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Research

Food consumption and nutritional status of sedentarized Baka Pygmies in Southern Cameroon: wild foods are less important for those who farm

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ABSTRACT. The sedentarization of Pygmies in the Congo Basin has triggered a profound transformation in their traditional lifestyles, particularly affecting dietary habits and food consumption. We employed 24-hour dietary recalls in 10 sedentarized Baka Pygmy villages in southeastern Cameroon, gathering data on diet composition, diversity (Household Dietary Diversity Score, HDDS), and nutrient intake per adult male equivalent (AME) from 67 homes (28% of all households). Our findings revealed that 62% of consumed foods were agricultural produce, 29% were locally produced or purchased products, and the remaining 9% comprised items sourced or hunted from the wild. The average HDDS per village was low (4.1±1.56) and mean total energy intake was 1734.9±1,031.8 kcal/AME, with significant contributions from cultivated foods. There was a negative correlation between the consumption of cultivated and wild foods. Moreover, a considerable proportion of households (78.7%, ranging from 22.4% to 97%) exhibited nutrient consumption below the lower 95% uncertainty interval found in a Cameroonian nutrient supply study. Additionally, 78.3% of respondents fell below WHO/FAO recommendations for 21 nutrients, even after adjusting for the Baka's shorter stature. This high prevalence of insufficient nutrient intake underscores the urgent need for targeted interventions to address nutritional deficiencies within this population. We show Baka households rely more on cultivated foods and are less dependent on wild sources. Understanding the profound transformation in dietary patterns and its repercussions on the health and overall well-being of the studied marginalized Indigenous communities is pivotal in devising strategies to enhance their survival. This shift in dietary profiles often stems from complex factors, including socioeconomic challenges, environmental changes, and cultural shifts. To address these issues effectively, a comprehensive approach that integrates cultural sensitivity, community engagement, and sustainable practices is imperative.

Key Words: *diet quality; food provenance; Mintom; HDDS; Indigenous peoples; nutrient intake*

INTRODUCTION

Once primarily subsistence-oriented, numerous Indigenous Peoples worldwide, traditionally relied on a diverse range of wild plants and animals as food. These "traditional," or first foods, have played pivotal roles in religious practices, cultural traditions, economic activities, and medicinal rituals, shaping the overall dietary patterns of Indigenous societies. In recent decades, however, a discernible shift in the dietary habits of traditionally foraging societies has transpired, marked by an increasing reliance on domesticated crops and processed foods (Piperata et al. 2011, Crittenden and Schnorr 2017). This transition becomes more pronounced with the sedentarization of nomadic Indigenous Peoples, a notable phenomenon affecting many such communities. In the Congo Basin, home to various Indigenous Pygmy groups (see use of the term Pygmy in Hewlett 2014 and Olivero et al. 2016), ongoing efforts to sedentarize them, often by encouraging settlements along roads, have further contributed to this transformative shift in their traditional lifestyles and diets. This has been documented for the Baka in the Republic of Congo and Cameroon (Robillard and Bahuchet 2012).

Of the reported 30,000 indigenous Baka (Leclerc 2012) in Cameroon, the exact number who have transitioned from their traditional hunter-forager lifestyle to a sedentary way of life is unknown. Sedentarization of Baka has been shaped by various factors, with historical initiatives, such as those spearheaded by the French colonial government, contributing to the encouragement of settlement along logging roads as early as 1910 (Pemunta 2019, Pemunta et al. 2019). These efforts intensified during the 1950s–1960s and continued after Cameroon's independence in 1972 (Jean 1975, Pourtier 1989, Bahuchet 1992, Bailey et al. 1992, Leclerc 2012, Coquery-Vidrovitch 2017). The setting up of villages along roadsides, from which inhabitants could have access to health services, education, and participation in the market economy, was identified as potential advantages of these settlement initiatives (Kuhnlein and Receveur 1996, Kuhnlein 2009, 2015, Kuhnlein et al. 2009). Nevertheless, the establishment of settlements along roads has deeply impacted not only the livelihood strategies of Baka Pygmies but also their cultural practices, diets, and overall well-being (Joiris 1998, Rupp 2003, Pemunta 2019, Pemunta et al. 2019, Fa et al. 2021).

Although precise figures are unavailable, population estimates conducted between 1983 and 1991(cited in Bigombe Logo 2007) suggest that traditional hunter-gatherers in Cameroon may constitute as few as 6% of the Baka population. The majority of Baka communities depend on diverse food sources, encompassing traditional options such as fish, wild meat, and wild edible plants, as well as cultivated and locally produced/bought foods. Previous studies on the dietary habits of sedentarized Baka groups have provided general assessments of foods consumed (see FAO et al. 2021), but there is a lack of information on nutrient intake for Baka, both at the individual and household levels. Assessing the changing reliance on traditional foods by Indigenous communities holds significant importance. This is critical for understanding the dynamic interconnection between these

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communities and their traditional food sources. Traditional foods serve as the foundation of Indigenous cultures and are pivotal in maintaining the overall health, well-being, and socioeconomic structure of these communities.

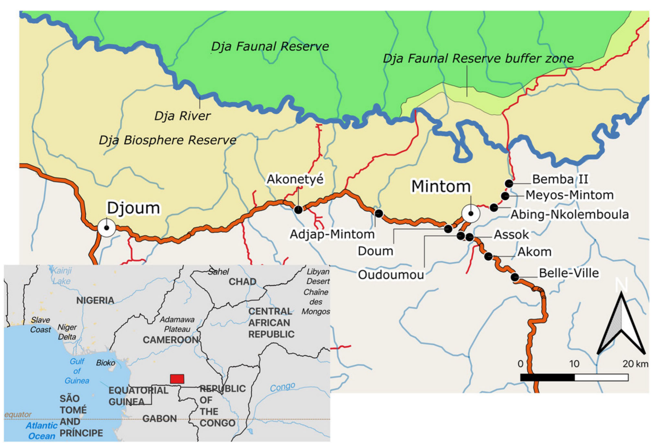
In this study, we examine food consumption of Baka households living in a number of roadside settlements in southeastern Cameroon. We conducted 24-hour dietary recalls in 10 villages to examine the types and significance of consumed foods, especially wild versus cultivated or prepared ones; the impact of village location and agricultural participation on energy and nutrient intake; household dietary diversity in the study villages; and variations in energy and micronutrient consumption across villages in comparison to WHO/FAO Dietary Recommended Intake and nutrition data.

METHODS

Study area

This study was conducted in 10 Baka villages along the Djoum-Mintom road south of the Dja Faunal Reserve (DFR) and bordering the Dja Biosphere Reserve, southeast Cameroon (Fig. 1). These communities participated in a larger project (Ref: 24-029, "Enabling Baka to Attain Food Security, Improved Health and Sustain Biodiversity") funded by the UK Government Darwin Initiative Programme (Darwin Initiative 2020).

Fig. 1. Study area showing the locations of 10 study villages in Southeast Cameroon. This map was generated using publicly available map data from Open Street Map, diva-gis (http://diva-gis.org/) and Natural Earth (https://www.naturalearthdata.com/). The delineation of the Dja Biosphere Reserve's southern border is based on Bruce et al. (2018). The map was previously published by Ávila Martin et al. (2020).



The vegetation of the study area is a mosaic of evergreen and semi-deciduous forest (Letouzey 1985) covering low-relief terrain (altitude ranging 600–700 m.a.s.l.). Commercial timber extraction and mining operations in the area penetrate previously undisturbed forests. This is primarily facilitated by the construction of dirt roads, coupled with a rise in agricultural and hunting activities, which together exert additional pressures on the region's ecosystems (Global Forest Watch 2000, Morgan et al. 2019). These roads connect the study villages to market areas as well as to the main towns of Mintom and Djoum, most of which is tarmacked (Fig. 1). The forests bordering the roads are largely degraded as a result of human settlements and agricultural expansion. Wildlife habitats have also been impacted by the substantial influx of logging laborers and an expansion of the wild meat trade, threatening the daily lives of Indigenous Peoples and local communities that not only depend on natural forest resources for their food and medicines, but also whose cultural identity is closely tied to the forest (Ichikawa 2006, 2014, Hattori 2014, Yasuoka 2014, Pemunta 2019).

The region is characterized by a four-season equatorial climate; a major dry season (mid-November to mid-February), a minor rainy season (mid-February to mid-May), a minor dry season (mid-May to mid-August), and a major rainy season (mid-August to mid-November). Rainfall recorded for Djoum averages 1500–2000 mm per year (World Weather Online 2020). Year-round average temperature is around 25 °C.

Study population

A population census was conducted in the 10 villages (Table A1.1), resulting in the identification of 237 dwellings (Ávila Martin et al. 2020). Most dwellings in the area are mud-lattice houses referred to as "poto-poto" and traditional leaf huts or "mungulu." A total of 172 (72.57%) dwellings were occupied during the study (Ávila Martin et al. 2020). Occupied dwellings accommodated an average of 4.33 ± 2.77 (range 1–17) people. Vacant houses belonged to families who were away in the forest during the study period. Village populations varied from 25 in Meyos-Mintom to 111 in Akom. Bantu-speaking farming villages were interspersed among Baka villages along the Djoum-Mintom road.

Both the Baka and Bantu-speaking farmers engage in agriculture and trade non-timber forest products (NTFP) to varying extents. The main food crops cultivated by both groups are plantain, banana, and cassava. However, cocoa, which is the primary cash crop for Bantu-speaking farmers, is not commonly grown by the Baka. Recently, subsistence farming has increased in a number of Baka villages because of the impact of the "food sovereignty program" (FSP) implemented by Zerca y Lejos (ZyL), a Spanish NGO working on development and health support for Baka communities in the region since 2001 (Zerca y Lejos 2020a, 2020b). ZyL's FSP, initiated in 2018 and implemented in five villages (Assok, Akom, Bemba, Doum, Nkolemboula), sought to provide agricultural training to families, with a particular emphasis on empowering women. The focus was on enhancing their cultivation skills for subsistence crops, specifically cassava, peanuts, plantains, and bananas. By imparting essential agricultural skills, the program sought to equip families with the knowledge and tools necessary to grow their own crops. This not only addressed immediate nutritional needs but also fostered long-term resilience against external factors impacting food availability. The training served as a sustainable solution to promote community well-being and reduce dependence on external food sources. Although crop yields are still modest, one immediate impact has been a reduction in Baka men working for Bantu-speaking farmers to secure agricultural foods.

In all study villages, animal source foods are derived from hunting wild animals or fishing (Ávila Martin et al. 2020, Fa et al. 2021). Men predominantly engage in hunting away from their villages, while women set traps near or within their farms and practice dam fishing in the dry season. Some hunted animals are sold, mainly to neighbors (Ávila Martin et al. 2020).

According to our work with hunters in the study villages (Fa et al. 2021) forest areas utilized for hunting and NTFP harvesting by the villages are accessible to all hunters within the village. Hunting territory boundaries are mutually recognized and respected by all hunters. Individual hunting territories are determined based on the hunter's knowledge of the landscape and its wildlife. There are unwritten rules of respect among hunters, such as refraining from setting snares in areas where others have already set them. Bantu-speaking farmers also hunt in the same areas as the Baka hunters, although their movements and activities were not monitored. Generally, encounters between Bantu and Baka hunters from adjacent villages in the forest are non-confrontational. However, conflicts can arise when resident hunters encounter strangers, particularly large and well-organized hunting parties, who wish to hunt within Baka traditional hunting territories.

Sampling

Field work was conducted with permission from the Cameroonian Ministry of Scientific Research and Innovation (MINRESI), under a permanent agreement with the Center for International Forestry Research (CIFOR). ZyL obtained authorization to work with human subjects through Arrete No. 00034/A/MINATD/DAP/SDLP, granted by the Ministry of Territorial Administration and Decentralization of the Government of Cameroon.

At the start of the Darwin umbrella project in 2017, we conducted a general meeting with all villagers from the 10 Baka villages. During this meeting, we introduced the project's objectives and expressed our intention to recruit volunteers. We approached each village chief to encourage the cooperation of villagers at every stage, including focus group discussions and personal household visits.

We surveyed a sample of households in two time periods regarding their food intake and food sources in two time periods. We chose these periods based on availability of field staff to carry out the work as well as to cover most seasons. As a result, we surveyed five villages (Assok, Bemba, Doum, Belleville, and Nkolemboula), from 4–24 September 2018 (end of the short dry season, beginning of the long rainy season), and the remaining five villages (Adjap, Akom, Akonetye, Meyos, and Odoumou) from 17 April to 8 May 2019 (short rainy season).

All chosen households willingly participated in this study, adhering to the principles of free prior and informed consent (FPIC; Buppert and McKeehan 2013). Because of literacy challenges, oral consent, rather than written consent, was obtained, with a read statement emphasizing (1) no negative consequences or coercion for participation; (2) the right to withdraw at any time (United Nations 2013); and (3) the assurance of anonymity and confidential treatment of personal information. An oral consent record sheet documented date, project details, location, and participant agreement. As interviews were the exclusive data collection method, the project posed minimal risk. Initial meetings were open to all village members, including children; however, individuals under 18 years of age, considered minors by Cameroon law, were not involved in the interviews. The study adhered to ethical research guidelines set by the Social Research Association (Social Research Association 2021).

Upon conclusion of our work, a workshop was organized to exchange results, presenting findings from this study and other investigations conducted within the broader Darwin project to the local communities. This collaborative event served as a platform for sharing insights, fostering dialogue, and engaging community members in discussions about the collective outcomes of these research efforts.

To ascertain the minimum number of samples required to meet statistical criteria, we employed a sample size calculator from Maple Tech International LLC. (2022). Our calculations indicated a minimum of 67 out of the 172 households identified from our village censuses, was necessary to achieve a 70% confidence level with a ±5% margin of error. The estimated margin of error was 9.2%.

Dietary data collection

Food intake

Considering the social dynamics and food-sharing practices observed among Baka households, we defined a household as a communal space where food is prepared and consumed. Identification relied on the declaration of the individual responsible for meal preparation, commonly the mother or grandmother, referred to here as "the respondent." This approach, recognizing the significance of kinship ties within the Baka community (Reyes-García et al. 2019), enabled us to grasp the collective nature of food-related activities and comprehend the dynamics of food sharing within these households.

To collect data on food consumption, we utilized a structured open-ended questionnaire that prompted respondents to recall all meals and the number of individuals who consumed them within the 24 hours prior to the survey, following the guidelines provided by FAO (2018). When necessary, we asked participants for more detailed information regarding the preparation method and specific recipes used. Within each household, we requested respondents to recall all the foods consumed during each meal. These food items were categorized into three main groups: (1) NTFPs including wild meat, fish, and plants; (2) locally produced/bought food (purchased or obtained by other means); and (3) agricultural food. Some households in villages involved in ZyL's FSP, were able to grow their own foods after receiving training on cultivating and storing different crops (Zerca y Lejos 2022). We documented which families were involved, which served as a variable in our generalized linear model (GLM) analyses, enabling us to examine the influence of agricultural activities on food intake.

Within each household, we requested the participation of the adult responsible for meal preparation to report all the food items that were prepared and consumed the previous day. This included obtaining information on the number of individuals who consumed each meal, categorized by sex and age into three groups: children (under 18), adult females, and adult males. Enumerators were trained to probe for commonly overlooked food items such as condiments, oils, and snacks. Portion sizes were estimated using a combination of methods, including direct weighing using portable electronic scales, standardized measuring cups and pots for volumes, and locally calibrated cooking utensils (as indicated in Table A1.2). Additionally, local market surveys were conducted to record average weights of specific food items such as cassava and plantain, considering variations across different seasons.

Our study did not account for food-away-from-home (FAFH) consumption, food eaten outside the household in venues such as bars or canteens, primarily in Mintom, as well as meals consumed when in the forest. Participants reported infrequent consumption of FAFH, particularly processed foods, citing cost as a limiting factor in our discussions. Notably, we excluded foods such as fruits eaten in the fields or forest, as accurately estimating consumption outside the household has proven challenging (Margetts and Nelson 1997).

Prior to data collection, our 24-hour recall interview protocol was reviewed by one of the authors (SA), who is a member of the Baka community, to ensure cultural appropriateness and language suitability. We recorded household food intake from Mondays through Thursdays. Therefore, our coverage included both weekends and weekdays to account for potential variations in dietary patterns between these two groups of days, e.g., the influence of social events on Saturdays and Sundays. The collection of food intake information on weekdays was designed to obtain a representative sample of typical dietary patterns observed during regular working days. All questionnaires were administered in the field by two of the authors (EAM and SA).

Food provenance

We considered whether each food item consumed was cultivated, collected, or hunted from the wild or locally produced/bought. We calculated the relative contribution (energy and nutrients) of these foods to measure reliance on each group.

Dietary diversity

To assess household dietary diversity and approximate household food access, we used the Household Dietary Diversity Score (HDDS). A diverse diet is often associated with a higher likelihood of meeting nutritional needs, as different foods contribute different nutrients (Swindale and Bilinsky 2006). The HDDS serves as a population-level indicator, providing an important metric in evaluating food security.

The HDDS is determined by counting the number of food groups consumed by a household within a specified reference period. A higher dietary diversity score indicates a more varied household diet and is associated with factors such as caloric and protein adequacy, the percentage of protein sourced from animal products, and household income (Swindale and Bilinsky 2006). The 24-hour HDDS, derived from data collected through our recall interviews, offers a snapshot of a household's food access and socioeconomic status (Kennedy et al. 2011).

From data gathered in our 24-h recalls, we classified food items into the 12 following categories as suggested by Kennedy et al. (2011): (1) cereals; (2) white tubers and roots; (3) fruits; (4) vegetables; (5) meat (including wild meat and insects); (6) fish; (7) eggs; (8) milk and milk products; (9) legumes, nuts, and seeds; (10) oils and fats; (11) sweets; and (12) spices, condiments, and beverages. Each food group was assigned a score of either 1 (if consumed) or 0 (if not consumed). The resulting household score ranged from 0 to 12, representing the total number of food groups consumed by that particular household.

Nutritional analysis

We calculated the total volume of foods consumed during each meal, measured in grams, and for foods assessed volumetrically, in milliliters, following the approach outlined by Charrondière et al. (2013). For the analysis of food intake and the determination of nutritional values encompassing calories, macronutrients, and micronutrients, we employed the Nutritics nutrition analysis software (Nutritics 2022). This software provides a comprehensive platform for assessing the nutritional content of various foods and meals, including macronutrients (such as carbohydrates, proteins, and fats) and micronutrients (including vitamins and minerals) as well as energy.

Nutritional data for commonly consumed foods such as cassava and plantain were sourced from the Nutritics databases. Values for locally specific plant species in West Africa were obtained from food databases in Oguntona and Akinyele (1995), Stadlmayr et al. (2010), and Vincent et al. (2020). For wild meat from rodents (e.g., Emin's pouched rat, *Cricetomys emini*, brush-tailed porcupine, *Atherurus africanus*) and ungulates (blue duiker, *Philantomba monticola*, red duikers, *Cephalophus* spp.), nutritional composition values were taken from Ajayi and Tewe (1978, 1983), Ajayi (1979), and Malaisse and Parent (1982). In the absence of nutritional values for ornate monitor (*Varanus ornatus*) meat, values for crocodile meat from Luthada-Raswiswi et al. (2019) were used instead. Nutritional information for locally produced foods was directly extracted from the packaging labels.

Statistical analysis

To ensure comparability among different foods, we converted the number of individuals consuming each meal into adult male equivalent (AME) units. The AME units represent energy requirements based on gender, age, and physiological status, expressed as a proportion of the energy requirements of an average adult male (WHO and FAO 2004, Weisell and Dop 2012). Males above 20 years were assigned a weight of 1, females above 20 years were assigned a weight of 0.86, children between 5 and 20 years were assigned a weight of 0.91, and children below 5 years were assigned a weight of 0.78.

To analyze seasonal differences in food types, HDDS, and macronutrients per AME, we used the non-parametric exact two-sample Kolmogorov-Smirnov test. A generalized linear model (GLM) was used to assess food intake, energy, and macro- and micronutrients in relation to the following: village's distance to Mintom (in kilometers), season (coded as 1 to 4), participation in the ZyL agricultural training program (coded as 0 or 1), quantities of cultivated, purchased, and wild foods (in grams), HDDS (coded as 1 to 7), and red palm oil (coded as 0 or 1). Red palm oil, derived from the African oil palm (*Elaeis guineensis*), was included because of its nutritional and antioxidant properties (Oguntibeju et al. 2009, Tonukari et al. 2013, Rodríguez et al. 2016, Boadu et al. 2021). It is considered a healthier alternative to standard palm oil because of its minimal refining process, which retains more nutrients and is very high in vitamin A.

The GLM equations for food items were defined as: x ~ distance + season + development, while for macro- and micronutrients: x ~ distance + season + development + cultivated foods (g) + locally produced/bought foods (g) + wild food (g) + HDDS + red palm oil, assuming a normal error distribution. Before applying the GLM, we assessed the normality of the data using the non-parametric exact two-sample Kolmogorov-Smirnov test with a two-sided alternative hypothesis. Out of the 37 parameters, 19 showed non-normal distribution ($p < 0.5$; Tables 1 and 2), with seven of them exhibiting zero-inflation (locally processed/bought,

Table 1. Variables associated with food intake in 67 24-h recall surveys based on generalized linear model (GLM) analysis. Only significant coefficients are shown.

	n	KS statistics[‡]	Distance to Mintom	Monitoring season [1 or 2]	Agricultural development [yes/no]
Cultivated g	67	D = 0.12, p = 0.24	-0.041, p = 0.031	494.2, p = 0.041	n.s.
Manufactured/purchased g[†]	54[†]	D = 0.17, p = 0.07	n.s.	n.s.	n.s.
Total wild food g[†]	54[†]	D = 0.20, p = 0.06	n.s.	-182.0, p = 0.018	n.s.

[†]Original data were zero-inflated. After removal of the zero values, the remaining n data were normally distributed. Sample size n refers to the sample size after the removal of the zero values.
[‡]Kolmogorov-Smirnov test statistics for normal distribution.

total wild food, oligosaccharides, selenium, vitamin D, vitamin K, biotin B7). In cases of zero-inflation, we first fitted a zero-inflated Poisson model, but the analysis resulted in each case in a singularity, indicating that the equations could not be resolved. We then removed all zero values, and subsequent Kolmogorov-Smirnov tests on the reduced datasets indicated normal distributions. These seven parameters accounted for observations ranging from 2.2% to 85.1% (mean = 40.5%) of the values. The remaining non-normally distributed parameters were cube-transformed, resulting in normal distributions.

To compare nutrient intake in grams per AME, we referenced nutrient supply data for the general Cameroonian population from 2011 (Smith 2016, Smith et al. 2016) and Central African data from 2017 (Gebremedhin and Bekele 2021), as well as the WHO/FAO recommendations for energy, protein (FAO 1997), and micronutrients (WHO and FAO 2004). The years 2011 and 2017 were the most recent dates for which published data were available. It should be noted that the WHO/FAO recommendations are based on global, predominantly Western adults, whereas the Baka population is significantly smaller (Funk et al. 2020a). Therefore, we applied a conversion factor of 0.9044, derived from the mean worldwide male height of 171.28 cm (Roser et al. 2013) and the mean male height of the Baka population, 154.91 cm (n = 130, data from Funk et al. 2020a), to make the WHO/FAO recommendations specific to the Baka population. All statistical analyses were conducted using the R statistical analysis software R (R Foundation for Statistical Computing 2021). The zero-inflated Poisson regression utilized the R package "pscl" (Jackman 2015).

RESULTS

We sampled a total of 67 households out of the 172 occupied households in the study villages, 39% of all households. The percentage of households sampled varied by village, ranging from 17.4% (4 households out of 23) in Akonetye to 100% in Meyos-Mintom (5 out of 5). On average, we sampled 44.41 ± 23.70% of households per village (ranging from 30% to 100%). The average number of consumers per meal was 6.0 ± 3.6 persons (1–17, median = 6). Recorded AMEs per meal were 6.2 ± 2.7 (0.8–12.9; median = 5.8), average adults per meal 3.5 ± 2.0 (1–12, median = 3), and 3.6 ± 1.9 (1–9, median = 3) children (< 5 y).

Main consumption patterns

In the 67 24-h recalls we recorded a total of 584 consumption events of 44 food items eaten in the study households (Table A1.3). Percentages of consumption of the different food groups show that spices, condiments and beverages were the most prevalent and the sweets food group was the least common (Fig. 2a). Most foods consumed were cultivated (62%), followed by locally processed/bought (29%) and collected or hunted in the wild (9%). The estimated average weight of cultivated and wild foods per recall was negatively correlated (Fig. 2b). Consumption of more than 2 kg of cultivated foods per household was associated with much lower amounts of wild foods eaten (mean = 12.2 ±18.6 g, n = 14), whereas higher average amounts of wild foods (mean = 156.4 ± 211.7 g, n = 53) were typical in households consuming less than 2 kg of cultivated foods; these differences were significant (Kolmogorov-Smirnov test, D = 0.476, p = 0.007).

Among the 67 households surveyed across the study villages, the calculated mean weight of all consumed foods was 1.75 ± 0.89 kg/AME. This comprised 1.52 ± 0.92 kg/AME of cultivated items, 0.26 ± 0.80 kg/AME of locally processed/bought items, and a nominal 0.13 ± 0.20 kg/AME categorized as "wild foods." The latter included wild meat (0.03 ± 0.10 kg/AME), caterpillars (0.05 ± 0.12 kg/AME), fish (0.005 ± 0.02 kg/AME), and mushrooms (0.04 ± 0.12 kg/AME; Fig. 3). Wild foods were recorded in 52 out of the 67 sampled households (78%). By weight, they made up an average of 9.04 ± 13.30% (median = 2.05; range 0–50.6%) of all foods consumed, where no wild foods were recorded in 15 (22%) of all sampled households.

In terms of frequency of food items eaten in all sampled households, the four most commonly cultivated items consumed were chili pepper (75/131), cassava (35/131), plantain (35/131), and bananas (34/131). Top locally processed/bought goods were salt (71/166), Maggi seasoning sauce (66/166), and red palm oil (11/166). The most commonly eaten wild foods were caterpillars (16/57), mushrooms (7/57), bush mango (6/57), and red duiker (5/57). We recorded only one case of purchased domestic meat, chicken. No seasonal differences were observed for total foods (Kolmogorov-Smirnov D = 0.108, p = 0.76), locally processed/bought foods (D = 0.220, p = 0.31), wild meat (D = 0.073, p = 0.69), fish (D = 0.051, p = 0.75), and mushrooms (D = 0.246, p = 0.10); but significant seasonal differences were observed for caterpillars (D = 0.387, p < 0.001; Fig. 4).

The amounts of consumed cultivated food were positively associated with being closer to the city of Mintom and with the season but were not associated with our measures of agricultural development (GLM analysis; Table 1). The consumption of locally produced/bought food was found to vary significantly by season, but there was no observed relationship between amounts consumed of this group of foods and distance to Mintom or agricultural development of households.

Table 2. Macro- and micronutrient intake per adult, as estimated by adult equivalent units (AME), compared with general Cameroonian nutrient consumption (Smith 2016, Smith et al. 2016) and the recommendations by the Food and Agriculture Organization (FAO 1997) for energy and protein and World Health Organization and FAO (WHO and FAO 2004) for micronutrients. Empty cells indicate that no values were published. The last two columns show the mean amounts consumed for those households with less than 2 kg and those with more than 2 kg consumed cultivated foods, respectively.

	Cameroon			Baka observed		Worldwide	Baka observed				< 2kg cultivated	> 2kg cultivated
Nutrients	High 95% UI	Median	Low 95% UI	Mean ±SD	N < low 95% UI [%]	WHO/FAO recommendation[†]	Mean as % of WHO/ FAO	Inade-quacy [%][‡]	Height-corrected Inadeq. [%][§]	Height-corrected and buffered Inadeq. [%][|]	Mean amount ±SD	Mean amount ±SD
Energy kcal	2671	2638	2612	1735±1032	86.6	2944.0	59	91.0	86.6	70.1	1468±798.4	2744±1212[¶]
Carbohydrates g	452.1	439.4	431.7	318.3±216.9	74.6						250.2±136.9	575.9±270.9[¶]
Protein g	69.3	67.6	66.1	32.5±27.7	86.6	49.0	66	74.6	73.1	65.7	32.8±29.3	31.6±21.2[¶]
Fat g	57.4	54.4	51.8	36.4±37.0	74.6						38.9±34.7	34.5±46.2[¶]
Sodium mg	239.9	226.3	217.7	1007±835.1	22.4						1039±879.0	883.8±654.9
Potassium mg	4831	4696	4576	3982±2337	73.1						3319±1668	6492±2833[¶]
Calcium mg	421.8	395.9	376.8	275.4±213.0	73.1	1000.0	28	98.5	97.0	95.5	214.7±139.0	505.2±284.8[¶]
Phosphorus mg	1566	1442	1371	560.5±368.4	97.0						461.0±267.4	938.2±458.2[¶]
Magnesium mg	727.6	646.0	601.6	356.6±254.7	86.6	224.0	159	25.4	20.9	14.9	297.8±168.1	579.1±386.0[¶]
Iron mg	22.4	20.8	19.4	10.9±9.4	83.6	9.1	120	56.7	50.7	43.3	9.3±8.7	16.6±10.3[¶]
Zinc mg	13.2	12.4	11.8	5.4±3.8	92.5	4.2	129	46.3	37.3	31.3	4.9±3.6	7.4±4.2[¶]
Copper mg	2.6	2.4	2.2	1.9±1.5	76.1						1.6±1.3	2.8±1.9[¶]
Selenium ug				6.4±9.2		34.0	19	100.0	97.0	92.5	8.6±12.7	5.8±8.1
Iodine ug				10.4±17.6		150.0	7	100.0	98.5	68.7	22.1±11.0	7.3±12.1[¶]
Vitamin A Retinol equivalent ug	1344	1053	247.0	1715±4310	41.8	600.0	286	59.7	53.7	50.7	820.4±1234	5102±8519[¶]
Vitamin D ug				0.6±3.3		5.0	12	98.5	97.0	97.0	0.7±3.7	0.1±0.3[¶]
Vitamin E mg				4.0±4.6		10.0	40	91.0	88.1	82.1	3.7±4.0	5.1±6.5[¶]
Vitamin K1 ug				0.5±0.8		65.0	1	100.0	98.5	98.5	0.7±0.5	0.4±0.5[¶]
Thiamine B1 mg	2.2	2.0	1.8	0.8±0.7	94.0	1.2	69	85.1	80.6	68.7	0.6±0.4	1.6±1.1[¶]
Riboflavin B2 mg	1.2	1.1	1.0	0.6±0.4	85.1	1.3	46	97.0	94.0	85.1	0.5±0.3	0.9±0.4[¶]
Niacin total B3 mg	29.2	19.5	16.6	9.7±8.4	86.6						7.4±5.9	18.3±12.5[¶]
Niacin mg	26.4	20.5	17.7	7.7±5.9	86.6	16.0	48	92.5	86.6	80.6	6.1±4.1	13.5±7.9[¶]
Pantothenic acid B5 mg				2.4±2.9		5.0	47	91.0	85.1	77.6	3.7±2.3	2.0±2.8[¶]
Vitamin B6 mg	3.1	2.8	2.6	1.5±1.5	80.6	1.3	116	53.7	50.7	41.8	1.3±1.1	2.1±2.4[¶]
Folic acid B9 ug				181.4±112.1		400.0	45	92.5	91.0	85.1	155.0±97.2	281±111.6[¶]
Vitamin B12 ug				0.2±1.0		2.4	8	97.0	95.5	94.0	0.2±1.1	0.0±0.0[¶]
Biotin B7 ug				12.5±19.9		30.0	42	88.1	85.1	80.6	23.9±12.8	9.5±15.4[¶]
Vitamin C mg	202.4	184.4	176.6	202.3±153.0	50.7	45.0	449	4.5	3.0	3.0	149.1±85.6	406.7±185.4[¶]

[†] Recommended safe intake for adult males for energy and protein (FAO 1997) and micronutrients (WHO and FAO 2004).
[‡] Percentage of households with inadequacy in relation to the WHO / FAO recommendations expressed as the percentage of adult males smaller than the recommendation.
[§] Ditto with WHO / FAO recommendations corrected for Baka stature compared with the world mean stature of adult men.
[|] Ditto WHO / FAO recommendations corrected for Baka stature compared with the world mean stature of adult men and assuming that households have underreported 15% of their food and, thus, nutrients.
[¶] The GLM analysis identified the number of cultivated foods as a significant coefficient.
UI: uncertainty interval.

Dietary diversity

Mean HDDS scores for all 24-h recalls were 4.1 ± 1.56 (median = 4, range = 1–7, Fig. 4, Tables A1.4, A1.5). The highest HDDS average was in Meyos (4.8 ± 1.4) and Nkolemboula (4.8 ± 1.6) and the lowest in Bemba II (2.8 ± 1.9). There were no detectable differences between the seasons (Kolmogorov-Smirnov D = 0.083, $p = 0.94$, Fig. 3).

Nutrient consumption

Macro- and micronutrient composition varied widely between households and villages as evidenced by large standard deviations (Fig. 4, Table 2). Figure 4 shows the consumption of nutrients per AME in all villages pooled and stratified per season. Mean total energy intake was 1734.9 ± 1031.8 kcal, carbohydrates 318.3 ± 216.9 g, protein 32.5 ± 27.7 g, and fat 36.4 ± 37.0 g. The contribution of carbohydrates to diets was highest for all villages (71.0–95.6%), followed by protein (3.2–16.6%), and lowest for fat (1.2–19.4%). For energy (Kolmogorov-Smirnov D = 0.167, $p = 0.31$) and carbohydrates (D = 0.168, $p = 0.65$) no significant seasonal differences were detected, but there were significant inter-village differences for protein (D = 0.539, $p < 0.001$) and fat (D = 0.339, $p = 0.03$). Table 2 summarizes the average amounts of macro- and micronutrients.

GLM analysis showed that the amounts of the various consumed macro- and micronutrients were significantly impacted by different combinations of variables (Table 3). Cultivated food weight was the most widespread parameter significantly contributing to energy content and 32 macro- and micronutrients (n = 27), followed by HDDS (n = 18) and red palm oil (n = 14). The smallest number of significant variables impacting energy content and macro- and micronutrients were season (n = 5), total wild food (n = 4), distance to Mintom (n = 2), and agricultural development and locally produced/bought food (n = 1, each). The GLM analysis, which covered 28 micronutrients, identified the quantity of cultivated food as a significant factor for 26 of them (Table 3). Within this subset, the consumption of over 2 kgs of cultivated foods was associated with higher average values for 16 micronutrients, whereas six showed lower average values (Table 2).

Fig. 2. (a) Consumption of groups of all recorded food items (n = 44) in 584 consumption events and (b) relationship between cultivated and wild food: observed data and regression. The regression was not significant (Pearson's r = -0.24, p = 0.055, n = 67).

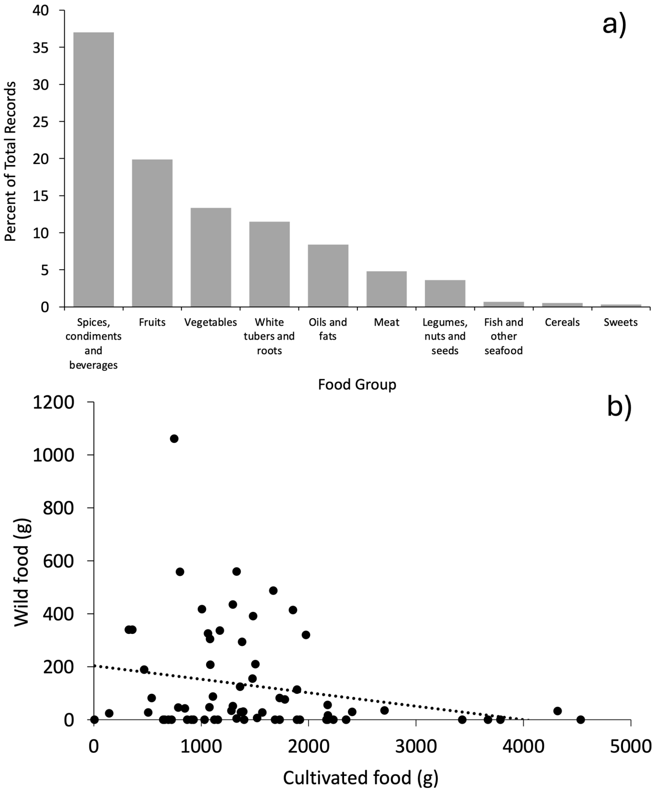
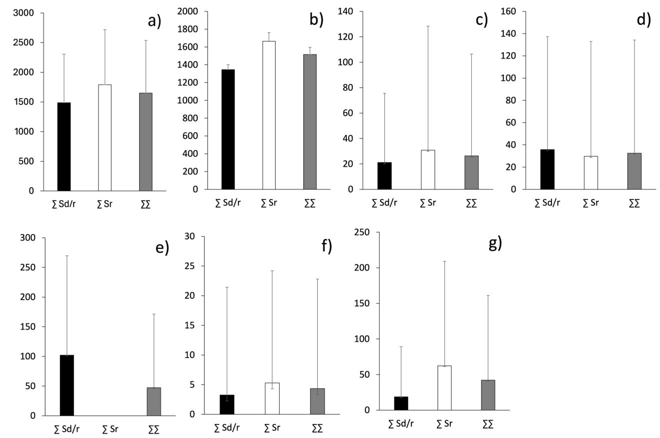


Fig. 3. Average ± SD amounts (g) of different food categories during different seasons and combined. Data on five villages were collected using 24h recall surveys. Key: (a) Total food (g); (b) Cultivated (g); (c) Manufactured/purchased; (d) Wild meat; (e) Caterpillars; (f) Fish; (g) Mushrooms. Black bars: dry/rainy season; White bars: rainy season; Grey bars: combined seasons.



Comparisons with reported regional dietary supply and WHO/FAO Dietary Recommended Intake

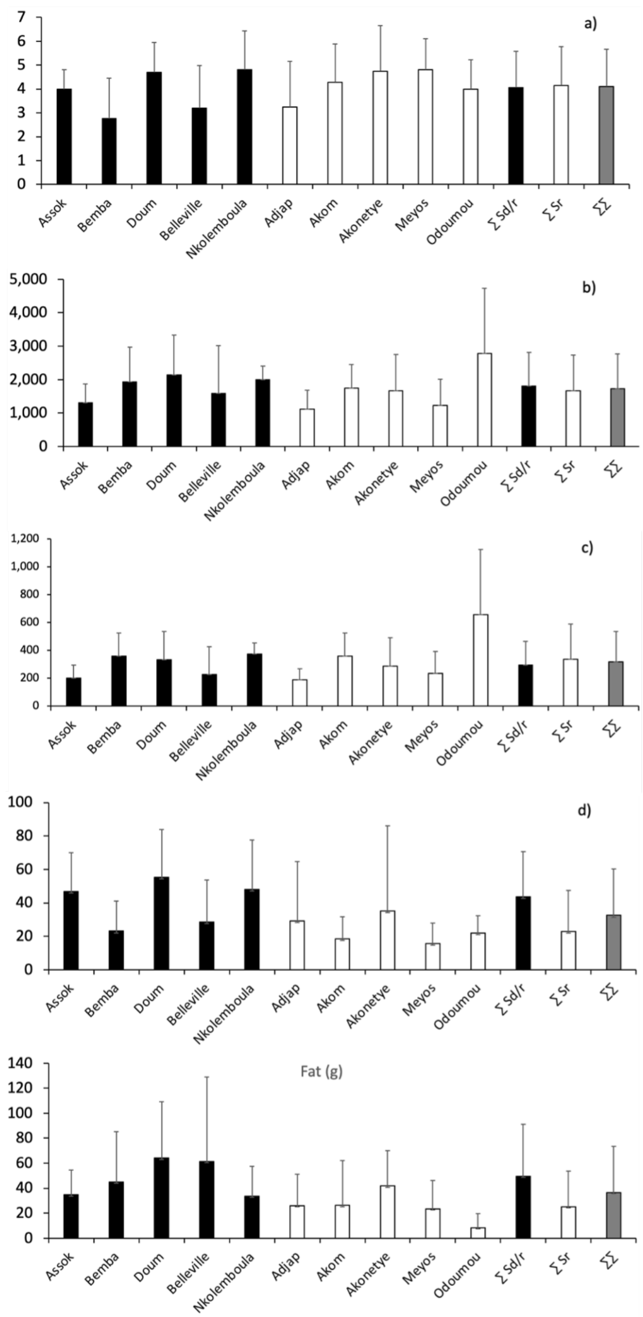
Table 3 compares the energy and macro- and micronutrient intake per AME with the Cameroonian population nutrient supply study and the WHO/FAO recommended energy, protein, and micronutrients consumption levels. For the 22 items for which the Cameroonian nutrient consumption was published, between 22.4 and 97% of households (mean = 78.7%) had values smaller than the lower 95% uncertainty interval for the Cameroonian nutrient consumption. The energy intake of 92.5% of households was lower than the mean of 2940 kcal supply reported for Central Africa; the values were 91.0% lower than the mean of 521 g of carbohydrates, 92.5% lower than the mean of 80.3 g of protein, and 80.6% lower than the mean of 60.4g of fat. For the 21 nutrients for which there are WHO/FAO recommendations, between 4.5% and 100% of households (mean = 78.3%) had nutritional intake lower than the recommendation (median = 91%). When adjusting the WHO/FAO recommendations for the average shorter stature of the Baka, the range is 3% to 98.5% (mean = 74.8%, median = 86.6%).

DISCUSSION

An increasing number of studies have focused on the impact of nutritional transition on Indigenous communities. This transition, marked by a shift from traditional, locally sourced foods to an increased reliance on imported alternatives, has been linked to a decline in nutritional security (Damman 2005, Reyes-García et al. 2019). These diet changes are typically associated with economic development, improved income levels, and urbanization. As part of these processes, individuals often gain the financial means to acquire a broader range of foods beyond their traditional or locally produced staples. Their greater access to cash income facilitates the purchase of "novel foods," which may include processed and convenience foods, as well as items that were previously considered luxuries or were unavailable. Perhaps because of their limited integration into mainstream economies, Pygmy populations in the Congo Basin, overall, are not affected by the nutrition transition observed in other Indigenous groups (Popkin 2004).

However, there are other situations in which Indigenous Peoples are deprived access to traditional foods obtained through hunting, fishing, and gathering (Kuhnlein and Receveur 1996, Kuhnlein 2015, Batal et al. 2021). In many cases, this may be a result of ongoing impacts of colonial assimilation policies (Egeland and Harrison 2013), e.g., where hunter-gatherers are displaced and are encouraged to live away from their ancestral environments as in the case of the Baka Pygmies in our study. In these circumstances, in which cash is scarce, the main means open to the Baka to access food is by working for farming neighbors or themselves engage in cultivating subsistence crops. A health and nutrition study of adult Baka foragers in the Central African Republic underscores the influence of immigration, heightened gun hunting, and wildlife trade in diminishing foragers' reliance on forest resources (Remis and Jost Robinson 2014). Despite no significant differences in anthropometric measures of nutritional status between communities, the study found that hemoglobin data revealed disparities in access to forest products among villages with varying proximity to community hunting zones. Poor dietary diversity and low incorporation of purchased foods in their diet suggest an incomplete shift to a market economy, resulting in impoverished diets.

Fig. 4. Average ± SD Household Dietary Diversity Score (HDDS) and nutrient consumption per adult male equivalent (AME) in each study village and summarized over the dry/rainy (Sd/r: dotted) and rainy seasons (Sr: squared) and combined (solid). Data on five villages were collected in both seasons using 24h recall surveys. (a) HDDS; (b) Energy (kcal); (c) Carbohydrates (g); (d) Protein (g); (e) Fats (g). Black bars: dry/rainy season; White bars: rainy season; Grey bars: combined seasons.



Published studies of diets of the Baka in Cameroon are limited to general descriptions of foods eaten and seasonal patterns of their use. For example, Hirai (2014) point out for the Baka in Gribe, to the east of our study villages, that a typical meal, as in our case, is a combination of a staple and a sauce, staples being plantain, cassava, cocoyam, sweet potato, maize, and wild yams, while rice and spaghetti may be purchased occasionally. The sauce usually contains wild meat, fish, caterpillars, snails, termites, leafy vegetables, or mushrooms, which may be mixed. Seasonal differences in food procurement are also marked where in particular the dry season is often associated with greater food insecurity. In a dietary study of the Batwa in Uganda, most households reported greater difficulty in acquiring sufficient quantities and quality of food during the dry season (Patterson et al. 2017). In Cameroon, from the major dry season to the minor rainy season, some Baka engage in slash and burn of new fields for Bantu farmers or for themselves, whereas others prefer long stays in the forest for fishing, hunting, and gathering. Although the major dry season offers less variety in wild foods, annual wild yams and non-seasonal cultivars (cassava and plantain) make up an important proportion of foods consumed. Inland traditional capture fisheries also provide an abundant resource during the dry season and are a valuable safety net for many Congo Basin populations (Dounias and Oishi 2016).

Quantitative 24-h dietary recalls (in some cases coupled with food weighing) are considered an accurate method to assess food intake. In our study we were unable to undertake two or more non-consecutive days within a week per household to account for daily variation in food intake especially of irregularly consumed foods (Fiedler et al. 2012). Typically, the main errors in dietary assessment are linked to misreporting. Energy intake below or above the true intake is a systematic bias that can lead to incorrect results and conclusions in dietary studies. In a systematic literature search of 24-h recall studies, Poslusna et al. (2009) found that the percentage of under-reporters was about 30% and energy intake was underestimated by approximately 15%. These studies were done in relatively affluent countries where the variety and number of food items consumed by respondents are much greater than what we observed in the Baka communities in the current study. Whether misreporting is likely to be less significant for simple diets is unknown. More detailed studies of the nutritional status of Indigenous Peoples in situations similar to those of the Baka in Cameroon may shed further light on foods that may have been under or misreported as well as the reasons for this (e.g., from the Brazilian Amazon, Horta et al. 2013, or the Philippines, Duante et al. 2022). A limitation of this study is that we did not include data on foods consumed away from home and therefore, we likely underestimate food consumption.

A constraint on our study was the difficulty of increasing our sample size of households monitored. Obtaining detailed data on household food access or individual dietary intake is time-consuming and expensive, and our team was limited by the fact that potential respondents were often away from their houses at some times of the day, e.g., early morning. We attempted to visit the villages in the evening when families were together but this was not always possible. Despite these potential shortcomings, our analyses of data obtained from the 67 sampled households were robust enough to draw some conclusions. Our results

Table 3. Variables associated with macro- and micronutrient intake in 67 24-h recall surveys based on generalized linear model (GLM) analysis. Only significant coefficients are shown.

	n	tf[‡]	KS statistics[§]	Distance to Mintom	Season [wet or dry]	Agricultural participation [yes/no]	Cultivated food [g]	Locally produced / bought [g]	Total wild food [g]	HDDS	Red Palm Oil [yes/no]
Energy kcal	67		D = 0.08, p = 0.77				0.872			231.700	-580.300
Carbohydrates g	67		D = 0.09, p = 0.57				0.186			26.529	-95.155
Protein g	67		D = 0.15, p = 0.07		-19.410		0.011		0.080	4.507	
Fat g	67		D = 0.16, p = 0.052	0.002	-29.590		0.009			11.730	-19.410
Starch g	67		D = 0.12, p = 0.23				0.120			43.447	
Oligosaccharide g[†]	17		D = 0.25, p = 0.20								
Fibre g	67		D = 0.11, p = 0.31				0.012		0.015	1.885	-8.167
Polysaccharide g	67		D = 0.16, p = 0.06		-9.745		0.013			2.882	-10.200
Sugars g	67	y	D = 0.10, p = 0.53				0.001		0.002		
Sodium mg	67		D = 0.12, p = 0.29							289.858	
Potassium mg	67		D = 0.14, p = 0.12				2.205			253.200	-1264.0
Calcium mg	67		D = 0.13, p = 0.19				0.150			4.379	
Phosphorus mg	67		D = 0.13, p = 0.19				0.307			77.290	-203.900
Magnesium mg	67		D = 0.16, p = 0.054			87.420	0.222				-129.200
Iron mg	67	y	D = 0.11, p = 0.36		-0.468		0.0004			0.109	-0.232
Zinc mg	67		D = 0.13, p = 0.19				0.002		0.005		
Copper mg	67	y	D = 0.11, p = 0.41		-0.219		0.0002			0.057	-0.204
Selenium ug[†]	35		D = 012., p = 0.63								
Iodine ug	67	y	D = 0.11, p = 0.34				0.0005				
Vitamin A Retinol equivalent ug	67	y	D = 0.13, p = 0.20				0.002				4.298
Vitamin E mg	67	y	D = 0.05, p = 0.99	0.00003			0.0003			0.213	
Vitamin K 1 ug[†]	47	y	D = 0.10, p = 0.63					0.002			
Thiamine B1 mg	67	y	D = 0.10, p = 0.44				0.0002				
Riboflavin B2 mg	67		D = 0.09, p = 0.59				0.0003			0.066	
Niacin total B3 mg	67	y	D = 0.10, p = 0.54				0.0005			0.108	-0.330
Niacin mg	67		D = 0.13, p = 0.18				0.005				-2.886
Pantothenic acid B5 mg	67	y	D = 0.10, p = 0.47				0.0003				
Vitamin B6 mg	67		D = 0.15, p = 0.08				0.0008				
Folic acid B9 ug	67		D = 0.10, p = 0.44				0.086			19.346	-63.867
Biotin B7 ug[†]	44		D = 0.19, p = 0.06				0.011				
Vitamin C mg	67		D = 0.13, p = 0.19				0.132			23.660	

[†] Original data were zero-inflated. After removal of the zero values, the remaining n data were normally distributed.
[‡] tf = transformed data by cube root transformation for right-skewed data: $y = abs(y)^{(1/3)}$.
[§] Kolmogorov-Smirnov test statistics for normal distribution.

indicate that none of the households achieved the recommended daily intake of calories and many micronutrients. Our GLM analysis identified that only one nutrient, magnesium, was associated with those households that consumed more agricultural products. A methodological limitation was the occurrence of zero-inflated nutritional parameters, which do not comply with the requirement of normally distributed data for GLM. We solved this by removing the zero values, resulting in normally distributed data. An alternative approach is to model zero-inflation during analysis by converting the observed continuous variables into counts and applying a zero-inflated Poisson regression as implemented in the R package "pscl" (Zeileis et al. 2008). However, the application of "pscl" did not result in z values for any of the parameters, thus making interpretations impossible. As a result, we retained the approach of removing zero values accepting a loss of data. Although the loss of data was large (between 2.2% and 85.1%, mean = 40.5%), it involved only six of 37 parameters. Moreover, the removal appears not to have resulted in interpretation biases as the results of the seven parameters is not noticeably different from the results of the other parameters, e.g., regarding the comparisons with nutrient supply and WHO/FAO recommendations.

HDDS, as used in our study is a widely employed qualitative measure of food consumption that reflects household access to a variety of foods, and is also a proxy for nutrient adequacy of the diet of individuals. It is a rapid, user-friendly, and easily administered low-cost assessment tool where scoring and analysis of the information collected is straightforward. HDDS scores consist of a simple count of food groups that a household or an individual has consumed over the preceding 24 hours. It is meant to reflect, in a snapshot form, the economic ability of a household to access a variety of foods.

Measures of dietary diversity collected at the individual level such as Minimum Dietary Diversity (MDD) for children 6–23 months, have been shown to be positively associated with mean micronutrient adequacy of the diet (Working Group on Infant and Young Child Feeding Indicators 2006). Our GLM results demonstrate that nutrient intake is correlated with HDDS values. Although more research is needed, dietary diversity could be a suitable surrogate of nutrient adequacy of the population, but also applicable at the individual level. If the objective is to assess economic access to food, or to estimate which food groups households are consuming, then the household-level indicator is a more appropriate measure (FAO 2018). Because household dietary diversity generally increases as income increases, this indicator can be used as a proxy for the access dimension of food insecurity, one of the indicators frequently used to assess how interventions designed to increase household income have affected food consumption (Swindale and Bilinsky 2006).

In most households in our study, the primary source of calories was derived from cultivated starchy foods. Similar to findings by Gallois et al. (2020) for Baka communities, cassava and plantain were predominant in the meals of our study population. The shift in Baka diets from relying on forest products to incorporating more starchy agricultural foods has been observed since the 1980s (Hladik et al. 1989), with a significant increase in recent times (Gallois et al. 2020). Studies to compare our results on dietary diversity with other local and Indigenous communities are scarce. Ebile et al. (2021) provide evidence that the diets of Mbororo women in northwest Cameroon, who cultivate home gardens (Ebile et al. 2022) and who consume mostly starchy staples, vitamin-A rich vegetables, palm oil, milk, and milk products, exhibited low iron content, rendering them susceptible to nutritional anemia.

Sedentarized Baka communities consume a mixed diet that includes varying amounts of farmed and traditional foods. Many of these groups still combine their lives in the village with some time spent in forest camps. This occasional immersion in the forest has been linked to stress reduction and improved nutritional status (Hagino et al. 2014). However, diets of Baka exclusively living in forest camps tend to include higher proportions of starchy staples (wild yams), meat, fish, but also legumes, and nuts, overall more varied and nutritious than the diets of Baka living in roadside villages (Reyes-García et al. 2019).

Although our study shows that the proportion of traditional foods consumed and their absolute quantities were relatively low, even a small inclusion of wild meat (and other wild foods) in diets could be crucial in improving the nutritional status especially of children. This has been demonstrated by Golden et al. (2011) where anemia in children in northeastern Madagascar was lower in those children who consumed even small amounts of wild meat. However, further research is needed to confirm this in our study villages.

Data on energy and nutrient intake presented in this paper highlight severe food stress in the Baka population. This nutritional inadequacy aligns with our earlier study that shows that malnutrition levels are significant in these villages (Funk et al. 2020b). Undernourishment not only impacts morbidity rates but as seen in other groups, also reduces life expectancy. Baka have a life expectancy of 35 years, significantly lower than their Bantu neighbors who live roughly 22 years longer (Anderson et al. 2016). Micronutrient deficiencies rank among the top 20 risk factors for morbidity and impaired quality of life, with particular burdens falling on populations in poorer countries, women of reproductive age, and young children. However, they are sufficiently prevalent (among more than 2 billion people globally) to affect almost all population segments to some degree (Lopez et al. 2006).

Sedentarization has clearly impacted the Baka in their daily lives and their overall well-being. Yamauchi et al. (2000), for example, observed changes in physical activity and subsequent daily energy expenditure due to the lifestyle change away from a nomadic existence. Dounias and Froment (2006) showed there was an increased risk of cardiovascular diseases and nutritional disorders as well as alcoholism among sedentarized Baka. However, some studies have demonstrated that even a modest insertion into the wider market structure, which is enabled by sedentarization, can negatively affect diets and overall health (Reyes-García et al. 2019).

By examining Body Mass Index (BMI) values in Pygmy compared to non-Pygmy groups, Funk et al. (2020a) demonstrated that there is a declining or stagnant trajectory of Pygmy BMI over age, in contrast to the general trend of increasing body weight over age in the other groups. These results do not necessarily reflect the influence of ethnicity per se, but may be a result of the fact that Pygmy populations are socially, materially, and nutritionally deprived groups. More specifically, Funk et al. (2020b) confirmed that in Baka children, stunting in this group was one of the highest global rates relative to the WHO child growth standard. These health conditions are almost certainly the result of impoverished diets.

We have shown in other research on the same Baka populations that hunting and gathering non-timber forest products is still a fundamental activity for many families (Ávila Martin et al. 2020, Billong Fils et al. 2020). In the present study, we found that households that consumed < 2 kgs of cultivated food during the recall day, use wild foods including wild meat much more than those households eating > 2 kgs. This connection underscores the significance of forest products for families who, either by choice or necessity, do not engage in subsistence crop cultivation. It emphasizes that for these households, wild products play a fundamental role in securing their food supply. Generally, individuals consuming over 2 kgs of cultivated foods had better micronutrient intake, though there were notable exceptions, namely vitamins D, K1, B5, B6, B7, and B12. This suggests that although cultivated foods substantially contribute to nutritional intake, they are not able to provide adequate micronutrients at least in the quantities that are currently consumed. Hence, it is crucial to promote agricultural practices while maintaining a diet that includes wild meat to ensure adequate intake of several key nutrients.

Foods from the forest are no doubt important for Baka communities to varying degrees for their food security, but also for their spiritual well-being. Because Pygmy communities are affected by loss of access to forest lands and resources (see Fa et al. 2021) as the forest frontier is pushed back, they spend more time in fixed settlements along roads. Here, health problems are more prevalent because of increased exposure to infected malarial mosquitoes, the build-up of parasites due to increased population density, lack of adequate sanitation, and the rise in sexually transmitted diseases (Ohenjo et al. 2006). Within Batwa Pygmy communities in Uganda, where malnutrition and food insecurity are common, individuals who are particularly undernourished or severely food-insecure may have elevated risk for *Plasmodium falciparum* infection (Lewnard et al. 2014). Links between malaria and iron deficiency in African children have been established; Muriuki et al. (2021) suggest that intervention that halves the risk of malaria episodes would reduce the prevalence of infectious diseases in African children by 49%. Nevertheless, compared with nearby non-Pygmy communities, forest-based communities in northern Republic of Congo have a lower prevalence of disease despite their more limited access to health care (Lewis 2002). However, parasite loads in village-based Pygmies were much higher than in Bantu communities, and both groups had higher loads than forest-based Pygmy groups (Froment 2001).

CONCLUSION

Our findings highlight a pronounced level of food stress within the studied Baka population. The limited quantities of food and low intake of some key nutrients underscore the severity of nutritional challenges faced by this community. To comprehensively understand these challenges and their potential correlation with recent lifestyle changes, further investigations involving a larger and more geographically diverse sample are imperative.

These findings can catalyze broader discussions involving local and national stakeholders responsible for nutrition and health-related policies. Their involvement is essential for developing targeted interventions and policies to enhance the nutritional well-being of the Baka people and similar communities situated across the forest-sedentarized gradient.

Author Contributions:

J. E. F. was responsible for study design, conception, data preparation, data analyses, and wrote the first draft. E. A. M., G. R. B., S. A., and R. O. were responsible for data collection, revised all drafts. S. M. F. was responsible for data preparation and data analysis, prepared figures and/or tables, revised and edited all drafts. A. I. assisted in the data analyses, revised drafts of the paper. F. L. analyzed the nutritional data, reviewed drafts of the paper. All authors read and approved the final version.

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Data Availability:

The original contributions presented in the study are included in the article/Supplementary Material; further inquiries can be directed to the corresponding author.

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Appendix 1

Food consumption and nutritional status of sedentarized Baka Pygmies in Southern Cameroon: wild foods are less important for those who farm

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Table A1.1. Sampled households and occupied households in the ten Baka villages.

Village	Location	Houses			
		Total	Occupied	Sampled households	Total
Abing-Nkolemboula	N 02°42'20"/E013°19'43"	14	12	5	41.7
Adjap-Mintom	N 02°40'16"/E 013°15'13"	20	15	8	53.3
Akom	N 02°37'28"/E 013°19'11"	37	24	14	58.3
Akonetyé	N 02°42'03"/E 013°00'08"	32	23	4	17.4
Assok	N 02°39'21"/E 013°17'12"	36	23	7	30.4
Belle-Ville	N 02°35'23"/E 013°21'48"	11	10	5	50.0
Bemba II	N 02°44'44,5"/ E 013°21'13"	20	14	4	28.6
Doum	N 02°40'16"/ E 013°15'13"	30	24	10	41.7
Meyos-Mintom	N 02°43'30"/E 013°20'50"	7	5	5	100.0
Odoumou	E 02°39'32"/E 013°39'20"	30	22	5	22.7
Grand Total		237	172	67	39.0

Table A1.2. Sample sizes of weights and SD of food items assessed in households and Djoum market.

Food item	Unit Sold	n	Mean	SD
Onion	50 F	3	81.3	18.1
	100 F	3	154	9.5
	150 F	3	256.7	26
Tomato	single	3	70.3	5
Market peanuts	Glass 100F	3	103	5
	Box 500F	4	511	30.9
	1 cup 250 ml	3	157.7	1.2
Village peanuts	Glass 100F	3	102	2.6
	Box 500F	3	529.7	11
	1 cup 250 ml	3	165	2.6
Rice	Box 350F	1	690	
	1 cup 250 ml	3	224	0
Cassava	Large	1	1713	
	Medium	1	805	
	Small	3	397.3	157.4
	Very small	2	154	2.8
Bush mango	1/2 cup 125 ml	3	60.7	3.2
Salt	1/2 cup 125 ml	3	138	1.7
Prunes (African plums)	Large	2	131.0	1.4
	Medium	2	71.0	7.1
	Small	3	55.3	17.9
Caterpillars	1 cup (250ml)	3	89.3	3.1

Table A1.3. List of food items consumed, their provenance and source of nutritional information.

	Common names				
Food group/Provenance	English	French	Boulou/Baka	Measure	Source
Cereals					
Bought	Pasta, white, dried, boiled	Macaroni		g	9
Bought	Rice (white, basmati, boiled)	Riz		g	9
Fish					
Fished food	Bar' fish	Poisson fumé	bar	g	9
Fished food	Freshwater fish mixture	Melange des poissons		g	9
Fished food	River fish	Tocó' fish		g	9
Fruits					
Collected food	African pear (*Dacryodes edulis)*	prune		g	10
Cultivated	Avocado, flesh only, average, weighed with skin and stone	Avocat		g	9
Cultivated	Bananas, raw, flesh only, weighed with skin	Banane		g	9
Bought	Citrus fruit			g	9
Cultivated	Plantain (*Musa musa* × *paradisiaca*)	Plantain	ndó	g	9
Legumes, nuts, and seeds					
Collected food	Bush mango (*Irvingia gabonensis*)	Mango Sauvage	Ndo'o	g	10
Bought	Peanuts (*Arachis hypogaea)*	Arachides 'd'anglo'		g	9
Bought	Pumpkin seeds (*Cucurbita maxima*)	Cocombre	Cocombre	g	9
Bought	Palm nuts (*Elaeis guineensis*)	Noix palmiste		g	10
Meat					
Hunted food	Blue duiker (*Philantomba monticola*)	Lièvre	Opkweng	g	1; 3; 2; 7
Collected food	Caterpillars (*Imbrosia truncata*)	Chenilles		ml	6, 11
Bought	Chicken	Poulet		g	9
Hunted food	*Emin's pouched rat (Cricetomys emini)*	Rat		g	1; 3; 2; 8
Hunted food	Monitor (*Varanus ornatus*)	Varane		g	7
Hunted food	Red duiker (*Cephalophus* spp.)	Biche		g	1; 3; 2; 8
Oils and fats					
Bought	Palm nut oil (*Elaeis guineensis*) emulsion	Soup de noix		ml	9
Bought	Moabi oil (*Baillonella toxisperma)*	Huile de moabi		ml	5

Bought	Palm oil	Huile Mayor	Huile rouge	ml	9
Spices, condiments and beverage					
Bought	Basil, fresh			g	9
Bought	Chilli pepper, scotch bonnet (*Capsicum chinense)*	Piment	Lamba	g	9
Bought	Ginger (*Zingiber officinale*)	Gingembre	Ginjá	g	9
Bought	Maggi Cube bouillon	Cube	Cube	g	Manufacturer
Bought	Salt	Sel		g	9
Bought	Parle-G	Biscuits		g	Manufacturer
Vegetables					
Cultivated	Zom leaves (*Solanum nigrum*)	Feuille Zzóm		g	10
Cultivated	Cassava leaves	Feuille de manioc		g	9
Cultivated	Folon (*Amaranthus dubius*)	Feuille Folong		g	10
Cultivated	Garlic	Aïl		g	9
Collected food	Mushrooms	Champignons		g	4
Cultivated	Ndolé leaves (*Vernonia amygdalina*) Epinard	Épinard sauvage	Épiná	g	10
Cultivated	Okra (*Abelmoschus esculentus*)	Gombó		g	9
Cultivated	Onions	Oignon		g	9
Cultivated	Taro leaves	Feuille de macabó	Pkwalanga	g	10
Cultivated	Tegue leaves (*Gnetum africanum?*)			g	10
Cultivated	Tomato fruit	Tomate fruit		g	9
Cultivated	Tomato puree	Sachet Tomate		g	8
White tubers and roots					
Cultivated	Cassava (*Manihot esculenta*)	Manioc		g	9
Cultivated	Sweet potato (*Ipomoea batatas)*	Batate		g	9
Cultivated	Taro, boiled in unsalted water (Eddoes) (*Colocasia antiquorum*)	Macabó		g	9

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Table A1.4. Frequency of consumption of all recorded food items by food groups in the sampled households in the ten study Baka villages.

Food group	No.	Number of times used	%
Spices, condiments and beverages	5	216	37.0
Fruits	5	116	19.9
Vegetables	12	78	13.4
White tubers and roots	3	67	11.5
Oils and fats	3	49	8.4
Meat	6	28	4.8
Legumes, nuts and seeds	4	21	3.6
Fish	3	4	0.7
Cereals	2	3	0.5
Sweets	1	2	0.3

Table A1.5. Dietary diversity calculated for all sampled households in each of the 10 sampled Baka villages.

Village	Mean	SD
Abing-Nkolemboula	4.8	1.6
Adjap-Mintom	3.3	1.9
Akom	4.3	1.6
Akonetyé	4.8	1.5
Assok	4.0	1.2
Belle-Ville	3.2	2.1
Bemba II	2.8	1.8
Doum	4.7	1.8
Meyos-Mintom	4.8	1.4
Odoumou	4.0	1.7