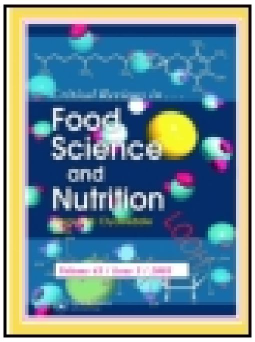

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REVIEW

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Nutrient composition of *Parkia biglobosa* pulp, raw and fermented seeds: a systematic review

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ABSTRACT
There is increasing evidence that nutrient differences observed among crop varieties or animal breeds belonging to the same species are sometimes greater than differences between species. *Parkia biglobosa* is an important tree species that provides edible products and income to rural households in West Africa. To better understand intra-species nutrient variability of *P. biglobosa* edible products, a review on the nutrient content of its pulp and seeds (raw and fermented) was conducted. Google scholar and the keywords "*P. biglobosa*" AND "nutrition" were used to screen the available literature from 1980 onwards, and the Zotero software was used to manage references. A step-wise assessment of titles, abstracts and full papers, led to a selection of 69 papers from which data were retrieved following FAO INFOODS guidelines. After data harmonization and quality checks, 42 papers were retained and used to extract data to populate a nutrient database. Despite an apparent abundance of nutrient analyses focused on *P. biglobosa*'s edible products, the quality of data available was poor and very few authors presented additional information, such as soil characteristics, climate, maturity at harvest, etc. that could influence the nutritional content of the products. Many data gaps remain. The present study will stimulate further investigations into nutrient composition of *P. biglobosa* products and ultimately will contribute to selecting nutritionally "+" trees for multiplication and/or domestication of the species.

KEYWORDS
Parkia biglobosa; proximate composition; minerals; vitamins; seed; pulp; food composition table

Introduction

Within-species differences in nutrient content between crop varieties and animal breeds can sometimes be greater than the differences between species (CBD/WHO, 2015; Lutaladio, Burlingame, and Crews 2010). For example, nutrient differences from 5.6 up to 14.6 g protein/100 g edible portion in rice have been documented (Burlingame, Charrondiere, and Mouille 2009; Kennedy et al. 2017). Consequently, the consumption of 200 g of rice per day can represent from less than 25% to more than 65% of the recommended daily intake of proteins, depending on the variety consumed (Kennedy and Burlingame 2003). For bananas, nutrient differences across varieties from less than 1 up to 8500 μg β-carotene/100 g of edible portion have been documented (Burlingame, Charrondiere, and Mouille 2009). In other words, consuming one dessert banana a day or consuming one orange-fleshed high β-carotene variety could make the difference between being Vitamin-A deficient or not (Ekesa et al. 2015; Englberger et al. 2006). These findings have led to an increased awareness of the importance of documenting and understanding within-species nutrient differences in food composition (Burlingame 2004) and to the development of the FAO nutrition indicators for biodiversity: food composition (1) and food consumption (2) (FAO 2008; FAO 2010).

In Burkina Faso, *Parkia biglobosa* (Jacq.) R.Br. ex G. Don f. (Fabaceae; Mimosoideae) is a tree of utmost importance as a source of edible products and income for the vast majority of rural households (Thiombiano et al. 2013; Vinceti et al. 2018). The species, known as néré in Francophone Africa, is indigenous to sub-Saharan Africa (Hopkins 1983) and has a very wide distribution range (Figure 1). It has been ranked by local people among the top priority tree species in Burkina Faso (ICRAF 2006; Kristensen and Lykke 2013), and its importance is documented all across West African countries (Hall et al. 1997; Teklehaimanot 2004). *Parkia biglobosa* pulp is a good source of energy and vitamin C, while the fermented grains contribute calcium, lipids and proteins to the diets of vulnerable populations in West-Africa (Orwa et al. 2009) (Figures 2, 3 and 4). Although the quantity of "soumbala" (fermented seeds) consumed at each meal is rather low, the fact that soumbala is consumed regularly makes it an important source of nutrients (Boedecker et al. 2014).

Several studies on tree population structure of *P. biglobosa* have shown poor regeneration and ageing of the stands,

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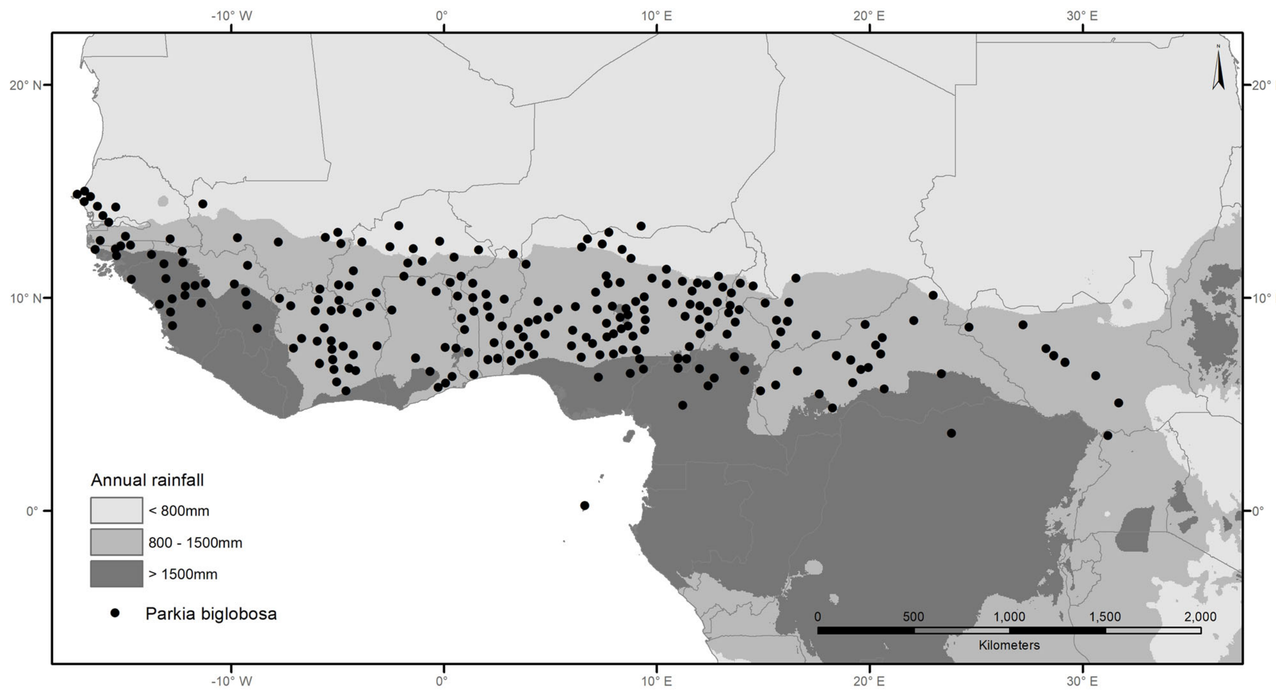

Figure 1. Geographic distribution of Parkia biglobosa in relation to annual rainfall (adapted from Hall et al. 1997).

Figure 2. An individual of Parkia biglobosa from a Parkland in Burkina Faso (credit: Barbara Vinceti, Bioversity International).

which may result in complete disappearance over time (Bouda and Nikiema 1996; Ouedraogo 1995; Raebild, Hansen, and Kambou 2012). Factors such as overexploitation, shortening of the fallow period and a drier climate have been suggested as responsible for this decline (Boffa 1999; Bouda and Nikiema 1996; Gijsbers, Kessler, and Knevel 1994; Nikiema 1993; Teklehaimanot 2004). In some areas, due to extreme competition in accessing the resource, people harvest *P. biglobosa* pods before their complete maturity, and this is likely to affect the regeneration of the species and the quality (taste and nutritional properties) of the edible products derived from the pods (Pehou et al. 2020).

Differences in growth, drought-resistance and morphology between *P. biglobosa* individuals from different populations across its distribution range have been described (Bouda et al. 2013; Ouedraogo et al. 2012). Similarly, published values derived from different studies about the nutritional composition of edible products from *P. biglobosa* present huge variability. This seems to be common for other tree species. Stadlmayer et al. (2013) reported large variability in values after compiling data from published food composition studies for 10 different indigenous fruit species from Sub-Saharan Africa. Some studies mention factors such as climate, soils or provenances as potential explanatory

Figure 3. Fruits (pods) of Parkia biglobosa from a Parkland in Burkina Faso. Pulp and seeds are consumed as edible products (credit: Barbara Vinceti, Bioversity International).

Figure 4. Balls of soumbala derived from the fermented seeds of Parkia biglobosa, sold as a condiment at the market (credit: Barbara Vinceti, Bioversity International).

variables for these differences, but their specific influence has not been studied so far.

The objective of this literature review is to compile a nutrient database with values extracted from publicly available data sources for *P. biglobosa* pulp and seeds (raw and fermented) to better understand the within-species variability in the nutritional properties of this tree. This will underpin a new research agenda that combines results from the genetic characterization of different populations of *P. biglobosa*, with an understanding of the variation in nutrients in the resource base. The ultimate objective is to inform the selection of optimal sources of planting material for forest restoration projects at different sites.

A systematic literature review was conducted to address the following questions: what is the level of within-species variation in proximate, mineral and vitamin content in *P. biglobosa* pulp, raw and fermented seeds? Are there any patterns in nutritional values identifiable across studies and different sites located in different regions of the species distribution range? Are there studies conducted in multiple locations combining research on nutritional content with environmental and/or genetic aspects? Are there studies assessing the relative weight of different factors determining the observed within-species differences in nutritional composition (e.g. soil, rainfall regime, level of maturity at the time of harvesting)? Are there research gaps?

Methodology

Literature search

An initial scoping search of scientific literature was performed screening multiple search engines and bibliographic databases (Google Scholar, Microsoft Academic, CiteSeer, Bioline International, Science Direct, Plos One, African Journals online, Directory of Open Access Journals, Web of Science, Medline, Pubmed, Agris, Agricola, CAB Abstracts, Food Science and Technical abstracts – FSTA). Searches included both open access and standard subscription-based journals, both peer-reviewed and gray literature.

After the initial search iterations, Google Scholar appeared to be the broadest source of information, including the same hits generated by other search engines or databases. A broad range of search terms was tested including the scientific name of the species (*Parkia biglobosa*), the English (African locust bean) and French (Nére) common names, and local names of the edible raw products or products processed from fermentation of *P. biglobosa* seeds (dawadawa). These were combined with the following additional search terms: nutrition, nutritional composition, nutritional analysis, vitamin or mineral content. The combination of keywords *Parkia biglobosa* AND nutrition turned out to be the most comprehensive and included all results derived from other combinations of terms. After this initial testing of search terms, in June 2018 a literature search was performed in Google Scholar using the search terms *Parkia biglobosa* AND nutrition, to gather information on the nutrient composition of the different edible products derived from *P. biglobosa*. The review focused on scientific publications released from January 1980 onwards.

The reference list obtained from the search in Google Scholar was imported in Zotero, an open-source reference management software (www.zotero.org) and duplicates were removed. Subsequently, titles and abstracts were screened, and full papers of relevant documents were collated for further reading. Based on a screening of the full-text, the following articles were further discarded: papers presenting secondary data (reported from previous papers), papers with results shown only in graphs or in the form of value ranges without precise figures, papers dealing with processed edible tree products mixed with additional ingredients, papers focused on other tree species of the same genus or papers only presenting amino acid or fatty acid profiles, which were outside the scope of this review.

Database compilation

After the selection, the remaining papers were used to extract nutrient data and to compile a first draft nutrient database in excel, using the INFOODS food component identifiers (tagnames) and the FAO/INFOODS compilation tool as a guide (FAO/INFOODS 2009; INFOODS 2012). Nutrients were entered in excel exactly in the way they were presented in the original paper, accompanied with units and methods used for the nutritional analysis or reference thereto. Huge variability was observed in the expression of units and denominators. Data were harmonized and recalculated into g (proximate), mg (minerals and antinutrients), or μg (vitamins) per 100 g fresh weight of edible portion (EP) to enable comparisons across studies. Some data were expressed on a dry matter (DM) basis, without providing moisture or DM percentages; these were recalculated on the basis of a 100 g fresh weight of edible portion (EP), using the average moisture content calculated from our database. The results of these recalculations were presented in a second draft nutrient database with standardized data. A data quality check was performed, further excluding any papers with implausible data. The sum of proximates (water, fat, protein, carbohydrate, fiber and ash) was checked and papers with values outside of the 95–105 g range were excluded. Some papers did not mention whether the data were expressed on a dry or a fresh weight basis. Therefore, assumptions had to be made following the example found in Stadlmayer et al. (2013). If the sum of proximates, excluding moisture content, totaled 100 or more, the assumption was that the values were reported on a dry weight basis and were therefore converted to a fresh weight basis. When only a few proximate values were reported, they were compared with values in the West African Food Composition Tables (WAFCT) for plausibility and papers with divergent values were excluded. Some papers were inconsistent/incoherent: e.g. the proximate composition was within the 95–105 range for one product and outside the range for another product. These papers were also completely excluded from the study. Mineral values were added up and those papers in which the sum of minerals was more than double the ash value were discarded (Stadlmayer et al. 2013). For vitamins or anti-nutrients, thresholds for quantitative checks were not available. After excluding all the cases above, a final database with harmonized values from selected papers was compiled and used as the basis for the review of nutrient values presented in this paper. Micro-nutrient values for *Parkia biglobosa* products available in the WAFCT were extracted and presented in our result tables (in the first line) in order to enable comparisons.

Data presentation and analysis

An overview table was constructed presenting the main characteristics of the studies selected for this review: author and year of publication, *P. biglobosa* product(s) analyzed, nutrients analyzed, number of lab replications carried out, origin of the samples (market or collected directly from the trees), geographical region and any further information regarding environmental or seasonal factors that might have influenced the nutrient composition presented in the paper. Some papers contained an imprecise description of sampling methods, sample preparation procedures, and/or about sampling sites. Furthermore, some papers did not specify the exact edible product analyzed and/or whether the lab analyses were conducted in replicates or not. Simple descriptive statistics were used to summarize results.

A geographic map was developed showing all the sampling sites reported in the final selection of articles retained for this review. This enabled to visualize the geographic distribution of the research conducted across the main ecoregions in West Africa, and to compare the spatial distribution of nutritional studies with the range of *P. biglobosa*. Those studies missing precise information regarding the sampling sites (beyond the country level) were positioned on the map using the geographic centroid value of the country were the research had been conducted, reported in the article.

Nutrient data from the final excel database were extracted and presented in separate tables for each of the nutrient categories considered (proximate, minerals, vitamins and anti-nutrients) and grouped based on the different *P. biglobosa* edible product examined (raw product, fermented product and pulp) for ease of comparison. Values presented in this review might slightly differ from the values found in the original papers, due to the conversions applied to harmonize units and denominators for all values.

A preliminary attempt to identify patterns in nutrient composition was made. However, the objective was not to directly compare values found in the various papers, given that the studies presented in the literature differed to a large extent in sampling strategy, product preparation and/or methods for laboratory analyses. Methodological procedures were compared with FAO/INFOODS recommended methods. Nutrient values derived from unknown or non-recommended methods were flagged in our tables; exceptions were made for vitamins (non-recommended methods were mostly used) and for anti-nutrients (no recommendations on methods were available). Papers referring to AOAC methods, without presenting further details or explanations, were assumed to have used the recommended methods for proximates and minerals. This assumption was not extended to vitamins and minerals.

Results

Metadata

Figure 5 shows an overview of the literature search process and data flow. The main search was performed in June 2018 in Google Scholar, using the keywords "*Parkia biglobosa*" AND nutrition; it generated 3500 hits which were all scanned for relevance against title and abstract. By repeating a thorough search in Food Science and Technology Abstracts (FSTA, the second most relevant database, as revealed by the first pilot screening of the literature), a total of five additional relevant references, not found in the previous search in Google Scholar, were included in the list of articles to be considered. This resulted in 108 papers for which full texts were collected in Zotero. Just one document, a dissertation, had to be excluded because it was inaccessible.

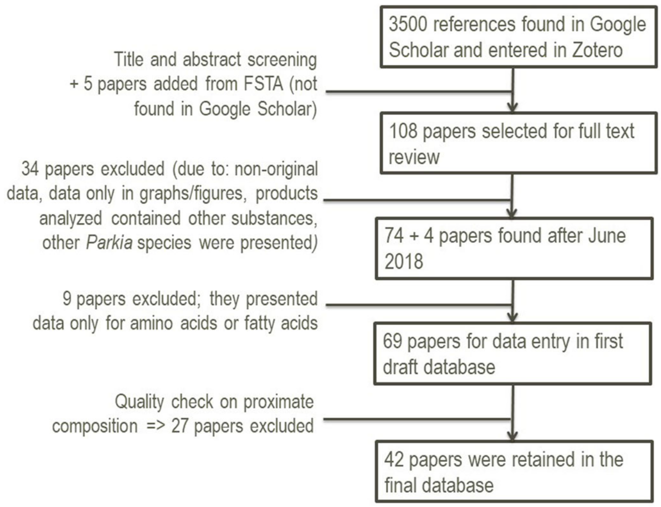

Figure 5. A flow diagram describing the different phases of the literature review, the number of records discarded and retained at each step, and the reasons for exclusion.

After reading the full content, 34 papers were excluded from the database based on the following reasons: they were review papers presenting non-original data, did not present exact values (data were only presented in graphs or ranges), only processed products had been analyzed mixing other ingredients with *P. biglobosa* seeds or pulp. Some papers reported the same data found in others. In cases of dataset "duplicates" between two different papers, only the first one published was retained. Finally, some papers did not match our expectations regarding content, e.g. the full text focused on a different *Parkia* species.

Subsequently, another four relevant papers published in the two months following the formal ending of the literature search were added. Nine papers were further excluded because they were only dealing with amino acids or fatty acid profiles. This brought down the number to 69 papers that were used to extract nutrient values for the different *P. biglobosa* edible products. On this basis, a first draft nutrient database was developed. Data were harmonized into the same units and denominators and this resulted in a second draft database. Further data quality checks on proximate values in the second draft database, led to the exclusion of another 27 papers. Finally, 42 papers provided the data for the final nutrient database. Only seven out of these 42 papers were consistent in mentioning the denominator (fresh weight EP or dry weight) for all nutrient categories presented. Eight papers mentioned a denominator for one nutrient category, but not for another. For 22 papers, we made assumptions regarding the denominator, based on the sum of the proximate values (see methods 2.2). Five papers did not present full proximate range data and nutrient values had to be compared with the WAFCT. Assumptions made on how the proximate values were expressed were extended to the other nutrients.

Table 1 provides an overview of key content from the 42 papers that made it into the final nutrient database: author and journal names, specific products analyzed, nutrient categories analyzed, number of replicate analyses in the laboratory, sample origins, geographical area and other environmental characteristics. The 42 papers selected were published in a wide range of journals in different science categories, from food and nutrition sciences to biology, chemistry, ethnobotany, agriculture, livestock, technology and applied biosciences. Papers from food and nutrition journals were not necessarily better in presenting correct units, denominators, sampling and analysis methods than papers from other journal categories. The analyzed products were treated and described in many different ways in the papers. Four papers did not clearly describe the edible products analyzed and referred to seed or pulp in general terms. In one case, it was necessary to make a "reasonable" guess about whether the product actually analyzed was pulp or seed. Given these heterogeneous elements across the selected papers, comparisons between papers to identify potential patterns in the nutrient composition according to geographical location, climate, soil or genetic parameters were not carried out. Other parameters that differed across papers were sampling strategies and laboratory methods used. Seven papers did not indicate whether laboratory analyses were carried out in duplicates or not, and four papers presented values of standard deviations in their results but did not mention the number of replicate analyses.

Table 2 summarizes the food product categories and nutrients analyzed in the different papers. Most studies analyzed fermented seed and presented proximate data. Figure 6 shows a map with the bioclimatic regions of West Africa and the location of the sampling sites of all 42 articles retained in this review, based on indication provided in the articles themselves. When only the region of sampling was indicated in the paper, we tagged the capital of that region on the map. Often, papers dealing with fermented products only mentioned the market where the product was bought (and not the origin of the product). Two papers (9 and 30) did not include further information on the sample location beyond the country; these studies were positioned in the centroid of the country and were marked with a different symbol (triangle). Four papers covered multiple sampling sites. The research presented in the 42 selected articles was mainly conducted in Nigeria (28), followed by Ghana (4), Benin, Burkina Faso, Chad and Ivory Coast (2 studies in each country) and Cameroon and Mali (1 study in each). Most study sites were located in the Guinean ecozone (23), followed by the Sudanian ecozone (17) and only six study sites fell in the Guineo-Congolian ecozone.

Nutrient database observations

Tables 3a, b, c; 4a, b, c; 5a, b, c and 6a, b, c present the proximate, mineral, vitamin and antinutrient content for raw seeds, fermented seeds and pulp products of *P. biglobosa*.

Proximate composition (Tables 3a, b and c)

The default methods used in the selected literature were mostly the FAO/INFOODS recommended methods for

Table 1. Summary characteristics of papers used for the review.

No	Author	Journal	Product	Nutrient analyzed[1]	Replicate	Product Source	Country	Region	Other information
1	Abey and Abey 2016	Food and Public Health	1. Seed dehulled, dried then milled 2. Seed dehulled, cooked for 6 hrs, dried then milled 3. Seed dehulled, irradiated at 5KGy, dried then milled 4. Seed dehulled, irradiated at 10KGy, dried then milled 5. Seed dehulled, irradiated at 10KGy, cooked for 6 hrs, dried then milled	Prox, Min, Anti	Triplicate	Whole seed obtained from market and processed in the laboratory	Nigeria	Oja, Oba, Akure, Ondo state	
2	Adamu and Oyetunde 2013	Leena and Luna International, Oyama, Japan	Whole seed, milled to powder	Prox, Min	NI	Whole seed obtained from the market	Nigeria	Oba market at Ikere, Ekitit state	
3	Afolayan et al. 2014	Journal of Emerging Trends in Engineering and Applied Sciences	Mature pulp, sun-dried	Prox, Min, Vit, Anti	NI	Collected from the grain deport	Nigeria	Giwa local government area, Kaduna state	procured between April and June
4	Aja, Offor, and Orji 2015	International Journal of Current Microbiology and Applied Sciences	Pulp dried and milled to powder	Prox, Anti	NI	Collected from Agara Oza village	Nigeria	Agara Oza village in Abakaliki, Ebonyi state	
5	Ajayi et al. 2018	African Journal of Food Science	Fermented seed oven dried at 65 °C for 20 hrs	Prox, Min, Vit, Anti	Triplicate	Freshly fermented seed obtained from the market	Nigeria	Oja Oba market in Ado-Ekiti, Ekiti state	
6	Akintayo, 2004	Bioresource Technology	Whole seed milled to powder	Prox	Triplicate	Not clear	Nigeria	Ado-Ekiti, Ekiti state	
7	Akubor, 2016	FVW Trends in Science and Technology Journal	Mature and ripe pulp sun-dried for 48 hrs	Prox, Min, Vit	Triplicate	Local farm	Nigeria	Ugwaka-Ollah township, Kogi state,	
8	Appiah et al. 2012	African Journal of Food Science	Fermented seed for 72 hrs then sun-dried for 4 hrs	Prox, Min	Triplicate	Fresh seeds from market fermented in laboratory	Ghana	Central market of Kumasi, Ashanti region	
9	Azokpota, Hounhouigan, and Nago 2006	International Journal of Food Microbiology	Fermented seed for 24 hrs	Prox	Triplicate	Laboratory fermentation	Benin		
10	Bamigboye et al. 2012	Nigerian Journal of Nutrient sciences	1. Fermented seed for 72 hrs then analyzed for vitamins 2. Fermented seed for 72 hrs, oven dried at 60 °C for 18 hrs, milled then analyzed for minerals	Min, Vit	NI but SD presented	Seed sample obtained from market and fermented in a laboratory	Nigeria	Bodija market in Ibadan	
11	Boateng et al. 2014	1. Livestock research for	1. Seed: no description 2. Fermented seed for 4 days then sun-dried	Prox, Min	6 replicates	Seeds from market then fermented in laboratory	Ghana	Kumasi market	

		rural development						
12	Borquaye et al. 2017	Cogent Food and Agriculture	Fermented seed (spices): from market	Prox, Min, Vit, Anti	Triplicate	Fermented seed obtained from the market	Ghana	Asafo and Kejetia markets in Kumasi
13a	Camara et al. 2016a	International Journal of Biological and Chemical sciences	Mustard: fermented	Prox	Triplicate	Fermented seed obtained from the market	Ivory Coast	Korhogo (Local production)
13b	Camara et al. 2016a	International Journal of Biological and Chemical Sciences	Mustard: fermented	Prox	Triplicate	Fermented seed obtained from the market	Ivory Coast	Abidjan (from Korhogo, Guinea and Burkina Faso)
13c	Camara et al. 2016a	International Journal of Biological and Chemical Sciences	Mustard: fermented	Prox	Triplicate	Fermented seed obtained from the market	Ivory Coast	Bouake: (local production, Guinea and Burkina Faso)
14	Camara et al. 2016b	African Journal of Food Science	Nere mustard: fermented	Prox, Min	Triplicate	Fermented seed obtained from the market	Ivory Coast	Korhogo
15	Dosumu et al. 2012	Nigerian Food Journal	1. Fermented seed naturally without catalyst (woro) 2. Fermented seed with a catalyst (pete)	Prox, Min	Duplicate	Fermented seed (condiments) from market	Nigeria	Pata market in Ilorin, North Central Nigeria
16	Egbebi, Seidu, and Muhammad 2016	Savant journal of Agricultural Research	Fermented seed (iru)	Prox, Anti	NI	Fermented seed (iru) obtained from market	Nigeria	Oja Oba market at Ado-Ekiti, Ekiti state
17	Esenwah and Ikenebomeh 2008	Pakistan Journal of Nutrition	1. Seed boiled for 8 hrs then dehulled 2. Processed seed: The dehulled seed boiled for 30 mins 3. Processed (hydrated) seed fermented at 37 °C for 24 hrs 4. Processed (hydrated) seed fermented at 37 °C for 48 hrs 5. Processed (hydrated) seed fermented at 37 °C for 72 hrs	Prox, Anti	Four replicates	Dry raw bean seeds obtained from the market then processed/ fermented in laboratory	Nigeria	Kawo Market, Kaduna state
18	Ezugwu, Okoye, and Ene 2018	International Journal of Food Science and Nutrition	1. Seed dehulled, dried at 60 °C for 6 hrs, then milled 2. Seed boiled at 100 °C for 8 hrs, dehulled, dried at 60 °C for 10 hrs then milled 3. Fermented seed at 29 °C for 48 hrs, dried at 60 °C for 12 hrs then milled	Prox, Min, Anti	Triplicate	Mature bean seed obtained from the market then processed/ fermented in laboratory	Nigeria	Ogige market in Nsukka, Enugu state

(continued)

Table 1. Continued.

No	Author	Journal	Product	Nutrient analyzed[1]	Replicate	Product Source	Country	Region	Other information
			4. Fermented seed at 29 °C for 72 hrs, dried at 60 °C for 12 hrs then milled						
19	Gouado et al. 2007	Pakistan Journal of Nutrition	Dried fruit (pulp)	Vit	Triplicate	Dried fruit obtained from the market	Cameroon	Ngaoundere market, Adamaoua province	Samples bought in January 2004
20	Ibeabuchi, Ojukwu, and Ijeoma 2013	Natural Products, An Indian Journal	1. Seed powdered: no clear description 2. Fermented seed for 96 hrs (iru) powdered	Prox	NI	Raw seed from market and fermented in laboratory	Nigeria	Nsukka market, Enugu state	
21	Ifesan, Akintade, and Gabriel-Ajobiewe 2017	International Food Research Journal	1. Seed cooked for 2 hrs, dehulled then fermented for 36 hrs at 30 °C 2. Seed cooked for 2 hrs, dehulled, pressure cooked for 15min then fermented for 36 hrs at 30 °C 3. Seed cooked for 2 hrs, dehulled, pressure cooked for 30 min then fermented for 36 hrs at 30 °C	Prox, Min	Triplicate	Seeds obtained from the market and processed/ fermented in laboratory	Nigeria	Local market in Akure	
22	Iheke et al. 2017	American Journal of Food Technology	1. Seed dehulled by cracking, dried for 7 days then milled 2. Seeds cooked for 5hrs, dehulled, cook for 1 hr, fermented for 4 days, sun-dried for 4 days then milled	Prox, Min, Anti	NI but SD presented	Raw and dried seed obtained from the market	Nigeria	Kings market in Osun-Ekiti, Ekiti state	
23	Ijarotimi and Keshinro 2012	Acta scientiarum Polonarum	1. Seeds dehulled, oven dried them milled 2. Seeds soaked for 7 days, dehulled, cooked for 1 hr the fermented for 1 day, dried at 60 °C for 20 hrs then milled	Prox, Min, Anti	Triplicate	Seeds obtained from the market, processed/ fermented in laboratory	Nigeria	Erekensan market, Akure	
24	Kayalto et al. 2013	Food and Nutrition Sciences	Pulp powder	Prox, Min, Vit	Triplicate	Pulp obtained from market	Chad	Kelo, 370km south of N'Djamena	Analyzed between July 2011 to April 2012
25	Jide et al. 2018	The Pharmaceutical and Chemical Journal	Dehulled seed, dried and grounded	Prox	Triplicate	Raw seed from the market	Nigeria	Owo main market in Oja Oba, Ondo state	
26a	Koura et al. 2014	Journal of Applied Biosciences	Dehulled seed	Prox	Triplicate	Collected from natural stands	Benin	Materi, Toucountouna and Natitingou villages in Atacora Department	

26b	Koura et al. 2014	Journal of Applied Biosciences	Dehulled seed	Prox	Triplicate	Collected from natural stands	Benin	Parakou, Sinende and Kalale villages in Borgou Department	
27	Kronborg et al. 2014	Ethnobotany Research and Applications	1. Fermented seed: high-quality soumbala 2. Fermented seed: low-quality soumbala	Prox, Vit	Triplicate	Soumbala obtained from market in ten villages	Burkina Faso	Cascade region, Comoe province	- Collected in November to December 2010 and in November 2011 - South-Sudanian zone - Temperature, rainfall and vegetation well described
28	Lockett, Calvert, and Grivetti 2000	International Journal of Food Sciences and Nutrition	1. Seed: no description 2. Fruit: no description	Prox, Min	Duplicate	Collected from communities	Nigeria	Adamawa state	
29a	Makalao et al. 2016	International Journal of Biological and Chemical Sciences	Pulp dried	Prox, Min, Vit	Duplicate	Market	Chad	Bongor, Mayo-Kebbi Department	- Analyzed between June 2012 to May 2013 - Sahelo-Sudanian zone
29b	Makalao et al. 2016	International Journal of Biological and Chemical Sciences	Pulp dried	Prox, Min, Vit	Duplicate	Market	Chad	Gaya, Kabbia Department	- Analyzed between June 2012 to May 2013 - Sudanian zone
29c	Makalao et al. 2016	International Journal of Biological and Chemical Sciences	Pulp dried	Prox, Min, Vit	Duplicate	Market	Chad	Lai, Tadjile Department	Aanalyzed between June 2012 to May 2013 - Sudanian zone
30	Nadro and Umaru 2004	Nigerian Journal of Biotechnology	1. Pulp powder: harvested during dry season 2. Pulp powder: harvested during wet season	Prox, Vit	6 replicates	Harvested during dry and wet seasons	Nigeria		harvested during dry and wet season
31	Ndukwe and Solomon 2017	International Journal of Biochemistry Research and Review	1. Seed: no description 2. Fermented seed (dawadawa)	Prox, Anti, Min	Triplicate	Both raw and fermented seed obtained from market	Nigeria	Tildey market along bauchi	
32	Nordeide et al. 1996	International Journal of food Sciences and Nutrition	1. Fermented seed: dried 2. Pulp flour: dried	Prox, Min, Vit	NI	Fermented seed and flour from the market	Mali	Koutiala	Samples collected in May 1994
33	Nyadanu et al. 2017	Genetic Resources and Crop Evolution	1. Seed dried, dehulled then milled to powder 2. Pulp dried then milled to powder	Prox	NI but SD presented	Harvested from the villages	Ghana	Asante Mampong, Atebubu, Yeji and Kwame danso in Transitional zone of Ghana. *Coordinates for Atebubu was*	-Transitional zone - Vegetation, rainfall, agro-ecological zone and ethnic group presented

(*continued*)

Table 1. Continued.

No	Author	Journal	Product	Nutrient analyzed[1]	Replicate	Product Source	Country	Region	Other information
								used to generate map	
34	Ogunyinka et al. 2017	Food Science and Nutrition	Fermented seed, oven dried at 50 °C then milled	Prox, Min, Anti	Triplicate	Fermented seed from the market	Nigeria	Ijebu-ode, Ogun state	
35	Okpala, 1990	Nigerian Journal of Botany	1. Mature seed dried at 60 °C then dehulled 2. Mature fruit dried at 60 °C then pulped	Prox, Min	Triplicate	Harvested from trees within the campus	Nigeria	Zaria, Kaduna state	Samples collected between 10 May to 19 July 1984
36	Oladele and Agunbiade 2018	Octa Journal of Biosciences	Fermented seed after 7-day storage	Prox, Min	Triplicate	Fermented seed obtained from market	Nigeria	Irese market, Akuro ondo state	
37	Oluwaniyi and Bazambo 2014	Global Journal of Pure and Applied Sciences	1. Raw seed milled 2. Partially fermented seed, milled then dried 3. Completely fermented seed, milled then dried	Anti	Triplicate	Raw seed handpicked from tree; fermented seed obtained from a local market	Nigeria	Ilorin	
38	Omafuvbe et al. 2004	Pakistan Journal of Nutrition	1. Raw whole seed 2. Seed boiled for 12 hrs then dehulled 3. Seed boiled, dehulled then fermented for 72 hrs	Prox, Vit	NI but SD presented	Seeds obtained from local market and processed in local factories	Nigeria	Ile-ife	
39	Osuntogun et al. 2004	Pakistan Journal of Nutrition	1. Seed: no description 2. Fermented seed (Iru): no description	Min, Anti	4 or 3 replicates	Obtained from market	Nigeria	Ile-ife	
40	Thiombiano et al. 2014	African Journal of Biotechnology	Pulp milled and dried	Prox, Min	triplicate	Collected from three households	Burkina Faso	Saria, Boulbi, Kokologho, Noumoudara, Sakoinse, Pobe-Mengao *Coordinates for Kokologho was used to generate map*	
41	Umaru et al. 2007	African Journal of Biotechnology	Pulp dried at room temperature then milled to powder	Anti	Triplicate	Collected from Numan local government area	Nigeria	Numan local government area, Adamawa state	Collected between April and May 2005
42a	Urua et al. 2013	International Journal of food Sciences and Nutrition	1. Whole seed soaked for 12 hrs, sun-dried then milled: from Obudu 2. Dehulled seed after boiling for 40min then sun-dried then milled: from Obudu 3. Fermented for 72 hrs, sun-dried then milled: Obudu	Prox, Anti	NI	Mature seed collected and processed in a laboratory	Nigeria	Indi-abed in Obudu in northern across river state	Collected in September 2010

42b	Urua et al. 2013	International Journal of food Sciences and Nutrition	1. Whole seed soaked for 12 hrs, sun-dried then milled: from Boki 2. Dehulled seed after boiling for 40 min then sun-dried then milled: from Boki 3. Fermented for 72 hrs, sun-dried then milled: from Boki	Prox, Anti	NI	Mature seed collected and processed in a laboratory	Nigeria	Bafin in Boki in northern across river state	Collected in September 2010
42c	Urua et al. 2013	International Journal of food Sciences and Nutrition	1. Whole seed soaked for 12 hrs, sun-dried then milled: from Obanliku 2. Dehulled seed after boiling for 40 min then sun-dried then milled: from Obanliku 3. Fermented for 72 hrs, sun-dried then milled: Obanliku	Prox, Anti	NI	Mature seed collected and processed in a laboratory	Nigeria	Sankwala in Obanliku LGAs in northern across river state	Collected in September 2010

Key: Prox: proximate composition ; Min: minerals; Vit: vitamins; Anti: anti-nutrient ; NI: Not Indicated.

proximate composition: oven drying for moisture content, Kjeldahl method with 6.25 conversion factor for crude protein, Soxhlet solvent extraction for crude fat, dry ashing for ash and (total or available) carbohydrates by difference. Exceptions to these methods were indicated in Table 3. Most fiber values were expressed as the least recommended crude fiber component, unless otherwise indicated (see details in Table 3).

Moisture content for the unfermented seeds ranged from 1.2 to 13.06 g/100 g EP, protein content from 20.93 to 36.46 g/100 g EP, fat content from 8.06 to 32.02 g/100 g EP; ash content from 1.2 to 5.9 g/100 EP, fibers from 0.39 to 17.37 g/100 g EP and available carbohydrates from 13.2 to 54.21 g/100 g EP. These values were within the range of the values presented in the WAFCT (Stadlmayer et al. 2012).

Moisture content for the fermented seeds ranged from 4.92 to 63.5 g/100 g EP, protein content from 3.22 to 49.69 g/100 g EP, fat content from 7.44 to 37.13 g/100 g EP; ash content from 0.56 to 8.26 g/100 g EP, fibers from 1.49 to 14.3 g/100 g EP and available carbohydrates from 0.09 to 53.5 g/100 g EP. No values for fermented seeds were available in the WAFCT. Moisture content for pulp ranged from 4.5 to 13.2 g/100 g EP, protein content from 0.62 to 6.89 g/100 g EP, fat content from 0.8 to 25.62 g/100 g EP; ash content from 2.47 to 8.36 g/100 g EP, fibers from 2.55 to 14.23 g/100 g EP and available carbohydrates from 32.2 to 80.8 g/100 g EP. All values, except for paper 4 (lowest range for protein and fiber; low in carbohydrates and very high in fats) and 30 (highest ranges for protein and fat; very low in carbohydrates) were within the range of the WAFCT values. Some papers presented total carbohydrates, other papers available carbohydrates. Carbohydrates were mostly calculated by difference (100 minus the other proximate values, including or not fiber). The comparison of nutritional values for unfermented and fermented products within the same paper, when both products were analyzed, showed that moisture and fat content mostly increased with fermentation, while ash, fiber and carbohydrate content decreased. For protein, the pattern was unclear (sometimes it increased, sometimes it decreased).

Four papers (13, 26, 29, 42) compared nutritional data of samples collected at different locations. The first paper (13) compared fermented products bought from three different markets in Ivory Coast and indicated that the products were processed differently according to the customs of the different ethnic groups. Products bought on the Korhogo market were processed locally, products on the Abidjan market originated from Korhogo (Ivory Coast), Guinea or Burkina Faso, and products on the Bouake market from Bouake (Ivory Coast), Guinea or Burkina Faso. The second paper (29) presented data for *P. biglobosa* pulp bought in three markets from different regions in Chad (all within the Sudanian agro-ecological zone, see Figure 6). Unfortunately, the exact origin of the pulp bought on the market could not be determined, so this study did not enable an assessment of nutrient differences among provenances. At the same time, the differences in proximate composition of different samples within this paper were quite small compared to the differences with values reported in other papers. The third paper presented data for whole seeds, dehulled seeds and fermented seeds from the Guineo-Congolian zone (42a and 42c on the map in Figure 6) and a location at the border of the Sudanian and Guinean agro-ecological zone (42b). No pattern could be identified for any nutrient, looking for consistently highest or lowest values within a certain origin for all three products. The fourth paper (26) compared data for dehulled seeds from three villages in Atacora Department (Sudanian agro-ecological zone) and three villages in Borgou Department (Guinean agro-ecological zone) in Benin. The moisture content of dehulled *P. biglobosa* seeds was higher for all three villages in Borgou compared to all three villages in Atacora, while the protein content was systematically higher in Atacora than in Borgou. Fat content (higher in Atacora) and ash content (higher in Borgou) followed a similar pattern, but with very small differences. We observed that values extracted from within a paper (comparing different locations or product treatments, etc.) presented less variation than the values for the same product treatment presented by different authors.

Table 2. Summary table with number of papers presenting data for the different *Parkia biglobosa*'s food products and the different nutrient categories.

Products	N	Proximate	Vitamins	Minerals	Ani-nutrients
Unfermented seed	20	18	1	10	9
Fermented seed	25	22	6	16	12
Pulp	13	11	7	8	3

Minerals (Tables 4a, b and c)

Less data were available for mineral composition of edible *P. biglobosa* products. Calcium, magnesium, iron and zinc were the most analyzed minerals, with fewer papers dealing with manganese, sodium, potassium, copper or phosphorus. Most papers followed the FAO/INFOODS recommended methods: Atomic Absorption Spectroscopy for iron, zinc, calcium, magnesium, manganese and cupper; and flame photometry for the analysis of sodium and potassium. In Table 4, values obtained from unknown or non-recommended methods were indicated with superscripts. For phosphorus, FAO/INFOODS recommendations suggest either colorimetry or ICP-MS (Inductively Coupled plasma Mass Spectrometry). In four papers the phosphovanado molybdate (yellow) colorimetric method was used; in all other papers, methods that were not in the FAO/INFOODS lists were used, therefore they were indicated as unknown or non-recommended ("other methods used"). All values were recalculated as mg/100 g EP, however, in many cases, assumptions had to be made regarding denominators. Ranges of mineral content varied widely among authors, up to five orders of magnitude, from as low as 0.21 mg/100 g EP up to 49780 mg/100 g EP for sodium content in fermented seeds. Paper 35 reported the highest values for magnesium, potassium and phosphorus, the second highest level of calcium in unfermented seeds, the highest values of calcium and phosphorus in the pulp. Paper 34 seemed to present systematically high

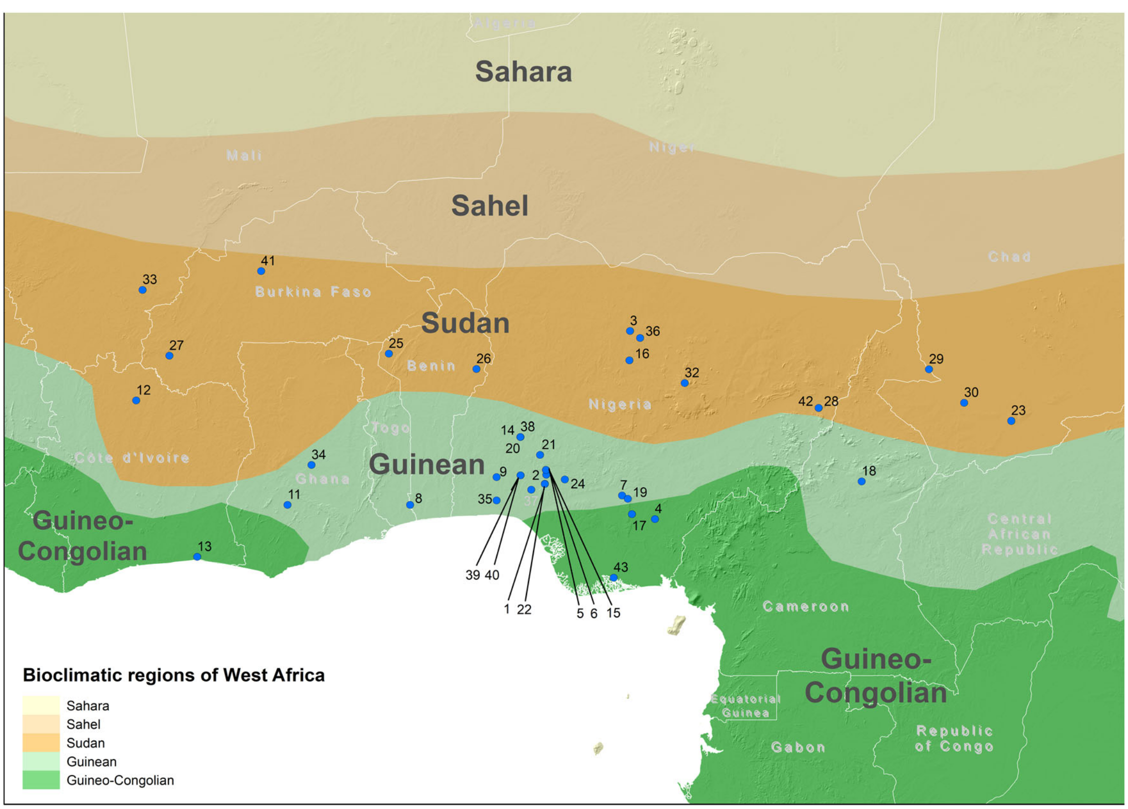

Figure 6. Map with location of the sampling sites reported in the 42 articles retained for this literature review. The main bioclimatic regions of West Africa are delineated based on annual rainfall (adapted from CILSS 2016). The positioning of the sampling sites is based on indications provided in each individual paper. The numbering of the sites in the map corresponds with the numbering of the articles in this review (see list of the 42 references in Table 1). If the original article mentioned only the region of sampling and not the precise site, the point on the map was located in correspondence of the capital of that region. When only the country was indicated in the article (n. 9 and 30), the point on the map was marked with a different symbol (triangle), positioned in correspondence with the geographic centroid of the country. Multiple letters associated with the same number indicate that multiple sites were investigated in the specific paper.

Table 3a. Proximate composition for raw *Parkia biglobosa* seed products in g/100g fwb.

No	Product	Energy Kj (Kcal)	MC	Protein	Fat	Ash	Crude Fiber	CHO Available	Total CHO
	Dried seed*	1860 (444.55)	7.0	32.3	19.5	4.1	4.1	33.0	
1	Seed dehulled, dried then milled	1973.90 (471.77)	4.59 ± 0.13	31.32 ± 4.49	32.37 ± 4.59	5.90 ± 4.59	5.31** ± 4.59	19.51 ± 4.59	
1	Seed dehulled, cooked for 6 hrs, dried then milled	2015.82 (481.79)	4.5 ± 0.24	30.45 ± 0.11	32.53 ± 0.10	5.70 ± 0.03	5.00** ± 0.01	19.63 ± 0.23	
1	Seed dehulled, irradiated at 5KGy, dried then milled	1977.90 (472.73)	4.53 ± 0.09	31.25 ± 0.12	32.03 ± 0.11	5.62 ± 0.03	5.56** ± 0.02	20.59 ± 0.28	
1	Seed dehulled, irradiated at 10KGy, dried then milled	1971.75 (471.26)	4.57 ± 0.1	31.0 ± 0.12	32.32 ± 0.09	5.49 ± 0.02	5.34** ± 0.02	20.49 ± 0.25	
1	Seed dehulled, irradiated at 10KGy, cooked for 6 hrs, dried then milled	2047.41 (489.34)	4.64 ± 0.12	30.72 ± 0.11	32.46 ± 0.11	5.49 ± 0.04	5.45** ± 0.02	20.42 ± 0.40	
2	Whole seed, milled to powder		1.32	33.89	8.06	3.07	0.39	53.27	
6	Whole seed milled to powder		10.18 ± 0.02	32.4 ± 1.2	26.52 ± 1.02	1.2 ± 0.12	16.6 ± 0.8	13.2	
11	Seed: no clear description		11.9	27.5	13.2	5.62	12.4	29.4	
17	Seed boiled for 8 hrs then dehulled by removing the testae****		7.76	24.91 ± 1.13	18.28 ± 1.01	4.38 ± 0.33			44.66
17	Processed seed: the dehulled seed boiled for 30 min****		7.76	25.39 ± 1.15	24.20 ± 1.06	3.44 ± 0.25			39.20
18	Seed dehulled by cracking, dried at 60 °C for 6 hrs, then milled to powder	160084 (382.61)	9.45 ± 0.04	21.26 ± 0.06	10.31 ± 0.01	4.19 ± 0.01	3.84 ± 0.04	45.8 ± 3.54	
18	Seed boiled at 100 °C for 8 hrs , dehulled, dried at 60 °C for 10 hrs then milled	1584.02 (378.59)	10.06 ± 0.03	21.24 ± 0.06	10.71 ±0.06	3.93	3.66 ± 0	54.21 ± 0.01	
20	Seed powdered : no description		1.2	32.04	15.33	5.24	9.50	35.60	
22	Seed dehulled by cracking, dried for 7 days then milled		5.95 ± 0.21	35.65	27.82 ± 0.33	4 ± 0	5.55 ± 0.07	21.04 ± 0.6	
23	Seeds dehulled, oven dried them milled	1852.63 (442.79)	7.76	31.03 ± 0.37	16.80 ± 0.35	3.68 ± 0.45	7.45 ± 0.33	33.28 ± 0.22	
25	Dehulled seed, dried and grounded		11.21 ± 0.51	25.52 ± 0.31	20.65 ± 0.71	5.45 ± 0.25	8.4 ± 0.21	28.77 ± 0.25	
26a	Dehulled seed: Atacora department from Natitingou village		9.13	24.43 ± 0.51	20.50 ± 0.35	3.3 ± 0.01			
26a	Dehulled seed: Atacora department from Materi village		9.71	30.43 ± 0.57	19.66 ± 0.26	3.24 ± 0.06			
26a	Dehulled seed: Atacora department from Toucountouna village		9.57	25.53 ± 0.2	19.88 ± 0.86	3.17 ± 0.01			
26b	Dehulled seed: Borgou department from Sinende village		12.91	21.54 ± 0.66	18.81 ± 0.36	3.35 ± 0			
26b	Dehulled seed: Borgou department Kalale village		13.06	21.51 ± 0.57	18.47 ± 0.55	3.82 ± 0.52			
26b	Dehulled seed: Borgou department Parakou village		11.57	22.09 ± 2	17.15 ± 0.81	3.61 ± 0			
28	Seed: no description		7.76	27.73	14.70	4.59	14.84	30.37	
31	Seed: no description	1515.53 (362.22)	7.85 ± 0.05	32.76 ± 0.21	13.9 ± 0.5	5.6 ± 0.1	17.37 ± 0.32	22.52 ± 0.27	
33	Seed dried, dehulled then milled to powder		9.27 ± 0.52	20.93 ± 0.83	26.33 ± 0.69	3.91 ± 0.28	4.92** ± 0.19	34.18 ± 0.48	
35	Mature seed dried at 60 °C then dehulled			31.6				47.63	
38	Raw whole seed		8.6 ± 0.6	28.33 ± 0.64	16.18 ± 0.18	4.94 ± 0.27	10.69 ± 0.18	31.99 ± 0.46	
38	Seed boiled for 12 hrs then dehulled		51.9 ± 0.7	15.10 ± 0.096	10.05 ± 0.14	1.54 ± 0.144	2.21 ± 0.048	20.20 ± 0.19	
42a	Whole seed soaked for 12 hrs, sun-dried then milled from Obudu		7.02 ± 0.05	27.64 ± 0.06	17.42 ± 0.03	4.12 ± 0.08	4.8 ± 0.05	39.01 ± 0.05	
42a	Dehulled seed after boiling for 40 min, sun-dried then milled from Obudu		6.4 ± 0.02	29.75 ± 0	10 ± 0.02	1.85 ± 0.12	10.17 ± 0.03	41.83 ± 0.09	
42b	Whole seed soaked for 12 hrs, sun-dried then milled from Boki		7.59 ± 0	31.5 ± 0	8.32 ± 0.03	4.43 ± 0.03	6.27 ± 0.03	41.53 ± 0.05	
42b	Dehulled seed after boiling for 40 min, sun-dried then milled from Boki		6.63 ± 0.01	27.64 ± 0.12	27.22 ± 0.01	2.17 ± 0.01	6.23 ± 0.03	30.11 ± 0.16	
42c	Whole seed soaked for 12 hrs, sun-dried then milled from Obanliku		6.4 ± 0	25.89 ± 0.06	9.5 ± 0.01	4.35 ± 0.02	6.8 ± 0.05	47.06 ± 0.05	
42c	Dehulled seed after boiling for 40 min, sun-dried then milled from Obanliku		6.02 ± 0.01	36.46 ± 0.06	19.63 ± 0.01	2.95 ± 0.61	7.32 ± 0.05	27.62 ± 0.06	

Table 3b. Proximate composition for fermented *Parkia biglobosa* seed products in g/100g fwb.

No	Product	Energy Kj (Kcal)	MC	Protein	Fat	Ash	Crude Fiber	CHO, Available	Total CHO
5	Fermented seed oven dried at 65 °C for 20 hrs		4.92 ± 0.02	17.40 ± 0.01	8.75 ± 0.02	8.26 ± 0.01	2.48 *** ± 0.01	53.50 ± 0.07	
8	Fermented seed for 72 hrs then sun dried for 4 hrs		10.23 ± 0.07	49.69 ± 0.04	26.85 ± 0.07	4.32 ± 0.04	1.49 ± 0.1	7.43 ± 0.01	
9	Fermented seed for 24 hrs		21.55	31.93 ± 0.47	28.32 ± 0.16	5.02 ± 0.08	2.82 ± 0.08	10.36 ± 0.16	
11	Fermented seed for 4 days then sun dried		18.9	36.8	16.6	3.38	4.51	19.8	
12	Fermented seed (spices): from market	1452.56 (347.17)	32.79 ± 0.08	38.6 ± 2.24	19.13 ± 0.33	0.56 ± 0.28	5.52** ± 0.18	3.4	
13a	Mustard: fermented (Korhogo)	2146.22 (512.96)	15.35 ± 3.28	30.48 ± 3.65	37.13 ± 2.69	2.81 ± 0.06			14.21 ± 3.49
13b	Mustard: fermented (Abidjan)	1848.78 (441.87)	23.86 ± 4.09	28.47 ± 3.1	26.66 ± 2.88	4.25 ± 0.06			16.74 ± 1.92
13c	Mustard: fermented (Bouake)	1889.49 (451.60)	19.55 ± 3.66	28.84 ± 5.74	29.2 ± 3.34	4.04 ± 1.32			18.35 ± 0.61
14	Nere mustard: Fermented (Korhogo)	2101.08 (502.17)	14.57 ± 2.01	33.98 ± 3.03	34.53 ± 3.64	3.05 ± 0.42			13.87 ± 3.27
15	Fermented seeds naturally without a catalyst (woro)	1720.38 (411.18)	25.41 ± 0.6	24.09 ± 1.2	25.42 ± 0.9	3.57 ± 1.4			21.51
15	Fermented seeds with a catalyst (pete)	1716.28 (410.20)	27.01 ± 0.6	26.13 ± 0.7	27.56 ± 0.4	4.85 ± 1.5			14.42
16	Fermented seed (iru)		26.61	16.98	18.38	3.97	11.79	22.28	
17	Processed (hydrated) seed fermented at 37 °C for 24 hrs****		21.55	24.77 ± 0.37	20.80 ± 0.60	2.71 ± 0.09			30.18
17	Processed (hydrated) seed fermented at 37 °C for 48 hrs****		21.55	25.04 ± 1.14	22.08 ± 0.64	2.60 ± 0.16			28.73
17	Processed (hydrated) seed fermented at 37 °C for 72 hrs****		21.55	25.74 ± 0.31	27.25 ± 1.14	2.59 ± 0.24			22.88
18	Fermented seed at 29 °C for 48hrs, dried at 60 °C or 12 hrs then milled	2.877.17 (687.66)	9.66 ± 0	21.45 ± 0.04	11.19 ± 0	3.37 ± 0.03	3.54 ± 0.05	49.99 ± 0.08	
18	Fermented seed at 29 °C for 72 hrs, dried at 60 °C or 12 hrs then milled	1626.86 (388.83S)	9.74 ± 0.06	22.62 ± 0.01	11.32 ± 0.01	3 ± 0.14	3.25 ± 0.04	49.66 ± 0.11	
20	Fermented seed for 96hrs (iru) powdered		11.3	39.5	17.3	2.39	7.4	23.02	
21	Seed cooked for 2 hrs, dehulled then fermented for 36 hrs at 30 °C		10.21 ± 0.08	26.73 ± 0.61	37.91 ± 0.90	3.56 ± 0.04	14.30 ± 0.13	7.27 ± 0.59	
21	Seed cooked for 2 hrs, dehulled, pressure cooked for 15 min then fermented for 36 hrs at 30 °C		6.63 ± 0.07	25.88 ± 0.05	31.04 ± 0.10	0.60 ± 0.02	13.36 ± 0.18	22.48 ± 0.26	
21	Seed cooked for 2 hrs, dehulled, pressure cooked for 30 min then fermented for 36 hrs at 30 °C		7.49 ± 0.04	35.36 ± 0.08	33.41 ± 0.43	0.86 ± 0.02	7.40 ± 0.02	15.46 ± 0.39	
22	Seeds cooked for 5hrs, dehulled, cook for 1hr, fermented for 4 days, sun dried for 4 days then milled		9.47 ± 0.01	37.87 ± 0.06	34.44 ± 0.01	2.84 ± 0	3.25 ± 0.07	12.14 ± 0.08	
23	Seeds soaked for 7 days, dehulled, cooked for 1hr, fermented for 1 day, dried at 60 °C for 20 hrs then milled	1500.69 (358.67)	21.55	27.74 ± 0.18	14.61 ± 0.15	1.84 ± 0.16	5.22 ± 0.39	29.034 ± 0.30	
27	Fermented seed: high quality soumbala		11	33.15	19.25 ± 2.79	2.79			33.80
27	Fermented seed: low quality soumbala		13.6	31.64	19.60 ± 3.08	3.076			32.09
31	Fermented seed (dawadawa)	1516.28 (362.4)	24.66 ± 0.06	31.38 ± 0.06	26.28 ± 0.05	2.42 ± 0.06	15.17 ± 0.15	0.09 ± 0.12	
32	Fermented seed: dried	2786.54 (666.0)	6	37.2	35.5	6.7			14.6
34	Fermented seed, oven dried at 50 °C then milled	1966.48 (470.0)	7.3 ± 0.3	32.4 ± 0.21	25.1 ± 0.11	4.3 ± 0.3	9.5 ± 0.32	21.4 ± 0.12	
36	Fermented seed after 7 day storage		63.5 ± 0.25	3.22 ± 0.3	7.44 ± 0.06	1.78 ± 0.2	11.83 ± 0.28	12.14 ± 0.24	
38	Seed boiled, dehulled then fermented for 72 hrs		44.1 ± 0.8	11.12 ± 0.44	20.29 ± 0.28	1.68 ± 0	8.72 ± 0.22	14.09 ± 0.67	
42a	Fermented for 72 hrs, sun-dried then milled from Obudu		13.47 ± 0.01	27.19 ± 0.06	30.75 ± 0.01	2.38 ± 0.01	2.63 ± 0.07	23.58 ± 0.07	
42b	Fermented for 72 hrs, sun-dried then milled from Boki		13 ± 0	34.64 ± 0.06	32.4 ± 0.01	2.67 ± 0.09	4.7 ± 0.05	12.59 ± 0.17	
42c	Fermented for 72 hrs, sun-dried then milled from Obanliku		14.83 ± 0.15	29.59 ± 0.15	32.65 ± 0.03	2.27 ± 0.11	5.4 ± 0.05	15.26 ± 0.14	

Table 3c. Proximate composition for *Parkia biglobosa* pulp products in g/100g fwb.

No	Product	Energy Kj (Kcal)	MC	Protein	Fat	Ash	Crude Fiber	CHO, Available	Total CHO
	Pulp flour*	1410 (337.0)	7.7	4.6	1.3	4.1	13.3	69	
3	Mature pulp, sun-dried		11.55	3.19	1.84	6.86	6.03	66.39	
4	Pulp dried and milled to powder		10.4	0.62	25.62	3.75	2.55	57.06	
7	Mature and ripe pulp sun-dried for 48 hrs	1429.25 (341.60)	10	2.8	0.8	2.9	2.7	80.8	
24	pulp powder	1272.10 (304.04)	13.2 ± 0.22	4.59 ± 0.22	2.49 ± 0.65	5.17 ± 0.29			
28	Fruit: no description		10.59	4.55	1.83	8.05	14.23	64.51	
29a	Dried pulp from Mayo-Kebbi department (Bongor)	1121.6 (268.07)	4.7 ± 0.29	5.62 ± 0	1.94 ± 0.08	7.78 ± 0.1			
29b	Dried pulp from Kabbai department (Gaya)	1111.06 (265.55)	5.62 ± 0.23	5.77 ± 0.31	2.23 ± 0.01	7.67 ± 0.04			
29c	Dried pulp from Tandjile department (Lai)	1138.8 (272.18)	4.83 ± 0.47	6.56 ± 0.15	1.94 ± 0.07	7.96 ± 0			
30	Pulp powder: harvested during dry season		11.30 ± 2.04	8.5 ± 0.07	36.8 ± 1.86	5.73 ± 0.37			37.66 ± 2.01
30	Pulp powder: harvested during wet season		15.83 ± 0.78	7.5 ± 0.92	37.10 ± 2.1	7.47 ± 1.21			30.7 ± 0.46
32	Pulp flour: dried	1677.78 (401.0)	4.5	3.3	2.3	5.4			84.5
33	Pulp dried then milled to powder		12.93 ± 0.02	2.15 ± 0.34	1.33 ± 0.05	2.47 ± 0.11	6.9** ± 0.26	74.22 ± 0.46	
35	Mature fruit dried at 60 °C then pulped			3.18				32.2	
40	Pulp milled and dried	1472.56 (351.95)	9.94	3.78 ± 0.01	1.99 ± 0.01	4.98 ± 0.01			79.73 ± 1.69

Each value is a mean of independent replications ± SD. Values without SD were presented in respective papers without SD. Blank values were not determined.
*Reference values adopted from West African food composition table (Stadlmayr et al. 2012). This was not based on the quality of its data but on the authenticity of the document.
**Unknown whether crude or total dietary fiber.
***Total dietary fiber.
****Moisture content not presented in the paper; to convert the proximate values from dry weight into fresh weight basis, the average moisture content from all other data entries for the specific product category was calculated.

Table 4a. Mineral composition of raw *Parkia biglobosa* seed products in mg/100g fwb.

No	Product	Fe	Zn	Ca	Mg	Mn	Na	K	Cu	P***
	Dried seeds*			291						384
1	Seed dehulled, dried then milled	1.39** ± 0.02	4.0** ± 0.11	14.01** ±0.52	4.40** ± 0.78		2.75 ± 0.10	17.37 ± 1.57		3.50 ± 0.37
1	Seed dehulled, cooked for 6 hrs, dried then milled	1.65** ± 0.04	4.96** ± 0.02	17.48** ±1.03	3.33** ± 0.23		2.56 ± 0.07	13.82 ± 0.62		5.49 ± 0.03
1	Seed dehulled, irradiated at 5KGy, dried then milled	1.36** ± 0.11	4.38** ± 0.72	17.35** ± 0.2	3.25** ± 0.10		2.44 ± 0.17	14.56 ± 0.14		4.06 ± 0.06
1	Seed dehulled, irradiated at 10KGy, dried then milled	1.18** ± 0.19	6.05** ± 0.06	15.14** ±1.82	3.44** ± 0.13		2.42 ± 0.10	16.51 ± 0.62		3.82 ± 0.52
1	Seed dehulled, irradiated at 10KGy, cooked for 6 hrs, dried then milled	1.039** ± 0.03	4.0** ± 0.56	10.66** ± 0.18	2.72** ± 0.24		2.079 ± 0.12	14.85 ± 0.14		3.20 ± 0.17
2	Whole seed, milled to powder	60	20	270	390	10				
11	Seed: no description			0.568	0.93		0.19	1.76		0.27**
18	Seed dehulled by cracking, dried at 60 °C for 6 hrs, then milled			178.3 ± 0.1	143.4 ± 0.24	0.13 ± 0.01	20.27 ± 0.1	54.32 ± 0.04		169.5** ± 0.03
18	Seed boiled at 100 °C for 8hrs , dehulled, dried at 60 °C for 10 hrs then milled			175.4 ± 0	140.3 ± 0	0.38 ± 0	23.77 ± 0.04	56.28 ± 0.11		170.8** ± 0.01
22	Seed dehulled by cracking, dried for 7 days them milled	6.5	4.1	2450	280	2.8	26	306	0.5	1.1
23	Seeds dehulled, oven dried then milled	2.03 ± 0.09	2.35 ± 0.14	1.13 ± 0.13	4.48 ± 0.01	1.20 ± 0.02	1.32 ± 0.23	2.057 ± 0.05	3.83 ± 0.14	100.0 ± 0.18
28	Seed: no description	5.42	4.37	574	257	6.76			1.29	293**
31	Seed: no description			380** ± 50						90** ±50
35	Mature seed dried at 60 °C then dehulled			1084.5	583.34			937.77		715.32**
39	Seed: no description	11.5 ± 2	4.27 ± 0.2		270 ± 9.3				1.8 ± 0.18	

Values are mean of independent replications as per the author ± standard deviation. Blank spaces indicate the author did not determine the value. No author analyzed cobalt. Only one author analyzed selenium (0.48 ± 0.01).

*Reference values adopted from West African food composition table (Stadlmayr et al. 2012). This was not based on the quality of its data but on the authenticity of the document.

**Non-recommended method or method unknown.

***No method is recommended by FAO/INFOODS, papers 1,7,10 and 22 used phophovanado molybdate (yellow) colorimetry and paper 23 an unspecified colorimetric method.

Table 4b. Mineral composition of fermented *Parkia biglobosa* seed products in mg/100g fwb. Values are mean of independent replications as per the author ± standard deviation. Blank spaces indicate the author did not determine the value. No author analyzed cobalt. Only one author analyzed selenium (0.48 ± 0.01).

No	Product	Fe	Zn	Ca	Mg	Mn	Na	K	Cu	P
5	Fermented seed oven dried at 65 °C for 20 hrs	14.13 ± 0.01	1.51 ± 0.02	0.24 ± 0	0.26 ± 0		0.23 ± 0	0.69 ± 0	0.64 ± 0.02	
8	Fermented seed for 72 hrs then sun-dried for 4 hrs			637** ±00	136 ± 1		28 ± 0.1	1322 ± 0.04		375** ±0.1
10	Fermented seed for 72hrs, oven dried at 60 °C for 18 hrs, milled	1.7 ± 0.1	2.4 ± 0.04	188.7 ± 0.4	334 ± 1.1		135.5 ± 0.2	557 ± 1.2		94.3 ± 0.2
11	Fermented seed for 4 days then sun-dried			0.47	0.75		0.21	0.69		0.49**
12	Fermented seed (spices): from market	11.65 ± 0.09	3.06 ± 0.07	295.9 ± 0.11	90.58 ± 0.10	3.0 ± 0.04		16.92 ± 0.12	0.72 ± 0.03	
14	Nere mustard: Fermented	12.16** ± 0.63	7.87** ± 0.45	316.7** ± 70			184.0** ±43.9	509.4** ±10.8		506.33** ± 29.4
15	Fermented seed naturally without catalyst (woro)	16.63 ± 0.08	7.14 ± 0.01	910** ±1.06	7.14 ± 0.01	4.59 ± 0.01	31.84 ± 0.10	23.26 ± 0.09	2.14 ± 0	
15	Fermented seed with a catalyst (pete)	11.733	4.90 ± 0.01	855** ±1.10	7.24 ± 0.01	4.08 ± 0.0	27.45 ± 0.16	20.71 ± 0.08	1.73 ± 0.01	
18	Fermented seed at 29 °C for 48 hrs, dried at 60 °C for 12 hrs then milled to powder			179.6 ± 0.01	145.7 ± 0.06	0.47 ± 0.02	24.71 ± 0.13	57.71 ± 0.13		172.5** ± 0.05
18	Fermented seed at 29 °C for 72hrs, dried at 60 °C for 12 hrs then milled to powder			181.27 ± 0.05	146.34 ± 0.02	0.73 ± 0.04	24.89 ± 0.03	58.35 0.01		173.38** ±0.04
21	Seed cooked for 2 hrs, dehulled then fermented for 36 hrs at 30 °C	4.08** ± 0.01	3.24** ± 0.08	292.3** ±4.16	247.6** ± 1.52		71.31** ±0.45	92.5** ±0.91	6.02** ±0.02	
21	Seed cooked for 2 hrs, dehulled, pressure cooked for 15min then fermented for 36 hrs at 30 °C	3.62** ± 0.6	0.05** ± 0.02	179.3** ±6.02	164.3** ± 0.57		3.74** ± 0	130.6** ±2.08	14.59** ±0.06	
21	Seed cooked for 2 hrs, dehulled, pressure cooked for 30min then fermented for 36 hrs at 30 °C	8.61** ± 0.04	0.61** ± 0.8	214** ±4.58	189** ± 1.71		3.22** ± 0.1	171.4** ±1.81	1.67** ± 0	
22	Seeds cooked for 5 hrs, dehulled, fermented for 4 days, sun dried for 4 days then milled	7.8	5.5	2750	260	4.8	36	146	0.7	1.02
23	Seeds soaked for 7 days, dehulled, then fermented for 1 day, dried at 60 °C for 20 hrs then milled	2.43 ± 0.018	1.17 ± 0.0092	1.33 ± 0.046	3.32 ± 0.92	2.03 ± 0.092	1.22 ± 0.14	1.2 ± 0.14	1.15 ± 0.0092	69.87 ± 0.14
31	Fermented seed (dawadawa)			300** ± 50						200** ± 100
32	Fermented seeds: dried	35	5.9	460						
34	Fermented seed, oven dried at 50 °C then milled	220 ± 100	50 ± 20	1970 ± 340	2300 ± 110	50	49780 ± 1	2.17 ± 0.02	0.02 ± 0.01	
36	Fermented seed after 7 day storage	0.018 ± 0.0	0.6 ± 0.0	10.86 ± 0.04	9.521 ± 0.0		111.22	13.76 ± 0.0	0.298 ± 0.0	
39	Fermented seed (iru): no description	9.3 ± 0.2	8.61 ± 0.6		137 ± 14.1				3.6 ± 0.6	

*Reference values adopted from West African food composition table (Stadlmayr et al. 2012). This was not based on the quality of its data but on the authenticity of the document.
**Non-recommended method or method unknown.
***No method is recommended by FAO/INFOODS, papers 1,7,10 and 22 used phophovanado molybdate (yellow) colorimetry and paper 23 an unspecified colorimetric method.

Table 4c. Mineral composition of *Parkia biglobosa* pulp products in mg/100g fwb.

No	Product	Fe	Zn	Ca	Mg	Mn	Na	K	Cu	P
	Dried pulp*	3.6	0.8	118	88		5	1670	0.02	123
3	Mature pulp, sun-dried			221.7						31.40**
7	Mature and ripe pulp sun-dried for 48 hrs	42 ± 0.6	0.8 ± 0.2	27 ± 0.9	13 ± 0.3		70 ± 0.1	764 ± 0.2	0.9 ± 0.7	412
24	Pulp powder	14.82 ± 2.49	7.79 ± 0.44	142.0 ± 4.11	73 ± 1.14					
28	Fruit: no description	0.98	1.03	253.9	180.61	4.86			0.87	125.17**
29a	Dried pulp from Mayo-Kebbi department (Bongor)	69.16 ± 1.11	23.62 ± 1.4	10.84 ± 0.12	108.37 ± 1.31					
29b	Dried pulp from Kabbai department (Gaya)	62.76 ± 0.20	4.90 ± 0.58	40.04 ± 1.40	81.17 ± 0.25					
29c	Dried pulp from Tandjile department (Lai)	111.38 ± 3.21	45.35 ± 0.15	43.20 ± 3.21	107.68 ± 2.21					
32	Pulp flour: dried	15	1.6	130						
35	Mature fruit dried at 60 °C then pulped			1087.1	4.01			534.61		640.10**
40	Pulp milled and dried	7.93	0.52	0.21	0.085	0.33		1.056	0.26	0.014**

Values are mean of independent replications as per the author ± SD. Blank spaces indicate the author did not determine the value. No author analyzed cobalt. Only one author analyzed selenium (0.48 ± 0.01).
*Reference values adopted from West African food composition table (Stadlmayr et al. 2012). This was not based on the quality of its data but on the authenticity of the document.
**Non-recommended method or method unknown.
***No method is recommended by FAO/INFOODS, papers 1,7,10 and 22 used phophovanado molybdate (yellow) colorimetry and paper 23 an unspecified colorimetric method.

Table 5a. Vitamin composition for raw *Parkia biglobosa* seed products in µg/100g (except Vit C, expressed in mg/100g).

No	Product	Beta-Carotene	Other Pro Vit A	Vit C (Ascorbic acid)	Vit B1	Vit B2	Vit B3	Vit B6	Vit B9	Vit B12	Vit D	Vit E[#]
	*Dried seed			6	0.30	0.20	3.0			0	0	
38	Raw whole seed											19740
38	Seed boiled for 12 hrs then dehulled											8800 ±48

Table 5b. Vitamin composition for fermented *Parkia biglobosa* seed products in µg/100g (except Vit C, expressed in mg/100g).

No	Product	Beta-Carotene	Other Pro Vit A	Vit C (Ascorbic acid)	Vit B1	Vit B2	Vit B3	Vit B6	Vit B9	Vit B12	Vit D	Vit E#
5	Fermented seed oven dried at 65 °C for 20 hrs			0.56 ± 0.01	770 ± 10	48 ± 0	1310 ± 10	1490 ± 10	30 ± 0	450 ± 10	290 ± 10	23480 ± 10
10	Fermented seed for 72 hrs then analyzed for vitamins	1268.4 ± 5.1		6.24 ± 0.07		50 ± 10						0.76 ± 0.03
12	Fermented seed (spices): from market			15.4								
14	Fermented seeds bought from market		60720 ± 5060**/##	19.31								
27	Fermented seed: high-quality soumbala	7.44										385.64
27	Fermented seed: low-quality soumbala	7.73										399.04
38	Seed boiled, dehulled then fermented for 72 hrs											8.26 ± 0.048

Table 5c. Vitamin composition for *Parkia biglobosa* pulp products in µg/100g (except Vit C, expressed in mg/100g).

No	Product	Beta-Carotene	Other Pro Vit A	Vit C	Vit B1	Vit B2	Vit B3	Vit B6	Vit B9	Vit B12	Vit D	Vit E#
	*Pulp flour			26	0.94	0.74	1.2			0	0	
3	Mature pulp, sun-dried	10463		542.4								
7	Mature and ripe pulp sun-dried for 48 hrs	27000		34.***	121000	16000						
19	Dried fruit (pulp)	11.73** ±0.95	166.34** ± 2.47									
24	Pulp powder	33.85 ± 0.25		75.29***								
29a	Pulp: Mayo-Kebbi department from Bongor			198.859*** ± 0.181								
29b	Pulp: Kabbia department from Gaya			156.802*** ± 0.179								
29c	Pulp: Tandjile department from Lai			179.167*** ±0.019								
30	Pulp powder: harvested during dry season	5		2.8*** ±0.019	50 ± 2	52 ± 2					0.016 ± 0.003	1450 ± 18
30	Pulp powder: harvested during wet season	4		3.16*** ±0.053	34 ± 3	46 ± 4					0.013 ± 2	1090 ± 15
32	Pulp flour: dried	1190*										

Values are independent replications for every author ± SD. Blank spaces indicate value not determined.
*Reference values adopted from the West African food composition table.
**HPLC method recommended by FAO/INFOODS.
***Actual equivalent measured not mentioned in the paper (only Vitamin C).
#Equivalent mentioned in paper: tocopherol (paper 5); alpha-tocopherol (paper 10); total tocopherol (paper 38); Vitamin E only (papers 27 and 30).
##Value for total pro-vitamin A carotenoids, including beta-carotene.

Table 6a. Anti-nutrient and other nutrient composition for raw *Parkia biglobosa* seed products in mg/100g fwb.

No	Product	Trypsin inhibitor	Phytic acid	Phytate	Oxalates	Cyanide	Saponin	Tannin
1	Seed dehulled, dried then milled		$119.26^{b} \pm 1.91$	$33.39^{c} \pm 11.45$*	14.31 ± 1.91			$1.91^{e} \pm 0$
1	Seed dehulled, cooked for 6 hrs, dried then milled		$113.65^{b} \pm 1.91$	$32.47^{c} \pm 4.78$*	5.73 ± 12.41			$1.91^{e} \pm 0$
1	Seed dehulled, irradiated at 5KGy, dried then milled		$149.89^{b} \pm 1.91$	$42.01^{c} \pm 3.82$*	8.59 ± 99.29			$1.91^{e} \pm 0$
1	Seed dehulled, irradiated at 10KGy, dried then milled		$105.93^{b} \pm 1.91$	$29.58^{c} \pm 0.95$*	10.50 ± 17.18			$1.91^{e} \pm 1.91$
1	Seed dehulled, irradiated at 10KGy, cooked for 6 hrs, dried then milled		$89.64^{b} \pm 2.86$	$31.47^{c} \pm 24.80$*	5.72 ± 0			$1.91^{e} \pm 65.79$
17	Seed boiled for 8hrs then dehulled by removing the testae	$267.50^{a} \pm 7.38$	$221.38^{b} \pm 27.67$					$3689.6^{f} \pm 276.72$
17	Processed seed: The dehulled seed boiled for 30 mins	$101.46^{a} \pm 24.9$	$138.36^{b} \pm 18.45$					$2315.22^{f} \pm 442.75$
18	Seed dehulled by cracking, dried at 60 °C for 6 hrs, then milled to powder	15830 ± 10		83 ± 10	280 ± 0		280 ± 0	420 ± 10
18	Seed boiled at 100 °C for 8 hours , dehulled, dried at 60 °C for 10 hrs then milled to powder	6320 ± 30		540 ± 0	160 ± 0		130 ± 10	150 ± 0
22	Seed dehulled by cracking, dried for 7 days then milled			1566 ± 117	680 ± 19		5473 ± 231	208 ± 42
23	Seeds dehulled, oven dried them milled	$12250^{a} \pm 5$		3340 ± 30	$3570^{d} \pm 20$			$2100^{f} \pm 20$
31	Seed: no description		44.51 ± 0.06		164.99 ± 0.06			8.51 ± 0.04
37	Raw seed milled			$2.19^{c} \pm 0.1$	$0.13^{d} \pm 0$		6190 ± 540	
39	Seed from market:			46.41 ± 2.0				318.5^{e}
42a	Whole seed soaked for 12 hrs, sun-dried then milled: from Obudu		55.79		2882.38			
42a	Dehulled seed after boiling for 40 min, sun-dried then milled: from Obudu		37.44		2774.49			
42b	Whole seed soaked for 12 hrs, sun-dried then milled: from Boki		92.41		1770.58			
42b	Dehulled seed after boiling for 40 min then sun-dried then milled: from Boki		69.50		2520.99			
42c	Whole seed soaked for 12 hrs, sun-dried then milled: from Obanliku		79.036		1965.74			
42c	Dehulled seed after boiling for 40 min, sun-dried then milled: from Obanliku		48.03		3514.85			

Values are independent replications for each author ± SD. Missing values were not determined.
*Result presented as phytate-phosphorus (phytate-P).
[a,b,c,d,e,f]Values marked with the same superscript letter were obtained using the same analytical method.

Table 6b. Anti-nutrient and other nutrient composition for fermented *Parkia biglobosa* seed products in mg/100g fwb.

No	Product	Trypsin inhibitor	Phytic acid	Phytate	Oxalates	Cyanide	Saponin	Tannin
5	Fermented seed oven dried at 65 °C for 20 hrs	810		10	10		10	0
12	Fermented seed (spices)			1500	760^{d}			
16	Fermented seed (iru)			1648^{c}	108		318	539
17	Processed (hydrated) seed fermented at 37 °C for 24 hrs	73^{a} ± 9	130 ± 10					2320^{f} ± 880
17	Processed (hydrated) seed fermented at 37 °C for 48 hrs	55^{a} ± 18	120 ± 10					1830^{f} ± 270
17	Processed (hydrated) seed fermented at 37 °C for 72 hrs	32^{a} ± 5	90 ± 3					1610^{f} ± 380
18	Fermented seed at 29 °C for 48 hrs, dried at 60 °C for 12 hrs then milled	886 ± 6		60 ± 2	24 ± 1		5 ± 1	36 ± 8
18	Fermented seed at 29 °C for 72 hrs, dried at 60 °C for 12 hrs then milled	656 ± 34		60 ± 2	18 ± 1		19 ± 1	34 ± 0
22	Seeds cooked for 5hrs, dehulled, cook for 1 hr, fermented for 4 days, sun dried for 4 days then milled			3790 ± 117	680 ± 19		3936 ± 39	472 ± 31
23	Seeds soaked for 7 days, dehulled, cooked then fermented for 1 day, dried at 60 °C for 20 hrs then milled	7^{a} ± 1		8 ± 1	13^{d} ± 3			12^{f} ± 2
31	Fermented seed (dawadawa)		15.28 ± 0.05		84.99 ± 0.07			6.05 ± 0.05
34	Fermented seed			174 ± 20	189 ± 10			
37	Partially fermented seed, milled then dried			2^{c} ± 0.1	0.05^{d} ± 0		2360 ± 130	
37	Completely fermented seed, milled then dried			1.^{c}5 ± 0.03	0.04^{d} ± 0		2200 ± 110	
39	Fermented seed			22.75				980 ± 180
42	Fermented for 72 hrs, sundried then milled: from Obudu		38.45		1497.92			
42	Fermented for 72 hrs, sundried then milled: from Boki		48.34 ± 23		818.50			
42	Fermented for 72 hrs, sundried then milled: from Obanliku		43.53		1145.83			

Values are independent replications for each author ± SD. Missing values were not determined.
*Result presented as phytate-phophorus (Phytate-P).
[a,b,c,d,e,f]Values marked with the same superscript letter were obtained using the same analytical method.

Table 6c. Anti-nutrient and other nutrient composition for *Parkia biglobosa* pulp products in mg/100g fwb.

No	Product	Trypsin inhibitor	Phytic acid	Phytate	Oxalates	Cyanide	Saponin	Tannin
3	Mature pulp, sun dried	0.41 ± 0.32		1.67^{c}	0.93^{d}	0.08	0.34	0.32
4	Pulp dried and milled to powder	410		50	400			28340
41	Pulp dried at room temperature then milled to powder			2130^{c} ± 510	11100^{d}		12230 ± 460	930 ± 110

Values are independent replications for each author ± SD. Missing values were not determined.
*Result presented as phytate-phophorus (Phytate-P).
[a,b,c,d,e,f]Values marked with the same superscript letter were obtained using the same analytical method.

values for several minerals (iron, zinc, calcium, magnesium, manganese and sodium) in the fermented product analyzed, while paper 22 reported the highest calcium values in unfermented and fermented seeds. Paper 11 presented systematically low values for minerals in both unfermented and fermented products. Papers 5 and 23 also showed low mineral values (except phosphorus) for the fermented product, while paper 40 systematically reported the lowest mineral values for pulp (except for iron). Like for the values of proximate composition, variation was much greater among papers than within the same paper. Six papers presented mineral data on fermented and unfermented seeds; however, no clear pattern relating a possible increase or decrease of mineral content due to fermentation could be found. One paper presenting mineral data was a multilocation study, analyzing nutrient values for *P. biglobosa* pulp bought in three different markets in Chad.

Vitamins (Tables 5a, b and c)

Very little data was available regarding vitamin content of edible *P. biglobosa* products. The most analyzed were beta-carotene and other pro-vitamin A components, followed by Vitamin C and Vitamin E. Few papers presented Vitamin B or D data. The methods used for vitamin analyses were in most cases unknown or not found among the FAO/INFOODS recommended methods. Only 3 papers used an FAO/INFOODS recommended method for beta-carotene and/or other pro-vitamin A carotenes (papers 14, 19 and 32). None of the other analysis were carried out using FAO/INFOODS recommended methods. Furthermore, most papers did not present (correct) equivalents and/or units. Four papers mentioned that ascorbic acid was analyzed (5, 10, 12 and 14); the others reported they conducted Vitamin C analyses. Regarding Vitamin E, paper 5 mentioned tocopherol as equivalent, paper 10 alpha-tocopherol and paper 38 total tocopherol; the other papers mentioned Vitamin E. To the extent possible, all values were recalculated on a μg/100 g EP basis (except for Vitamin C on a mg/100g EP basis). Similarly to the case of minerals, a lot of assumptions had to be made regarding denominators. Ranges of vitamin content varied widely among authors, up to five orders of magnitude, from 0.76 ug/100 g EP to 23480 ug/100 g EP for Vitamin E. Similarly to what was found for proximate and mineral composition, variation among authors was much larger than variation in values from comparisons within the same paper. Vitamin E content in paper 38 seemed to have gone down substantially after fermentation. The study comparing pulp from three markets in Chad was the only multi-location study reporting vitamin data (Vitamin C).

Anti-nutrients and other nutrients (annex 1)

The most analyzed anti-nutrients and other compounds were oxalates, tannins and phytates; few papers presented values for trypsin inhibitor, saponins or cyanides. There are no FAO/INFOODS recommended methods for anti-nutrients and large heterogeneity was observed in the way antinutrients were analyzed and expressed, with differences in methods, active components, units, denominators, often without properly describing methods and/or the actual components analyzed, making conversions into mg/100 g EP extremely prone to errors. The antinutrient values should be interpreted with care and are presented in this paper only to illustrate how difficult it is to compare data if authors do not describe adequately what sampling approach, sample preparation, analytical methods and/or units, denominators and equivalents were used. Different papers most likely measured different equivalents. In our database (Table 6), we reported data as found in the original articles, harmonized them to the extent possible, using the same unit and denominator (mg/100 g EP). Anti-nutrient values derived from the same analytical method were marked with the same superscript in Table 6. We noted that paper 42 systematically recorded high oxalate values across the different locations sampled, for whole and dehulled unfermented seeds as well as fermented seeds. Paper 17 presented high values for tannins in the fermented seeds, while paper 3 presented systematically low values for all anti-nutrients in the pulp.

Discussion

To better understand within-species variability in nutritional properties of *P. biglobosa*'s pulp and seeds, a nutrient database was developed with values extracted from available data for *P. biglobosa* pulp, raw and fermented seeds. Out of a total of 69 relevant papers, 27 had to be excluded after a quality check on the proximate composition. Like in Stadlmayer et al. (2013) and McBurney et al. (2004), we had to collate data highly inconsistent in quality, accompanied by unclear descriptions of sampling methods, of the specific products analyzed, of laboratory protocols used, and presented without sufficient level of detail in the papers (e.g. lack of denominators). Thus, it can be concluded that, despite an apparent wealth of information on *P. biglobosa* pulp and seed nutrient composition, the quality of this information is low and presents several gaps.

Given the many different products analyzed and the different and/or unclear methods used, it was not possible to provide a precise answer to our first research question, about the level of within-species variation in proximate, mineral and vitamin content in *P. biglobosa* pulp, raw and fermented seeds. While the proximate composition was more or less in line with the data in the WAFCT, mineral and vitamin values showed huge variance. The selected papers that presented systematically high(er) or low(er) nutrient values than in other studies did not necessarily use different analytical methods. The variance found could be associated to a multitude of factors, including differences in sample preparation: for example, the extreme high value for sodium in paper 34 might be simply due to a contamination of the sample during the fermentation process. While we discarded those studies that explicitly added particular substances to the fermentation process, we did not filter out articles where a questionable descriptions of sample preparation was presented, or where the samples tested came from the market and could have contained additives. Paper 13 mentioned that differences in seed processing existed between different cultural groups and indeed the largest differences were found among fermented products derived from *P. biglobosa'* seeds. Significant differences were recorded also for vitamin values in the pulp (beta-carotene and vitamin C); this pattern was confirmed by data from the WACFT, that presented very different values of Vitamin C in flour versus sun dried mature pulp. It has to be noted that many vitamins are heat sensitive and that vitamin content is influenced by the time interval between harvest and lab analyses. Finally, slight differences in fruit maturation can be associated with large differences in vitamin content.

We noted that, in general, values extracted from the same papers (comparing different locations or product treatments, etc.) showed much less variation than the values reported by different authors for the same product treatment or the same location. Only four papers (13, 26, 29, 42) compared nutrient composition of *P. biglobosa* products across different locations. Two papers compared fermented seeds from different markets, so the differences found could have been due to different processing methods. Another paper presented only one data point per each location, per type of product, so the sampling was too small to draw any conclusions. Only a paper (26) presented data points for three villages in the Atacora Department in Benin (Sudanian agro-ecological zone) and for three villages in the Bourgou Department (Guinean agro-ecological zones) with some clear patterns in the differences detected for proximate content between the Atacora and Bourgou samples. Whether these differences are due to soil characteristics, climate (rainfall patterns and/or temperature) or different *P. biglobosa* provenances remains to be studied. No studies assessed the relative weight of different factors determining the observed within-species differences in nutritional composition (e.g. soil, rainfall regime, level of maturity at the time of harvesting). Some papers (17 out of the 42 selected) compared their findings with other studies and attempted to provide tentative explanations for the differences observed. These related to different stages of maturity/ripeness, differences in sample preparation and handling, storage conditions, laboratory analysis methods, soil, climate and seasonality. Eleven of these 17 papers also attributed the observed variation in nutritional data to potential differences among varieties/provenances/genotypes.

Recommendations

Many gaps in *P. biglobosa* nutrient composition data remain despite the wealth of studies on this species. Data quality is generally low and comparability of data among authors is very problematic. Besides pointing out the inadequate expression of nutrients, McBurney et al. (2004) also refer to issues with (incorrect) recycling of data from previous papers, leading to a 1000-fold increase in nutrient contents in some cases. Non-original data were excluded from this review, but we noticed in analogy with McBurney an issue with recycling vague methods and/or descriptions as well as lacking or incorrect nutrient expressions.

We recommend that authors provide clear descriptions of (a) the specific products analyzed (seeds with hull, without hull, mechanically dehulled or dehulled after boiling, dried or not, and the processing methods used for fermented seeds); (b) sampling methods, indicating how many samples were collected, whether they were analyzed as composite sample or not, how the samples were processed and how many replicate analyses were carried out in the laboratory; (c) analytical methods with proper references; and (d) nutrient expressions (correct equivalents, units plus mention of the denominator).

Given the growing interest in intra-species variability of nutrient composition, we furthermore strongly recommend presenting complementary data in addition to nutrient composition data, to make nutrient data location/ecoregion-specific. Soil characteristics, rainfall patterns, temperature, agro-ecological zone, harvesting time, degree of product maturity, tree management practices and genetic provenance, all influence the nutrient composition of our foods. We are only at the beginning of understanding the influence of these variables on some crops. Despite the great focus of nutritional studies on *P. biglobosa*, not much research on these aspects has been carried out for *P. biglobosa* edible products. Disentangling the complexity in the relationship between environmental and genetic factors and the nutrient composition of edible products from *P. biglobosa* will help to identify nutritionally plus trees for multiplication and/or breeding purposes, and to ultimately contribute to better nutrition for populations living in resource poor settings such as rural West Africa.

Conclusion

A nutrient composition database was collated with data about *P. biglobosa* pulp and both raw and fermented seeds, through a systematic online search of relevant scientific literature and a careful compilation of nutrient data into an excel file. A total of 42 papers were retained for the construction of the final nutrient database.

Several gaps in nutrient data were identified. Particularly for vitamins, data were very scarcely reported. It was not possible to detect any patterns in nutrient composition based on environmental characteristics or genetic provenance due to a lack of (quality) data and very deficient documentation of the environmental context where sampling has been carried out. The paper by Koura et al. (2014) however seemed to indicate that such differences exist for *P. biglobosa* edible products. Some recommendations were formulated regarding minimum standards for reporting nutrient data as well as for presenting complementary information that would make nutritional data better interpretable and usable.

The huge differences in nutrient content found could not be clearly attributed to specific factors, such as, for example, differences in analytical methods used, sample processing, maturity of the samples, environmental characteristics (e.g., climate, soil) of the collection site, provenance of the samples, etc., This means that it would be difficult, or impossible, with the data available, to formulate any recommendation on intakes of *P. biglobosa* edible products that would meet daily needs for specific nutrients (especially for minerals and vitamins). The quantities of fermented products derived from *P. biglobosa* consumed per meal are small, but intakes are regular and complement otherwise monotonous staple-based diets, so *P. biglobosa* edible products constitute an important source of nutrients. A better understanding of the main factors determining variation in their nutrient content would indicate whether it is possible to identify "+" trees, and/or management practices for improved nutrient content of *P. biglobosa* edible products.

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Disclosure statement

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