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Energetic Value Estimates of Wild and Domesticated Food Items Consumed by Congolese BaYaka Foragers

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Cover Page Footnote

Author contributions: SLL, ANC, and LB conceived of the paper. SLL and YRO collected the field data. LB sourced the energetic values from the literature. LB wrote the paper and created the dataset, with help from SLL. ANC gave critical feedback on the study design and report. Acknowledgments: Funding for data collection was provided to SLL by the Cambridge International Trust, the SSHRC Doctoral Scholarship (Award no. 752-2016-0555), and the Cambridge School of Biological Sciences Fieldwork Fund. SLL was funded by a postdoctoral fellowship from the Alexander von Humboldt Foundation. We would like to thank Prof. Clobite Bouka-Biona and other staff from IRSEN, who facilitated the acquisition of research permits and infrastructure, Dzabatou Moise, who served as a community liaison, and our field assistant, Mékouno Paul. Thanks as well to Sarah M. Pope and Adam H. Boyette for fieldwork support, and Vidrige Kandza, Valéry Malécot, and Haneul Jang for help with species identification.

FIELD NOTE

Energetic Value Estimates of Wild and Domesticated Food Items Consumed by Congolese BaYaka Foragers

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ABSTRACT

We present a dataset that systematically estimates the energetic value of wild and domesticated food resources collected and consumed by Congolese BaYaka foragers. This dataset is unique in that it accounts for everyday practices of food processing and consumption. Reported values of inedible portions, moisture content, and estimated energetic values (kilocalories/gram) were extracted from field research and the published food chemistry and nutrition literature. These data are central to understanding how nutritional needs are met in rainforest environments and will allow for current and future tracking of diet composition in this and similar ecologies. The dataset is available at https://doi.org/10.6084/m9.figshare.19446938.v10

INTRODUCTION

This paper describes a dataset of energetic value estimates (kilocalories/gram) for the field weights of foods consumed by Congolese BaYaka foragers. To-date, few studies have systematically estimated the energetic value of BaYaka food resources (see Kitanishi 1995), despite their importance to better understanding how nutritional needs are met in rainforest environments (Bahuchet et al. 1991), the development of food collection skills in young foragers (Crittenden et al. 2013), food security (Benoit et al. 2021), and the role of wild foods in times of nutrition transition (Pollom et al. 2020). To fill this gap, we reviewed the food composition and nutrition literature to provide the best available kilocalorie per gram estimates for resources collected by BaYaka in July-September 2018, following best practices in nutritional anthropology (Crittenden and Schnorr 2017). Our dataset is unique in that it accounts for everyday practices of food processing and consumption. To promote reproducibility, the following text details our methodology.

ETHNOGRAPHIC AND ECOLOGICAL BACKGROUND

BaYaka are a population of mobile hunter-gatherers who primarily subsist on forest resources including hunted and trapped game, honey, fish, wild tubers, nuts, seeds, leafy greens, caterpillars, mushrooms, and palm nuts (Bahuchet 1988; Kitanishi 1995). BaYaka supplement their diets with low-maintenance gardens where they primarily grow cassava (*Manihot esculenta*),

corn (*Zea mays*), plantains (*Musa* sp.) (Boyette et al. 2022) and several species of tubers from the genus *Dioscorea* (personal observation). BaYaka also maintain trade relationships with their farmer neighbors, from whom they purchase or trade for cultigens and other resources such as salt and bouillon cubes.

Like other foragers, BaYaka maintain a gendered division of labor (Hewlett 1991). Men primarily hunt and collect honey, and women primarily collect plant-based resources. That said, this gendered division of labor is very flexible, with both men and women participating in all subsistence activities when necessary (Marlowe 2007). Children are also active foragers who may collect resources with adults or in the multi-aged mixed-gender peer group (Lew-Levy et al. 2019).

For this study, we collected food return data over a six-week period in a BaYaka forest camp along the Motaba River in the Likouala Department of the Republic of the Congo between July and September 2018. The camp was situated in the Congolian Lowland Forest ecoregion, which is primarily characterized by a closed forest consisting of broadleaf evergreens (Digital Observatory for Protected Areas Explorer 2021). Data were collected in the tropical wet season, during which caterpillars (**kongo**) (Figure 1) and bail fishing (**doka**) are important subsistence activities (Jang and Boyette 2021; Mabossy-Mobouna et al. 2016).

BaYaka travel large distances to forage (Jang et al. 2019). To reduce the energetic burden associated with carrying heavy loads, nuts and seeds such as *Plukenetia conophora* (**kaso**) or *Irvingia excelsa* (**payo**) are processed at the foraging patch to remove heavy inedible plant parts (e.g., husks) before returning to camp. Animals are also often partially processed before returning to camp: they may be gutted or skinned, quills and feathers may be removed, or when returning from especially long hunting trips, meat may also be lightly smoked for preservation. Cassava tubers (**boma**) are retted to leach toxins, usually in shallow ponds between the garden and the camp. Many sweet foods are eaten raw on the trail, such as junglesop (*Anonidium mannii*, **mobe**) and *Aframomum* sp. (**ngai ngai**). Foods that are easily roasted may also be eaten during short breaks from foraging, such as the tubers of serendipity berry (*Dioscoreophyllum cumminsii*, **mela**) (Figure 2), caterpillars, and meat. While BaYaka often roast foods while snacking, most in-camp meals are cooked in pots or in *Marantaceae* leaves.

FIGURE 1. Kongo, edible caterpillars (Lucie Benoit)

FIGURE 2. Mela, *D. cumminsii* (Lucie Benoit)

THE CONGO BASIN FOOD ENERGETIC VALUES DATASET

We designed our dataset for ease of use by researchers with limited experience working with nutritional values. It is available as an Excel (.xlsx) file with tabs at: https://doi.org/10.6084/m9.figshare.19446938.v10. The "Plants & Fungi" tab outlines the estimated energetic values for 34 plant and fungi items consumed by BaYaka. The "Animals & By-products" tab outlines the estimated energetic values for 19 animal and animal by-product (mead, honey, eggs) items consumed by BaYaka. The "Bibliography" tab includes the bibliographic information for each source cited in Sheets 1 and 2. Finally, the "Supplementary Tables" tab provides additional information regarding how nutritional values were calculated, as cited in the "Plants & Fungi" and "Animals & By-products" tabs.

Table 1 gives the list of animal and animal by-products included in our dataset. Table 2 below gives the list of plant and fungi included in our dataset. Note that we may add species and refine identification as the dataset evolves. Table 3 details the columns reported in the "Plants & Fungi" tab, and Table 4 details the columns reported in "Animals & By-products" tab. Researchers can locate the processing condition of specific items using their Yaka, English, or scientific name. Researchers can then directly multiply the field (i.e., wet) weight by the final kilocalories/gram, to estimate the amount of energy in their sample. Additional information regarding each step of the calculation process is provided in the Excel sheet and here.

TABLE 1. List of Animal and Animal By-products Included in the Dataset.

Yaka	English	Scientific
Unknown	Bat	*Hypsignathus monstrosus* and other species
Nyodi	Bird	--
Ngbumo	Black-fronted duiker	*Cephalophus nigrifrons*
Mboloko	Blue duiker	*Philantomba monticola*
Ngomba	Brush-tailed porcupine	*Atherurus africanus*
Kongo	Caterpillars	*Imbrasia truncate* and other non-identified species
Basui	Fish	--
Eta	Frog	--
Mabongi	Grub	--
Gombe	Lizard	--
Nganda	Long-snouted mongoose	*Xenogale naso*
Kema	Monkey	--
Ngolo	Rat	*Cricetomys* sp.
Njua	Red river hog	*Potamochoerus porcus*
Moseme	Snake	--
Kudu	Turtle	--
Make	Egg	--
Djeme	Honey	--
Duma	Mead	--

Note that we may add species and data as the dataset evolves. Please refer to the online dataset for latest updates.

TABLE 2. List of Plant and Fungi Included in the Dataset. ***Note that palm wine and palm nuts are derived from the same species.***

Family	Yaka	English	Scientific
Annonaceae	**Mobe**	Unknown	*Anonidium mannii*
Apocynaceae	**Maondo**	Unknown	*Landolphia* sp.
Araceae	**Maika** and **dunda**	Taro tuber / taro leaves	*Xanthosoma sagittifolium*
Arecaceae	**Mbila**	Palm nut	*Elaeis guineensis*
Arecaceae	**Meleku/Molenge**	Palm wine	*E. guineensis*
Caricaceae	**Papaye**	Papaya	*Carica papaya*
Convolvulaceae	**Benje**	Sweet potato	*Ipomea batatas*
Dioscoreaceae	**Ekule**	Wild yam	*Dioscorea semperflorens*
Dioscoreaceae	**Epangi**	Wild yam	*Dioscorea* sp.
Dioscoreaceae	**Esaa**	Wild yam	*Dioscorea* sp.
Dioscoreaceae	**Kobo**	Wild yam	*Dioscorea* sp.
Dioscoreaceae	**Ndiki**	Wild yam	*Dioscorea* sp.
Dioscoreaceae	**Ngangi**	Wild yam	*Dioscorea burkilliana*
Euphorbiaceae	**Boma** and **jabuka**	Cassava / cassava leaves	*Manihot esculenta*
Euphorbiaceae	**Kaso**	Owusa Nut	*Plukenetia conophora*
Fabaceae	**Mbala**	Unknown	*Pentaclethra macrophylla*
Gnetaceae	**Koko**	Unknown	*Gnetum buchholzianum*
Irvingiaceae	**Payo**	Unknown	*Irvingia excelsa*
Malvaceae	**Cacao**	Cacao	*Theobroma cacao*
Menispermaceae	**Mela**	Wild yam	*Dioscoreophyllum cumminsii*
Moraceae	**Pusa**	African breadfruit	*Treculia africana*
Musaceae	**Gondo/Bolo**	Plantain/Banana	*Musa* sp.
Pandaceae	**Kana**	Panda	*Panda oleosa*
Poaceae	**Mombombo**	Corn	*Zea mays*
Rubiaceae	**Mbeku**	Unknown	*Psychotria* sp.
Rutaceae	**Citron**	Lemon	*Citrus limon*
Rutaceae	**Malala**	Orange	*Citrus aurantium*
Sapindaceae	**Matokodi**	Unknown	*Chytranthus* sp.
Sapotaceae	**Mondonge**	Unknown	*Chrysophyllum* sp.
Solanaceae	**Konji**	Peppers	*Capsicum* sp.
Unknown	**Kango**	Unknown	Unknown
--	**Makombo**	Mushooms	--
Urticaceae	**Ediki**	Monkey fruit	*Myrianthus arboreus*
Zingiberaceae	**Ngai ngai**	Unknown	*Aframomum* sp.

Note that we may add species and refine identification as the dataset evolves. Please refer to the online dataset for latest updates.

TABLE 3. Description of Columns Presented in Plants & Fungi Tab.

Variable Name	Type	Description
Index	Number	An index number from one to 56 to help locate records.
Family	Name	The botanical family that the plant belongs to.
Yaka	Name	The Yaka name for the food item.
English	Name	The English name for the food item.
Scientific	Name	The scientific name for the food item.
Processing_Condition	Condition	To avoid carrying extra weight, many foods collected by BaYaka are processed at the collection site (e.g., nuts are husked). This variable describes what parts of the food item were discarded and/or retained before it was weighed in camp.
Processing_Condition Details	Description	A detailed description of what was discarded and/or retained before being weighed in camp.
final_kcal/g	Value	The amount of kilocalories for 1 gram of wet matter of a sample for the processing condition, accounting for subtracted inedible parts. Calculated as: (1-Proportion_Inedible) X kcal/g_wet. This final value can be multiplied directly with field (or wet) weights to estimate total kilocalories/gram for items.
Proportion_Inedible	Proportion	The proportion of the plant returned to camp that is not digestible (e.g., husks, seeds) to food consumed. Calculated as: inedible (g)/consumed (g). When field notes measuring the inedible proportion for specific items were incomplete or absent, these values are estimated or extracted from the published literature.
Proportion_Moisture	Proportion	The proportion of the consumed food which is water. All values are from the published literature. Calculated as: (consumed wet weight (g) - consumed dry weight (g))/consumed wet weight (g).
kcal/g_Wet	Value	The number of kilocalories per gram of consumed wet matter. All values are from the published literature.
kcal/g_Dry	Value	The number of kilocalories per gram of consumed dry matter. All values are from the published literature.
Details	Description	Where applicable, we provide the following additional information: Alternate scientific name: A synonymous or alternative scientific name. We include this to help navigate between publications. Proportion inedible: A detailed description of how the proportion inedible was calculated, including citation to the source text (Author Date). Proportion moisture: A detailed description of how the proportion moisture was calculated, including citation to the source text (Author Date). kcal/g_wet: A detailed description of how the kcal/g_wet was calculated, including citation to the source text (Author Date). kcal/g_dry: A detailed description of how the kcal/g_dry was calculated, including citation to the source text (Author Date).

TABLE 4. Description of Columns Presented in Animals & By-products Tab.

Variable Name	Type	Description
Index	Number	An index number from 57-92 to help locate records.
Yaka	Name	The Yaka name for the food item.
English	Name	The English name for the food item.
Scientific	Name	The scientific name for the food item.
Pro-cessing_Condition	Condition	To avoid carrying extra weight, many animals collected by BaYaka are processed at the collection site (e.g., birds are feathered and gutted). This variable tells us what food parts were discarded and/or retained before it was weighed in camp.
Final_kcal/g	Value	The amount of kilocalories for 1 gram of wet matter of a sample for each processing condition, accounting for subtracted inedible parts. Calculated as: (1-Proportion_Inedible) X kcal/g_wet. This final value can be multiplied directly with field (or wet) weights to estimate total kilocalories/ gramram for items.
Proportion_External	Proportion	Proportion of non-edible external parts (e.g., feathers, quills) to the entire animal (i.e., as caught), when applicable. All values are from the literature or field notes. Calculated as: External weight (g)/entire animal (g).
Proportion_Guts	Proportion	The proportion of guts to the entire animal (i.e., as caught). All values are from the literature or field notes. Calculated as: guts (g)/entire animal (g).
Proportion_Bone	Proportion	Proportion of bones to the entire animal (i.e., as caught). Calculated from published values or formulae.
Proportion_Inedible	Proportion	Calculated as: proportion_external + proportion_guts + proportion_bone
Proportion_Moisture	Proportion	The proportion of the consumed food which is water. All values are from the published literature. Calculated as: (consumed wet weight (g) - consumed dry weight (g)) /consumed wet weight (g).
kcal/g_Wet	Value	The number of kilocalories per gram of consumed wet matter. All values are from the published literature.
kcal/g_Dry	Value	The number of kilocalories per gram of consumed dry matter. All values are from the published literature.
Details	Description	Where applicable, we provide the following additional information: Family: The family of the species. Proportion inedible: A detailed description of how the proportion inedible was calculated, including citation to the source text (Author Date). Proportion moisture: A detailed description of how the proportion moisture was calculated, including citation to the source text (Author Date). kcal/g_wet: A detailed description of how the kcal/g_wet was calculated, including citation to the source text (Author Date). kcal/g_dry: A detailed description of how the kcal/g_dry was calculated, including citation to the source text (Author Date).

METHODOLOGY

Ethical approval for the present study was obtained from the University of Cambridge [PRE.2018.023]. In-country permission was received from the **Institut de Recherche en Sciences Exactes et Naturelles** (Brazzaville). Community and individual verbal consent was obtained during a village-wide meeting, a camp-wide meeting, and during one-on-one meetings before the start of the research. In what follows, we describe the procedures used in the order in which they occurred; we first collected field data, then searched through the food composition and nutrition literature, and finally we calculated the estimated energetic values.

Field Data

All foods collected and returned to camp by adults and children were weighed using a hanging spring scale (Figure 3). The research team recorded the Yaka name for the food article and noted the *processing condition* of each item, which is the degree to which inedible parts had been removed prior to being weighed in camp. This weight is the *field (or wet) weight*. Plants were identified by connecting the Yaka name given by participants with the Yaka and scientific names published by other researchers (Bahuchet 1985; Ebika et al. 2013; Gallois 2016; Thomas et al. 2007), or by the first author, an ethnobotanist who had conducted a total of four months of ethnographic fieldwork with BaYaka in 2017 and 2018. Where possible, mammals were identified using the *Kingdon Field Guide to African Mammals* (Kingdon 2015) with the assistance of research participants.

FIGURE 3. BaYaka participants look on as Yann R. Ouamba weighs a food package wrapped in *Marantaceae* leaves (still from video by Sarah Pope-Caldwell, printed with permission)

As mentioned, BaYaka often remove inedible parts of plants and animals before returning to camp. For example, some bananas/plantains were brought to camp unpeeled, while others were peeled in the garden. Porcupines caught in traps were sometimes returned to camp with their quills already removed, while the entrails and bones would be removed later in camp. Some nuts, especially those with heavier husks, were husked at the collection site. Whenever possible, the proportion of inedible to consumed parts—or *inedible proportion*—per species at different stages of processing was calculated in the field. The inedible proportion includes the discarded parts of the food item.

Whenever a participant returned with an unprocessed or semi-processed resource, we sat near them, and, with their consent, weighed the edible and discarded portions of the food as they processed them. However, this procedure was not always possible, because some foods are always fully processed at the collec-

tion site, or because processing the food requires destroying inedible parts, such as burning the hair off of a monkey. In these cases, plant parts were identified by the first author via their anatomy (Brice 2011; Mosango and Szafranski 1985; Provost 2011), and the inedible proportion was sourced from the published literature (see next section).

For animals, we accounted for the digestive organs and external components such as quills, skin, hair, and feathers using values in the published literature (see next section). Furthermore, as animals are rarely returned to camp deboned, it is necessary to estimate the proportion of an animal's skeletal mass and remove it from the animal weight to calculate the edible portion. To do this, we first sought out estimates for each specific species. If species-specific estimates were not available, we used published formulae for estimating the skeletal mass proportion for mammals and birds (see Prange et al. 1979). Note that since BaYaka often cook and/or roast skin, skin was considered an edible portion for meat.

Literature Review Protocol

To locate information on inedible proportions, moisture content, and energetic values, we prioritized published values from the United Nations Food and Agriculture Organization/INFOODS Food Composition Table for Western Africa (Vincent et al. 2019) and from the Food Composition Table for Use in Africa (Leung et al. 1968). These comprehensive reports primarily use values from the published literature for hundreds of plant and animal items. The quality of each paper is assessed by the Food and Agriculture Organization based on their acquisition and calculation standards, which accounts for the methods and region of sampling, adjusts for moisture value when variation across samples exceeds 10 percent, and cross-checks scientific names. As the Food and Agriculture Organization primarily catalogues energetic values for cultigens, we turned to Leung et al. (1968) for further information on African wild plants and animals. As smoking foods to preserve them can affect caloric and moisture content, Vincent et al. (2019) and Leung et al. (1968) were preferred because they provide information about the processing condition prior to the analysis for energy calculation.

When information was unavailable in Vincent et al. (2019) and Leung et al. (1968), we searched through Kitanishi (1995) and Plant Resources of Tropical Africa (PROTA4U: https://www.prota4u.org/database/) hosted by Wageningen University (Netherlands), an international documentation program which compiles detailed information on uses and nutritional values for the plants of tropical Africa. We also conducted a literature search of relevant publications in the fields of nutrition, agriculture, and chemistry. In all cases, when processing condition or measurement units were not clear, we searched for the original reports cited in the text to find precise information on the methods and data. We only sourced energetic values from studies that reported this information.

To ensure that we sourced accurate energetic values for species collected and consumed by BaYaka, whenever possible we relied on single field and laboratory studies that reported the energy, moisture, and edible proportion values for each specific plant and animal species. When this was not possible, we deviated from this protocol in the following two ways. First, we combined reports to obtain a complete picture of all processing steps. For example, one paper might give a proportion of the feathers to body mass for a certain species of bird, but not the proportion of bones to body mass, and vice versa. In such cases, we combined values offered in different reports, though we acknowledge that proportion can vary according to the field site and sample. Second, when published energetic, moisture, or edible proportion values were unavailable for understudied species, we used data from species in the same genus, family, or clade. All such deviations are reported and justified in the *De-*

tails column in the dataset, with associated citations.

Using this protocol, we estimated each plant and animal's *proportion of moisture*. Since water does not have an energetic value, it is necessary to account for this moisture content when comparing the nutritional estimates of items. The moisture content is calculated in a laboratory setting, most often by drying a sample in a dedicated oven. The difference between the weight of the sample before and after the drying process gives the weight of the water. We report estimated energetic values as kilocalories/gram, a unit equivalent to 1,000 calories. To ensure standardization across kcal estimates, unless otherwise noted we report values for uncooked (i.e., raw) foods because these were uniformly available for both plants and animals. Note that it is usually best practice to account for drip loss, i.e., "the loss of weight in food (typically meat) due to the dripping away of tissue juices and the evaporation of water that occurs during the process of cooking or thawing" (Crittenden and Schnorr 2017:100). For animals that were smoked before being returned to camp, we accounted for drip loss by estimating values for grilled meat. In all other cases, we did not account for drip loss because BaYaka primarily cook food in pots or *Marantaceae* leaves thus limiting drip loss.

Calculating Energetic Values

We estimated kilocalories/gram following nutritional anthropologists Crittenden and Schnorr (2017) as follows:

1. Obtain the raw wet weight (g) for plants returned to camp
2. Obtain the edible wet weight (g) by subtracting the inedible portion (g) from the raw wet weight for each food resource by processing condition
3. Obtain the edible dry weight (g) by subtracting the moisture content from the edible wet weight
4. Obtain the edible weight to energy (kcal) by either:
   a. Multiplying the edible dry weight (g) by published kilocalories/gram dry values (for published dry weight food energy values), or
   b. Multiplying the edible wet weight (g) by published kilocalories/gram wet values (for published wet weight food energy values)

Mathematically, these steps take the following form:

1. Sample wet weight (g)
2. Edible wet weight (g) = sample wet weight (g) – sample wet weight (g) X inedible proportion
3. Edible dry weight (g) = edible wet weight (g) – edible wet weight (g) X moisture proportion
4. Energy in the sample =
   a. Edible dry weight (g) X kcal/g dry (for published dry weight food energy values)
   b. Edible wet weight (g) X kcal/g wet (for published wet weight food energy values)

LIMITATIONS

Our research team collected data with one extended family during one foraging season. To understand the full breadth of BaYaka diets, data should be collected across communities, locales, seasons, and years. To avoid bothering participants while they went about their food quest, we calculated inedible portions only once for each food. However, as these are mostly non-domesticated wild foods, inedible portions likely vary across samples from the same species. BaYaka also collect resources that are only ever consumed while outside of camp. We were unable to weigh and collect energetic values for these resources.

In some cases, the identification of wild plants and animals was challenging or imprecise. Future work will aim to identify plants using dried specimens and corresponding plant presses. We relied on the published literature for Yaka plant names. There are fewer energetic studies of wild plants in comparison to cultigens. BaYaka also often returned to camp with parts of animals rather than whole animals,

thus specific inedible proportions (e.g., proportion of bone for a duiker head or a porcupine foot) were not available. Furthermore, due to a lack of data, our methods were unable to account for the energetic content of bone marrow, which leads to an underestimation of energy and fat content for some species (e.g., marrow represents between 2-4 percent in African Ungulates weight; Blumenschine and Madrigal, 1993:563).

A final limitation is that the published literature derives energetic estimates from very small samples which were often homogenous in source and in analytical methods used to derive estimates. We look forward to improving our dataset with new energetic estimates as these become available. We also encourage researchers to contact us if they have additional BaYaka food resources which can be added to the dataset.

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