutic methods, including nutritional therapy, which is considered by some to be an alternative and is often perceived as less harmful and iatrogenic than drugs produced by the chemical industry (Marine, 2018).

## 2. Materials and Methods

### 2.1. Presentation of the Study Environment.

This study was conducted in three cities in the province of Haut-Katanga: Lubumbashi, the provincial capital; Kipushi, located 30 km from Lubumbashi; and Likasi, located 120 km from the provincial capital.

### 2.2. Plant Materials

Our plant material consists of fifteen plant species whose parts are consumed as vegetables. These were purchased in markets or harvested in the three cities that make up our study area and their surrounding areas. The scientific and vernacular names of these plant species are listed in Table 1.

**Table 1** : Species, edible part (EP), and common names.

N°	Scientific name	Family	Common names	Cn
1	<i>Ageratum conyzoides</i> L.	Asteraceae	Kitutangenze (kiluba), Milolo (Hemba), Kilibonde, Tshilibwende (Tshiluba)	Leaf
2	<i>Amaranthus spinosus</i> L.	Amarantaceae	Kibwabwa kyamiba, lengalenga yamiba, Tonga miba (Kiluba), lubondwe (Lamba, Bemba, Camba), Mboga miba (Swahili).	Leaf
3	<i>Bidens pilosa</i>	Asteraceae	Sokontwe (Bemba), Lukontwe, Nselatwende (Kiluba), Yimbwarambwata (tshokwe, Minungu), Kanika (Lala, Lamba), Kashisha (Mashi), Musong (Kanyoka), Nsanon (Rund), Ngoloso (Hemba)	Leaf
4	<i>Boscia salicifolia</i>	Capparaceae	Musasa (Lamba), Musebu (Bemba)	Leaf
5	<i>Celosia trigyna</i>	Amarantaceae	Kisandji (Lala, Lamba, Bemba), Madi-maban (Kanyoka), Katuni (Rund), Katshikitshiki (Kiluba, Yanzi)	Leaf
6	<i>Colocasia esculenta</i>	Araceae	Matabala (Tshiluba), Taro, Oreille d'éléphant (Français), Mahole (Swahili), Malemba (Kiluba), Mabenge (Ngwaka), Bifunu (Mashi).	Leaf
7	<i>Ipomoea aquatica</i> forsk	Convolvulaceae	Kalembuila (Bemba), Mulapalala (Lala, Lamba, Ndembo, Rund), lolwe (Kiluba), matembele ya mayi (Swahili RDC)	Leaf
8	<i>Isobertina angolensis</i>	Caesalpiniaceae	Mutobo (Bemba), Mahunire (Mashi), Mboza (Swahili).	Leaf
9	<i>Ledermannia tenuissima</i>	Podostemoideae	Koto, Mbizi ya moyi (Lingala), Longa-longa, malonga-longa, Kilonga-longa (Kikongo).	Leaf
10	<i>Mussaenda arcuata lam</i>	Rubiaceae	Tembwe tembwe (Tshiluba), rulant (Rund)	Leaf
11	<i>Nymphaea nouchali</i>	Nymphaeaceae	Male (Kiluba), Matuwa (Bemba)	Leaf
12	<i>Ocimum gratissimum</i>	Lamiaceae	Losobosolo (Swahili), Ndundu (Kinyarwanda)	Leaf
13	<i>Phaseolus vulgaris</i>	Amarantaceae	Kunde (Tshiluba, kiluba), Konde (Tetela)	Leaf
14	<i>Piper ombellatum</i>	Piperaceae	Bilombolombo (Tshiluba), Kyungulula (Kiluba), diembe, lisala, mikuku, peluku (Azande), mabila bondo (Rega), malombo (Lingala), tunda ya imbwa (Swahili), bois d'anisette ou grand baume (Français)	Leaf
15	<i>Solanum nigrum</i>	Solanaceae	Mutete wa ditto ou katete ka ntanda (Luba), Ndulwe (Lala, Bemba), Mulunda (Mashi).	Leaf

### 2.3. Study Methodology

The survey was conducted using semi-structured interviews and casual conversations based on a questionnaire guide. Informants (resource persons) were selected using a snowball sampling method based on allegations made by the population in the study areas. Personal data was processed in accordance with the principle of anonymization set out in the Declaration of Helsinki (Ambé, 2001; World Medical Association, 2008; Diarra *et al.*, 2016; Bashige, 2021) <sup>[4, 48, 15]</sup>. The study was conducted from December 2022 to August 2023, first among 111 traditional practitioners whose knowledge and identification of certain medicinal plants listed as vegetables was their prerogative, and then among 147 vegetable sellers to verify whether these plants were actually known and consumed by the population. The

questionnaire focused on the profile of the informant (age, gender, ethnic group, level of education, and how they acquired their healing skills). Botanical identification was carried out by comparison with the reference herbariums of the Faculty of Agricultural Sciences of UNILU and INRA/KIPOPO in Lubumbashi, where other vegetables were identified. The leaves of these harvested vegetables were made available for bromatological analysis and phytochemical screening.

### 2.4. Identification of Vitamins

#### Vitamin C

In the presence of H<sub>2</sub>SO<sub>4</sub>, the sample reduces KMnO<sub>4</sub> and becomes colorless: dissolve 1 g of sample in 100 ml of distilled water, heat to boiling, take 2 ml of juice and add to

4 ml of diluted H<sub>2</sub>SO<sub>4</sub>, immediately add a few drops of 10% KMnO<sub>4</sub>. The discoloration of the permanganate confirms the presence of vitamin C.

### Vitamin E

In the presence of HNO<sub>3</sub>, the sample turns yellow (Dohou *et al.*, 2003 ; Bruneton, 2009) <sup>[17]</sup> : dissolve 1g of sample in 100ml of distilled water, heat to boiling point, place a small amount of ointment on a watch glass, immediately add a small amount of 17% HNO<sub>3</sub> solution. The appearance of a yellow color confirms the presence of vitamin E.

### Vitamin A

Vitamin A is extracted by grinding the food and then adding 50ml of NaOH solution ; the mixture is warmed in a water bath after adding ethyl alcohol and a hydroquinone solution, and heated in a water bath to 90°C. Decanting is carried out after adding water and ethyl ether the first time, and petroleum ether the second time, with stirring. This mixture is extracted once or twice with petroleum ether, followed by washing the ether phase three times with water. The extract is then filtered, evaporated, and concentrated (Rougereau, 1984).

### Vitamin K

In the presence of a strong base (1% NaOH or KOH), vitamin K produces a characteristic red to purple-violet color (Dohou *et al.*, 2003 ; Bruneton, 2009) <sup>[17]</sup> : 25 ml of hexane were added to 5 g of the plant drug. The solution obtained was extracted using ultrasound for 30 minutes, sealing the end of the Erlenmeyer flask containing the macerate with plastic wrap. After filtration, 5 ml of filtrate was collected and then evaporated in the dark. The residue obtained was dissolved in 10 ml of methanol, then passed through a sonicator for 10 minutes for homogenization.

### 2.5. Determination of energy density (ED).

Energy density was determined based on the INCA (Individual National Food Consumption Survey) conducted by the Human Nutrition Research Center (INSERUM) (BELLISLE F., 2010) <sup>[10]</sup>.

It takes into account the nutritional values of a food (carbohydrates, fiber, proteins, lipids, etc.) according to the following relationship: ED = 2%. Fi + 4%. Glu + 9%. Li + 4%. Prot

With : - %. Fi : % total fiber  
 - %. Glu : % total carbohydrates  
 - %. Li : % lipids  
 - %. Prot : % protein.

Energy density is grouped into four categories (Atwater W. *et al.*, 1902) :

- From 0 to 0.6 cal : very low ED
- From 0.6 to 1.5 cal : low ED
- From 1.5 to 4 cal : medium ED
- From 4 to 9 cal : high ED

### 2.6. Determination of the Concentration (in mg/kg DM) of Mineral Elements

The mineral analysis of the targeted chemical elements was carried out jointly by the OCC/Katanga laboratory and the Agronomic Laboratory of the Faculty of Agronomic Sciences (FSA). In the latter laboratory, the analysis was performed

using X-ray fluorescence spectrometry. This non-destructive method is an analytical technique based on irradiating the minerals contained in the sample with X-rays. Each irradiated mineral absorbs an incident ray and consequently emits a characteristic fluorescence or radiation in the X-ray range. An OLYMPUS X-ray fluorescence device was used for this purpose.

### 2.7. Identification of bioactive substance groups

These bioactive substance groups were identified using standard solution reactions based on the appearance of precipitation for alkaloids using six reagents, namely: Bertrand, Dragendorf, Hager, Mayer, Sonneschein, foam formation for saponins, and color change for anthocyanins, flavonoids, quinones, steroids, tannins, and terpenoids (Abisch *et al.*, 1960 ; Lumbu, 1992; Bruneton 2009; Bashige *et al.*, 2018; Mbayo, 2019) <sup>[1, 31, 9, 35]</sup>. The search for cyanogenic glycosides aimed to identify any toxicity due to the presence of cyanides.

## 3. Presentation and Analysis of Results

### 3.1. Sociodemographic Data

#### 3.1.1. Data on Traditional Practitioners

**Table 2 :** Age groups of respondents in the cities of Lubumbashi, Likasi, and Kipushi.

	A. City of Lubumbashi		
	Age (Years)		
	39-50	51-60	61 and over
S/Total A	19	21	21
B. City of Kipushi			
S/Total B	5	11	9
C. City of Likasi			
S/Total C	0	10	15
Grand total	24	42	45
Percentage	21.62	37.84	40.54
Total	25(17)	122(83)	147 (100)

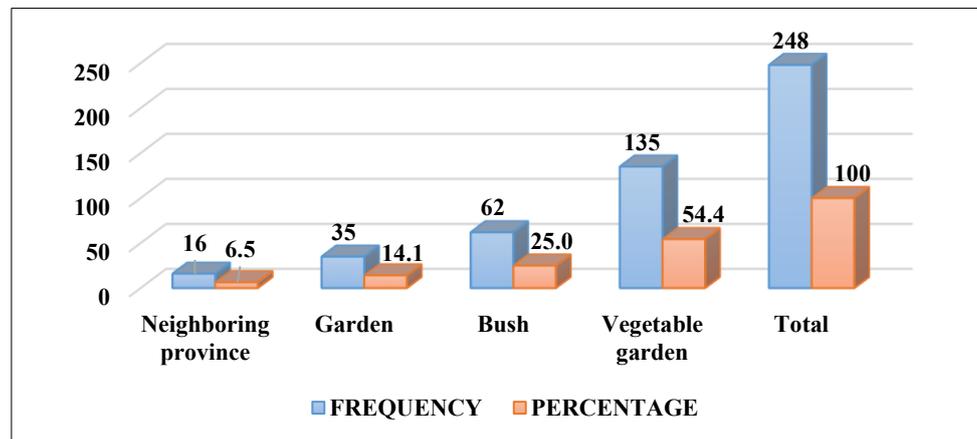
Based on their place of residence, 61 subjects, or approximately 65% of the total sample, represented the city of Lubumbashi, 25 peoples represented the city of Likasi (17.5%), and another 25 people represented the city of Kipushi (17.5%). Based on the gender of the 111 subjects surveyed, 58 were men and 53 were women. This represents 52.3% men and 47.7% women. In terms of age, the results of these surveys show that in 78% of cases, the people surveyed were at least 51 years old. The remaining 22% were subjects whose ages ranged from 39 to 50. Regarding the tribal affiliation of the traditional food practitioners surveyed, the indigenous people of Greater Katanga top the ranking with 72.08% of subjects. Within this majority group, the Luba of Katanga are in the lead with 34 subjects, or 31.51% of the total. Among the tribes from other Congolese provinces, the Luba of Kasai occupy the top position with 22.52% of the population surveyed. In terms of how the art of healing is acquired, in approximately 60% of cases, this activity is passed down through the family. A final concern regarding the identification of the traditional food practitioners surveyed related to their level of education. As can be seen, the lack of formal education observed (33% had not studied) among the traditional practitioners consulted proves that becoming a traditional practitioner requires more skill than formal training.

### 3.2. Sociodemographic data on vegetable sellers.

**Table 3 :** Distribution of the 147 vegetable sellers into three age groups

Age groups	Men (%)	Women (%)	Totals (%)
20- 30	1(0.7)	21(14.3)	22(15)
31- 49	23(15.5)	101(68.7)	124(84.3)
50 and over	1(0.7)	0	1(0.7)
Totals	25(17)	122(83)	147 (100)

A total of 147 vegetable sellers were surveyed, including 122 women (83%) and 25 men (17%), representing a female-to-male ratio of 5 :1. 84.3% of them belong to the 31-49 age group, which comprises 68.7% women and 15.5% men. On the other hand, the third age group, those aged 50 and over, is practically non-existent : it is represented by only one male subject, or 0.7%. In terms of tribal affiliation, the highest frequencies relate to three ethnic groups : the Luba of Katanga, the Luba of Kasai, and the Bemba, represented by 32, 31, and 24 subjects respectively, corresponding to a total of 87/147, or 59.2%.



**Fig 1:** Source of origin of vegetables sold

As for the source of the vegetables sold, the vegetables found in the various markets in our study areas come from four different places : 25% (62/248) of sellers get their vegetables from the bush, 54.44% (135/248) of sellers buy their

vegetables from vegetable gardens; 14.11% (35/248) of people sell vegetables from gardens, and 6.45% (16/248) sell vegetables from provinces neighboring Haut-Katanga province.

### 3.3. Nutritional values

**Table 4 :** Nutritional values of wild leafy vegetables.

N°	Scientific name	Fib (%)	Pro (%)	Lip (%)	Glu %	Vit A	Vit C	Vit K	Vit E	Energy density	
										Val (KJ)	Class
1	<i>Ageratum conyzoides</i>	9	1,5	2	5,5	++	+++	+	+	64	Very low
2	<i>Amaranthus cruentus</i>	15	4,38	5	6	+	++	++	++	27,83	Very low
3	<i>Bidens pilosa</i>	9	4,10	10	1	+++	++	++	+	30,67	Very low
4	<i>Boscia salicifolia</i>	7	1,48	10	1	+++	++	++	+	27,21	Very low
5	<i>Celosia trigyna</i>	7,8	1,6	2,7	3,5	--	+	--	+	60,3	Very low
6	<i>Colocasia esculenta</i>	2,5	5,75	1,5	2	+++	++	++	+++	13,14	Very low
7	<i>Ipomea aquatica</i>	6,3	4,65	5	1,5	++	+++	--	+	19,63	Very low
8	<i>Isobertina angolensis</i>	7,1	2,73	5	0,2	+++	--	+	+++	16,94	Very low
9	<i>Ledermannia tenu.</i>	3	2,35	1	1,2	++	+	++	++	6,97	Very low
10	<i>Mussaenda arcuata</i>	2,5	1,5	6,3	1,8	++	+++	++	+	74,90	Very low
11	<i>Nymphaea nouchali</i>	6,5	6,5	6,5	6,5	+++	++	+	+	79	Very low
12	<i>Ocimum gratiss.</i>	4,6	3,4	2,5	0,8	--	+	--	++	48,5	Very low
13	<i>Phaseolus vulgaris</i>	3,4	1,7	18,6	2,8	++	+++	+	+++	192,2	Medium
14	<i>Piper Umbellatum</i>	3,5	2,19	10	1,4	+++	++	++	+	111,34	Low
15	<i>Solanum nigrum</i>	16,8	3	3,3	4,9	++	+++	+	+	60	Very low

Several interesting findings emerge from the table above. First, dietary fiber concentrations were highest in the leaves of *Solanum nigrum* and *Amaranthus cruentus*, at 16.8% and 15% respectively, followed by *Ageratum conyzoides* and *Bidens pilosa*, at 9%. In terms of protein content, the highest levels ranged from 6.5% to 4.1%. These were *Nymphaea nouchali* (6.5%), *Colocasia esculenta* (5.75%), *Ipomea aquatica* (4.65%), *Amaranthus cruentus* (4.38%), and *Bidens pilosa* (4.10%). As for vitamins A, C, E, and K, they were

found at 90% in all organs. Vitamins E and C are well ahead, with frequencies of 15 and 14 times out of 15 (100% and 93.3%), while vitamins A and K come in second place with frequencies of 13 and 12 times out of 15 (86.6% and 80%). As for lipids and carbohydrates, respective levels of 18.6% and 6.5% were found in the leaves of *Phaseolus vulgaris* and *Nymphaea nouchali*. Furthermore, in terms of energy density, Table 4 shows that 87% of these leafy vegetables fall into the category of very low energy density vegetables.

### 3.4. Mineral Nutrients

**Table 5 :** Concentration (in mg/kg DM) of mineral elements.

N°	Vegetables	P	Cd	Co	Fe	K	Mg	Na	Se
1	<i>Ageratum conyzoid</i>	23,60	0,08	0,43	2,64	1245	42	1250	0,02
2	<i>Amaranthus cruet.</i>	33,04	0,35	0,52	2,67	5547,14	1740,51	416,40	0
3	<i>Bidens pilosa</i>	30,75	0,37	0,47	1,50	4170	2086	516,40	< LQ
4	<i>Boscia salicifolia</i>	33,90	0,19	0,36	3,10	1440	914,40	415,40	< LQ
5	<i>Celosia trigyna</i>	33,60	0,04	0,48	2,50	490	384,50	817,20	< LQ
6	<i>Colocasia escul.</i>	23	0,16	0,37	2,28	5240	2419	831,30	0,09
7	<i>Ipomea aquatica</i>	35,70	0,25	0,34	2,36	5740	1982	1483	0,061
8	<i>Isoblerlina angol.</i>	36,10	0,32	0,50	3,80	3560	3641	832,30	< LQ
9	<i>Ledermanniella</i>	26	<LQ	0,42	2,36	3786	2442	6723	0,03
10	<i>Mussaenda arcuata</i>	39,90	<LQ	0,59	1,53	6790	1523	1158	0,05
11	<i>Nymphese nouch.</i>	21	0,33	0,36	2,32	3770	3470	9016	< LQ
12	<i>Ocimum gratis.</i>	37,09	0,09	0,44	2,89	17456	5456	17568	0,05
13	<i>Phaseolus vulgaris</i>	41	0,20	0,39	3,30	18400	2200	416,40	0,04
14	<i>Piper Umbellatum</i>	48,15	<LQ	0,92	1,70	13786	2422	672,30	< LQ
15	<i>Solanum nigrum</i>	34,75	0,08	0,43	2,80	30120	3750,50	532,30	< LQ
Norme : FAO/OMS (mg/Kg)		10-50	0,20-0,40	0,36-0,52	100-300	ND	ND	ND	<0,01

This table shows that the eight chemical elements analyzed belong to three concentration categories, which are compared to the standards. The first category, which includes three elements (K>Na>Mg), corresponds to the highest concentrations. In this regard, the leaves of *Ipomoea aquatica* and *Amaranthus cruetus* have the highest potassium concentrations (5740 and 5547.14 mg/kg), followed by *Phaseolus vulgaris* and *Piper umbellatum* in sodium ((18400 and 13786 mg/kg respectively) and finally *Solanum nigrum* and *Isoblerlina angolensis* in magnesium (3750.50 and 3641 mg/kg respectively). This table shows that the eight chemical elements analyzed belong to three concentration categories, which are compared to the standards. The first category, which includes three elements (K>Na>Mg), corresponds to the highest concentrations. In this regard, the leaves of *Ipomoea aquatica* and *Amaranthus cruetus* have the highest potassium concentrations (5740 and 5547.14 mg/kg), followed by *Phaseolus vulgaris* and *Piper umbellatum* in sodium ((18400 and 13786 mg/kg respectively) and finally

*Solanum nigrum* and *Isoblerlina angolensis* in magnesium (3750.50 and 3641 mg/kg respectively).

1. The last category, characterized by the lowest levels, includes three elements (Cd, Co, and Se), of which cobalt and selenium both have concentrations below 1 mg/kg.
2. In the intermediate category, comprising two elements, the highest concentrations are those of phosphorus and the lowest those of iron. It should be noted here that *Piper Umbellatum* and *Phaseolus vulgaris* leaves contain the highest concentrations of phosphorus (48.15 and 41.0 mg/kg respectively), while iron concentrations are found in *Isoblerlina angolensis* and *Phaseolus vulgaris* leaves (3.80 and 3.30 mg/kg respectively).

### 3.5. Phytochemical analyses

The detection of different groups of bioactive substances in the functional foods under study makes it possible to associate their presence or absence with certain therapeutic properties they possess.

**Table 6 :** Families of bioactive groups in wild leafy vegetables

N°	Vegetables	Alca	Ant	Fla	Qui	Sap	Ste	Tan Tot	Ter	Tot (+)	Abon (%)
1	<i>Ageratum conyzoides L.</i>	--	+	+	+	+	+	++	++	7/8	87.5
2	<i>Amaranthus cruentus</i>	--	++	++	++	+++	--	++	++	6/8	75
3	<i>Bidens pilosa</i>	--	+	++	+++	+++	--	++	--	5/8	62.5
4	<i>Boscia salicifolia</i>	++	+	--	+++	+++	+++	+++	+++	7/8	87.5
5	<i>Celosia trigyna</i>	+	+	+	--	+++	++	+	+	7/8	87.5
6	<i>Colocasia esculenta</i>	--	++	++	--	+	++	+	++	6/8	75
7	<i>Ipomea aquatica</i>	+++	--	++	--	+++	+	+++	+++	6/8	75
8	<i>Isoblerlina angolensis</i>	--	--	--	+++	+++	+++	--	++	4/8	50
9	<i>Ledermanniella tenui.</i>	--	++	++	--	++	++	+	--	5/8	62.5
10	<i>Mussaenda arcuata lam</i>	--	--	++	--	+	++	++	++	5/8	62.5
11	<i>Nymphaeae nouchali</i>	--	+	+++	--	+	+	++	++	6/8	75
12	<i>Ocimum gratissimum</i>	++	--	++	++	++	--	+	+++	6/8	75
13	<i>Phaseolus vulgaris</i>	--	++	--	++	++	--	++	++	5/8	62.5
14	<i>Piper Umbellatum</i>	++	++	++	--	++	++	+	++	7/8	87.5
15	<i>Solanum nigrum</i>	+	--	--	--	+++	++	++	++	5/8	62.5
Total		6	10	11	7	15	11	14	13	87/120	72.5
		40	66.6	73.3	46.6	100	73.3	93.3	86.6		

This table shows that the extracts contain at least three groups of bioactive substances. The most abundant group of secondary metabolites are saponins (100%), tannins (93%),

terpenoids (86.6%), flavonoids (73.3%) and anthocyanins (66.6%). On the other hand, the rare groups in the vegetables analyzed are quinones (46.6%) and alkaloids (44%).

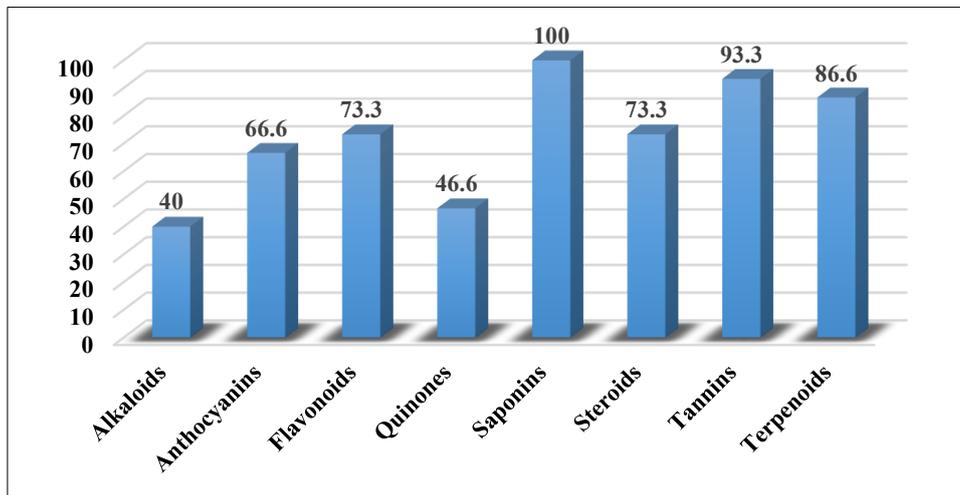


Fig 2: Abundance of bioactive substances

In this regard, the leafy vegetables under study belong to four groups based on their abundance of bioactive substances. These are four vegetables belonging to the first group with 87.5% abundance, including the leaves of *Ageratum conyzoides*, *Boscia salicifolia*, *Celosia trigyna*, and *Piper Umbellatum*. The second group, containing five vegetables with 75% abundance, includes the leaves of *Amaranthus*

*cruentus*, *Celosia trigyna*, *Ipomea aquatica*, *Nymphaea nouchali*, and *Ocimum gratissimum*. The third group, with 62.5% abundance, also contains five vegetables. These are the leaves of *Bidens pilosa*, *Ledermannia tenuissima*, *Mussaenda arcuata*, *Phaseolus vulgaris*, and *Solanum nigrum*. The last group, with 50% abundance, consists of a single vegetable, the leaves of *Isoblerlina angolensis*.

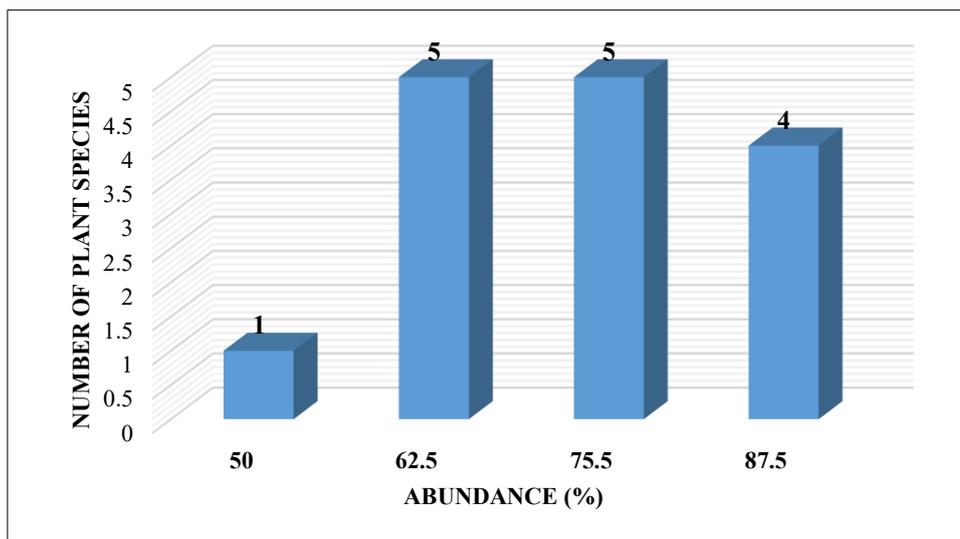


Fig 3: Number of plant species by abundance

#### 4. Discussion

Considering the number of traditional healers encountered in the city of Lubumbashi (61/111 traditional healers), representing 65% of the total number, was higher than in other sites. This preponderance can be explained by the rural exodus of populations attracted by urban advantages and even searching for safety from the multifaceted insecurity caused by the resurgence of armed groups within the province of Haut-Katanga in particular and the country in general. These initial results are consistent with those reported in previous studies conducted by Ngoy *et al.*, 2010; Lapeyre *et al.* 2011; Bakari 2015. Among the traditional practitioners we met, the number of men and women was very similar, 58 versus 53, or 52.25% men versus 47.75% women, respectively. The sex ratio recorded here differs significantly from that reported in the literature by other researchers who have worked on similar subjects. In those studies, the number

of men was significantly higher than that of women (Kahumba, 2000; Petit *et al.*, 2004; Bakari, 2011; Ngoy, 2013; Bakari, 2015) [25, 44, 6, 42]. Unlike aspects relating to traditional practitioners and the identification of listed medicinal vegetables, the sociodemographic characteristics of vegetable sellers show some differences: the 147 vegetable sellers surveyed consisted of 122 women (83%) and 25 men (17%), representing a female-to-male ratio of 5:1, whereas in the case of traditional practitioners, this ratio was 1:1.1. This high prevalence of women over men is justified, as we mentioned earlier, by the key role played by women in nutrition within households in African societies. We attribute this discrepancy mainly to the fact that our investigations focused on plant species that are both food and medicine, whereas those of the authors cited above focused solely on the therapeutic aspect of the plants collected. As is well known, in our society, traditional medicine is mainly

practiced by men. Similarly, food preparation is an activity that, in our cultures, is considered to be a female domain. However, in some other societies, the art of healing is practiced mostly by women in some cases and by men in others (Teklehaymanot, 2009, cited by Kalunga M, 2015). In the city of Lubumbashi and its surroundings, the art of healing being practiced by both genders can be explained by several reasons, including: (i) in urban centers, more and more traditional practitioners are deciding to showcase their knowledge through posters or audiovisual communications, an attitude rarely seen among female traditional practitioners; (2) the practice of traditional medicine may be linked to other socio-cultural characteristics of the tribes surveyed. Indeed, as this activity is mainly acquired through ancestral inheritance, it may be oriented towards men or women. Thus, depending on the region, there is a predominant sex ratio in favor of women or men (Longanga *et al.*, 2000; Alloh *et al.*, 2007; Kamagaju *et al.*, 2013; Muya *et al.*, 2014, Bakari, 2015) <sup>[26, 40, 6]</sup>.

The data from our study also showed that 78% of the traditional practitioners interviewed were aged 51 or over. This data highlights the fact that the traditional practitioners surveyed were older than the average life expectancy (43 years) in the DRC (DSCR, 2011; Bashige, 2016) corroborates several ethnobotanical studies conducted on medicinal plants in several African countries, which confirm that traditional medicine was mainly practiced by adults (Ngarivhume *et al.*, 2015; Betti *et al.*, 2013; Traoré *et al.*, 2013; Koudouvoa *et al.*, 2011 and Idowe *et al.*, 2010) <sup>[11, 46, 28]</sup>. The advanced age of our traditional practitioners is also justified by the existence of an initiation period into the art of healing with a master, usually a close relative (in 65% of cases). This long initiation period is also mentioned in previous studies conducted in Africa on medicinal plants (Tabuti *et al.*, 2012 in Uganda, Mukazayire *et al.*, 2011 in Rwanda, and Idowe *et al.*, 2010 in Nigeria) <sup>[37]</sup>. Furthermore, for vegetable sellers, 84.3% of this category of resource persons are between the ages of 26 and 49. This clearly shows that small-scale trade is generally carried out by young people. In addition, the virtual absence of people over the age of 50 can be explained by the physical effort required to carry out this activity. In this regard, older people are naturally disadvantaged.

As for the origin of the resource persons, the majority (72.08%) of those consulted were indigenous to Greater Katanga. Within this majority group, the Luba of Katanga ranked first with 34/111 subjects, or 31.51% of the total. Among the tribes from other Congolese provinces, the Luba from Kasai occupied the top position with 22.52% of the population surveyed. These results reflect the predominance of the Luba Kat tribe in the social configuration of the study area and, by extension, of the city of Lubumbashi (Hiernaux, 1964; Bruneau, 2009) <sup>[21]</sup>. The low representation of other Katanga ethnic groups among the traditional practitioners encountered is therefore a result of this consideration. The proportion of Luba traditional practitioners from Kasai (22.52%), which comes directly after that of the Luba-Kat, can be explained mainly by the large presence of Kasai peoples in the province of Katanga since colonial times (Hiernaux, 1964; Vincke, 1969; Dibwe, 2009) <sup>[21, 16]</sup>.

In terms of the educational level of traditional practitioners, one-third of respondents (49/147, or 33%) did not attend school. Far from considering this profession as one reserved for people who have not succeeded in their formal education,

training to become a traditional practitioner requires time and passion. It is therefore normal to devote oneself to it without necessarily having a minimum of formal education.

Regarding the source of functional foods sold, picking and market gardening are the two main sources of supply, with market gardening predominating. In fact, 25% of vegetables come from the bush, 54.44% from vegetable gardens, 14.11% from gardens, and 6.45% from provinces neighboring Haut-Katanga province. This aspect of the situation brings our results closer to those of Kanda *et al.* (2009), who conducted their study in Lomé (Togo) on the most commonly consumed leafy vegetables. Like us, these researchers found that the main source of leafy vegetables is market gardening. This clearly shows that the vegetables consumed in Lubumbashi and its surroundings are mostly domesticated exotic varieties, with almost no wild vegetables, despite their competitive nutritional value.

Furthermore, the proteins, carbohydrates, and fats or lipids present in the vegetables under study are major constituents or macronutrients in our bodies. These are organic molecules that can be assimilated by living organisms for their development and maintenance. Their presence in the leafy vegetables we investigated is entirely normal, as they are found in all vegetables in varying concentrations. Apart from the specific roles they play, proteins, carbohydrates, and lipids have a common role in providing energy. In addition, proteins and lipids also share a plastic role (Charles *et al.*, 2006). For proteins, nutrients that can renew cells and are necessary for infant growth, our investigations have shown that the leaves of *Nymphaea nouchali* (6.5%) and *Colocasia esculenta* (5.75%) are an excellent source. The protein contents we obtained are comparable to those reported by Razafimamonjison *et al.* (2017), who reported values of 12.5g per 100g of *Adansonia digitata* leaves, and those reported by Soro *et al.* (2012), who reported values of 33.32%, 29.90%, and 24.89% protein for *Amaranthus hybridus*, *Solanum nigrum*, and *Corchorus olitorius*, respectively <sup>[45]</sup>. In terms of lipids and carbohydrates, the leaves of *Phaseolus vulgaris* and *Nymphaea nouchali* had contents of 18.6% and 6.5% lipids and carbohydrates, respectively. These results are consistent with many others from previous research, which has shown that tropical vegetables, particularly leafy vegetables, are rich in protein and can contribute to ensuring food security for indigenous populations. Furthermore, due to their composition, they can also be a valuable source of calories, vitamins, fiber, minerals, and protein in the diet (Jansen *et al.*, 2004 cited by Mawuena 2021) <sup>[33]</sup>.

In addition, the high vitamin content in these leafy vegetables is a promising sign, especially since regular consumption could compensate for vitamin deficiencies in many people. Vitamin C, considered the most important antioxidant in extracellular fluids (Boss *et al.*, 2002, Berchache *et al.*, 2020), acts synergistically with vitamin E by exerting a reducing effect, trapping free radicals through the formation of ascorbyl radicals and thus acting as an enzymatic cofactor in cells (Carr *et al.*, 1999; Padayatty *et al.*, 2003) <sup>[13]</sup>, while vitamin E eliminates lipo-peroxyl radicals (Jiang *et al.*, 2001) <sup>[24]</sup> and protects cell homeostasis (Schubert *et al.*, 2018). The high vitamin C content of leafy vegetables is particularly important in our country, where there are many cases of anemia caused by malaria and immune deficiency. Consumers of these organs can enjoy several benefits, including detoxification due to the presence of radical species by trapping the excess electron and stabilizing this electron

by resonance, making the ascorbyl form less reactive than the initial radical species (Buettner, 1993). As for fiber, its concentration varied between 16.8% and 9% in the leaves of *Solanum nigrum*, *Amaranthus cruentus*, *Ageratum conyzoides*, and *Bidens pilosa*. The high fiber content of the functional vegetables studied would appear to favor them in terms of their effects on satiety, particularly fecal excretion and intestinal motor activity, followed by their postprandial lipid response and, finally, their characteristics in terms of colonic flora due to their prebiotic effects (Lairon, 2001 ; Lairon and Chanussot, 2001 ; James, Muir *et al.*, 2003) [29, 23]. In addition, fiber is recognized for its significantly positive effect on non-communicable diseases in general, such as cancer (Zong *et al.*, 2012), and metabolic diseases in particular, such as obesity and type 2 diabetes (Friedman, 2016). They may help strengthen the immune system and delay the development of tumors (Zong *et al.*, 2012).

According to the World Health Organization, minerals are important components of the human diet as they serve as cofactors in many physiological and metabolic processes, but their value can also be demonstrated by the absence of certain other minerals, high concentrations of which in the body are harmful (WHO, 2006). Indeed, the antihypertensive properties of vegetables are attributed to their high potassium content, which is thought to have a protective antioxidant effect against cardiovascular damage, especially in individuals who are sensitive to salt (Bennett *et al.*, 1991; Carmelle; Mizéhou, 2015; Ilunga F., 2017; IPI, 20011; Kalonji, 2018) [12]. High concentrations of magnesium, the second intracellular cation involved in calcium fixation, heart rate normalization, and blood sugar regulation, were found in *Dracaena reflexa* flowers and *Ocimum gratissimum* leaves, with respective values of 8614 and 5456 mg/kg DM. According to Sontia *et al.* (2007), cited by Combris (2019), epidemiological and experimental studies show an inverse correlation between serum magnesium and blood pressure. For calcium, the leaves of *Solanum nigrum* (9135 mg/kg DM) and *Piper umbellatum* (9840 mg/kg DM) again had the highest levels. The high levels of potassium and magnesium in the organs of the plant species studied can be explained by the fact that potassium is considered the major element in higher plants and magnesium, in addition to being the central atom in the chlorophyll molecule (responsible for the green color of plant leaves and photosynthesis), plays an important role as a cofactor in many enzymatic reactions, in the synthesis of proteins and nucleic acids, and has a protective effect by stabilizing membranes. Magnesium is also considered essential for calcium, potassium, and sodium ion homeostasis (Charles *et al.*, 2006). It should also be noted that the vegetables under study are also used to treat anemia. This is the case with the iron-rich leaves of *Bidens pilosa*. As is well known, heme or ferroprotoporphyrin contains an iron atom in ferrous Fe (II) form. When combined with hemoproteins, heme acquires the main functions of oxygen transport and storage (hemoglobin and myoglobin), electron transport (cytochromes of the respiratory chain) in redox reactions (cytochromes P450, catalase, peroxidase, cyclooxygenase, etc.), resulting in the production of red blood cells and, consequently, the eradication of anemia (Anderson *et al.*, 2010).

Due to their high water content and low fat content, the 10 vegetables have a low energy density. However, they facilitate energy reduction when consumed as part of a low-fat diet (for people who are obese or want to lose weight) and,

as a result, their consumption could contribute to a reduction in calorie intake (INRA, 2007 ; Pierre, 2019).

The abundance of bioactive substances in leaves can be explained, as reported by Hladik *et al.* (2000) and Lumbu *et al.*, (2005) cited by Mbayo (2019), by the fact that the leaves are where the plant's chemical substances are synthesized and the ripe fruits are where the plant stores them. As the preferred location for bioactive substances, the high consumption of these two organs is justified in human nutrition. Indeed, saponins, tannins, and terpenoids were the most abundant natural substances in the organs analyzed. Here too, this finding corroborates previous results from other authors concerning certain varieties of Fabaceae used to treat diarrhea (Lumbu *et al.*, 2005; Ngoy, 2013) [30, 42] and Euphorbiaceae for treating sexually transmitted diseases (Kahumba *et al.*, 2005) [30], constipation and malaria (Asase *et al.*, 2005), and female infertility (Kpegba *et al.*, 2011) [27]. Flavonoids and steroids are second in terms of quality. To this end, the literature also indicates that the protective effects of dietary flavonoids against cancer are justified by their ability to prevent angiogenesis and tumor cell escape and, in addition, play a positive role in the treatment of cardiovascular and neurodegenerative diseases (Badiaga, 2011; Kodjo *et al.*, 2017; Trigrine, 2014; Mbayo, 2019) [6, 27, 35].

As for the presence of alkaloids, the least represented group of natural substances, our results are consistent with those reported in previous studies (Hladik *et al.*, 1977; Milcente *et al.* 2003), which indicate that alkaloids are not often abundant in plants in general. However, together with terpenoids and quinones, they are involved in the treatment of several diseases and, particularly terpenoids, as apoptosis inducers.

## 5. Conclusion

This study has laid the scientific foundations for the use of fifteen edible wild leafy vegetables in traditional medicine in Lubumbashi (DR Congo) to treat certain diseases. It has highlighted for the first time the nutritional value and phytochemical composition of these vegetables, which are both edible and used in traditional medicine. The nutritional and therapeutic potential of these leafy vegetables, demonstrated *in vitro*, makes them candidates for further investigation, which could lead to the development of improved traditional medicines or the discovery of new molecules that can treat several diseases.

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