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# Local agro-ecological condition-based food resources to promote infant food security: a case study from Benin

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## Abstract
Children are still undernourished in many developing countries. A way to address this issue is to make better use of local food resources. The present study documents local plant and animal resources used for feeding infants and young children across the agro-ecological zones (AEZ) of Benin, with a focus on the availability of resources and consumption forms. It describes similarities and differences among the AEZs and identifies proposals for infant food formulations at the AEZ level. A literature review was performed and supplemented with a survey in 42 villages of eight AEZs of Benin. The selection of municipalities was based on the prevalence of food insecurity. In total 969 people were interviewed through focus group discussions and individual interviews using pre-established interview checklists and questionnaires. Data were processed with statistical tools, including non-metric dimensional scaling analyses, descriptive statistics and Chi$^2$ test of independence. Results showed disparities in the distribution and use of local food resources for infant foods in the AEZs. AEZ 1 represented by Karimama and AEZ 2 represented by Banikoara (both in the Sudanian zone, with about 900 mm rainfall per year in one long rainy season and one long dry season) had the lowest diversity of local food resources used in children's feeding, while AEZ 5 represented by Aplahoué and Ouèssè (both in the Guinean zone, with about 1200 mm rainfall per year over two rainy seasons and two dry seasons), and AEZ 8 represented by Adjohoun and Bopa (both in the Guinean zone with about 1200 mm rain per year) had the highest diversity. The baobab tree (*Adansonia digitata*) and groundnut (*Arachis hypogea*) were the plant resources recording the highest number of usages for food in general and infant foods in particular. High similarities in the species used for infant food existed among AEZs 5, 6, 7 and 8 whereas AEZ 1 and AEZ 4 had no match with resources used for infants in the other AEZs, mainly due to food cultures and availability. These findings indicate the usefulness and efficiency of an approach to formulate generic infant food formulas based on grouping AEZs with similar resources. Further studies are needed to assess the quantitative availability of local food resources throughout the year, the links between food prices and purchasing power of the population, and to assess the bioavailability of nutrients in infant foods made from local food resources in relation to food preparation methods.

**Keywords** Infant undernutrition · Agro-ecological zone · West Africa · Complementary foods

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## 1 Introduction

Food insecurity and undernutrition in all their forms remain serious health problems in developing countries. More than 2.6 million women and under-five-year old children die from undernutrition every year in low income and middle-income countries (IFPRI 2014). Undernutrition exposes those who survive to further developmental impairment, and around one in four people remain undernourished in sub-Saharan Africa (FAO 2014). In Benin, food insecurity, as determined by availability, accessibility, utilization of food and the stability of these three parameters, is high in low income households (INSAE 2015a).

Infant undernutrition ensues from the inadequacy of complementary foods and the nutritional needs of children during the weaning process (Latham 2001). Beyond six months of life, breast milk becomes qualitatively and quantitatively insufficient for the infant whose nutritional needs are increasing (Qasem et al. 2015). This period of six months to 24 months also highly influences the child's subsequent feeding behaviour and its development into adulthood (Azagoh et al. 2013). Indeed, healthy growth and development of infants and young children to their full potential require adequate nutrition and feeding practices, which include nutritionally balanced complementary feeding after about six months.

Undernutrition and brain development are correlated. According to Cordero et al. (1993) and Benítez-Bribiesca et al. (1999), undernutrition changes the structure of brain cells of children from a normal (extensive branching) structure to an abnormal structure (with shorter branching). Moreover, undernutrition can cause indirect losses due to poor cognitive functioning and deficits in schooling (Banque Mondiale 2006). Later in life it may lead to job losses related to poor physical condition, which subsequently can result in an income reduction of up to 10% for the individual, over the duration of his life, and a reduction of up to 2–3% of a country's GDP (Alwan 2011; Jusot et al. 2008). Therefore, it is necessary to introduce adequate foods in the diet of young children to supplement the intake of breast milk (Dillon 1989; Zannou Tchoko et al. 2011).

In low-income countries such as Benin, 23% of households are unable to afford the cost of good quality infant meals (PAM 2014a). Beninese mothers, who are generally in charge of food management in the household, usually feed their children with traditional porridge prepared from single or mixed cereal flours. In addition, up to 70% of rural as well as urban Beninese communities depend on endogenous locally available plant and animal resources since these are the easiest to tap into in the immediate environment (PAM 2014a). Plant resources are almost equally available across the country in all agro-ecological zones (AEZ) whereas animal resources are not equally distributed because of climate. In this respect, local populations have shaped knowledge systems, practices and decision-making processes to identify and prepare indigenous food resources for generations (Kuhnlein et al. 2009). Therefore it would always be easier for populations to collect food resources available locally in their environment for feeding infants and children than buying them far from home. Collection is practised because most of the plant resources concerned are spontaneous in nature and the germination techniques for most of them are not yet fully investigated. However, production and harvest are practised for some locally available plants, such as *Moringa oleifera*. As such, viable solutions to infant undernutrition could be more sustainable if adequate foods were designed, based on locally available food resources that communities already depend upon (Mitchikpe et al. 2010; Kageliza et al. 2014).

A variety of common and available plant and animal species exists from which local populations could source foods with good nutritional value. Indeed, previous studies showed that species such as *M. oleifera* (Ashok and Preeti 2012), *Adansonia digitata* (Chadare 2010), *Annona senegalensis* (Codjia et al. 2003), *Borassus aethiopum* (Codjia et al. 2003; Djagoun et al. 2010) as well as *Elaeis guineensis* (Akoègninou et al. 2006) are highly nutritious. However, the number and types of local food resources potentially usable for infant feeding vary according to AEZ in Benin and lead to a diversity in dietary profiles (Codjia et al. 2003; Achigan-Dako et al. 2010). Therefore, local specificities within Benin must be taken into account when designing complementary food formulas for different AEZs based on locally available resources.

This study identified local food resources suitable as ingredients for the development of adequate complementary infant food formulas based on materials available to local populations. First, the study documented local plant and animal resources used to feed infants and young children across the eight AEZs of Benin, with a focus on the availability of resources, consumption forms and nutritional value. Secondly, it described similarities and differences among AEZs as a basis for producing adequate generic infant food formulas.

## 2 Methods

### 2.1 Study design

#### 2.1.1 Study area

A cross-sectional survey was carried out in the eight AEZs of Benin (Fig. 1). AEZ 1 (Extreme northern) marks the northern limit of Benin by the presence of the Niger River and benefits from its three tributaries that are the Mekrou, the Alibori and the Sota. This area contains a large part of the forest reserve called West National Park of Niger. It covers a total area of 9057 km$^2$ with a population of 312,928 inhabitants (INSAE 2015a). Cropping systems rely on millet (*Pennisetum glaucum)* and sorghum (*Sorghum bicolor)*. Cotton (*Gossypium hirsutum*), maize (*Zea mays*), rice (*Oryza sativa*), onion (*Allium cepa*),

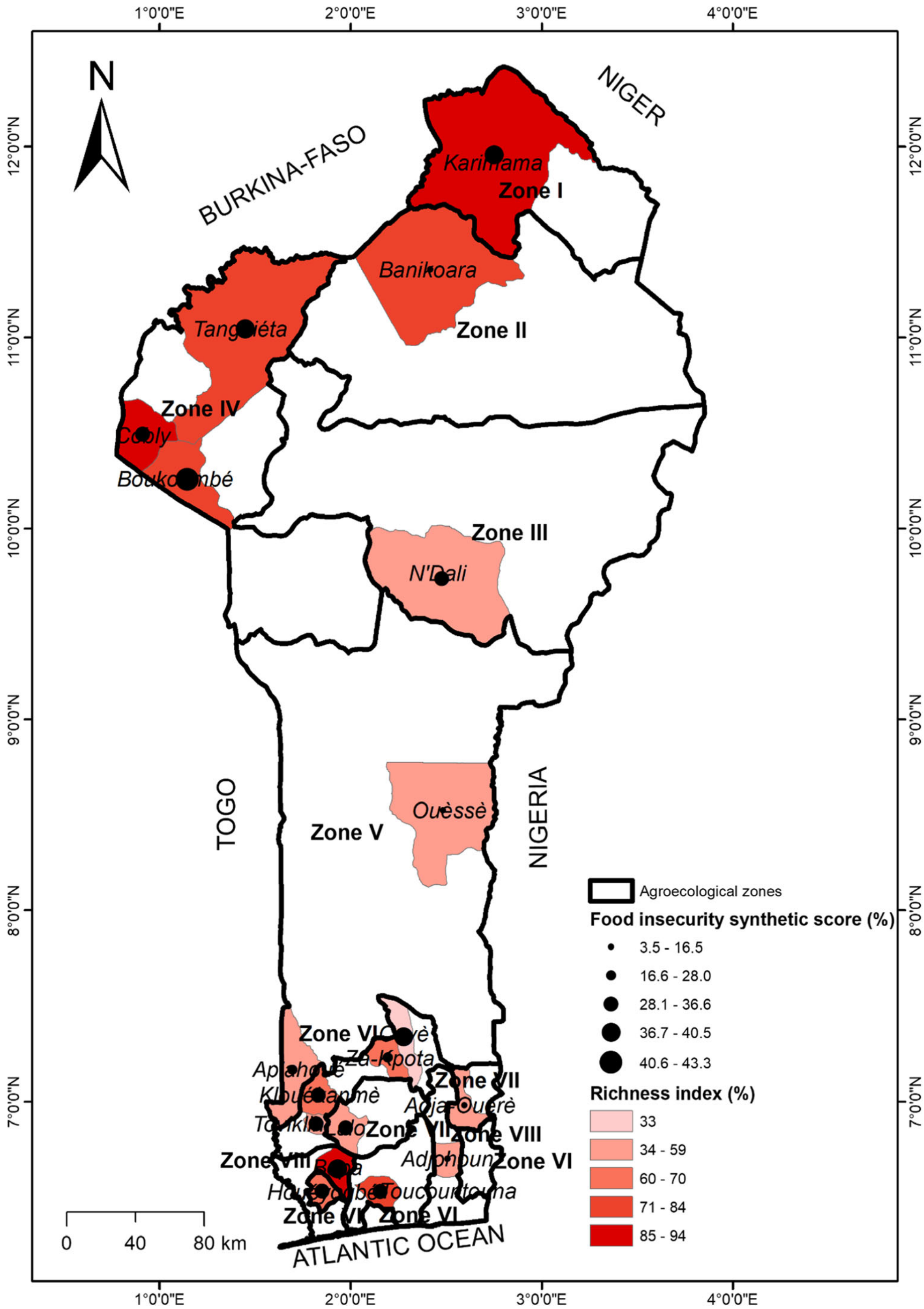


**Fig. 1** Agro-ecological zones of Benin. Legend: I, Extreme North; II, North cotton zone; III, South Borgou crop zone; IV, West Atacora zone; V, Central Benin cotton zone; VI, Zone des terres de barre; VII, Depression zone; VIII, Fishing zone. Food insecurity synthetic score represents the synthetic household groups with moderate and severe food insecurity (AGVSA 2014). Household richness index represents the proportion of households that are in the first two poorest quintiles of the richness index (INSAE 2013; Hounguevou 2016). Map source: UNDP, MEPN-Benin. United Nations Climate Change Map. Benin Climate Change Adaptation National Action Program (PANA-BENIN). January 2008. Cotonou, Benin

sweet potato (*Ipomoea batatas*) and vegetable crops grown along the Niger River are secondary crops in this zone. Its climate is of the Sudano-Sahelian type and includes the communes of Malanville and Karimama. The temperatures are excessive and reach 40 °C in the shade in the dry season. AEZ 2 (Northern Benin Cotton Zone) is mainly characterized by its specialization in cotton growing (the main development factor of these communes). AEZ 2 includes five communes, including Banikoara where the study was conducted. This area is watered by the same tributaries of the Niger River as AEZ 1 and is influenced by the continental trade wind, which often occurs as early as November. The area covers 20,930 km$^2$ and has 732,666 inhabitants (INSAE 2015a). Production systems are based on sorghum and maize supplemented by yams. AEZ 3 (Food zone of South Borgou) is essentially characterized by a very high availability of agricultural land, which is a major asset for food security. It includes eight communes, one of which is N'Dali. This is the domain of the humid Sudanese climate, marked by a rainy season from April to September and a dry season that lasts nearly five months. The area covers 23,442 km$^2$ and has 925,672 inhabitants (INSAE 2015a). Production systems are based on yams, cotton, maize and cashew. AEZ 4 (West Zone-Atacora) is characterized by the foothills of the Atacora mountain range and includes eight communes, of which Cobly, Toucoutouna, Boukoumbé, and Tanguiéta were surveyed. This area benefits from the presence of the Atacora Range, which gives it a special climate, with lower temperatures and more frequent thunderstorms than in other areas. Rainfall amounts vary from 800 to 1350 mm depending on the year. The main watercourse is the Pendjari with its tributaries. It covers an area of 16,936 km$^2$ and has 781,389 inhabitants (INSAE 2015a). Production systems are based on cereals in the northern part of the zone and tubers (especially yams) in the southern part. AEZ 5 (Cotton Zone of the Center) is the largest area of the country. It encompasses all the hilly departments, as well as parts of some other departments (Borgou, Donga, Couffo, Plateau and Zou). It is an area conducive to agriculture and welcomes "agricultural colonizers", mostly from AEZ 4. It is watered by the Ouémé River and its tributaries (Zou and Okpara), and its climate is of the Sudano-Guinean type. It covers an area of 32,163 km$^2$ and has 1,778,187 inhabitants (INSAE 2015a). Production systems in this area are based on crops, particularly tubers, legumes and cotton. AEZ 6 (Area of "clayey earth") is one of the most complex areas and is referred to as the "clayey earth area" because of the characteristics of its soils. It is located in the southern part of Benin and includes 22 communes from the departments of Atlantic, Couffo, Ouémé, and Zou. The climate is marked by two rainy seasons (March–July, October–November) and two dry seasons (December–February, August). Rainfall varies between 1000 and 1400 mm. The area covers 6391 km$^2$ and has 2,990,075 inhabitants (INSAE 2015a). Production systems are based on the cultivation of maize, cassava, cowpea and groundnut. In this AEZ, the rainfall regime is often disturbed, causing changes in the annual production cycles. AEZ 7 (Zone of depression) is so-called because it is located in a depression which, from west to east, is called the depression of Tchi in the department of Mono (commune of Lalo), depression of the Lama in the Atlantic and the Zou (the communes of Toffo and Zogbodomey, respectively) and Issaba in Ouémé (the communes of Adja-Ouèrè and Pobè). It is the smallest of the eight AEZs in terms of surface area. Its climate is comparable to that of AEZ 6, but with high relative humidity (about 85%). The area covers 6391 km$^2$ and has 554,405 inhabitants (INSAE 2015a). Maize associated with cassava, tomato, pepper, and cowpea constitute the basis of the production systems. AEZ 8 (Fishery Zone) is mainly characterised by inland and marine fisheries in addition to crop and livestock production. Geographically, it is the southernmost area, which occupies the fluvio-lacustrine parts of the departments of the Atlantic, Mono, Ouémé and Zou and includes 13 communes. It covers 3280 km$^2$ and has 1,822,362 inhabitants (INSAE 2015a). In this zone the production systems are based mainly on fisheries, maize, cassava, cowpea and vegetable crops. Here the low availability of land limits agriculture.

### 2.1.2 Literature review

A comprehensive literature review was conducted from May to October 2015. Peer-reviewed and non peer-reviewed papers were collected from the websites of relevant institutions (University of Abomey-Calavi, International Institute of Tropical Agriculture – IITA, Institut de Recherche pour le Développement – IRD) and through online databases (AGORA, Web of Science, Scopus, Science Direct and Google Scholar) (see Chadare et al. (2018)). The review focused on plant and animal food resources available in Benin with potential for use as complementary food nationwide. Information gathered included distribution by morphological type, seasonal availability, and consumption forms across AEZs, and food component value. Targeted food components included macronutrients, minerals, amino and fatty acids, vitamins and antinutritional factors (Chadare et al. 2018). A total of 1046 studies from Benin and elsewhere were explored for species used in infant food preparation, organs used (leaves, roots, stem, bark, seeds, fruits), sources of supply and distribution by AEZ. A food resource is defined as a specific organ or part of a given species that is used for infant food. The literature review provided also an overview of the local food resources and their nutritional value. The information collected allowed the selection of the 34 most nutritious local resources in the country with a special focus on protein and micronutrients. They were listed along with their photographs, and this list was complemented by photos of resources collected from the most frequented local markets of the survey areas. This list was used during the field survey, to allow the informants to recognize resources that they use to feed their children. It also allowed informants to add other resources when they were not present on the sheet or among the photos from the local markets.

### 2.1.3 Field survey

**Study area selection process.** The survey took place in each of the eight AEZs of Benin in July and September 2015. One to four districts were explored per AEZ. They were randomly selected mainly because of the high prevalence of household food insecurity (34–45%) (PAM 2014a), with the exception of Banikoara district (AEZ 2), and Adja Ouèrè (EAZ 7) which had relatively low levels of food insecurity (9.5 and 3.5% respectively). In each district, villages for the field survey were selected based on three criteria (1) geographical access (i.e., easy access, difficult access, and medium access); (2) socio-linguistic criteria (i.e., villages with a predominant dialect, in practice this meant that in a given village we considered the two major ethnic groups of the district or AEZ it belonged to; see Fig. 1 for further information on ethnic groups of AEZs). For instance, in Karimama (AEZ 1), one focus group discussion was conducted for each of the Dendi and Bariba women; (3) economic criteria, concentrating on villages with limited resources. In practice 5–6 villages were visited per AEZ, leading to a total of 42 selected villages.

**Participants.** The sample used in the present study targeted two groups: mothers/carers and key informants. Key informants were selected among women who were experienced in infant food preparation and practices, rural development agents at district level, health and/or nutrition service agents, and NGOs active in child nutrition. Women constituted almost 90% of the sample size. In target villages, the sampling was randomly done with the help of zone leaders and women were selected who were able to participate in focus group discussions. In total, 969 persons were interviewed: 820 of them participated in the focus group discussions and 149 in individual interviews. On average 3–4 participants were identified for individual interviews per village and 20 participants for two focus group discussions per village (10 participants per focus group discussion). In total, 13 ethnic groups were included in this survey, namely Adja 21%, Ottamari 18%, Fon 11%, Dendi, Peuhl, Tchabè and Wém 7% each, and Goun, Péda, Baatonu, Maxi, Yoruba, and Nagot 4% each. In addition, 13 local markets were surveyed to assess the physical diversity and prices of local food resources that could be used in infant food according to abundance and shortage periods.

**Data collection approach.** Before starting the collection of field data, informed consent was obtained from the participants who voluntarily accepted participating in the survey. Focus group discussions were combined with individual interviews with the key informants in each selected district of the AEZs. Interview guidelines and a structured questionnaire were elaborated for the focus group discussions and individual interviews, respectively. In addition, food lists and photos were used to facilitate the identification of food resources by the participants. The focus group discussions were each conducted with approximately 10 participants, selected each time based on the age of their children (between 4/6 and 24 months), their willingness to participate and their availability. A dictaphone was used to record the group discussions and interviews, and to secure information. The questions were related to usage forms, main processing operations, knowledge of food resources, especially for children, knowledge of dietary and health issues for children, sources and factors that affect the use of local food resources in child feeding, and obstacles and factors that hamper the use of local food resources. The data collected were related to the availability of local food resources, their modes of utilization in infant feeding practices, processing techniques, and their sources of supply.

### 2.1.4 Identification of local food resources

After the field work, with photos and collected samples, the scientific names of plant species were identified using *La Flore Analytique du Bénin* (Akoegninou et al. 2006). The unknown local food species were identified at the National Herbarium of the University of Abomey-Calavi. The identification of fish species was done at the laboratory of aquaculture at the University of Abomey-Calavi. The remaining unknown species were named by their local names and associated with a photo.

## 2.2 Statistical methods

The analysis of data mainly comprised descriptive statistics (count, percentage) and bar plots from the ggplot2 package (Wickham 2009) using the statistical software R 3.3.1 (Team 2016). Cross tabulations were established first between food species and AEZs, and secondly between food resources and AEZs. Chi$^2$ of Pearson tests were performed on these cross tabulations to assess whether the number of animal or plant species depended on the AEZ. In addition, abundance–occurrence plots were established for each AEZ to assess the main food species used for infant food, based on the number of uses associated with a given species and how often it was mentioned. To compare the diversity of species and food resources among AEZs, the effective numbers of species and food resources were computed using the exponential of the Shannon-Wiener index (Stohlgren 2007) which can be obtained through the following formula:

$$H = \sum P_i \log_2(P_i)$$

where $P_i$ is the proportion of species or food resources per AEZ.

A non-metric multidimensional scaling analysis[1] was performed to assess the similarities between AEZs in terms of species and food resources used for infant food. Then, bar plots were used to compare the diversity in utilization on the one hand and the groups of food resources on the other hand for AEZ 2 (food secure zone used as reference) as compared to the other AEZs. Bar plots were used to present the main source of supply of food resources in the different AEZs.

[1] **Main idea:** Non-metric multidimensional scaling (NMDS) is a multivariate statistical method that uses proximities between observations to construct their spatial representation. NMDS is an extension of the former MDS or principal coordinates analysis (PCoA) (Torgerson 1952). Indeed, MDS methods were developed to use metric distance measures between observations in order to generate their corresponding metric coordinates (Young et al. 1995). These methods are limited in application due to the assumption that the distance data to be analysed must be metric in character (Shepard 1980). NMDS is an indirect gradient analysis approach (non-parametric alternative of PCoA) which produces an ordination based on a distance or dissimilarity matrix. Unlike methods which attempt to maximize the variance or correspondence between objects in an ordination, NMDS attempts to represent, as closely as possible, the pairwise dissimilarity between observations in a low-dimensional space. Any dissimilarity coefficient or distance measure may be used to build the distance matrix used as input. NMDS is a rank-based approach, meaning that the original distance data is substituted with ranks. While information about the magnitude of distances is lost, rank-based methods are generally more robust to data which do not have a known distribution. NMDS can tolerate missing pairwise distances, can be applied to dissimilarity matrix built with any dissimilarity measure and can use quantitative, qualitative, or mixed variables (Buttigieg and Ramette 2014).

**Technical considerations before analysis:** The non-metric multidimensional scaling (NMDS) analysis is an iterative algorithm (the most common is the Shepard-Kruskal algorithm), which generates the so-called stress values that represent the quality of the configuration of pairwise points (Kruskal 1964b). The algorithm can quickly become computationally demanding when data sizes are large. An issue of NMDS is the selection of the appropriate number of axes (Kruskal 1964b). Therefore, after an initial ordination, we examined the stress values provided by the algorithm. As a rule of thumb, an NMDS ordination with a stress value around or above 0.2 is deemed suspect and a stress value approaching 0.3 indicates that the ordination is arbitrary. Stress values equal to or below 0.1 are considered fair, while values equal to or below 0.05 indicate good fit (Kruskal 1964a). Allowing the algorithm to ordinate in more dimensions can reduce the stress; however, allowing more than 3 dimensions quickly makes interpretation more challenging (Buttigieg and Ramette 2014). One way to select the appropriate number of dimensions is to plot the observed stress values against the number of dimensions used in a series of NMDS runs. Generally, adding more dimensions does not lead to marked drops in the stress value, so an NMDS that uses two or three axes is a good choice.

**After analysis:** The standard NMDS procedure focuses on accurately representing the distances in a distance matrix in an ordination. It does not attempt to create a visualisation which, for example, maximises the separation between points. Minimising overlap between points in an ordination is helpful in interpretation, thus principal components analysis may be applied to NMDS axis scores. This effectively rotates an NMDS solution to ensure the first NMDS axis lies along the direction of maximum scatter. Several implementations of the NMDS routine do this automatically. However, performing this manually is not difficult and can be very insightful (Kenkel and Orlóci 1986). Reading NMDS plots is quite straightforward: individuals that are ordinated closer to one another are likely to be more similar than those further apart. However, the scale of the axes is arbitrary as is the orientation of the plot. Tight clusters of points that are well-separated from other clusters may indicate sub-populations in the data. The stress of the solution would be minimally affected by rearranging points in a tight cluster. Re-running an NMDS with only those objects in a given cluster may reveal more informative patterns (Buttigieg and Ramette 2014).

## 3 Results

### 3.1 Foods and food resources from plant and animal origin used for infant food by agro-ecological zone

Table 1 presents the number of animal and plant species and the number of food resources used by local populations to feed infants according to AEZ in Benin. In all AEZs, the proportion of plant species (74–92% of all species) used was higher than the proportion of animal species (8–26%). AEZ 8 was the zone with the highest proportion of animal species and the lowest proportion of plant species, while the lowest proportion of animal species and the highest proportion of plant species were recorded in AEZ 2. There was no significant difference between the proportions of animal and plant food species used by households among AEZs ($P > 0.05$, Table 1). A similar trend was observed for the number of food resources per AEZ. The Chi$^2$ test showed no significant difference between animal and plant food resources among AEZs (Table 1).

### 3.2 Diversity of species used as food resources for infant food

Up to 116 species were recorded as sources of food for infants, of which 86 were plant species and 30 animal species (including fish, crab, insects, snails, and shrimps). The lowest diversity of food resources was recorded in AEZ 1 (Karimama) and AEZ 2 (Banikoara), whereas the highest diversity was found in AEZ 5 (Aplahoué, Ouèssè) and AEZ 8 (Adjohoun, Bopa). Table 1 shows, based on the Shannon-Wiener index, that from a given AEZ to another, the species and food resource diversities were low (1.53–1.64) with five equally-common species or food resources used per AEZ. However, the food species and resources used by local populations to feed their children varied from one AEZ to another (Table 2). In general, leaves, fruits, nuts, seeds, arils, pulps, tubers, flowers, and bark were recorded to be used for infant food, of which leaves, fruits and seeds were the most commonly used plant organs. Leaves were often used for herb infusions, for vegetable sauce and slimy sauces. Seeds and nuts were used as flavouring agents and as an enhancer of a food's energy value. Fruits were mostly consumed raw (Table 2).

*Adansonia digitata* (baobab) leaves were used as leaf powder for a slimy/gluey sauce often used in cooking; *Glycine max* (soyabean) seeds and *Parkia biglobosa* nuts were used in all AEZs for *afitin* (a fermented seasoning). Baobab and *Arachis hypogaea* (groundnut) were the species with the highest number of usages (viz. seven different usages as detailed in Table 2). Some species were specific to some AEZs, i.e. used only in those AEZs for infant food (Table 3).

Table 4 illustrates the occurrence and the abundance (as number of different uses) of species used for infant foods in the AEZs. Baobab was the most frequently cited species for infant food

**Table 1** Species and food resources distribution within agro-ecological zones in Benin. Number of species or food resources (proportion in %) and Shannon H index (Effective number of species = exp.(H))

| | AEZ* 1 | AEZ 2 | AEZ 3 | AEZ 4 | AEZ 5 | AEZ 6 | AEZ 7 | AEZ 8 | *P* value (Chi 2 test) | H (ENS) |
|---|---|---|---|---|---|---|---|---|---|---|
| Species distribution (%) | | | | | | | | | | |
| Animal species (meat and fish) | 6 (21.4) | 2(8.3) | 7 (17.5) | 11 (25.5) | 9 (17.3) | 8 (20.0) | 11 (23.9) | 14 (26.4) | 0.684 | 1.53(5) |
| Plant species | 22 (78.6) | 22 (91.7) | 33 (82.5) | 32 (74.4) | 43 (82.7) | 32 (80.0) | 35 (76.1) | 39 (73.6) | | 1.64(5) |
| Total | 28 | 24 | 40 | 43 | 52 | 40 | 46 | 53 | | |
| Food resources distribution (%) | | | | | | | | | | |
| Animal food (meat and fish) | 6 (17.7) | 2 (5.9) | 7 (14.3) | 11 (22.0) | 9 (14.3) | 8 (17.4) | 11 (21.2) | 14 (23.3) | 0.475 | 1.53(5) |
| Plant food | 28 (82.3) | 32 (94.1) | 42 (85.7) | 39 (78.0) | 54 (85.7) | 38 (82.6) | 41 (78.9) | 46 (76.7) | | 1.62(5) |
| Total | 34 | 34 | 49 | 50 | 63 | 46 | 52 | 60 | | |

*AEZ: Agro-ecological zone; ENS: Effective number of species

AEZ 1: Karimama; AEZ 2: Banikoara; AEZ 3: N'Dali; AEZ 4: Cobly, Boukoumbé, Tanguiéta, Toucountouna; AEZ 5: Aplahoué, Ouèssè; AEZ 6: Covè, Houéyogbé, Klouékanmè, Toviklin, Zakpota; AEZ 7: Adja-Ouèrè, Lalo; AEZ 8:. Adjohoun, Bopa

preparation by the population of all AEZs (up to 23% of the interviewees); except for AEZs 7 and 8 where the most frequently mentioned species was *Pelloluna leonensis* (4% of the interviewees). Moreover, baobab was recorded as the main species used (with a number of usages that varied from three to six according to AEZs) for infant feeding in all AEZs.

In AEZ 1 (Karimama), the main plant species used for infant food were *A. digitata*, *Hibiscus sabdariffa*, *A. hypogaea*, *Abelmoschus esculentus*, *A. cepa*, whereas the principal protein-provider species was *Achatina* sp. (snail). In AEZ 2 (Banikoara), *A. digitata*, *Anacardium occidentalis*, *A. hypogaea*, *A. esculentus* were the main plant species used for infant food, while the principal protein-provider here was a fish species called *Dowèviko* in the Adja local language. The principal species used for infant food in AEZ 3 (N'Dali) can be grouped into two categories: plant species (*A. digitata*, *A. occidentalis*, *A. esculentus*, *G. max*, *H. sabdariffa*) and two snail species, namely *Achatina* sp. and *Limicolaria* sp., which were also the principal providers of protein in the AEZ (Table 4). In AEZ 4 (Cobly, Boukoumbé, Tanguiéta, Toucountouna), the main species used for infant food were plant species such as *A. digitata* and *A. esculentus*, small fish species called *Adjomana* (in *nateni* local language) and the snail *Achatina* sp., which were the principal protein-providers. The main species used for infant food in AEZ 5 (Aplahoué, Ouèssè) were plant species such as *A. digitata*, and *A. esculentus*, a fish species called *Akoko* (in *Maxi* local language), and a snail species (*Achatina* sp.). The fish and snail species were the main protein providers in the infant food used in the zone. The main species that characterized AEZ 6 (Covè, Houéyogbé, Klouékanmè, Toviklin, Zakpota) for infant food were plant species such as *A. digitata*, *A. occidentalis*, *A. esculentus*, *H. sabdariffa*, *Solanum macrocarpon*, and fish species such as *Dowèviko* (in the Adja local language), *P. leonensis*, *Penaeus* sp., and *Tilapia*. In AEZ 7 (Adja-Ouèrè, Lalo), local people used mainly *A. hypogaea*, *A. esculentus* (both plant species), *Achatina* sp. (snail species), and fish species such as *Abobi* (in *Adja* local language), *Dowèviko* (in Adja), *Noukoudotokpa* (in *Goun* local language), *P. leonensis*, *Penaeus* sp., and *Tilapia*, as the main species used for infant food. Concerning AEZ 8 (Adjohoun, Bopa), fish species such as *Clarias gariepinus*, *Cyprius carpio*, *Dowèviko* (in the Adja local language), *P. leonensis*, and *Tilapia*, plant species such as *A. digitata*, *A. esculentus*, *Vitex doniana*, *Vigna unguiculata* and *P. biglobosa*, followed by the snail species *Achatina* sp. were the principal species used for infant food (Table 4).

Figure 2 shows a non-metric multidimensional scaling plot that evaluated the relationship between the uses of a species for infant food and the associated AEZs. It expresses the similarities between AEZs according to species used by the local population to feed children. The final stress value from the analysis was 0.072, implying that the fitting was fair. AEZ 2 and AEZ 3 have a high similarity in terms of species used for infant foods. There was also a high similarity between AEZs 5, 6, 7 and 8. However, AEZ 1 and AEZ 4 both had no similarity of food species used for infant feeding as compared to the other AEZs.

## 3.3 Use patterns and supply sources of food resources in AEZs

Many different ways to process the available resources into foods were encountered in the AEZs. The recorded food types were: 'cheese' (grains of *G. max*), afitin (fermented seeds of *P. biglobosa*), raw foods that were essentially fruits (of *A. digitata*, *P. biglobosa*, *A. senegalensis*, *Balanites aegyptiaca*, *Vitellaria paradoxa*, *Chrysophyllum albidum*, *Cola nitida*, *Irvingia gabonensis*, *Synsepalum dulcificum*, *V. doniana*) and nuts (*A. hypogaea)* but also tubers (*Cyperus esculentus*), dried products (arils of *Blighia sapida*, fish, plant leaves),

**Table 2** Main usages of local resources for infant food in Benin

| Type of resources | Uses | Species used[AEZ] (Organ) |
|---|---|---|
| Plant resources | Afitin | Adansonia digitata[1](S); Arachis hypogaea[2](N); Glycine max[2](S); Parkia biglobosa*(N) |
| | Almond/Toasted almond | Adansonia digitata[1](S) [2](A) |
| | Boiled/Dried/Toasted aril, leaf, nut, tuber | Allium cepa[1](L); Anacardium occidentalis*(N); Arachis hypogaea[1,2,3,7](N); Blighia sapida[2,3,4](A); Cyperus esculentus[5,6,8](T); Monodora myristica[4](N) |
| | Butter and oil | Vitellaria paradoxa[2,3,4](N) |
| | Cheese cooking | Glycine max[2,3,5,7,8](S) |
| | Condiment | Allium cepa[4](L); Arachis hypogaea[6](N); Blighia sapida[4](A); Citrullus lanatus[5,6,7,8](N); Cucumeropsis mannii[5](N); Cucurbita maxima[1](N); Hibiscus sabdariffa[1,2,3](Fl); Sesamum sp. [1](S); Solanum sp. [5](Fr); Solanum macrocarpon[2,3,5,6,7,8](Fr) |
| | Flat cake | Arachis hypogaea[2](N); Glycine max[3](S) |
| | Fried mushroom | Pleurotus tuber-regium[5] |
| | Herb tea | Annona senegalensis[5](L); Balanites aegyptiaca[6](L); Caesalpinia bonduc[5](L); Ehretia cymosa[5](L); Heliotropium indicum[7,8](L); Jatropha curcas[8](L); Lippia chevalieri[5](L); Psidium guajava[4](L); Pterocarpus erinaceus[5,7,8](L); Sorghum bicolor[1,2,3,5,6,7,8](Sp); Stachytarpheta indica[8](L); Telfairia occidentalis[7](L) |
| | Juice/Nectar | Hibiscus sabdariffa[1,2,3,5,6,7,8](Fl); Tamarindus indica[1,2,3,4](Fr) |
| | Other meals of which the species is the principal element | Cajanus cajan[4,5,6,7,8](S); Dioscorea sp. [5](T); Vigna unguiculata[4,5,6,7,8](S) |
| | Powder and/or sauce of the powder | Adansonia digitata[2,3,4,5,6,7,8](P); Arachis hypogaea[2,3,4,5,6,7,8](N); Digitaria exilis[4](G); Glycine max*(S); Khaya senegalensis[8](B); Moringa oleifera[2,3,4,5,6,7,8](L); Oryza sativa[5](C); Parkia biglobosa[1,2,3,5,8](P); Red Koata[+](dendi) [1](B); Yellow Koata[+](dendi) [1](B) |
| | Raw food | Afraegle paniculata[5](Fr); Anacardium occidentalis[1,2,3,4,5](Fr); Annona senegalensis*(Fr); Arachis hypogaea[1,7](N); Balanites aegyptiaca[2](Fr); Blighia sapida[2,4,5](A); Chrysophyllum albidum[6,8](Fr); Cola nitida[4](N); Detarium microcarpum[1](Fr); Diospyros mespiliformis[2](Fr); Ficus sycomorus[3](Fr); Irvingia gabonensis[3,5,6,7](Fr); Paullinia pinnata[5](Fr); Parkia biglobosa*(Fr); Psidium guajava[3,5,7,8](Fr); Sterculia tragacantha[7](Fr); Synsepalum dulcificum[7](Fr); Uvaria chamae[5](Fr); Vitellaria paradoxa[1,2,3,4](Fr); Vitex doniana[4,5,6,8](Fr) |
| | Slimy sauce | Abelmoschus esculentus[1,2,3,4,5,7,8](L, Fr); Adansonia digitata*(L); Ceratotheca sesamoides[1,3,4](L); Cissus sokodense[4](L); Corchorus olitorius[1,3,4,5,6,7,8](L); Corchorus sp.[3](L); Corchorus trilocularis[3](L); Hibiscus acetossela[4](L); Irvingia gabonensis[5,6,7](N) |
| | Spice | Bixa orellana[4](S); Cochlospermum tinctorium[2,3,4](B); Xilopia aethiopica[4,5](S) |
| | Vegetable sauce | Alternanthera brasiliana[7](L); Alternanthera sessilis[8](L); Amaranthus sp. [2,3,4,5,6,7,8](L); Bidens pilosa[8](L); Boerhavia diffusa[3](L); Celosia sp. [2,3,4,5,6,7,8](L); Celosia trigyna[3](L); Cleome gynandra[5,6,7,8](L); Colocasia esculenta[5,6,7,8](L); Crassocephalum rubens[6,7,8](L); Erigeron floribundum[3](L); Gmelina arborea[3](L); Hibiscus acetossela[1,2,3](L); Hibiscus sabdariffa[1,2,3,4,5](L); Hybanthus enneaspermus[3](L); Launaea taraxacifolia[5,6,7,8](L); Ludwigia perennis[6,7,8](L); Manihot esculenta[3,5,6,7,8](L); Milicia excelsa[6,8](L); Moringa oleifera[1,2,4,5,6,7,8](L); Ocimum basilicum[5](L); Ocimum gratissimum[3,5,6,7,8](L); Senna obtusifolia[1,2](L); Senna occidentalis[2,5,6,7](L); Sesamum radiatum[3](L); Solanum macrocarpon[2,3,4,5,6,7,8](L); Talinum triangular[3,5,6,7,8](L); ernonia amygdalina[4,5,6,7,8](L); Vigna unguiculata[4,5,6,7,8](L); Vitex doniana[5,6,8](L); Pleurotus tuber-regium[3,7,8] |
| Animal resources | Braised fish or meat | Limicolaria sp. (M); Tilapia[1,2,3,5,6,7,8](M); Clarias gariepinus[7,8](M); Cyprius carpio[8](M); Heterotis niloticus[8](M); Parachanna obscura[8](M); Pelloluna leonensis[5,6,7,8](M); Protopterus annectens[3,8](M); Penaeus sp. [5,6,7,8](M); Morsi johumba[4](M); Azlélé[+8](M); Adjomana[+4](M); Hondjabima[+4](M); Fato-faro[+1](M); Gari[+1](M); Dessi[+1](M); Wassi[+1](M); Ahouévi[+5](M); Akoko[+5](M); Dowèviko[+5](M); Fluegea virosa[7,8](M) |
| | Fried fish or meat | Achatina sp. [3,4,5,6,7,8](M); Limicolaria sp. [3,5,6,7](M); Tilapia*(M); Clarias gariepinus[8](M); Cyprius carpio[8](M); Parachanna obscura[8](M); Abobi[+6](M); Noukoudotokpa[+7](M); Callinectes amnicola[5,6,7,8] |

**Table 2** (continued)

| Type of resources | Uses | Species used[AEZ] (Organ) |
|---|---|---|
| | Powder and/or sauce of the powder | *Achatina sp.*[1](Sh); *Tilapia*[5,6,7,8](M); *Pelloluna leonensis*[6,7,8](M); *Penaeus* sp.[6,7](M); *Gari*[+ 1](M); *Dowèviko*[+ 5](M); *Fluegea virosa*[+ 7,8](M); *Sowan (bourou)* (bariba) [+ 3](M) |
| | Sauce | *Tilapia*[2,3,6,8](M); *Cyprius carpio*[8](M); *Pelloluna leonensis*[6,7,8](M); *Penaeus* sp. [8](M); *Adjomana*[+4](M); *Hondjabima*[+4](M); *Fato-faro*[+ 1](M); *Gari*[+ 1](M); Dessi[+1](M); Wassi[+1](M); *Ahouévi*[+ 1](M); *Akoko*[+ 5](M); *Abobi*[+ 6](M); *Noukoudotokpa*[+ 7](M); *Akpéréhounkpé*[+ 4](M); *Callinectes amnicola*[8](M) |
| | Toasted fish or meat | *Macrotermes bellicosus*[4](M); *Ruspolia differens*[4](M); Bapouaba[+4](M) |

A: Aril; B: Bark; C: Corn; Fl: Flower; Fr: Fruit; L: Leaves; M: Meat; N: Nut; P: Pulp; S: Seed; Sh: Shell; Sp: Spatha; T: Tuber

AEZ 1: Karimama; AEZ 2: Banikoara; AEZ 3: N'Dali; AEZ 4: Cobly, Boukoumbé, Tanguiéta, Toucountouna; AEZ 5: Aplahoué, Ouèssè; AEZ 6: Covè, Houéyogbé, Klouékanmè, Toviklin, Zakpota; AEZ 7: Adja-Ouèrè, Lalo; AEZ 8:. Adjohoun, Bopa

Resources[+] : The scientific name of the resource is not yet known, thus we put its local name with the local language

roasted, braised and fried foods (fish, insects, shrimps), slimy/gluey and vegetable sauces (seeds of *I. gabonensis*, leaves of *A. digitata*, *P. biglobosa*, leaves of *M. oleifera*, bark of *Cochlospermum tinctorium*), juices (from fruits of *Tamarindus indica*, flowers of *H. sabdarifa*), direct cooking in sauces (fishes, crabs), cooking with water (leaves of *M. oleifera*, *Cajanus cajan*, *V. unguiculata*, tubers of *Dioscorea* sp.). Some preservation techniques were mentioned such as smoking for fish (*Wassi, Dessi*, etc.) and snails, drying (*sowan bourou*), and shade drying for certain leaves (*Corchorus olitorius*, *Amaranthus* sp.).

AEZ 2 (Banikoara) was found to be similar to AEZ 3 (N'Dali) with respect to the species used, although the zones have very different levels of food security (due to many reasons as explained in the discussion). Figure 3 shows that in AEZ 1 (Karimama), AEZ 6 (Covè, Houéyogbé, Klouékanmè, Toviklin, Zakpota), AEZ 7 (Lalo) and AEZ 8 (Adjohoun, Bopa), local populations did not mention the use of food resources such as spices, oils and butter for infant feeding. In AEZ 3, local populations did not mention the use of leaves for herb tea as opposed to AEZ 2 and other areas where herb tea was used for infants. Sauces were mentioned and widely used in all AEZs. Indeed, a pair-wise comparison revealed that the majority of food resources available in the AEZs was frequently used for sauces, as powder (flour obtained from dried leaves or other plant organs), and raw (fruits). The number of food species that were used for juice and toast was greater in AEZ 1 than AEZ 2. With AEZ 2 and AEZ 3, the majority of food resources available in these zones were frequently used for sauce, powder, and raw fruit with up to 41 and 53% respectively for AEZ 2 and AEZ 3. For AEZ 2 and AEZ 4, Fig. 3 shows that the majority of food resources available in these

**Table 3** Species specific to AEZs in Benin

| AEZ | Species |
|---|---|
| AEZ 1 | *Curcubita maxima*, *Detarium microcarpum*, *Sesamum* sp., *Fato-faro*[+], *Gari*[+], *Dessi*[+], *Wassi*[+] (in dendi local language) |
| AEZ 2 | None |
| AEZ 3 | *Diospyros mespiliformis*, *Boerhavia diffusa*, *Celosia trigyna*, *Corchorus* sp., *Corchorus trilocularis*, *Erigeron floribundum*, *Ficus sycomorus*, *Gmelina arborea*, *Hybanthus enneaspermus*, *Sesamum radiatum*, and *Sowan*[+] (*bourou*) (in dendi local language) |
| AEZ 4 | *Bixa* orellana, *Cissus sokodense*, *Cola nitida*, *Digitaria exilis*, *Hibiscus acetossela*, *Monodora myristica*, *Macrotermus bellicosus*, *Ruspolia differens*, *Adjomana*[+] (in *nateni* local language), *Hondjabima*[+] (in *nateni* local language), *Morsi johumba*[+] (in *yindé* local language), *Akpéréhounkpé*[+] (in *yindé* local language), and *Bapouaba*[+] (in *nateni* local language) |
| AEZ 5 | *Caesalpinia bonduc*, *Cucumeropsis mannii*, *Dioscorea sp.*, *Ehretia cymosa*, *Lippia chevalieri*, *Ocimum basilicum*, *Oryza sativa*, *Paullinia pinnata*, *Solanum* sp., *Uvaria chamae*, *Akoko*[+], *Dowèviko*[+] (in *mahi* and *adja*, *fon* local languages respectively) |
| AEZ 6 | *Abobi*[+] (in *adja* local language) |
| AEZ 7 | *Alternanthera brasiliana*, *Sterculia tragacantha*, *Synsepalum dulcificum*, *Telfairia occidentalis*, *Noukoudotokpa*[+] (in *fon* local language) |
| AEZ 8 | *Alternanthera sessilis*, *Bidens pilosa*, *Jatropha curcas*, *Khaya senegalensis*, *Stachytarpheta indica*, *Callinectes amnicola*, *Cyprius carpio*, *Heterotis niloticus*, *Parachanna obscura*, *Azlélé*[+] (in *wémè* local language) |

AEZ 1: Karimama; AEZ 2: Banikoara; AEZ 3: N'Dali; AEZ 4: Cobly, Boukoumbé, Tanguiéta, Toucountouna; AEZ 5: Aplahoué, Ouèssè; AEZ 6: Covè, Houéyogbé, Klouékanmè, Toviklin, Zakpota; AEZ 7: Adja-Ouèrè, Lalo; AEZ 8:. Adjohoun, Bopa

Resources[+] : The scientific name of the resource is not yet known, thus we used its local name in the local language

**Table 4** Occurrence (% of number of respondents) and number of usages (in brackets) of most important species used for infant food in AEZs in Benin

| Species | AEZ 1 | AEZ 2 | AEZ 3 | AEZ 4 | AEZ 5 | AEZ 6 | AEZ 7 | AEZ 8 |
|---|---|---|---|---|---|---|---|---|
| Plant | | | | | | | | |
| *Abelmoschus esculentus* | $4.17^{4}$ (1) | | $3.77^{4}$ (1) | $4.08^{4}$ (1) | | | $3.13^{4}$ (1) | $2.90^{4}$ (1) |
| *Adansonia digitata* | $22.92^{22}$ (6) | $12.5^{18}$ (6) | $9.43^{10}$ (3) | $12.24^{12}$ (3) | $5.63^{8}$ (3) | $6.89^{8}$ (3) | $6.25^{8}$ (3) | $2.90^{4}$ (2) |
| *Allium cepa* | $4.17^{4}$ (2) | | | | | | | |
| *Anacardium occidentalis* | $4.17^{4}$ (2) | $4.17^{4}$ (2) | $3.77^{4}$ (2) | $4.08^{4}$ (2) | | $3.45^{4}$ (2) | | |
| *Arachis hypogaea* | $6.25^{6}$ (3) | $8.33^{8}$ (4) | $3.77^{4}$ (2) | $4.08^{4}$ (2) | | | $4.69^{6}$ (3) | |
| *Balanites aegyptiaca* | | $4.17^{4}$ (2) | | | | $3.45^{4}$ (2) | | |
| *Blighia sapida* | | $4.17^{4}$ (2) | | | | | | |
| *Colocasia esculenta* | | | | | | | | $2.90^{4}$ (2) |
| *Cyperus esculentus* | | | | | | $3.45^{4}$ (2) | | $2.90^{4}$ (2) |
| *Glycina max* | | $4.17^{4}$ (2) | $5.66^{6}$ (3) | | | $3.45^{4}$ (2) | $3.13^{4}$ (2) | $2.90^{4}$ (2) |
| *Hibiscus sabdariffa* | $6.25^{6}$ (2) | $4.17^{4}$ (2) | $5.66^{6}$ (2) | | | | | |
| *Irvingia gabonensis* | | | | | | $3.45^{4}$ (2) | $3.13^{4}$ (2) | |
| *Moringa oleifera* | | $4.17^{4}$ (2) | | | | | | |
| *Parkia biglobosa* | $4.17^{4}$ (2) | $4.17^{4}$ (2) | $3.77^{4}$ (2) | | | | | $2.90^{4}$ (2) |
| *Pleurotus tuber-regium* | | | $3.77^{4}$ (2) | | | | | |
| *Solanum macrocarpon* | | | $3.77^{4}$ (1) | | | $3.45^{4}$ (2) | $3.13^{4}$ (1) | $2.90^{4}$ (1) |
| *Vigna unguiculata* | | | | $4.08^{4}$ (2) | | $3.45^{4}$ (2) | $3.13^{4}$ (2) | $2.90^{4}$ (2) |
| *Vitellaria paradoxa* | | $4.17^{4}$ (2) | | $4.08^{4}$ (2) | | | | |
| *Vitex doniana* | | | | | | | | $2.90^{4}$ (2) |
| Animal | | | | | | | | |
| *Abobi*$^{+}$ | | | | | | | $3.13^{4}$ (2) | |
| *Adjomana*$^{+}$ | | | | $4.08^{4}$ (2) | | | | |
| *Clarias gariepinus* | | | | | | | | $2.90^{4}$ (2) |
| *Cyprius carpio* | | | | | | | | $2.90^{4}$ (2) |
| *Dowèviko*$^{+}$ | | $4.17^{4}$ (2) | | | | $3.45^{4}$ (2) | $3.13^{4}$ (2) | $2.90^{4}$ (2) |
| *Gari*$^{+}$ | $4.17^{4}$ (2) | | | | | | | |
| *Noukoudotokpa*$^{+}$ | | | | | | | $3.13^{4}$ (2) | |
| *Pelloluna leonensis* | | | | | | $3.45^{4}$ (2) | $4.69^{6}$ (3) | $4.35^{6}$ (3) |
| *Penaeus sp.* | | | | | | $3.45^{4}$ (2) | $3.13^{4}$ (2) | |
| *Tilapia* | | | $5.66^{6}$ (3) | | | $3.45^{4}$ (2) | $3.13^{4}$ (2) | $2.90^{4}$ (2) |

AEZ 1: Karimama; AEZ 2: Banikoara; AEZ 3: N'Dali; AEZ 4: Cobly, Boukoumbé, Tanguiéta, Toucountouna;

AEZ 5: Aplahoué, Ouèssè; AEZ 6: Covè, Houéyogbé, Klouékanmè, Toviklin, Zakpota; AEZ 7: Adja-Ouèrè, Lalo;

AEZ 8:. Adjohoun, Bopa

Resources$^{+}$ : The scientific name of the resource is not yet known, thus we put its local name with the local language

zones was frequently used for sauce, powder, and raw fruit, with up to 41% for AEZ 2 and 36% in AEZ 4. In both AEZ 2 and AEZ 5, food species were used for preparing sauces and for direct consumption (fruit). Concerning AEZ 6, the most common types of food resources used in comparison with AEZ 2 were as a powder and raw fruit. For AEZ 7, the most common types of food resources used in comparison with AEZ 2 were sauces and powders. Up to 12% of food resources available in AEZ 7 were used as braised food (on charcoal) whereas in AEZ 2 it was just 3% of food resources. For AEZ 8, the most common food resource used in comparison with AEZ 2 was sauce. Up to 17% of food resources available in AEZ 8 were used as braised (on charcoal) whereas in the AEZ 2 it was just 3% of food resources.

Figure 4 illustrates the difference between categories of food resources used for infant food based on the comparison of the situation in AEZ 2 to one of the other AEZs. In general, there was no difference between AEZs except the non use of food from tree bark for infant food in AEZ 6 and 7. In AEZ 2, leafy vegetables, fruits, and oil seeds were the most commonly used food groups from the available food resources. Fruits, leafy vegetable, oil seed, and fish were indicated for AEZ 1; leafy vegetable and fruits for AEZ 3; leafy vegetable and fruits for AEZ 4; leafy vegetable, fruits and fish for AEZ 5; leafy vegetable, fish, and

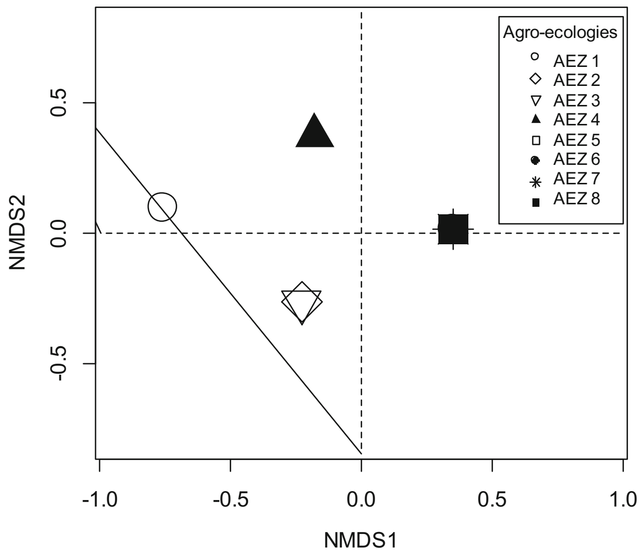


**Fig. 2** Similarities between AEZs with respect to food species used for infant food in Benin. NMDS1: Non Metric Dimensional Scale 1; NMDS2: Non Metric Dimensional Scale 2; AEZ 1: Karimama; AEZ 2: Banikoara; AEZ 3: N'Dali; AEZ 4: Cobly, Boukoumbé, Tanguiéta, Toucountouna; AEZ 5: Aplahoué, Ouèssè; AEZ 6: Covè, Houéyogbé, Klouékanmè, Toviklin, Zakpota; AEZ 7: Adja-Ouèrè, Lalo; AEZ 8: .Adjohoun, Bopa

fruits for AEZ 6; leafy vegetable, fish, and fruits for AEZ 7; and leafy vegetable, fish, and fruits for AEZ 8 (Fig. 4).

Food resources were obtained by collecting from the wild, purchasing them in markets, and from home gardening. Food resources were mainly purchased (50%) in the AEZs (crop production is the main source of income for local populations), followed by home gardening (18–25%) and collecting (< 20%) (Fig. 5). The most purchased food resources were some legumes, oil seeds, fruits, and fish. Species related to these purchased food resources were *A. digitata*, *V. paradoxa*, *Achatina* sp., *V. doniana*, and *V. unguiculata*. The foods acquired this way complemented the food resources produced by the dwellers.

## 4 Discussion

### 4.1 Food insecurity in relation to AEZs

Food security is attained when an individual has access at all times to enough food for an active and healthy life (Stringer 2016). FAO currently uses four measurable and interrelated components to estimate the number of food insecure people at country level, namely (i) availability; (ii) access; (iii) utilization; and (iv) stability (FAO 2014; Stringer 2016). In general, the four components are complementary, and infant food security must consider all of them at once. Barrett (2010) described the four food security components as inherently hierarchical. Food availability implies there must be enough physical quantities or supplies of food available to provide everyone with an adequate number of calories. So for individuals to be considered food secure, there must be adequate food supplies available and people must have access to these supplies. Yet, having proper access to enough calories does not mean that an individual has a nutritionally sound diet. Consequently, the third food security component (utilization) addresses food security issues related to diet quality, food safety and adequate intake of macronutrients and essential vitamins and minerals. Finally, stability introduces a temporal dimension accounting for risks to availability, access and utilization from economic shocks, natural disasters, or political instability.

The present study contributes to food security by assessing the diversity of local food resources for the preparation of complementary foods for children between 6 and 24 months old in the eight AEZs of Benin. It showed there was considerable variability in the geographical distribution of food resources and the ways in which they were utilized. This diversity can be explained by the climate and the soil characteristics (UNDP and MEPN-Benin 2008), that are important conditions for the presence of a species in a given area. Food diversity is also influenced by access through other channels such as gifts and purchases in markets (Anihouvi 2002). Most resources used in infant feeding in the AEZs were purchased from the market, home grown or collected, with the first option being the most frequently mentioned. This implies that market exchange favours the accessibility of resources in areas where the climatic conditions do not allow the presence of the resource seasonally or for the whole year.

Access to local food resources varied substantially from one AEZ to another and within the same AEZ, depending on several factors, including physical and economic purchasing power of the households. Indeed difference in physical access was a criterion we used to choose the villages where the survey took place. A critical situation of food insecurity for infants was noticed in AEZs where food species and resources were highly diversified. Although food species were often very diverse, their utilisation was neither obvious nor optimal for ensuring good nutritional uptake and the stability of their access was not well known. This situation was especially the case for Bopa district (AEZ 8). Bopa is located in the fisheries zone (a zone with a high diversity of local food resources, with 14 animal species and 39 plant species reported to be used in infant feeding practices). According to the global analysis of vulnerability to food security (AGVSA 2014), the district of Bopa has a very high prevalence of food insecurity (40%), in contrast to the Adjohoun district in AEZ 8 where the situation is less alarming (16%) (PAM 2014b). The study of the food situation in the district of Bopa revealed that despite the advantageous geographical situation (i.e. its closeness to Lake Ahémé), only 8.3% of the children met their protein needs (Grembombon 2003). Overfishing and the use of prohibited fishing gear by the fishing communities of Bopa have accelerated the depletion of food resources in the lake. Intensive fishing activities have apparently contributed to reduced availability of fish foods

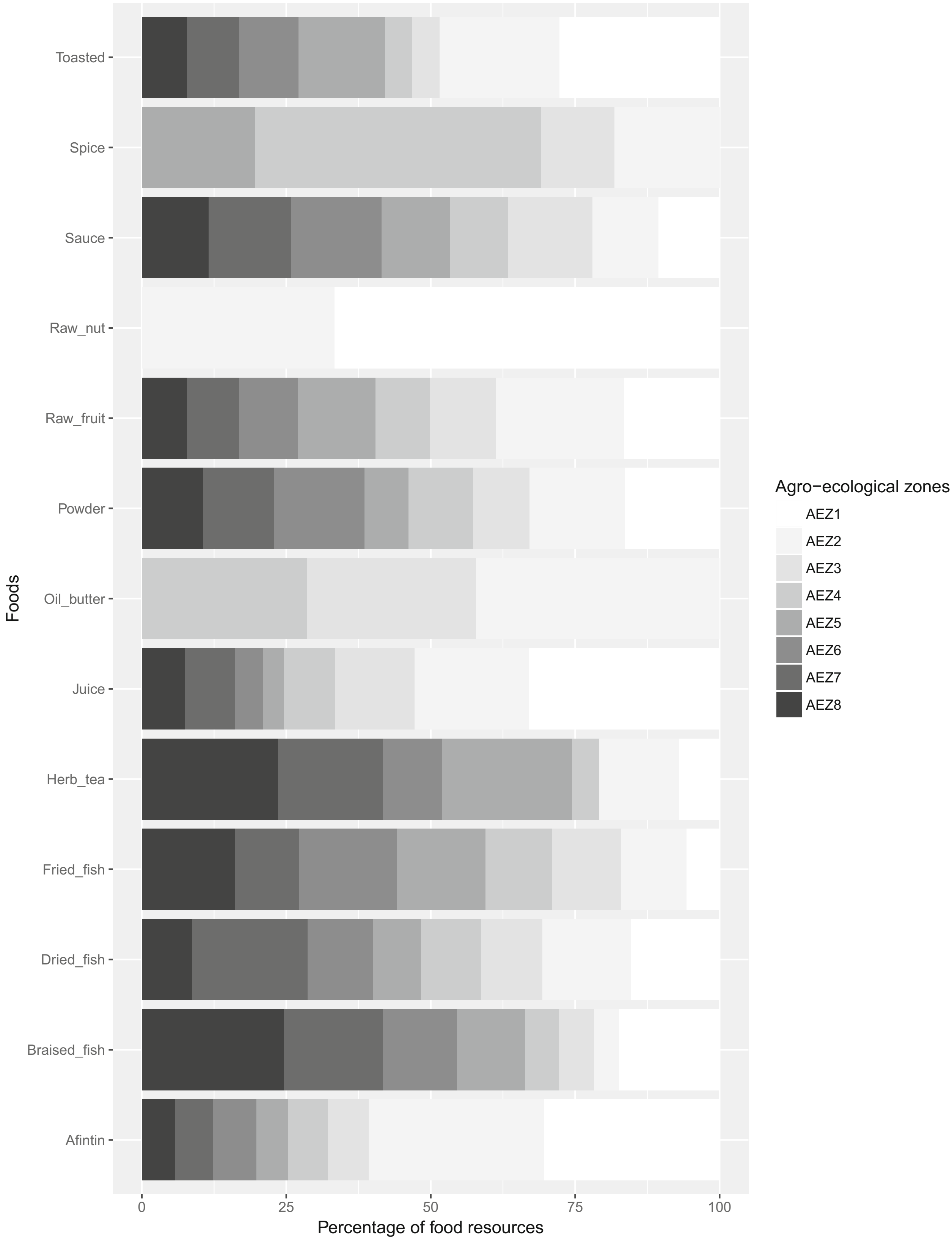


**Fig. 3** Use patterns of food resources in AEZs in Benin. The proportion represents the part of of a given usage in an AEZ. A missing color indicates that the usage is not practiced in the AEZ. AEZ 1: Karimama; AEZ 2: Banikoara; AEZ 3: N'Dali; AEZ 4: Cobly, Boukoumbé, Tanguiéta, Toucountouna; AEZ 5: Aplahoué, Ouèssè; AEZ 6: Covè, Houéyogbé, Klouékanmè, Toviklin, Zakpota; AEZ 7: Adja-Ouèrè, Lalo; AEZ 8: Adjohoun, Bopa

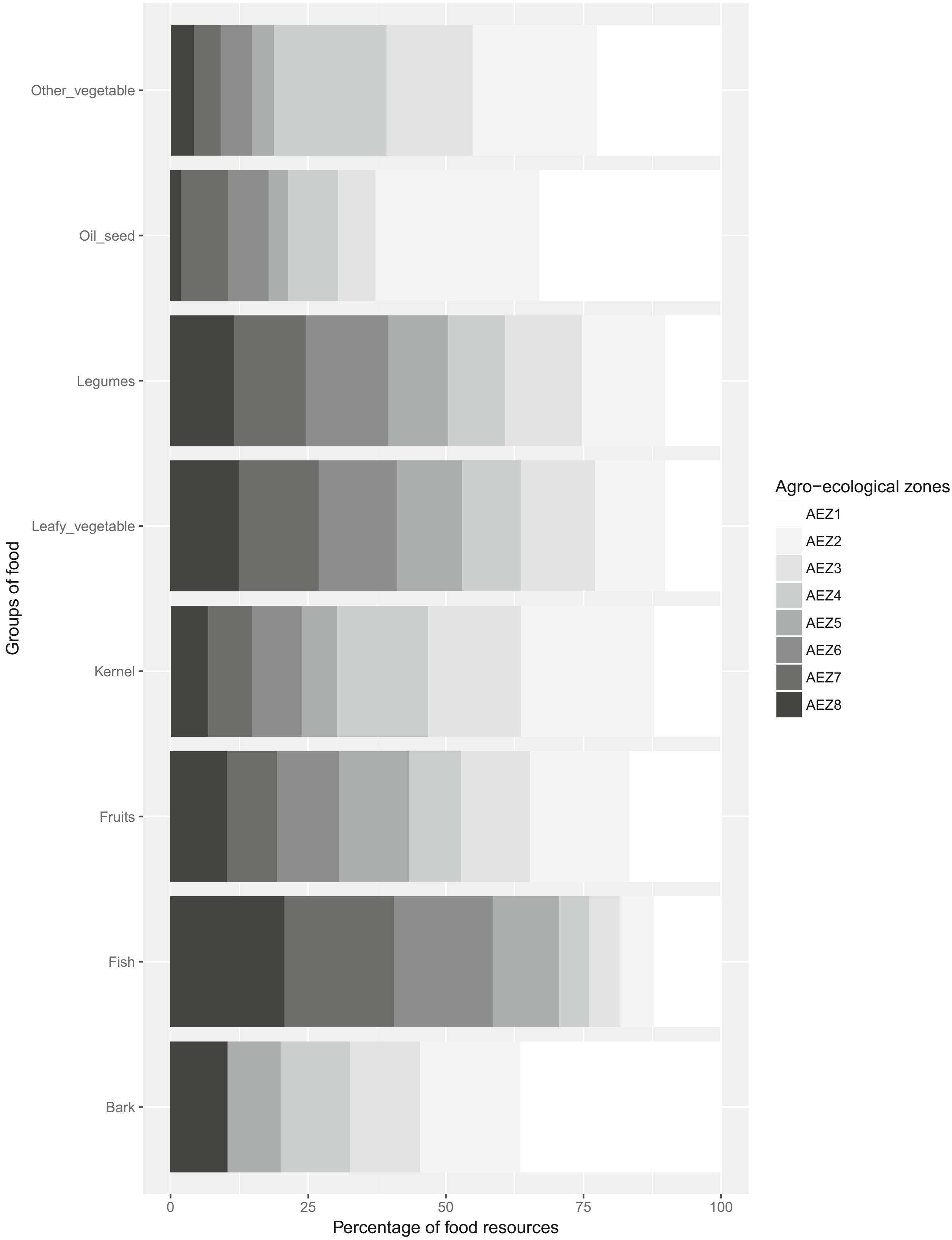


**Fig. 4** Main food resources groups used for infant food in AEZs in Benin. The proportion represents the importance of a given food group in an AEZ. A missing color indicates that the food group is not considered in the AEZ. AEZ 1: Karimama; AEZ 2: Banikoara; AEZ 3: N'Dali; AEZ 4: Cobly, Boukoumbé, Tanguiéta, Toucountouna; AEZ 5: Aplahoué, Ouèssè; AEZ 6: Covè, Houéyogbé, Klouékanmè, Toviklin, Zakpota; AEZ 7: Adja-Ouèrè, Lalo; AEZ 8: .Adjohoun, Bopa

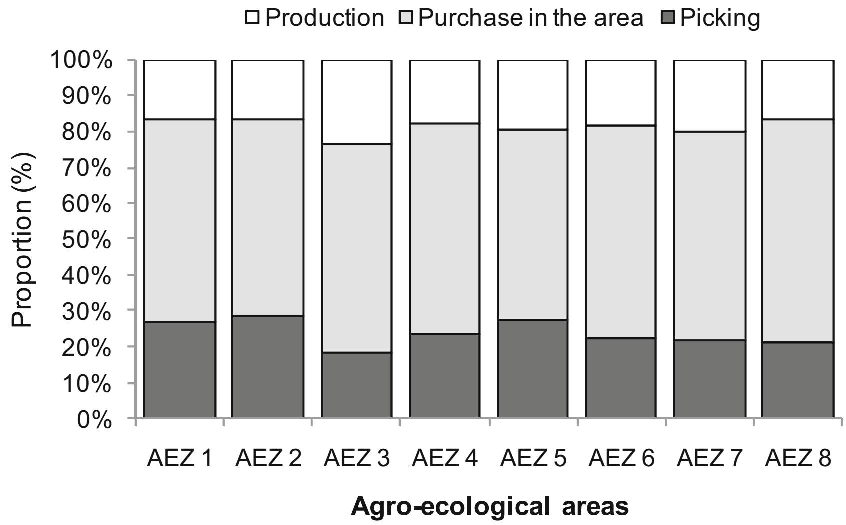


**Fig. 5** Sources of supply of food resources in the agro-ecological areas of Benin. AEZ 1: Karimama; AEZ 2: Banikoara; AEZ 3: N'Dali; AEZ 4: Cobly, Boukoumbé, Tanguiéta, Toucountouna; AEZ 5: Aplahoué, Ouèssè; AEZ 6: Covè, Houéyogbé, Klouékanmè, Toviklin, Zakpota; AEZ 7: Adja-Ouèrè, Lalo; AEZ 8: .Adjohoun, Bopa

and consequently their low use in the feeding of children from 6 to 24 months.

The districts of Boukoumbé, Cobly, Tanguiéta and Toucountouna (AEZ 4) also have a high prevalence of food insecurity: 43%, 36%, 38 and 37%, respectively. Analysis of the survey data showed that fish and fish products were not of great importance in the feeding of infants aged 6–24 months. Fish farming activities were very limited in all those districts. Fish farming is mainly practised by non-natives, who sell their produce on local markets. At the same time, only 3% of the population in that rural area belong to the richest first quintile. In Atacora district, 72% of the population belong to the two poorest quintiles (INSAE 2015b). To this the low income of the mothers must be added, which is also one of the risk factors for chronic undernutrition (Anihouvi 2002) because it reduces their economic access to good quality foods. To satisfy the protein needs of their children, the population has therefore turned to alternative sources of protein available at lower costs, notably insects. However, seasonality in the availability of edible insects is another risk factor for food insecurity as these insects are exclusively harvested from the wild and are not preserved. Moreover, in districts such as Boukoumbé and Cobly, the uneven distribution of rainfall during the rainy season and the degradation of ecosystems could be aggravating factors for food insecurity. Further studies are needed to add more detail to the other food security components, namely utilization and stability, in order to assess, with respect to international standards, the status of food insecurity in these agro-ecological zones.

## 4.2 The paradox of large food diversity and food insecurity in certain AEZs

Our study showed that AEZ 1 (Karimama) and AEZ 2 (Banikoara) had approximately the same number of local food resources that can be used in infant feeding; 34 food resources were recorded in AEZ 1 (Karimama) and from 28 to 34 species in AEZ 2 (Banikoara). Though the number of resources was the same, and the number of species used in infant feeding approximately the same, there was a considerable discrepancy in the level of food security in the districts selected for the study. The prevalence of food insecurity was high (39%) in the district of Karimama while Banikoara can be considered to be in a less critical situation (with 9.5% food insecurity) and a lower food insecurity prevalence compared to the national average of 11% (PAM 2014a).[2] Also, AEZ 2 (Banikoara) and AEZ 3 (N'Dali) had a high similarity in terms of the species used for infant foods (Fig. 3). However, the prevalence of food insecurity in N'Dali was 35% while the one in Banikoara was 9.5%. There was also a high similarity of the species used for infant food between AEZ 5 (districts of Aplahoué and Ouèssè), AEZ 6 (Covè, Houéyogbé, Klouékanmè, Toviklin and Zakpota), AEZ 7 (Adja-Ouèrè and Lalo) and AEZ 8 (districts of Adjohoun and Bopa). The food insecurity levels of these districts in 2014 were variable at 26% for Aplahoué, 16% for Ouèssè and Adjohoun, 39% at Covè, 34% at Houéyogbé and Klouékanmè, 35% at Toviklin and Lalo, 28% at Zakpota and 40% for Bopa (PAM 2014a). At least 1.5 times more local resources and species used in infant foods were recorded in those AEZs when compared to Banikoara (AEZ 2). In summary, the AEZs with a high diversity of local food resources and species used for infant food were also the ones with high prevalence of food insecurity, with the exception of Adja-Ouèrè district where high food diversity coincided with low food insecurity (3.5%) (PAM 2014a).

[2] The global analysis of vulnerability and food security was conducted through two surveys: a household survey based on an interview with the head of household; and a community survey which allows collecting quantitative and qualitative information on sample villages, based on group discussions organized with key informants in each village. The survey was carried out on a sample of 15,000 households at national level.

Only AEZ 2 (district of Banikoara), which is less food insecure, showed the lowest food and species diversity. This indicates that a diversity of foods is not enough to ensure food security and that other parameters need to be considered. Mello et al. (2010) demonstrated that beyond the availability of various foods, food security is significantly associated with food use behaviours of populations. Likewise, Barrett (2010) stated that food diversity is necessary but is not sufficient to achieve food security, which is a complex combination of several other factors. Indeed, FAO stated in its regional overview of food insecurity in Africa report that millions of African families still suffer from poverty (FAO 2014), although the proportion of poor people in Sub-Saharan Africa living on less than US$ 1.25 a day had declined by 23% between 1993 and 2011. On the contrary, for Benin, the proportion of poor people has increased from 33% in 1995 to 36.2% in 2011 (CIA World Factbook 2015).

Aside from food accessibility, the other pillars of food security, which are availability, utilization and stability (AGVSA 2014), are also very important. As most resources are seasonal, their availability depends on the time of the year. Use of traditional but good preservation methods may guarantee availability beyond the season. This is the case in most AEZs but more pronounced in AEZ 2, when we looked for instance at the processing of leaves into powder. In addition, a high valorization of oilseeds was noticed in AEZ 2. For utilization, AEZ 2 showed a high discrepancy with other AEZs. Although they had a limited number of resources, the inhabitants of the district of Banikoara mentioned many diverse uses and hence a high use-value for most species. More specifically, in AEZ 1, 6, 7 and 8, local populations did not use food resources such as spices, oil and butter in infant foods. While fat should be consumed in moderation, oils and butter improve the bioavailability of lipo-soluble micronutrients and improve the energy value of infant food (Keast et al. (2013). In AEZ 3, local populations did not mention the use of leaves for herbal tea, contrary to findings for AEZ 2 and other areas where herbal tea was used for infants. Indeed, infusions of herb tea may protect thermo-sensitive micronutrients from leaves from total destruction (Toda 2011). Food utility and utilization was not perceived in the same way in all the AEZs, which is also a source of justification of the paradox of food diversity associated with food insecurity.

Leafy vegetable sauces appeared to be an important way to use local food resources in the feeding of infants in AEZ 5 (Aplahoué, Ouèssè), AEZ 6 (Covè, Houéyogbé, Klouékanmè, Toviklin, Zakkpota) and AEZ 7 (Adja-ouere, Lalo). This reflects the remarkable importance of leafy vegetables in the diet of young children, especially in AEZ 6, where women value these locally available food resources very highly. Indeed, the availability and low costs of leafy vegetables justify their high use, unlike products of animal origin that are little used because of their high costs and sometimes also because of their low diversity in most districts of AEZ 6 (Covè, Houéyogbé, Klouékanmè, Toviklin, Zakkpota) and AEZ 7 (Adja-ouèrè, Lalo). Accordingly, the low prevalence of food insecurity in the district of Adja-ouèrè (3.5%) compared to Lalo (35%), could be due to the diversification of protein sources in the diet of the children (fish, mushroom, and snails of *Limicolaria* sp.). Moreover, notwithstanding the availability of fishery products (especially fish) due to the proximity to rivers such as the Niger, Mékrou, and Alibori, just a small proportion of women in the Karimama district used fish in their children's diets. Fish is predominantly destined for marketing in the surrounding districts. This low intake of protein by children in the district of Karimama, coupled with a limited supply of essential micronutrients (iron, vitamins A and C, calcium), as a consequence of the low use of local food resources, maintains the occurrence of deficiencies and nutritional diseases (Ibironke 2014; Burchi and De Muro 2016).

Limitations of our study include a lack of data related to available quantities and prices of foods combined with information on the purchasing power of the households. This information would be very helpful for a more profound analysis of food insecurity. Also, the available quantities of food resources for the households throughout the year were not fully documented in the present study. In addition, price information related to periods of abundance and shortage of resources was scarce, lacked precision and varied considerably from one informant to another, from one AEZ to another, and even from one district to another.

### 4.3 Similarities between AEZs and consequences for infant food formulation and policies

This study is part of a larger one that aimed at designing infant food formula for AEZs in Benin using locally available food resources. Pointing out similarities between AEZs in terms of food resources provides orientation on the number of food formulas to be designed for all AEZs. One generic infant food formula may be designed for similar AEZs. Indeed, the present study showed that there are similarities between AEZ 2 and AEZ 3 on the one hand and between AEZs 5, 6, 7 and 8 on the other in terms of the food species used for infant feeding. These similarities can be explained by the fact that adjacent AEZs shared some ethnic groups, which have similar food behaviour. This implies that a generic infant food formulation using local ingredients from species used in the

AEZs may have a similar formula for AEZ 2 and AEZ 3; and another generic formula could be developed for AEZs 5, 6, 7 and 8. Additionally, one specific formula is required for AEZ 1 and 4, provided that the resources used from the species there are almost the same. The similarities are related to the regions of the country. AEZs 1, 2 and 3 are districts located in the north of Benin whereas AEZs 5, 6, 7 and 8 are located in the south. This approach also allows the development of food formulations that are properly aligned to the different socio-cultural cooking preferences and behaviours in northern and southern Benin. Based on our findings, there is a diversity of food species available and used and none of them provides all nutrients necessary for infant food formulae. In such a process, which is the follow-up step of this study (based on our findings we will propose fortified products that take into account the similarity between AEZs and micronutrient deficiencies to be addressed), proposed formulations should contain ingredients that are rich in energy (plant resources), protein (animal resources) and micronutrients (Pangaribowo et al. 2013). In addition, this study has contributed to updating existing biodiversity databases in Benin and the West African region. It has provided insight on the food resources used for infant feeding in the AEZs of Benin and many ecological characteristics and food species are shared with other countries in the West African region. There is a need for more work to scientifically identify the species that could not be determined for some of the resources collected during our study.

## 5 Conclusion

Our study on local food resources identified a large diversity in food species used for feeding infants aged 6–24 months in Benin. From one AEZ to another, the food resources varied in their diversity as well as in the way in which they were used to feed children. These dissimilarities were linked to the agro-ecological conditions and also to the know-how of local communities in relation to these local food resources. The high variability in the utilization and accessibility of the resources explains the high rate of prevalence of food insecurity, especially in the agro-ecological zones that do have a high diversity of foods available. Similarities between AEZs in terms of species used for infant feeding, as determined in this study, offer opportunities to design adequate infant food formulas. Further studies are needed to assess the quantitative availability of local food resources throughout the year, assess links between food prices and purchasing power of the population, and assess the bioavailability of nutrients in infant foods made from local food resources in relation to food preparation methods.

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### Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Informed consent** Oral informed consent was obtained from all individual participants in the study.

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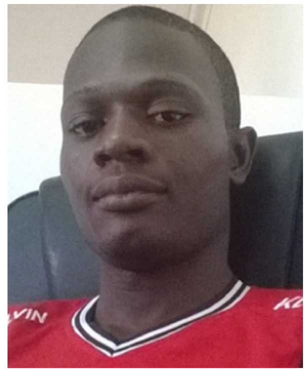
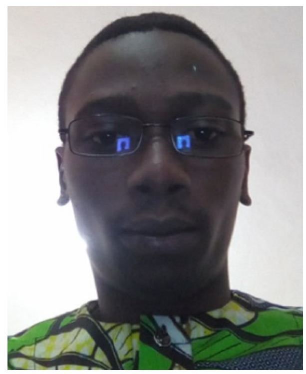


**Juvencio Odilon G. Ayosso** is a student at the Laboratory of Food Sciences in the Faculty of Agronomic Science of the University of Abomey-Calavi (Republic of BENIN). He holds an MSc in standards, food quality control and food technology. Juvencio works on research topics related to nutrition and food sciences, especially infant feeding and valuing of endogenous foods. He is also working as food safety assistant.



**Sèwanou Hermann Honfo** is a PhD student in Biometry at the Faculty of Agronomic Sciences, University of Abomey-Calavi, in Benin. He is an expert in biological data analysis, sampling and experiment designs, and ethnobotany studies. He is a member of the Laboratory of Biomathematics and Forestry Estimations (Labef) of the Faculty of Agronomic Sciences, University of Abomey-Calavi, and currently is a research assistant in FSA.

**Prof. Folachodé Pierre Polycarpe Kayodé** obtained an engineering degree in 1999 from the University of Abomey-Calavi, Benin, in Nutrition and Food Science. He completed his PhD thesis in 2006 at Wageningen University. Since 2006 he has been a staff member of the School of Nutrition and Food Science and Technology of the University of Abomey-Calavi. Polycarpe's expertise is in food quality and food product development with special attention to micronutrients. His work in education and research is characterized by an interdisciplinary approach and the integration of natural and social sciences.

**Dr. Ir. Anita Rachel Linnemann** obtained a double Master's degree from Wageningen University, The Netherlands, in Tropical Agriculture and Food Technology. She completed her PhD thesis, entitled 'Ecophysiology of bambara groundnut (Vigna subterranea (L.) Verdc.)', and has been a staff member of the Food Quality and Design group of Wageningen University since 1995. Anita's focus is on the development of food technological solutions as a means to enhance nutrition security in developing countries, in particular at the bottom-of-the-pyramid in sub-Saharan Africa. For this purpose she applies a consumer-orientated perspective in combination with local food resources and tailor-made food technological practices. Her work in education and research is characterised by an inter- and trans-disciplinary approach and the integration of natural and social sciences.

**Prof. Djidjoho Joseph Hounhouigan** graduated in 1994 with a PhD from Wageningen Agricultural University, The Netherlands. His expertise is in the characterization of tropical products and product development based on traditional food products, especially fermented cereals, fruits and vegetables, roots and tubers, non-timber forest products, and leguminous grains. He has more than 30-years of experience in higher education and research and has supervised numerous Eng., MSc and PhDs.