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# **Ethno-ecological Variability in the Consumption of Leafy Green Plants in the Republic of Benin**

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## **Author's contribution**

*The sole author designed, analysed, interpreted and prepared the manuscript.*

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## **ABSTRACT**

Beninese's dietary habits related to Amaranth (*Amaranthus cruentus*), African basil (*Ocimum gratissimum*) and African eggplant (*Solanum macrocarpon*) were studied in eleven districts of Republic of Benin. Data were collected from five hundred households on their consumption habits. Results showed that these leafy vegetables are consumed, either alone or accompanied by other leafy vegetables, depending on seasonal availability, health-promotion, and taste. Diversification and greater access to leafy green vegetables could improve individuals' nutritional profile.

**Keywords:** *Benin; dietary habits; food consumption; local criteria; green leafy vegetables.*

## **1. INTRODUCTION**

A diet rich in a diversity of plant resources has shown to enhance one's health and nutritional profile [1]. In Sub-Saharan Africa (SSA), the consumption of indigenous leafy vegetables plays an important role in the nutrition and health

of rural poor because of general availability, richness in micronutrients, and for their medicinal virtues [2,3,4]. In the Republic of Benin, biodiversity inventories of traditional leafy vegetables reveal that more than 180 plant species are regularly cultivated, or semi-cultivated as wild plants, and play a significant

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role in daily nutrition [5]. Most prominent among these plant species are Amaranth (*Amaranthus cruentus*, *Amaranthaceae*), African basil (*Ocimum gratissimum*, *Lamiaceae*) and African eggplant (*Solanum macrocarpon*, *Solanaceae*), which are valued for their nutritional and medicinal benefits [5,2,6]. For example, African basil is often used as spice and aromatic herbs for culinary purposes [7] and is also used in folk medicine for the treatment of upper respiratory tract infections, diarrhoea, skin diseases, pneumonia, cough, conjunctivitis intestinal worms and gastrointestinal disorders [2,8,9]. The leaves of Amaranth are used for treatment of colds, coughs, stomach aches, diarrhoea, skin rashes, back aches, constipation, fever, haemorrhage, kidney complaints and anaemia [2,10]. Medicinal uses of African eggplant include the treatment of tooth aches, allergic rhinitis, skin diseases, rheumatic diseases, joint pains, throat and stomach problems gastro-oesophageal reflux diseases, constipation, ulcers, diabetes and for weight reduction [2,11,12]. These leafy vegetables exhibit antioxidant properties that offer protection against oxidative-stress related diseases [13,14].

As popular as Amaranth, African basil and African eggplant are in the Republic of Benin, there is a lack of information on consumer's dietary habits and preservation techniques related to these plant resources. Although general information exists on their regional distribution, as well as their nutritional and medicinal values [5,2] ethno-nutritional information for these plant resources is poorly documented [6]. Moreover, there has been no previous research conducted on the ethno-food knowledge, endogenous processing, or preservation methods of these species. Given the diversity of socio-cultural groups and agro-ecological zones in Benin [2,15,16] a rich knowledge exists on the various dietary habits and unique characteristics of these indigenous leafy green vegetables. Yet this knowledge is poorly documented. This study aimed at characterizing the diversity among local dietary habits through the administration of a household survey on the consumption of Amaranth, African basil and African eggplant across different age, cultural and geographical groups in Benin. This research is a prerequisite for the future promotion and development of indigenous leafy green vegetables for their health and food security benefits.

## 2. METHODOLOGY

### 2.1 Study Area

This study was conducted in the Republic of Benin in West Africa Fig. 1. Benin is divided into three geographical areas (south, centre and north) and three major phyto-geographical regions (Guinean, Sudano-Guinean, and Sudanian) corresponding to the geographical areas [2,16]. Southern and central areas are relatively humid agro-ecological zones with two rainy seasons, with a mean annual rainfall between 1100 to 1400 mm/year. The northern area comprises an arid and semi-arid agro-ecological zone characterized by one rainy season with irregular annual rainfall of 800 and 950 mm/year [15]. Mean annual temperatures range from 26 to 28°C across Benin but often reach 35 to 40°C in far northern localities [15]. Vegetation patterns show a gradient from south to north resulting from a combination of climate and soils [2,16]. The Guinean zone is a semi-deciduous rainforest zone with ferrallitic soils located in the south while, Sudanian zone is a woodland and savanna region with ferruginous soils located in north. The Sudano-Guinean zone is a transitional zone characterized by a vegetation mosaic of forest islands, gallery forests and savannas [2,16]. Inhabiting these regions are approximately 42 distinct socio-linguistic groups, the largest in terms of population being the Adja, Fon, Bariba, Berba, Dendi, Fulani, Goun, Idatcha, Lopka-Yom, Nagot-Yoruba and Waama [2,16].

### 2.2 Sociocultural Characteristics of Republic of Benin Population

Benin is constituted with several ethnic groups which numerical importance is variable. At the national level, the Fon group is the most important with 39.2% of Benin's population followed by Adja (15.2%), Yoruba (12.3%), Bariba (9.2%), Peulh (7%), Otamari (6.1%) Yoa (4%), Dendi (2.5%) and other ethnic groups (1.6%). The different ethnic groups are unequally distributed over the national territory. Socio-cultural groups dominated by Fon are strongly localized in the south of the country. In the north, Bariba, Dendi and Peulh coexist. The Adja are concentrated in the Southwest. In the center and South-East of the country, there are Yoruba and related. The most widely practiced religions in Benin are Catholicism (27.1%), Islam (24.4%) and Vodoun (17.3%).

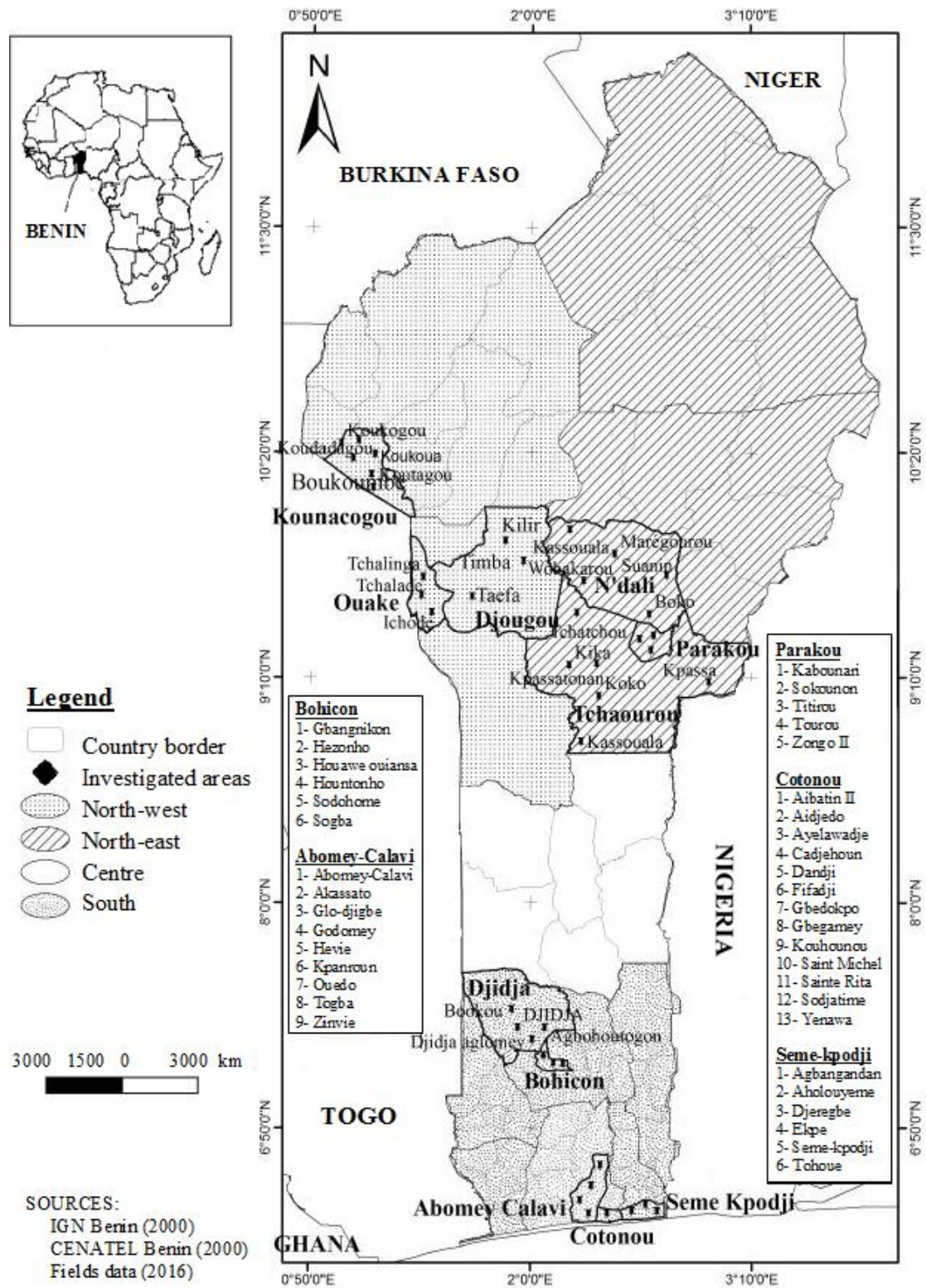


Fig. 1. Benin map showing the geographical location of the survey sites

## 2.3 Sampling

Field data were collected in October 2015 through December 2016 in eleven districts across three geographical areas (south: Abomey-Calavi, Bohicon, Cotonou, Djidja and Seme-kpodji; north-eastern: N'Dali, Parakou and Tchaurou and north-western: Boukoubme, Djougou and Ouake); each characterised by phyto-geographical and socio-linguistic diversity (Fig. 1; Table 1). District selection was based on previous works which showed distribution of leafy vegetables in the country [5,2]. Additional selection criteria included the existence of leafy vegetable fields-schools in some villages and a willingness to collaborate with research team. Thus, 64 villages, representing 24 socio-cultural groups (Adja, Ahoussa, Ani, Bariba, Biali, Ditamari, Dendi, Fon, Fulani, Goun, Gourmantche, Idatcha, Itcha, Kabiere, Lama, Lokpa, Mahi, Minan, Nagot, Pedah, Waama, Xlwa, Yom and Yoruba) were included in this study. (Fig. 1, Table 1). Households were randomly selected in each village, using bottle twirling method as described by Sossa-Vihotogbé, et al. [17]. From these groups, 500 women from various age and socio-cultural groups ( $N=24$ ) and localities were identified. The survey was directed towards girls and women because of their knowledge of household food consumption patterns [18]. Those interviewed include married, single, widowed or divorced women with basic and secondary education levels. Surveys were administered in the homes of informants, and in some cases with the aid of local interpreters.

## 2.4 Data Collection

Questionnaires were administered in person to 500 respondents. Those respondents were asked to identify: (i) household uses of leafy vegetables; (ii) consumption reasons; (iii) selection criteria; (iv) consumption frequencies; (v) processing methods; and (vi) traditional preservation techniques. The information recorded was based on local knowledge of Amaranth, African basil and African eggplant in relation with age, cultural and geographical groups of respondents.

## 3. RESULTS

### 3.1 Uses of Leafy Vegetables

Various species of traditional leafy vegetables were consumed within study areas (Table 2) and most of the households surveyed consumed a

minimum of five and a maximum of 17 different leafy green vegetables. Results indicated that 95% of surveyed households consume Amaranth, 95% consume African basil, 96% consume African eggplant, and 88% consume all three. According to geographic areas, consumption of Amaranth was highest in the north (east: 100% and west: 97%) than south (91%). In contrast, consumption of African basil and African eggplant were higher in the south (98% and 99%, respectively) and northwest (98% and 99%, respectively) than north-east (88% and 88%, respectively). Depending on age groups, respondents over the age of 51 have a high consumption of Amaranth (98%), African basil (100%) and African eggplant (98%) when compared to the other age groups. The age group of 18-30 eighteen consumed more Amaranth (97%) than age group of 31-50 (92%). Inversely, level of consumption of African basil and African eggplant 18-30 year olds (94% and 95%, respectively) was similar to that of the 31-50 year old age group (95% for both vegetables).

All socio-cultural groups surveyed consumed the three leafy vegetables except Gourmantche socio-cultural group who did not consume African basil. Ani, Kabiere, Lama, Lokpa, Mina, Pedah, Waama, Xlwa and Yom socio-cultural groups were unanimous about these leafy vegetables consumption while some variations was found within the other socio-cultural groups.

According to the respondents, each of these vegetables is prepared alone (100%) or in combination with one or both of the others (41%) or with other leafy vegetables species, such as leaves of Okra (*Abelmoschus esculentus*), African baobab (*Adansonia Digitata*), Jute mallow (*Corchorus olitorius*), Cassava (*Manihot esculenta*), Black benniseed (*Sesamum radiatum*) or Bitter leaf (*Vernonia amygdalina*).

### 3.2 Reasons for Consumption

Consumption of the investigated vegetables was rooted in households' dietary habits or those of their in-laws and it is transmitted generationally. Cultural mixing has also changed dietary habits of Bariba socio-cultural group who, previously, consumed African eggplant fruits only rather than its leaves. However, a dietary change has been occurred among Baraiba households and now consuming African eggplant leaves as well as fruits. Bariba informants noted that this change is a result of greater interaction with Ditamari, Fon, and Nagot cultural groups, and the process of knowledge diffusion that has occurred. The

reasons for this dietary change included favourable taste when added to traditional sauces as well as nutritive value (48%) related to their content in fibres, vitamins and minerals as well as their therapeutic properties (75%) against digestive disorders. For example, wrestlers from the Lokpa socio-cultural group consume African eggplant and its leaves, along with leaves of Okra and Cowpea (*Vigna unguiculata*), early in the morning of struggle festivals to acquire more strength before competition.

Consumption of African basil was found to be common among women within Bariba, Ditamari, Fon, Idatcha, Lama, Lokpa, Nagot, Waama, Yom and Yoruba socio-cultural groups. Consumption was noted to be most prevalent during periods of menstruation, pregnancy, and breastfeeding. Its therapeutic properties were multiple and were linked to its ability to remove blood clots, facilitate childbirth, clear waste after childbirth, treat postpartum infections, wound healing, and stimulate milk secretion.

In contrast, the non-consumption of the studied vegetables was related to lack of knowledge on processing methods (3.20%), bitter taste of African eggplant (2.40%), unpleasant odour of Amaranth (1.40%) and African basil (1.20%) and totemic considerations (0.40%).

### 3.3 Selection Criteria

The supply of leafy vegetables was secured through sharing (15.80%), by purchase at markets (76.40%), or at other production sites (home gardens: 35.60%, gardening sites: 16.40% and fields: 15.40%). Amaranth and African eggplant were most often purchased at markets (70.60% and 71.40%, respectively), fields (15% and 12%, respectively) and gardening sites (15% for both species). Conversely, African basil is most often obtained from home gardens (33.80%) and through sharing (15.40%). The availability of these vegetables varied according to seasons and species although their overall availability is greater during the rainy season. Amaranth (87%) and African eggplant (77%) were more available throughout the year than is African basil (65%). The criteria used in the selection of these vegetables included therapeutic properties (72%), taste (68%), availability\seasonality (55%), time required for processing (32%) and cost (15%). Based on a scale of 1 to 5, respondents were asked to identify the main attribute that influence selection. Mean scores revealed that the main criterion for Amaranth was Availability (2.59), therapeutic properties (3.29) for African basil, and taste (2.60) for and African eggplant.

**Table 1. List of villages surveyed and their socio-cultural groups**

Zones	Districts	Investigated areas	Cultural groups
South	Abomey-Calavi	Abomey-Calavi, Akassato, Godomey, Glo-djigbe, Hevie, Kpanroun, Ouedo, Togba, Zinvie	Fon
	Cotonou	Aibatin 2, Aidjedo, Ayelawadje, Cadjehoun, Dandji, Fifadji, Gbedokpo, Gbgamey, Kouhounou, Saint Michel Sainte Rita, Sodjatime, Yenawa,	Fon
	Seme-kpodji	Agbangandan, Aholouyeme, Djeregbe, Ekpe, Seme-kpodji, Tohoue	Goun
	Bohicon	Gbangnikon, Hezonho, Houawe ouianssa, Hountonho, Sodohome, Sogba	Fon
	Djidja	Agbohoutogon, Bookou, Djidja aglomey, Djidja centre	Fon
North-east	Boukoubme	Koudadagou, Koudogou, Koukoua, Kounacogou, koutagou	Ditamari
	Djougou	Kilir, Taefa, Timba	Dendi, Yom
	Ouake	Itchode, Tchalade, Tchalinga	Lokpa
North-west	N'Dali	Boko, Gomez Kaprou, Mareborou, Suanin, Wobakarou,	Bariba
	Parakou	Kabounari, Sokounon, Titirou, Tourou, Zongo II	Bariba, Dendi
	Tchaourou	Kaki koka, Kassouala, Kika, Kpassa, Tchatchou	Nagot

**Table 2. Dietary uses of traditional leafy vegetables consumed in study areas**

<b>Scientific names (English names)</b>	<b>Local names<sup>1</sup></b>	<b>Dietary utilization</b>		
		<b>Form of used</b>	<b>Processing methods</b>	<b>Beneficial effects</b>
<i>Abelmoschus esculentus</i> (Okra)	Bariba: Kôbusa, Ditamari: Tinoufanti, Fon: Féviman, Lokpa: Maatou, Nagot: Ewéila.	Fresh leaves, dried leaves or dried leaf powders	Cooking in boiling water containing softening ingredient (potash or kanmu: alkaline rock salt) to get a slimy soup.	Very nutritious, stimulate appetite and manage digestives disorders.
<i>Adansonia digitata</i> (African baobab)	Bariba: Sônnawourousou, Ditamari: Titonankanti, Fon: Azizonman, Lokpa: Kôtolassa, Nagot: Ewéotché.	Fresh leaves, dried leaves or dried leaf powders	Cooking in boiling water containing kanmu or potash to get a slimy soup.	Very nutritious, manage digestives disorders.
<i>Amaranthus cruentus</i> (Amaranth)	Bariba: Affônou, Ditamari: Aléfô, Fon: Fotètè, Lokpa: Aléfô, Nagot: Effô tètè.	Fresh leaves or pre- cooked (in salted boiling water)	Raw leaves are used as an ingredient of salad, addition of raw or pre-cooked form into tomato or onion-based sauce to get a vegetable soup.	Very nutritious, stimulate appetite and manage digestives disorders.
<i>Celosia argentea</i> (Cockscomb)	Bariba: Affônou, Ditamari: Tinonyawoti, Fon: Sôman, Nagot: Odjogodo.	Fresh leaves or pre- cooked (in salted boiling water)	Addition into tomato or onion- based sauce to get a vegetable soup.	Very nutritious.
<i>Ceratotheca sesamoides</i> (False sesame)	Bariba: Kpééwori, Ditamari: Siwadouanwe, Fon: Agbô, Lokpa: Hounoume, Nagot: Idjabô.	Fresh leaves or dried leaf powders	Addition into boiling water containing kanmu or potash to get a slimy soup.	Very nutritious, manage digestives disorders.
<i>Corchorus olitorius</i> (Jute mallow)	Bariba: Yôyôkou, Ditamari: Tifanwounti, Fon: Ninnouwi, Lokpa: Ayôyôkou, Nagot: Owoyô.	Fresh leaves	Addition into boiling water containing kanmu or potash to get a slimy soup.	Very nutritious, restore appetite and manage digestives disorders.
<i>Hibiscus sabdariffa</i> (Roselle)	Bariba: Sinri, Ditamari: Tikouan n'ti, Fon: Sinku, Lokpa: Ankpaman, Nagot: Kpakpa.	Pre-cooked leaves (in boiling water containing kanmu or potash)	Addition into tomato-based sauce to get a vegetable soup.	Very nutritious, manage digestives disorders.
<i>Justicia tenella</i>	Bariba: Kourôkountônu, Ditamari: Tinoukounti, Lokpa: Tiletoussi, Nagot: Djagoudjagou.	Fresh leaves or pre- cooked (in boiling water containing kanmu or potash)	Addition into tomato-based sauce to get a vegetable soup.	Very nutritious



Scientific names	Local names <sup>1</sup>	Dietary utilization		
<i>Manihot esculenta</i> (Cassava)	Bariba: Kpakiwourousou, Ditamari: Tikôkônouwôti, Fon: Finyinman, Lokpa: Agbedehatou, Nagot: Ewékpaki.	Pre-cooked leaves (in boiling water containing kanmu or potash)	Addition into tomato-based sauce to get a vegetable soup.	Very nutritious.
<i>Moringa oleifera</i> (Drum-stick tree)	Bariba: Yorouyara, Ditamari: Mounpèkom, Fon: Kpatiman, Lokpa: Lôtaha, Nagot: Lagalanga.	Fresh leaves or dried leaf powders	Fresh leaves are used to make teas and as an ingredient of salad and vegetable soup. Dried leaf powders are used as diet supplements.	Very nutritious, stimulate appetite and manage digestives disorders.
<i>Ocimum gratissimum</i> (African basil)	Bariba: Danbakarou, Ditamari: Tinassiyinti, Fon: Tchiayo, Lokpa: Assôhou, Nagot: Simonba.	Fresh leaves, crushed or pre-cooked (in boiling water containing kanmu or potash)	Raw leaves are used to make teas and as a seasoning, addition of crushed or pre-cooked leaves into tomato or onion-based sauce to get a vegetable soup.	Very nutritious, manage digestives disorders.
<i>Sesamum radiatum</i> (Black benniseed)	Bariba: Dossi, Ditamari: Tiwadounati, Fon: Akanmanku, Lokpa: Touhoonôme, Nagot: Dossé, Goolowo.	Fresh leaves or dried leaf powders	Cooking in boiling water containing kanmu or potash to get a slimy soup.	Very nutritious, manage digestives disorders.
<i>Solanum macrocarpon</i> (African eggplant)	Bariba: Sambinouwourousou, Ditamari: Tikawounfanti, Fon: Gboman, Lokpa: Mètécou, Nagot: Katakoukpakou.	Pre-cooked leaves (in boiling water containing kanmu or potash)	Addition into tomato or onion- based sauce to get a vegetable soup.	Very nutritious, manage digestives disorders.
<i>Talinum triangulare</i> (Water leaf)	Bariba: Odôndôn, Ditamari: Yêmontouo, Fon: Aglassoeman, Lokpa: Kamplékankann'dê, Nagot: Odôndôn.	Fresh leaves or pre- cooked (in boiling water containing kanmu or potash) and dried leaves	Addition of pre-cooked leaves or dried leaves into tomato-based sauce to get a vegetable soup.	Very nutritious, manage digestives disorders.
<i>Vernonia amygdalina</i> (Bitter leaf)	Bariba: Touwan, Ditamari: Souwaka, Fon: Amanvivè, Lokpa: Souwaka, Nagot: Eéwôh.	Pre-cooked leaves (in boiling water containing kanmu or potash)	Addition into tomato-based sauce to get a vegetable soup.	Very nutritious, manage digestives disorders.
<i>Vigna unguiculata</i> (Cowpea)	Bariba: Suiwourousou, Ditamari: Titouti, Fon: Ayiman, Lokpa: Tchaasé, Nagot: Oson.	Pre-cooked leaves (in boiling water containing kanmu or potash)	Addition into tomato-based sauce to get a vegetable soup.	Very nutritious, stimulate appetite and manage digestives disorders.



Scientific names	Local names <sup>1</sup>	Dietary utilization		
<i>Vitex doniana</i> (Black plum)	Bariba: Kounonkou, Ditamari: Timantoun n'ti, Fon: Fonman, Nagot: Ewa.	Fresh leaves or pre-cooked (in boiling water containing kanmu or potash)	Fresh leaves are used to make teas, addition of pre-cooked form into tomato-based sauce to get a vegetable soup.	Very nutritious, manage digestives disorders.

Sources: Survey in October 2015 and December 2016 and additional information from Dansi et al. (2008) and Achigan-Dako et al. (2010)

<sup>1</sup>:Choice of local languages is related to the main cultural groups encountered [Bariba (17.40 %), Ditamari (11.60 %), Fon (19.40 %), Lokpa (9.20 %) and Nagot (9.60 %)]

Therapeutic properties were an important selection criterion to Bariba, Gourmantche, Lokpa and Yom socio-cultural groups who lived in north-western part of the country. Inversely, respondents from Ani, Goun, Idatcha, Itcha, Nagot and Yoruba socio-cultural groups, living in southern areas and having between eighteen and thirty years old considered facility to transform of the leafy vegetables for their selection. Taste and cost were important criteria for Adja, Ahoussa, Fon, Kabiere, Mina and Xlwa socio-cultural groups, regardless their age and places of dwelling.

### 3.4 Frequency of Consumption and Processing Methods

Consumption frequencies varied according to vegetables species but most respondents reported that consumption occurred once or twice per week. At these frequencies, consumption of Amaranth (36% for both frequencies), African basil (once per week: 38% and two or three times per week: 29%) and African eggplant (once per week: 32% and two or three times per week: 45.00%) occurred regularly. The others consumption frequencies mentioned were 'four or five times per week' (Amaranth: 11%, African basil: 7% and African eggplant: 9%), 'once per day' (Amaranth: 1.4%, African basil: 2.4% and African eggplant: 0.8%) and 'once or twice per month' (Amaranth: 7%, African basil: 13% and African eggplant: 8%). These vegetables were used in processed form for sauces preparation with direct cooking (Amaranth: 62%, African basil: 49% and African eggplant: 75%) and pre-cooking (Amaranth: 47%, African basil: 28% and African eggplant: 36%) as the main processing methods. Fresh leaves are crushed on stone grinder (Amaranth: 4%, African basil: 40% and African eggplant: 7%) to create a paste which is used for sauces preparation. Dried leaves (Amaranth: 1%, African basil: 6% and African eggplant: 1%) and leaf powders (Amaranth: 5%, African basil: 3% and African eggplant: 1%) were also reported as ingredients used for sauces preparation.

Fresh leaves, crushed leaves, dried leaves and leaf powders were directly added to onion-based sauces (Amaranth) or tomato based sauce (Amaranth, African basil and African eggplant) supplemented with powder of Egusi (*Citrullus lanatus*) seeds after appropriate treatments making them palatable (Table 3). This processing method is used by most of socio-cultural groups encountered except Adja and

Gourmantche socio-cultural groups who did not apply it to any of these vegetables. Similarly, Itcha, Pedah and Xlwa socio-cultural groups did not apply it to African basil and African eggplant while Kabiere and Mahi people did not apply it to African basil alone and Yoruba people to African eggplant alone. Pre-cooking in boiling water is applied to fresh leaves and requires appropriate treatments before pre-cooked leaves can be added to a tomato-based sauce supplemented with Egusi seeds powder (Table 3). Pre-cooking requires use of additives like potash or bicarbonate of soda to maintain green color, to accelerate softening of African basil and African eggplant, and reduce bitterness of African eggplant. Pre-cooking is also practiced by most of socio-cultural groups met except Waama socio-cultural group who did not apply it to any of vegetables. Similarly, Ahoussa, Biali, Fulani and Gourmantche socio-cultural groups did not apply it to African basil. Sauces obtained from pre-cooking method and made of association of different leafy vegetables species require that each vegetable type was pre-cooked separately because of variability in pre-cooking time, thereafter they can be mixed together during processing. Concerning crushed form, fresh leaves were properly processed to obtain a paste which was added to onion-based sauce supplemented with Egusi seeds powder (Table 3). This method was known and used by most of socio-cultural groups except Mahi and Mina. Consumption of African basil under this form is used by pregnant and lactating women within Ani, Bariba, Ditamari, Fon, Idatcha, Lokpa, Nagot and Yoruba socio-cultural groups. Use of dried leaf and leaf powders for sauces preparation was common within Dendi, Ditamari, Fon, Lokpa and Yom socio-cultural groups. Many others ingredients were used during the preparation of sauces to enhance taste and thickness (spices, small fry fish, fermented African locust bean and Egusi seeds powder). These sauces accompanied cereal-based dishes (maize, millet, sorghum or rice paste; Akassa; Lio; rice; etc.) or tubers-based dishes (Amala, Eba, pounded yam, etc.).

Processing methods of each leafy vegetable require some unit operations (Table 3) among which washing and cooking were reported as the most important steps for Amaranth (59% and 36%, respectively), African basil (54% and 38%, respectively) and African eggplant (52% and 47%, respectively). Washing of African basil can be associated with trituration (10%) and this combination is an important step. Sorting was

also considered an important step for processing of Amaranth (20%), African basil (13%) and African eggplant (15%). It is essential to carefully perform each unit operation to avoid digestive disorders and vomiting after consumption of sauces made with Amaranth (71% and 17%, respectively), African basil (67% and 17%, respectively) and African eggplant (65% and 18%, respectively).

Most respondents (61%) preferred to purchase leafy vegetables in fresh and on site due to processing concerns (e.g., noncompliance with good hygiene and manufacturing practices) and exposure to dust and flies which are diseases vectors. The high price of processed leafy vegetables (1.20%) and the possibility of a mix with other leafy vegetables species (0.20%) also contributed to reasons why respondent prefer fresh forms. Few households stated that they would purchase processed vegetables even if they were available in pre-cooked and packaged (5.40%); pre-cooked, packaged and frozen (1.80%); packaged leaf powder (1.60%); fresh, packaged and refrigerated (0.60%) or dried and packaged (0.60%).

### 3.5 Multivariate Analysis on Consumption Frequencies and Processing Methods

The variability within consumption of Amaranth frequencies was related to socio-cultural groups inversely to processing methods which were linked to age groups and geographic areas. People from Bariba, Biali, Dendi, Ditamari, Fulani, Gourmantche, Lokpa, Pedah, and Yom socio-cultural groups consumed Amaranth two to five times per week. Inversely, those belonging to

Adja, Ahoussa, Ani, Fon, Goun, Idatcha, Itcha, Kabiere, Lama, Mahi, Mina, Nagot, Waama, Xlwa and Yoruba socio-cultural groups consumed Amaranth 'once per week'. People having more than fifty years old and living in southern part of the country applied pre-cooking to Amaranth while those aged from eighteen to thirty years old and living in northern part used direct cooking.

People belonging to Ahoussa, Bariba, Fulani, Idatcha, Mahi, Nagot, Waama and Yom socio-cultural groups consume African basil rarely ('once or twice per month'). Inversely, person from Adja, Biali, Ditamari, Dendi, Goun, Fon, Itcha, Kabiere, Lokpa, Mina, Pedah Xlwa and Yoruba socio-cultural groups consume it 'once per week' and 'two or three times per week'. Direct cooking and crushing were used by people from Ani socio-cultural group, having more than fifty years old and living in north-eastern areas. Pre-cooking was performed by people from Lama socio-cultural group aged from eighteen to thirty years old and who lived in southern and north-western areas.

People from Adja, Ahoussa, Ani, Dendi, Fon, Goun, Idatcha, Itcha, Kabiere, Lama, Mina, Nagot, Xlwa and Yoruba socio-cultural groups consume African eggplant 'once per week' contrary to those from Bariba, Biali, Ditamari, Fulani, Gourmantche, Lokpa, Mahi, Pedah, Waama and Yom socio-cultural groups who consumed it 'two or three times per week'. People living in southern areas applied pre-cooking, regardless of their age inversely to those who lived in northern areas and who performed direct cooking.

**Table 3. Various types of sauces obtained from each leafy vegetable**

Leaves form	Species	Additive/Ingredient	Unit operations	Sauces
Fresh	Amaranth, African basil, African eggplant	Tomato, onion, vegetable oil, seasoning	Sorting/clipping/washing/adding to sauce/cooking	Simple sauce 1
Dried and powders from dried leaf	Amaranth, African basil, African eggplant	Tomato, onion, vegetable oil, seasoning	Sorting (for dried leaf)/washing (for dried leaf) / adding to sauce/cooking	Simple sauce 2
Fresh	Amaranth, African basil, African eggplant	Potash Tomato, onion, vegetable oil, seasoning	Sorting/clipping/washing/pre-cooking/draining/ adding to sauce/cooking	Simple sauce 3
Fresh and crushed	African basil	Onion, vegetable oil, seasoning	Sorting/washing/crushing/adding to sauce/ cooking	Simple sauce 4

### 3.6 Leafy Vegetables Preservation

Leafy vegetables are highly perishable in fresh form and various preservation methods are used (53.80%) to avoid yellowing and deterioration. Short-term preservation methods, including storage in baskets, exposition to dew, storage in clay pots and blanching followed by soaking or refrigeration, are used for Amaranth, African basil and African eggplant, at ambient temperature, to extend shelf life at two or three days. Storage in baskets (24.20%) was the most popular method used by all socio-cultural groups as it allowed the extension of shelf life by an average of two days. This method consists of storing vegetables in baskets placed in a cool and dry place followed by the sprinkling of water (two or three times per day) to prevent dehydration. People from Bariba, Ditamari, Fon, Idatcha, Nagot and Yoruba socio-cultural groups preserved vegetables by spreading them on the roof or on the tufts of grass at nightfall (9.60%) and removing them in the morning to keep them away from heat and sunlight. This process was repeated for 3 days on average before significant deterioration occurred. Storage in clay pots (1.20%), which maintained coolness and humidity, also extended shelf life for up to two days. Blanching followed by soaking in water (11.20%) was also used by Ditamari, Fon and Goun socio-cultural groups to increase preservation. Ordinary sun-drying (4.00%) was used for by Bariba, Dendi, Ditamari, Lokpa, Nagot and Yom for African basil and African eggplant. Some socio-cultural groups (Ditamari and Lokpa, 5.00%) sun-dried blanched leaves and leaf powders were stored in a dry place for three to six months. Many factors hindered proper storage including exposure to heat, excessive drying, and high moisture. Thus, proper leaf washing, avoiding exposition to heat, regular water sprinkling on fresh leaves, storage of dried leaves and leaf powders in a dry place were main precautions taken by respondents to extend availability and shelf life of these leafy vegetables.

### 4. DISCUSSION

The information collected during this research indicates beneficial properties related to use of traditional leafy vegetables in household food systems. These findings confirm the findings of others who have reported on the dietary and medicinal benefits of leafy vegetables [19,5,2,8,9,11,10,17,12]. Amaranth, African basil and African eggplant were the most consumed by respondent; findings consistent with [2] who

also determined that Amaranth, African basil and African eggplant were amongst the top five of frequently used leafy vegetables in all phyto-geographical zones of Republic of Benin. However, the consumption of Amaranth, African basil and African eggplant does differ according to age, cultural and geographical groups. Consumption of Amaranth, African basil and African eggplant, in southern part of the country, was related to ethno-botanical knowledge of socio-cultural groups [6]. Similar observations were made by [19] and [17] on consumption of other traditional green leafy vegetables in northern areas of the country. Likewise, previous reports demonstrated that dietary habits depended on interactions between foods availability, cultural identity, geospatial environment and consumers' spending power [19,5,2,6,20].

Various reasons were mentioned to explain the consumption of the studied vegetables, including dietary habits, taste, need to diversify sauces, nutrients and therapeutic benefits. Traditional leafy vegetables were reported as highly nutritive foods containing vital components of balanced and healthy diets such as vitamins and their precursors, polyphenols, minerals, proteins and fibres [21,22,3,4]. Richness of Amaranth, African basil and African eggplant in vitamins were reported as well-known by Beninese who considered it a key selection criterion of these vegetables [6]. Therapeutic properties of the studied vegetables are widely recognized in folk medicine; for instance Amaranth species were recommended to children, lactating mothers and people who suffered of constipation, fever, bleeding, anemia or kidney problems [23,6]. Uses of African basil by pregnant women and lactating mothers to facilitate childbirth, clear waste after childbirth, stimulate milk secretion, treat postpartum infections and wound healing were reported by Dansi et al. [5] within Nagot socio-cultural group. The knowledge that respondent had on potential health benefits related to consumption of Amaranth, African basil and African eggplant could explain the high consumptions of these vegetables regardless age, cultural and geographical groups. However, some households mentioned lack of knowledge, organoleptic attributes and totemic considerations to justify the non-consumption of Amaranth, African basil and African eggplant. Similar reasons were recorded for the non-consumption of some traditional leafy vegetables [24,19,5,17].

The diversity of production sources (home gardens, gardening sites and fields) are used to gain access to plant resources throughout the year. Leafy vegetables were reported to be harvested from native vegetation, as well as cultivated fields, home gardens, and local markets [24]. Our findings revealed that many criteria were used for selection of Amaranth, African basil and African eggplant among which availability, taste and therapeutic properties were of paramount interest. Literature indicated that availability, the ability to process, nutritional properties, and taste were main criteria for selection of Amaranth, African basil and African eggplant.

According to Dinssa et al. [20], consumption of traditional leafy vegetables is increasing in Africa as a result of consumers' awareness on their nutritional properties and willingness to pay premium prices for quality food. This study lends further evidence to this finding and highlights the relationship between selection criteria and age, cultural and geographical groups of respondent. Consumption frequencies (key indicators of dietary habits) of Amaranth, African basil and African eggplant varied from once to thrice per week and could be easier and useful way to fully enjoy potential health benefits associated to these leafy vegetables [25] although variations were observed according to vegetables species and socio-cultural groups in this study.

The investigated households used Amaranth, African basil and African eggplant in various forms for sauces preparation with a preference for fresh form rather than dried form. This preference was reported in the northern part of the country [19,17]. The processing methods varied according to vegetable species, types of sauces, age and geographical groups. Direct cooking and pre-cooking were the most used methods and pre-cooking required the use of additives (potash or bicarbonate of soda) to accelerate the leaves' softening. Amaranth leaves were reported by respondent to be easily softened in salted boiling water; in agreement with report from Grubben et al. [23] on softening of Amaranth leaves after five to ten minutes in salted boiling water. However, processing of Amaranth, African basil and African eggplant required some key unit operations (sorting, washing and cooking) which must be achieved carefully and properly to avoid digestive disorders. This survey showed the use of some additional ingredients used to enhance the taste of leafy vegetables sauces; consistently with

findings of Sossa-Vihotogbé et al. [17]. Recipes used to process these vegetables in food systems were fairly homogeneous and not numerous and that could be a limiting factor to benefit of their health-promoting attributes. Indeed, processing methods are well-known to decrease nutritional properties of raw leaf whether by the diffusion of water-soluble components in pre-cooking water or by the destruction of thermo-labile and/or oxidizable substances [26,27]. The detrimental effects increase with the increase of water volume used, temperature and duration of exposure [26,27] although heat and water treatments were useful to reduce the incidence of health hazards caused by anti-nutritive factors (hydrocyanic acid, oxalic acid, alkaloids, saponins, etc.) contained in raw leaves [28,29].

Therefore, there is a need of diversification in forms used in food systems since limited dietary diversity was reported as a major challenge and source high prevalence of malnutrition and undernourishment in rural farming communities of sub-Saharan Africa [30]. Steaming was presented as the best approach to maintaining the nutritional quality of Amaranth, African basil and African eggplant [31]. Otherwise, the easy perishability of leafy vegetables posed major challenges for their storage and various methods were used by investigated households to avoid their yellowing and deterioration. Sun-drying, as a popular preservation method used to face scarcity periods, can increase shelf life and alter nutritional quality depending on drying conditions [24]. Oven-drying at 60°C have been demonstrated to allow higher retention of nutritional and sensory attributes while reducing contamination risk [3]. Blanching before sun-drying has been suggested as a valuable option for leafy vegetables preservation without compromising their quality [21,22]. The slowing-down ability of cold storage in metabolic processes (respiration and enzymatic activities) responsible of post-harvest losses offered promising prospects to extension of leafy vegetables shelf life and preservation of their nutritional quality [14]. The high perishability of traditional leafy vegetables was related to their small-scale production in Africa mainly intended to home consumption and local open markets [20]. Therefore, there is a need to develop value-added foods deriving from leafy vegetables extracts since perishability is the limiting factor for development of value chain of fresh leafy vegetables.

## 5. CONCLUSION

This study was conducted in eleven districts of southern and northern areas of Republic of Benin and allowed to gather information on households' dietary habits concerning leaves of Amaranth, African basil and African eggplant. Results obtained revealed that a diversity of leafy vegetables was used in the investigated areas for culinary and medicinal purposes with Amaranth, African basil and African eggplant as the most consumed green leafy vegetables. These leafy vegetables were mainly selected based on their availability (Amaranth), therapeutic properties (African basil) and taste (African eggplant) to be used alone or in association with other leafy vegetables for consumption. The importance of these selection criteria were dependent on age, cultural and geographical groups. The main supply mode of Amaranth, African basil and African eggplant was purchasing at market. The importance of these leafy vegetables in dietary habits of socio-cultural groups encountered were reflected by variability in weekly consumption frequencies, processing methods and preservation techniques used. An overall observation of relation between consumption frequencies, processing methods, age, cultural and geographical groups of each leafy vegetable revealed that consumption frequencies varied with socio-cultural groups while processing methods were related to age groups and geographic areas. Regarding information collected, lack of diversification within processing methods and consumption forms (other than sauces) are the major challenges of contribution of Amaranth, African basil and African eggplant in nutritional security of households in the investigated areas. Diversification of consumption forms could be addressed by incorporating the extracts obtained from these leafy vegetables to commonly consumed foods and beverages in order to enhance their nutrient profile without compromising their quality and consumers' acceptability.

## CONSENT

As per international standard respondents' written consent has been collected and preserved by the author(s).

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## COMPETING INTERESTS

Author has declared that no competing interests exist.

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