Nutrient-Rich Foods in Western African Food Supply: Applying Nutrient Profiling Models to the FAO Food Composition Table for Western Africa (WAFCT 2019)

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A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Public Health

University of Washington

2023

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Program Authorized to Offer Degree:

Nutritional Sciences

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Abstract

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Background: The Western Africa region faces a significant burden of malnutrition, including high rates of micronutrient deficiencies. Addressing this issue requires identifying and ensuring equitable access to local nutrient-dense foods. While nutrient profiling tools can serve for this purpose, most of them have been developed for high-income countries, requiring adaptation for the Western African context.

Objective: This study aimed to adapt and apply nutrient profiling models to the FAO/INFOODS Food Composition Table for Western Africa (WAFCT) 2019. The goal was to identify locally available nutrient-dense foods across different food groups.

Design: Analysis encompassed 909 WAFCT foods with complete data. The Nutrient-Rich Food (NRF) Index served as the nutrient density metric, employing three versions: two adapted for low- and middle-income countries (LMICs) (the NRF6.3 and NRF15.3), and the original NRF9.3, developed in a high-income country. The Carbohydrate Foods Quality Score (CFQS) assessed carbohydrate quality in 446 carbohydrate foods. Protein quality correction was conducted using the Protein Digestibility Corrected Amino Acid Score (PDCAAS) in 862 foods. Descriptive statistics, Pearson correlations, one-way ANOVAs, and independent and paired sample t-tests were employed for data analysis, with significance set at $\alpha=0.05$.

Results: Among food groups, vegetables obtained the highest NRF scores. African indigenous vegetables (AIV) demonstrated significantly higher nutrient density and protein content compared to non-indigenous vegetables. A considerable proportion (66.8%) of analyzed foods were classified as higher-quality carbohydrate foods. African indigenous grains (AIG) exhibited higher carbohydrate quality and nutrient density scores than non-indigenous grains, particularly when non-indigenous grains were unfortified. When utilizing nutrient profiling models specifically adapted for LMICs (NRF6.3 and NRF15.3), animal-sourced food groups attained higher nutrient density rankings compared to the ranking they obtained with the NRF9.3. Additionally, food groups had significant reductions in mean grams of protein per 100 grams of food after the PDCAAS adjustment; however, differences were most pronounced in plant-based foods.

Conclusion: Adapting nutrient profiling tools to the West African context allowed the identification of local nutrient-dense foods. AIV and AIG were sources of priority micronutrients and higher-quality carbohydrates. Animal-sourced foods also played a crucial role in providing essential micronutrients of public health significance in Western Africa. Governments, public health institutions, and academic organizations in the region should work together to recognize the nutrient density of these foods, increase their

accessibility and affordability, and promote their consumption through appropriate policies and programs.

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1. Introduction

Micronutrient deficiencies, also known as hidden hunger, remain a public health issue around the world, affecting more than 2 billion individuals globally (1). Recent evidence suggest that the actual number may be significantly higher. It is currently estimated that 1 in 2 pre-school aged children and 2 out of 3 women of reproductive age worldwide are suffering from at least one micronutrient deficiency (2). This issue is particularly prevalent in low- and middle-income countries (LMICs) (2).

Based on a global analysis of preschool-aged children, sub-Saharan Africa has the highest estimated prevalence (62%) of deficiency in at least one of three micronutrients (iron, zinc, and vitamin A), while a higher prevalence was observed among non-pregnant women of reproductive age in the same region (80% affected) (2). Within sub-Saharan Africa, Western Africa has one of the highest prevalence of dietary iron, iodine, and vitamin A deficiencies (3). Approximately 51.8% of women of reproductive age in this region are estimated to suffer from anemia (4). Research indicates that the high prevalence of micronutrient deficiencies in West Africa can be attributed to a complex interaction of contributing factors, with limited dietary diversity being a significant element (3).

A lack of dietary diversity leads to an inadequate consumption of essential micronutrients. This issue is prevalent in LMICs, particularly in Western Africa, where diets often lack iron, vitamin A, folate, zinc, calcium, and vitamin B12 (5). Furthermore, the quality of protein in these countries can also be a concern (6). These micronutrient deficiencies may lead to malnutrition, affecting an individual's physical state and resulting in poor health (7). Therefore, diets composed of diverse nutrient-dense foods are a crucial factor to prevent and address multiple micronutrient deficiencies (8,9). Therefore, the identification of nutrient-dense foods within the local Western African food supply holds significant importance.

Nutrient density of foods, commonly defined as the amount of selected nutrients per reference amount of food (i.e., 100 kcal, 100 g, serving size), can be assessed through methods that became known as nutrient profiling (10). Nutrient profiling models are used to evaluate the nutritional quality of foods and can aid in the formation of food patterns that promote a healthy life (11). These models have become an important public policy tool increasingly used by government bodies worldwide (12). Nutrient profiling models can be used for the development and implementation of dietary guidelines to address public health problems, as stated by the World Health Organization (WHO) (13). Nonetheless, these tools have been developed in high-income countries, and there is little guidance on how to adapt and use these tools in LMICs (14). In order to ensure the contextual relevance and suitability of nutrient profiling models, it is imperative to adapt them to local contexts, taking into consideration the specific nutrients of concern within the studied area.

The first essential requirement for the use of nutrient profiling tools is the availability of high-quality local nutrient composition data in electronic format (14). To achieve this, tremendous effort has been made by the Food and Agriculture organization of the United Nations (FAO) and the International Network of Food Data Systems (INFOODS) to develop a third iteration of a Food Composition Table (FCT) for countries in Western Africa. In 2019, the Food Composition Table for Western Africa (WAFCT 2019) was published (15). This high-quality FCT contains more than 1,000 foods frequently consumed in this region (16).

Despite being publicly available, to this date there is no study comprehensively analyzing the nutrient composition of the foods included in the WAFCT. Using nutrient profiling tools to analyze the WAFCT can provide important evidence needed for governmental bodies to design nutrition-related policies (12). Currently, only four out of the 16 countries in Western Africa have developed dietary guidelines for their population (17). Identifying and ranking healthful, nutrient-dense foods commonly consumed in West African countries above those of lower nutritional value can aid in the formulation of evidence-based dietary guidelines and nutrition interventions that promote health and wellbeing.

The aim of this study was to adapt and apply nutrient profiling techniques to the food items of the WAFCT to identify nutrient-dense foods across various food groups. By utilizing various nutrient profiling methods, including tools adapted to the local context, we aimed to pinpoint the food sources of nutrients of public health concern in the Western Africa region. Moreover, the study encompassed evaluations of both carbohydrate and protein quality, providing novel insights that can be beneficial for government agencies and organizations engaged in implementing nutrition interventions. The outcomes of this research will aid in the development of nutrition policies and programs aimed at promoting the consumption of nutrient-rich foods in the Western Africa region.

2. Methods

2.1 Nutrient Composition Database

The FAO/INFOODS Food Composition Table for Western Africa 2019 (WAFCT)(15) was the source of the nutrient composition data. This 2019 version is the third and most recent iteration developed to provide high-quality and relevant food composition data for foods consumed in Western Africa. It includes 1,028 foods and beverage entries, their names in English and French, their food group, and their nutritional composition data, including calories (kcal) and data on 39 food components (e.g., macro- and micronutrients). The WAFCT classifies foods into 14 different food groups including grains and cereals; legumes; starchy roots; fats and oils; fruits; vegetables; meat and poultry; seafood; milk and dairy; eggs; nuts and seeds; sauces and soup; miscellaneous foods; and beverages.

For comparison purposes, foods were aggregated into 9 food groups identified by 1-digit codes, obtained from the Food and Nutrient Database for Dietary Studies (FNDDS) 2017-2018 and supplied by the United States Department of Agriculture (USDA) (18). The nine groups are milk and dairy; meat, poultry, fish, and mixtures; eggs; beans, peas, legumes, nuts, and seeds; grain products; fruits; vegetables; fats, oils, and salad dressings; and sugars, sweets, and beverages. Given that the WAFCT does not contain any food subgroups, foods were also aggregated by 2-digit FNDDS codes, yielding 38 food subgroupings. Moreover, a subclassification of fruits and vegetables was applied based on the Minimum Dietary Diversity for Women Indicator (19). Fruits were grouped into “vitamin A-rich fruits” and “other fruits”, whereas vegetables were grouped into “dark green leafy vegetables,” “vitamin A-rich vegetables,” and “other vegetables.” Fortified foods were also identified and analyzed.

For the application of the different nutrient profiling models, complete data on the nutrients of interest was required for each food in the database. For foods with missing data on the nutrients of interest, nutrient data was searched, matched, and imputed when the food information was found in the FNDDS 2017-2018 dataset (18). Values of added sugars were also imputed for each food, as this variable was not included in the WAFCT. The added sugars of each individual ingredient of mixed dishes were summed to obtain the overall added sugars content. This was possible as the WAFCT contains recipes with separate ingredients and their quantities for every mixed dish included. When nutrient composition data was not available for foods with missing values, those foods were excluded. Additionally, foods with less than 10 kcal per 100 grams, alcoholic beverages, coffee, tea, herbs, and spices were excluded from the analyses as they are not suitable for the nutrient profiling tools used. The present study examined a total of 909 food items, all of which were characterized by complete data encompassing the entirety of the nutrients of interest.

Within the vegetable and grain food groups, a particular focus was placed on African indigenous foods, leading to the creation of subcategories. Under the designation of African Indigenous Vegetables (AIV), a total of 43 food items were categorized accordingly. Foods were classified as either "indigenous vegetables" if they were in their raw or minimally processed state, or as "preparations with indigenous vegetables" if they were incorporated into mixed meals or recipes. Dry vegetables were not included in the analyses. The selection of 43 food items originated from ten different vegetables: amaranth leaves, spider plant, jute mallow, cowpea leaves, native eggplant, pumpkin leaves, moringa, sweet potato leaves, okra, and okra leaves.

For the African indigenous Grains (AIG), 55 food items were assigned to this category. Included foods were raw or minimally processed grains, as well as flours derived from these grains. Mixed dishes using indigenous and non-indigenous grains were not included in the analyses. The 55 food items derived from five different grains: fonio, pearl millet, teff, sorghum, and native rice. Non-indigenous grains mainly included maize, wheat, rice, and oats. The different nutrient profiling models were applied to these subcategories.

2.2 Nutrient Profiling Models

2.2.1 Nutrient Rich Food Index

This study used the well-described Nutrient Rich Food Index (NRF) model to evaluate the nutritional quality of foods (20,21). NRF scores help differentiate nutrient-rich foods from energy-dense foods poor in nutrients. The scores were based on various nutrients to encourage (NRn) and certain nutrients to limit (LIMk). The $NRF_{n.k}$ scores were calculated by subtracting the k nutrients to limit (Nut_lim_j) from the n beneficial nutrients to include (Nut_inc_i) and multiplying them with 100 divided by energy density (ED) as follows:

$$NRn = \left(\frac{Nut\_inc_1}{DV_1} + \frac{Nut\_inc_2}{DV_2} + \ldots + \frac{Nut\_inc_i}{DV_n}\right) \times (100/ED)$$

$$LIMk = \left(\frac{Nut\_lim_1}{MRV_1} + \ldots + \frac{Nut\_lim_k}{MRV_k}\right) \times (100/ED)$$

$$NRFn.k = \left[\sum_{i=1}^{n} \frac{Nut\_inc_i}{(DV_i)} - \sum_{j=1}^{k} \frac{Nut\_lim_k}{(MRV_j)}\right] \times (100/ED)$$

In order to use nutrient profiling models adapted to the local context, three different versions of the NRF were used: the NRF9.3, the NRF6.3 Priority Nutrients and the NRF15.3 Priority Nutrients.

The NRF9.3 version is based on nine nutrients to encourage (protein, fiber, vitamin A (Retinol Activity Equivalents – RAE), vitamin C, calcium, iron, potassium, vitamin D, and magnesium), the NRF6.3 Priority Nutrients version is based on six nutrients to encourage (iron, zinc, calcium, vitamin A (RAE), vitamin B12, and folate), and the NRF15.3 Extended Priority Nutrients was based on 15 nutrients to encourage (vitamin A (RAE), vitamin D, vitamin E, vitamin C, vitamin B1, vitamin B2, vitamin B3 (Niacin Equivalents – NE), vitamin

B6, vitamin B12, folate, copper, calcium, iron, magnesium, and zinc). All three models included the same three nutrients to limit (LIM): sodium, saturated fats, and added sugars. Nutrient standards were those adopted by the Codex Alimentarius (22) (**Table 1**). The nutrient percent daily value was capped at 100% to avoid the over-representation of dietary adequacy.

Table 1. Reference Daily Values (DV) for micronutrients of interest.

Nutrients to encourage	Reference Daily Values	Nutrients to limit	Maximum Recommended Values
Protein (g)	50	Saturated fat (g)	20
Fiber (g)	25	Added sugars (g)	50
Vitamin A (RAE)	800	Sodium (mg)	2000
Vitamin C (mg)	100		
Vitamin D (mcg)	15		
Vitamin E (mg)	9		
Calcium (mg)	1000		
Iron (mg)	14		
Potassium (mg)	3500		
Magnesium (mg)	310		
Zinc (mg)	11		
Folate (mcg)	400		
Copper (mcg)	900		
Vitamin B1 (mg)	1.2		
Vitamin B2 (mg)	1.2		
Vitamin B3 (mg NE)	15		
Vitamin B6 (mg)	1.3		
Vitamin B12 (mcg)	2.4		

*Daily Values were taken from the Codex Alimentarius (22).

2.2.2 Carbohydrate Foods Quality Score

To assess the quality of carbohydrate foods, the novel Carbohydrate Foods Quality Score (CFQS) was used. The CFQS allows for the quality assessment of both grain foods and non-grain foods (i.e., fruits, vegetables, and legumes)(11). For this analysis, foods with ≥40% energy from carbohydrate (by 100 g dry weight) were included. Relevant grain-based mixed dishes were also included. Milk and dairy products were not included in the analysis, as they were not considered primary carbohydrate sources. Free sugars were defined as added sugars; sugars from 100% fruit juice; sugars in jams and jellies; and honey, sugars, and syrups. To generate in-depth data, the 2-digit FNDDS classification was used in the analysis of carbohydrate foods. Categories included were flours; breads; sweet bakery; cooked cereals, pasta, and rice; uncooked cereals; mixed grains; fruits; vegetables and tubers; legumes and pulses; and sugars and sweets. Given that only foods were included in the analysis, fruit juices and other beverages were omitted. The number of foods eligible to be used in the present analysis was 446 foods.

Dietary recommendations suggest reducing free sugar and sodium, while increasing fiber, potassium, and whole grains (11). Therefore, the components included for the CFQS analysis followed the ones used by Drewnowski et al. (11) and included energy density (kcal/100 gr), fiber, free sugar, sodium, potassium, and whole grains. The elements of the CFQS are listed in Table 1.

Table 2. Carbohydrate Food Quality Score (CFQS-5) Components

Components	**Component Scores**	**Score Range***	**Higher-quality carbohydrate foods**
Fiber	1 point if fiber ≥ 10 g/100 g carb portion; else 0 points	0 to 1	4 and 5 points
Free Sugar	1 point if free sugar <10 g/100 g carb portion; else 0 points	0 to 1	
Sodium	1 point if Na < 600 mg / 100 g dry weight; else 0 point	0 to 1	
Potassium	1 point if K > 300 mg/ 100 g dry weight; else 0 point	0 to 1	
Whole Grains	1 point if food is considered whole grains	0 to 1	

*Based on the five components, each carbohydrate food could score 0 to 5 points.

Fiber and free sugars had a 10% cutoff per 100 g portion. The cutoff level for sodium and potassium was based on <600 mg sodium and >300 mg potassium per 100 g dry weight. Foods considered as whole grains were those that had not undergone significant processing or removal of the grain kernel. The CFQS-5 model was used based on the cutoff values and scoring system presented in Table 1. This model contained 5 component scores (fiber, free sugar, sodium, potassium, and whole grains). In the CFQS-5 model, carbohydrate foods were eligible to score up to 5 points (1 point for each dietary component being measured), with carbohydrate foods scoring 4 and 5 points being classified as “higher quality”.

2.2.3 Protein Quality Assessment

In LMICs, the consumption of animal-sourced protein is usually lower compared to plant-source proteins (23). Previous studies have indicated that protein-quality differs among food sources, classifying as high-quality proteins those that contain essential amino acids in quantities that meet human requirements and are readily digestible (24,25). Based on this premise, a protein-quality adjustment was made. Foods were manually classified by their protein source into two categories: animal-sourced or plant-sourced. The animal-source category was also subclassified into meat and poultry protein; milk, eggs, and dairy protein; and fish and seafood protein. For mixed dishes, recipe ingredients were used to determine the percentage of protein of each of the types in the dish. Protein percent of daily value (%DV) per 100 kcal and the grams of protein per 100 grams of food were assessed. Protein daily value was established at 50 g, based on a 2000 kcal/day diet.

2.2.3.1 The Protein Digestibility-Corrected Amino Acid Score (PDCAAS)

The Protein Digestibility-Corrected Amino Acid Score (PDCAAS) was used to adjust protein quality, and scores were manually assigned to foods. PDCAAS values were collected from a variety of sources to obtain the most specific values for foods. In some cases, PDCAAS values were obtained for specific foods, and in other cases they were obtained for food groups. PDCAAS values and their sources can be found in the **Appendix 1**. Given that sugars, sweets, fats, and oils contain little to no protein and that there was limited PDCAAS data for items in these food groups, they were not included in the analysis. A total of 862 foods were adjusted for PDCAAS correction. Mean total protein %DV and grams of protein per 100 grams of food were compared to values after PDCAAS adjustment. Moreover, mean total protein %DV and grams of protein per 100 grams of food were plotted against energy density (in kcal/100 g).

2.2.3.2 Nutri-Score Protein Points and PDCAAS Adjustment

The Nutri-Score model represents a front-of-pack labeling system employed to categorize the nutritional quality of various products into five classes denoted by letters A to E (26). Utilizing an algorithm, this model assigns a range of points from 0 to 5 based on the total protein content per 100 g of food. Foods containing a total protein content of less than 1.6 g/100 g receive 0 points, while those with protein content exceeding 1.6 g/100 g are allocated 1 point. Moreover, foods with protein content surpassing 3.2 g/100 g, 4.8 g/100 g, 6.4 g/100 g, and 8 g/100 g receive 2, 3, 4, and 5 points respectively, with higher points representing higher-protein content foods (26). The protein points of the Nutri-Score were applied to the protein-source foods before and after PDCAAS adjustment. The frequency of foods for each protein point was compared among plant foods and animal foods, as well as before and after PDCAAS adjustment.

2.3 Statistical Analysis

Descriptive statistics was used to examine the distribution of food items by food group for the Nutrient Rich Food Index models. Mean, standard deviation, and median values of energy density, NRF9.3, NRF6.3, and NRF15.3 were calculated for each food group. Sensitivity analyses were conducted to evaluate the robustness of the findings, with and without the inclusion of outliers.

For all carbohydrate foods, the proportion and count of those that attain the highest scores were evaluated. To assess the impact of protein-quality correction, mean total protein %DV and grams of protein per 100 grams of food were evaluated before and after the PDCAAS correction. Paired sample tests were conducted to evaluate the significance of any differences observed. The correlations between CFQS and the different NRF versions, as well as grams of protein and micronutrients were assessed using Pearson correlations. One-way ANOVAs and independent t-tests were used to conduct multiple comparisons of nutrient density and protein content across food groups. The Bonferroni correction was used to adjust for multiple testing, and any significant differences were indicated. The significance level for all tests was set at $\alpha=0.05$. SPSS 28 statistical software (IBM) was used to perform all statistical analyses.

3. Results

3.1 Food Classification

Figure 1 shows the classification of the 909 WAFCT foods analyzed in this study. Following the classification used in the WAFCT, the 14 categories were cereals (18.6%), milk and dairy (2.5%), starchy roots and tubers (9.8%), legumes (12.7%), vegetables (12.4%), fruits (4.8%), nuts and seeds (3.3%), meat and poultry (13%), eggs (1.5%), fish and seafood (11.7%), fats and oils (3.9%), soups and sauces (3.7%), beverages (1.3%), and miscellaneous foods (0.8%). A subclassification of vegetables and fruits was included in the 14-category WAFCT food groups. Within the vegetable category (n=113), 52.2% were dark green leafy vegetables, 10.6% were vitamin A-rich vegetables, and 37.2% were other vegetables. Within the fruits category (n=44), 18.2% were vitamin A-rich fruits, and 81.8% were other fruits.

Based on the 1-digit FNDDS classification, the nine categories were milk and dairy (2.5%), eggs (1.5%), fats and oils (3.9%), grains (18.8%), vegetables (20.7%), fruits (7.7%), meat, poultry, and fish (27.8%), legumes, pulses, nuts, and seeds (15.5%), and sugars, sweets, and beverages (1.5%).

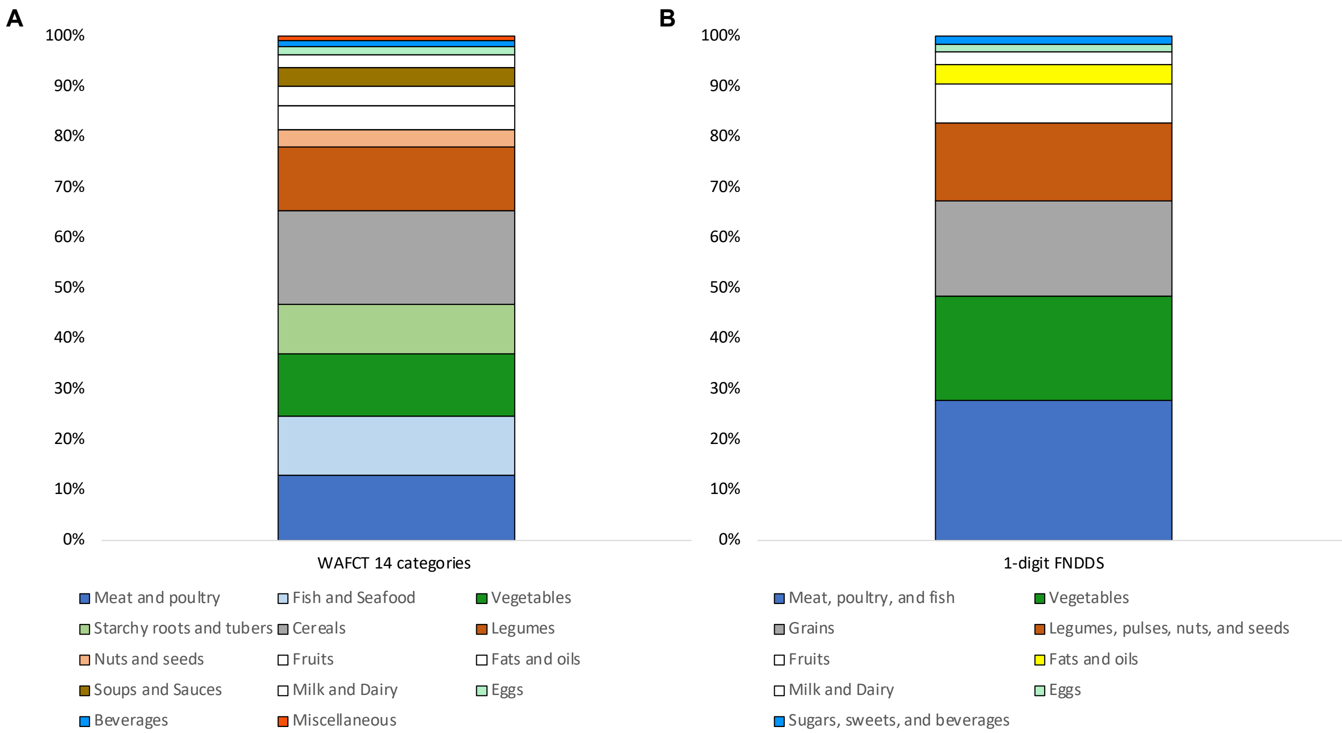

Figure 1. Distribution of the WAFCT 909 food based on (A) the WAFCT 14 categories and (B) the USA 1-digit FNDDS nine categories. WAFCT: Food Composition Table for Western Africa 2019, 1-digit FNDDS: one-digit codes of the USDA's Food and Nutrient Database for Dietary Studies (FNDDS) 2017-2018 categories.

The main differences observed between both classifications were the combination of food groups. Starchy roots and tubers (WAFCT) were combined with vegetables in the vegetables category of the 1-digit FNDDS classification; meat and poultry were combined with fish and seafood (WAFCT) within the meat, poultry, and fish group (1-digit FNDDS), and legumes were combined with nuts and seeds (WAFCT) in the legumes, pulse, nuts, and seeds food group (1-digit FNDDS).

3.2 Nutrient Density

This study used a Nutrient Rich Foods Index family of scores, which included the NRF9.3, NRF6.3 (priority micronutrients), and NRF15.3 (extended priority nutrients). **Table 3** shows mean, standard deviation, and median scores of the NRF9.3 by the 14 WAFCT food groups. Based on the NRF9.3, the vegetable group (263.0) had the highest score of all food groups, having a significant difference to the next highest food group score (fruits: 89.56). Fish and seafood, and legumes were the next food groups with highest scores. Fats and oils, and miscellaneous foods (containing mostly sugars and marmalades) were the food groups with lowest NRF9.3 scores.

Table 3. NRF9.3 scores by WAFCT food groups per 100 grams.

WAFCT Food Groups	No. of foods	Kcal/ 100 g	NRF9.3 scores		
			Mean[1]	SD	Median
Vegetables	113	72.57	263.00[a]	122.69	234.10
- Dark green leafy vegetables	59	62.25	344.12	105.28	360.28
- Other vit. A-rich vegetables	12	37.00	186.91	38.04	194.37
- Other vegetables	42	97.21	170.80	71.96	161.75
Fruits	44	98.82	89.56[b]	58.32	88.11
- Vit. A-rich fruits	8	59.13	118.87	46.66	125.92
- Other fruits	36	107.64	83.04	59.19	65.35
Fish and seafood	106	126.11	86.41[b]	41.47	77.67
Legumes	115	177.25	75.21[c]	11.40	76.87
Meat and poultry	118	211.29	56.74[d]	57.06	41.39
Starchy roots, and tubers	89	156.66	49.89[d]	28.17	46.78
Beverages	12	52.67	43.66[d,e]	47.94	60.41
Soups and sauces	34	130.97	40.96[d]	29.92	35.46
Eggs	14	171.24	39.86[d]	8.06	39.81
Cereals	169	224.10	31.32[e]	23.93	32.82
Milk and its products	23	192.22	28.37[e]	24.76	28.69
Nuts and seeds	30	499.93	27.40[e]	20.40	27.89
Fats and oils	35	880.71	-8.39[f]	21.37	-7.93
Miscellaneous	7	288.29	-15.49[f]	26.84	-15.26
P			<0.001		

Mean, standard deviation, and median NRF9.3 scores and Kcal. per 100 grams by WAFCT food groups. SD: Standard deviation.
[1] Means annotated with same-letter superscripts are not significantly different from each other.

Table 4 shows scores of the NRF6.3 by the 14 WAFCT food groups. The NRF6.3 assessed nutrients commonly lacking in LMICs(5). Based on NRF6.3 scores, vegetables were the food group with the highest score. After vegetables, fish and seafood were the second food group with highest score, followed by meat and poultry, eggs, and legumes. Fruits were found to be in the nineth place out of the 14 food groups. Moreover, miscellaneous foods, fats and oils, and beverages were the food groups with the lowest NRF6.3 scores.

Table 4. NRF6.3 scores by WAFCT food groups per 100 grams.

WAFCT Food Groups	No. of foods	Kcal/ 100 g	Mean NRF6.3 scores[1]		
			Mean[1]	SD	Median
Vegetables	113	72.57	138.73[a]	92.13	120.98
- Dark green leafy vegetables	59	62.25	201.62	76.43	206.47
- Other vit. A-rich vegetables	12	37.00	79.63	32.77	65.28
- Other vegetables	42	97.21	67.26	51.87	51.86
Fish and seafood	106	126.11	106.88[b]	56.35	111.03
Meat and poultry	118	211.29	90.39[c]	100.11	61.01
Eggs	14	171.24	79.34[c]	34.50	67.22
Legumes	115	177.25	36.82[d]	13.16	35.89
Soups and sauces	34	130.97	36.74[d,e]	36.81	33.91
Milk and its products	23	192.22	28.79[e,f,j]	26.94	26.06
Cereals	169	224.10	19.63[f,j]	22.13	15.83
Fruits	44	98.82	18.67[f]	24.13	19.80
- Vit. A-rich fruits	8	59.13	45.32	15.83	42.85
- Other fruits	36	107.64	12.74	21.60	12.33
Starchy roots, and tubers	89	156.66	16.77[f,j]	22.04	13.91
Nuts and seeds	30	499.93	6.35[g]	16.86	7.12
Beverages	12	52.67	5.64[g,j]	49.63	-3.69
Fats and oils	35	880.71	-10.32[h]	17.69	-7.93
Miscellaneous	7	288.29	-27.18[i]	27.34	-27.69
P			<0.001		

Mean, standard deviation, and median NRF6.3 scores and Kcal. per 100 grams by WAFCT food groups. SD: Standard deviation.

[1] Means annotated with same-letter superscripts are not significantly different from each other.

Table 5. NRF15.3 scores by WAFCT food groups per 100 grams.

WAFCT Food Groups	No. of foods	Kcal/ 100 g	Mean NRF15.3 scores		
			Mean[1]	SD	NRF15.3
Vegetables	113	72.57	344.19[a]	178.59	295.99
- Dark green leafy vegetables	59	62.25	451.96	163.40	445.86
- Other vit. A-rich vegetables	12	37.00	250.68	55.05	265.70
- Other vegetables	42	97.21	219.51	115.53	218.55
Fish and seafood	106	126.11	214.24[b]	73.46	210.97
Meat and poultry	118	211.29	195.91[b,c]	159.64	151.01
Eggs	14	171.24	137.60[c,d,j]	32.26	126.10
Fruits	44	98.82	106.83[d,e,j]	73.67	97.98
- Vit. A-rich fruits	8	59.13	147.63	41.95	153.82
- Other fruits	36	107.64	97.76	76.49	83.48
Soups and sauces	34	130.97	100.81[e,j]	47.32	93.58
Beverages	12	52.67	91.13[j]	90.29	87.91
Legumes	115	177.25	87.71[f,j]	21.40	87.58
Milk and its products	23	192.22	73.48[g,j]	46.52	65.56
Nuts and seeds	30	499.93	58.89[g,h,j]	32.78	69.01
Starchy roots, and tubers	89	156.66	57.84[g,h]	29.59	52.38
Cereals	169	224.10	49.84[h]	33.90	47.20
Fats and oils	35	880.71	11.90[i]	33.19	12.24
Miscellaneous	7	288.29	-10.98[i]	31.81	-13.63
P			<0.001		

Mean, standard deviation, and median NRF15.3 scores and Kcal. per 100 grams by WAFCT food groups. SD: Standard deviation.
[1] Means annotated with same-letter superscripts are not significantly different from each other.

Table 5 shows mean, standard deviation, and median scores of the NRF15.3 (extended priority nutrients) by the 14 WAFCT food groups. Based on the NRF15.3 scores, the ranking of food groups also changed. Since more nutrients were used in the model, the overall scores had a higher value. Like the previous NRF versions, vegetables were the food group with highest scores. Moreover, animal-sourced foods were also favored by this model compared to the NRF9.3. Fish and seafood was the second food group with highest scores, just as with the NRF6.3. The next food groups with highest scores were meat and poultry; eggs; fruits; and soups and sauces.

Using the different NRF versions and the subclassification of vegetables and fruits, significantly higher scores were observed in the dark green leafy vegetables followed by vitamin A-rich vegetables. Similarly, vitamin A-rich fruits had significantly higher scores compared to other fruits.

Table 6 shows a list of the top 20 foods with the highest scores for each of the NRF versions. Dark green leafy vegetables, both raw and boiled, lead all lists, as they were the most nutrient-dense foods. However, while the top NRF9.3 foods are only leafy vegetables, the top NRF6.3 and NRF15.3 lists also contain poultry, meat, fish, and organ foods.

Table 6. List of foods with the highest NRF scores.*

Ranking	Highest NRF9.3 scores	Highest NRF6.3 scores	Highest NRF15.3 scores
1	Amaranth, leaves, raw	Chicken liver, raw	Spinach, leaves, raw
2	Amaranth, leaves, boiled	Chicken liver, stewed	Cowpea, leaves, raw
3	Spinach, leaves, raw	Chicken liver, boiled	Spinach, leaves, boiled
4	Spider plant, leaves, raw	Chicken liver, grilled (without salt or fat)	Cowpea, leaves, boiled
5	Spinach, leaves, boiled	Spider plant, leaves, raw	Spider plant, leaves, raw
6	Cowpea, leaves, raw	Spider plant, leaves, boiled	Spider plant, leaves, boiled
7	Spider plant, leaves, boiled	Amaranth, leaves, raw	Chicken liver, raw
8	Jute mallow (bush-okra), leaves, raw	Chicken giblets, grilled (without salt or fat)	Amaranth, leaves, fresh, raw
9	Mint, leaves, raw	Beef liver, raw	Jute mallow (bush-okra), leaves, raw
10	Cowpea, leaves, boiled	Mint, leaves, raw	Chicken liver, stewed
11	Moringa (drumstick), leaves, boiled	Chicken giblets, raw	Amaranth, leaves, boiled
12	Moringa (drumstick), leaves, raw	Amaranth, leaves, fresh, boiled	Chicken liver, grilled (without salt or fat)
13	Jute mallow (bush-okra), leaves, boiled	Eggplant, leaves, raw	Moringa (drumstick), leaves, raw
14	Eggplant, leaves, raw	Spider plant, leaves, boiled	Moringa (drumstick), leaves, boiled
15	Eggplant, leaves, boiled	Cowpea, leaves, raw	Beef liver, raw
16	Green leafy vegetable, average, raw	Beef liver, grilled (without salt or fat)	Chicken liver, boiled (without salt)
17	Pumpkin, leaves, raw	Beef liver, stewed	Spinach, leaves, boiled
18	Moringa (drumstick), leaves, boiled (without salt)	Chicken giblets, boiled	Eggplant, leaves, raw
19	Parsley, raw	Spinach, leaves, raw	Cowpea, leaves, fresh, boiled
20	Pumpkin, leaves, boiled	Mola carplet, small whole fish, raw	Beef liver, stewed

*Foods highlighted in green are classified as African Indigenous Vegetables.

3.2.1 Nutrient Density in African Indigenous Vegetables (AIV)

Nutrient density and protein content of African indigenous vegetables (AIV) and mixed dishes containing AIV in the WAFCT was analyzed and compared with the rest of the vegetables. **Table 7** shows NRF scores for each subcategory. Using the three different NRF versions, AIV obtained significantly higher nutrient density scores compared to preparations with AIV and non-indigenous vegetables. Using the NRF9.3 (developed in high-income countries), the non-indigenous vegetables had an almost equivalent score compared to preparations with AIV; however, using the NRF6.3 and NRF15.3 (adapted to LMICs), both AIV and preparations with AIV had higher scores than non-indigenous vegetables. The predominance of AIV on the top 20 NRF scores list can also be observed in **Table 6**.

Table 7. NRF scores and Protein Quality for African indigenous vegetables (AIV) and other vegetables.

WAFCT Food Groups	No. of foods	Kcal/ 100 g	Mean (SD) NRF score			Protein content	
			NRF9.3	**NRF6.3**	**NRF15.3**	**Protein g/100g**	**Protein content after PDCAAS Adjustment**
African Indigenous vegetables (AIV)	25	46.28	339.14 (110.57)	198.17 (85.22)	451.43 (168.10)	3.81 (1.81)	2.76 (1.35)
Preparations with AIV	18	73.22	227.78 (186.87)	132.90 (108.21)	324.33 (233.89)	4.19 (1.80)	3.19 (1.43)
Non-indigenous vegetables	68	54.29	227.49 (109.73)	111.27 (82.93)	292.43 (157.77)	2.90 (2.10)	1.87 (1.31)

Protein content was also assessed, both before and after PDCAAS adjustment. Overall, preparations with AIV contained higher protein content compared to AIV and non-indigenous vegetables. This was mainly because various preparations contained fish and meat. Moreover, AIV also outperformed non-indigenous vegetables in protein content, both before and after PDCAAS adjustment.

3.2.2 Nutrient Density in African Indigenous Grains (AIG)

Nutrient density of African indigenous grains (AIG) in the WAFCT was analyzed and compared with non-indigenous grains. **Table 8** shows the nutrient density scores for indigenous and non-indigenous grains using the different NRF models. AIGs presented higher scores in the three models compared to non-indigenous grains; however, only the NRF9.3 score difference was statistically significant.

Furthermore, the non-indigenous grains subcategory contained 10 food items (i.e., flours) which have been fortified with various micronutrients. A second analysis was conducted comparing AIGs and non-indigenous grains without the fortified items. As a result, NRF scores for the three models were statistically significantly higher for AIG compared to non-indigenous grains, as shown in **Table 8**.

Table 8. Nutrient Density of African Indigenous Grains (AIG) and non-indigenous grains.

			Mean (SD) NRF score		
Grain Type	**No. of foods**	**Kcal/ 100 g**	**NRF9.3**	**NRF6.3**	**NRF15.3**
African Indigenous Grains	55	260.07	42.69 (19.20)	28.86 (11.39)	61.64 (19.96)
Non-indigenous Grains	55	277.65	30.00 (21.19)	23.21 (25.01)	56.46 (42.53)
P-value		*0.604*	*0.001**	*0.327*	*0.415*
Non-indigenous grains (without fortified flours)	45	261.04	29.63 (22.66)	13.04 (7.68)	44.01 (31.68)
P-value		*0.965*	*0.002**	*<0.001**	*0.001**

* Difference was statistically significant.

3.2.3 Nutrient Density in Fortified Foods

A total of 44 foods (4.8%) of the WAFCT were fortified with one or more micronutrient. For 39 of the 44 fortified foods, the WAFCT also contained information of their unfortified version. **Table 9** shows the mean values of the three NRF versions for specific foods and their fortified version. As expected, NRF values significantly increased in the fortified version of the presented foods, showing the impact of fortification on nutrient density as demonstrated by nutrient profiling scores. Most foods with negative scores continued having a negative score after fortification; however, their scores significantly improved, and with the NRF15.3 version, the mean score for fortified oils became positive.

Table 9. NRF mean scores of specific foods vs. scores of their fortified version.

	Unfortified version				Fortified version			
Food	**No. of foods**	**NRF9.3**	**NRF6.3**	**NRF15.3**	**No. of foods**	**NRF9.3**	**NRF6.3**	**NRF15.3**
Porridges	9	23.65	11.03	32.63	9	47.14	34.52	56.12
Maize Flour	3	22.30	9.33	33.71	3	52.19	39.93	64.38
Wheat Flours	1	15.07	21.58	48.94	8	27.43	76.69	125.76
Oils	9	-19.82	-19.81	3.53	18	-2.11	-2.10	21.24
Sugar	1	-49.83	-49.78	-49.36	1	-26.40	-26.34	-25.93

3.3 Carbohydrate quality

3.3.1 Identifying Carbohydrate Foods in the WAFCT 2019

For the Carbohydrate Foods Quality Score System analyses, a total of 446 foods were included in the analytical sample (**Figure 2** and **Table 10**). The 2-digit FNDDS food subgroups were used in this analysis. Out of the total number of carbohydrate foods in the WAFCT 2019 analyses, the sample includes 17 flours (4%); 5 (1%) breads; 3 (1%) sweet bakery products; 56 (13%) cooked cereals, pasta, and rice; 47 (10%) uncooked cereals; 42 (9%) mixed-grain dishes; 68 (15%) fruits; 114 (26%) vegetables and tubers; 89 (20%) legumes and pulses; and 5 (1%) sugars and sweets.

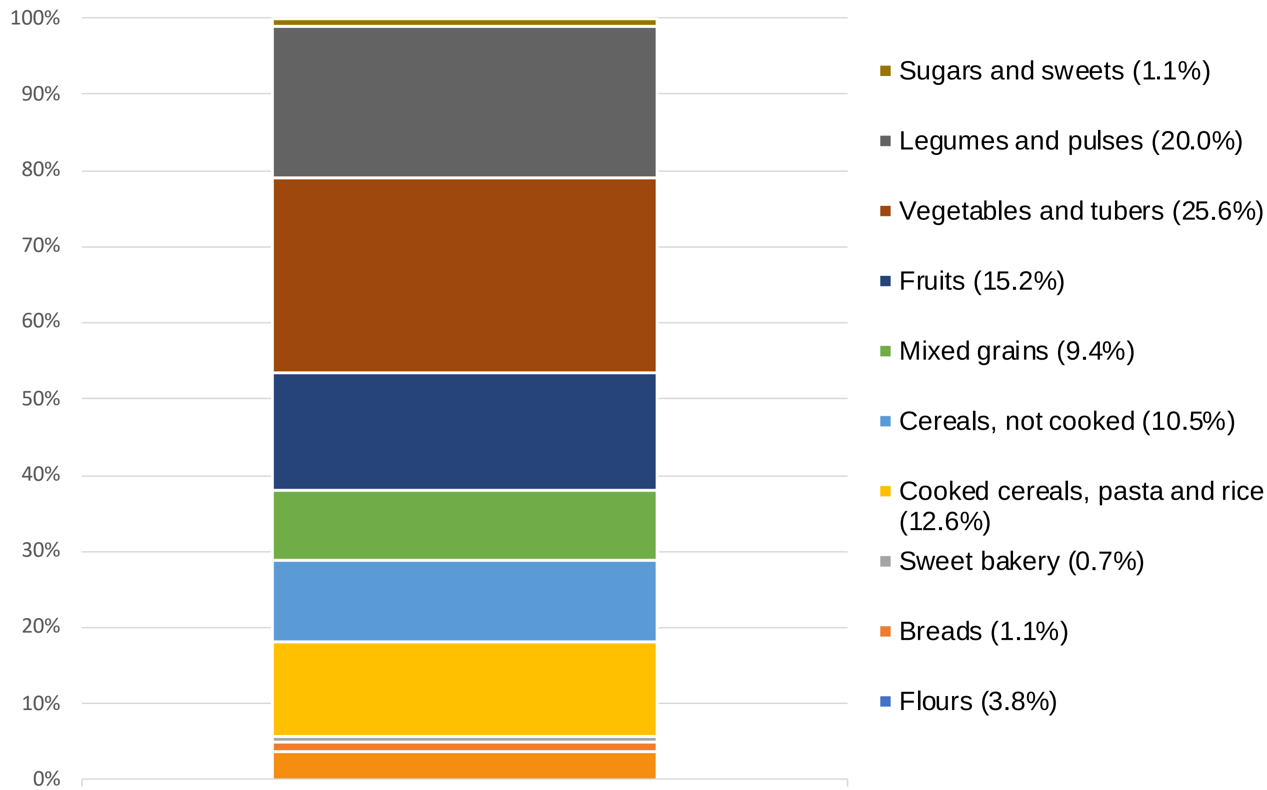

Figure 2. Distribution of Carbohydrate Foods in the FAO/INFOODS Food Composition Table for Western Africa (2019) (N = 446).

The present analysis excludes most mixed dishes in the WAFCT, as they contain significant amounts of fat and protein, making them not suitable for inclusion in a carbohydrate food scoring metric.

3.3.2 Components of the Carbohydrate Food Quality Scoring System

3.3.2.1. Component Scores

Table 10 shows the number and percentage of carbohydrate foods classified as higher quality based on single component and composite scoring systems. Almost all legumes and pulses (99%); vegetables and tubers (90%), and uncooked cereals (77%) contained 10g of fiber per 100 g of carbohydrate. A significant number of fruits (68%) and cooked cereals (57%) also contained high levels of fiber. Food groups with the lowest fiber content were sweet bakery, flours, sugars and sweets, and breads. Since most foods included in the WAFCT 2019 are considered to be unprocessed or processed to a minimal extent, just few foods contained free sugars. Therefore, almost all foods (95.7%) in our analysis earned the free sugars point. Sweet bakery products, sugars and sweets, and some fruits and mixed grains were the food items that contained higher sugar content.

The present study replicated Drewnowski et al.(11) component scores to assess carbohydrate quality in the WAFCT. Just as with free sugars, most carbohydrate foods contained less than 600 mg sodium/ 100 g dry weight and earned the sodium point. A few breads, mixed-grain dishes, and legumes contained higher levels of sodium. In terms of potassium levels, carbohydrate foods in vegetables and tubers (100%), fruits (99%), legumes and pulses (94%), and uncooked cereals (77%) contained >300 mg of potassium/ 100 g dry weight, as expected. Sweet bakery, breads, flours, sugars and sweets, and mixed-grain dishes were less likely to score potassium points.

Table 10. Number and Percentage of "Higher-Quality Carbohydrate Foods" Based on Single Component and Composite Scoring Systems.

	Component Scores[1]					Composite Scores[2]
	Fiber	**Free Sugar**	**Sodium**	**Potassium**	**Whole Grain**	**CFQS-5***
Flours (*n=17*)	1 (5.9%)	17 (100%)	17 (100%)	2 (11.8%)	1 (5.9%)	1 (5.9%)
Breads (*n=5*)	1 (20%)	4 (80%)	1 (20%)	1 (20%)	1 (20%)	1 (20%)
Sweet Bakery (*n=3*)	0 (0%)	0 (0%)	3 (100%)	0 (0%)	0 (0%)	0 (0%)
Cooked cereals, pasta, and rice (*n=56*)	32 (57.1%)	56 (100%)	55 (98.2%)	22 (39.3%)	34 (60.7%)	29 (51.8%)
Cereals, not cooked (*n=47*)	36 (76.6%)	47 (100%)	47 (100%)	36 (76.6%)	38 (80.9%)	36 (76.6%)
Mixed grains (*n=42*)	15 (35.7%)	39 (92.9%)	37 (88.1%)	12 (28.6%)	6 (14.3%)	7 (16.7%)
Fruits (*n=68*)	46 (67.6%)	61 (89.7%)	66 (97.1%)	67 (98.5%)	0 (0%)	44 (64.7%)
Vegetables and tubers (*n=114*)	103 (90.4%)	114 (100%)	111 (97.4%)	114 (100%)	0 (0%)	100 (87.7%)
Legumes and pulses (*n=89*)	88 (98.9%)	90 (100%)	86 (96%)	84 (94.4%)	0 (0%)	80 (89.9%)
Sugars and sweets (*n=5*)	1 (20%)	0 (0%)	5 (100%)	1 (20%)	0 (0%)	0 (0%)
TOTAL(n=446)	323 (72.4%)	427 (95.7%)	428 (96%)	339 (76%)	80 (17.9%)	298 (66.8%)

[1]For the component scores, higher-quality carbohydrate foods are those which earn a single point.
[2]For the composite scoring systems, a food must score 4 or 5 points in the CFQS-5 model.
*For example, 29 out of the 56 foods (51.8%) in the "Cooked cereals, pasta, and rice" category were considered higher-quality carbohydrate foods for scoring 4 or more points.

For the whole grain points, only 18% of carbohydrate foods obtained a point. Most uncooked cereals (81%) and cooked cereals, pasta, and rice (61%) scored a whole grain point, whereas a few or no breads, sweet bakery, flours, and sugars obtained a point. Vegetables and tubers, legumes and pulses, and fruits were ineligible for scoring whole grain points, as they do not contain whole grains.

3.3.2.2 Carbohydrate Food Quality Scores (CFQS)

As shown in **Table 10**, higher-quality Carbohydrate Foods were determined by the sum of their component scores. A total number of 298 Carbohydrate Foods (67%) were identified to be of higher quality, scoring 4 or 5 points. The distribution of higher-quality carbohydrate foods by food category is shown in **Figure 3**. Scores are based on the CFQS-5 model.

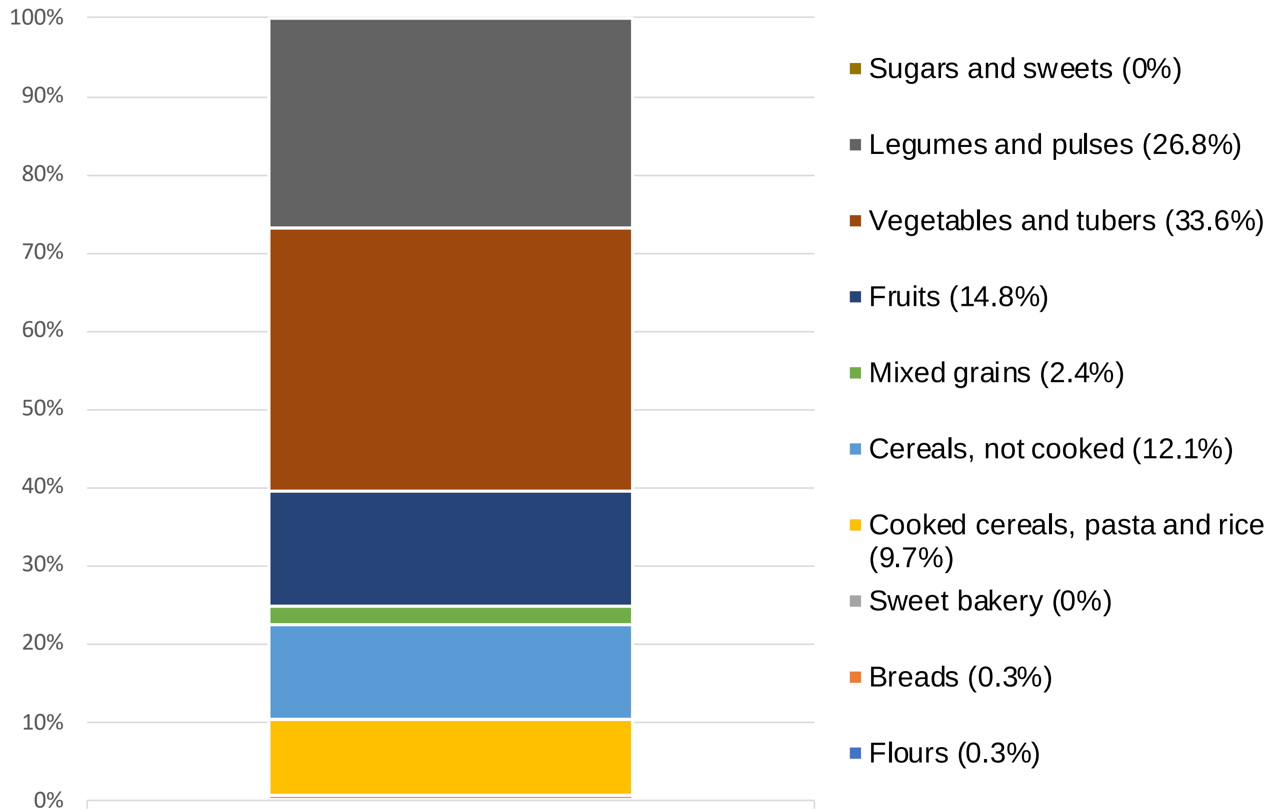

Figure 3. Distribution of higher-quality carbohydrate foods (based on the CFQS-5 model) by food group (N=446).

As shown in **Figure 3**, the distribution of higher-quality Carbohydrate Foods was mainly among three food groups: vegetables and tubers (34%), legumes and pulses (27%), and fruits (15%). Around 12% and 10% of higher-quality Carbohydrate Foods were part of the uncooked cereals, and the cooked cereals, pasta, and rice categories, respectively.

Figure 4A shows that most vegetables and tubers, and legumes and pulses scored 4 points, whereas scores of foods in the group of cooked cereals, pasta, and rice, were distributed among the 2-5 CFQS-5 points. **Figure 4B** shows that breads, sweet bakery, and most sugars make up the largest portion of the 1-point scores. Uncooked cereals and cooked cereals, pasta, and rice make up the largest portion of the 5-point scores.

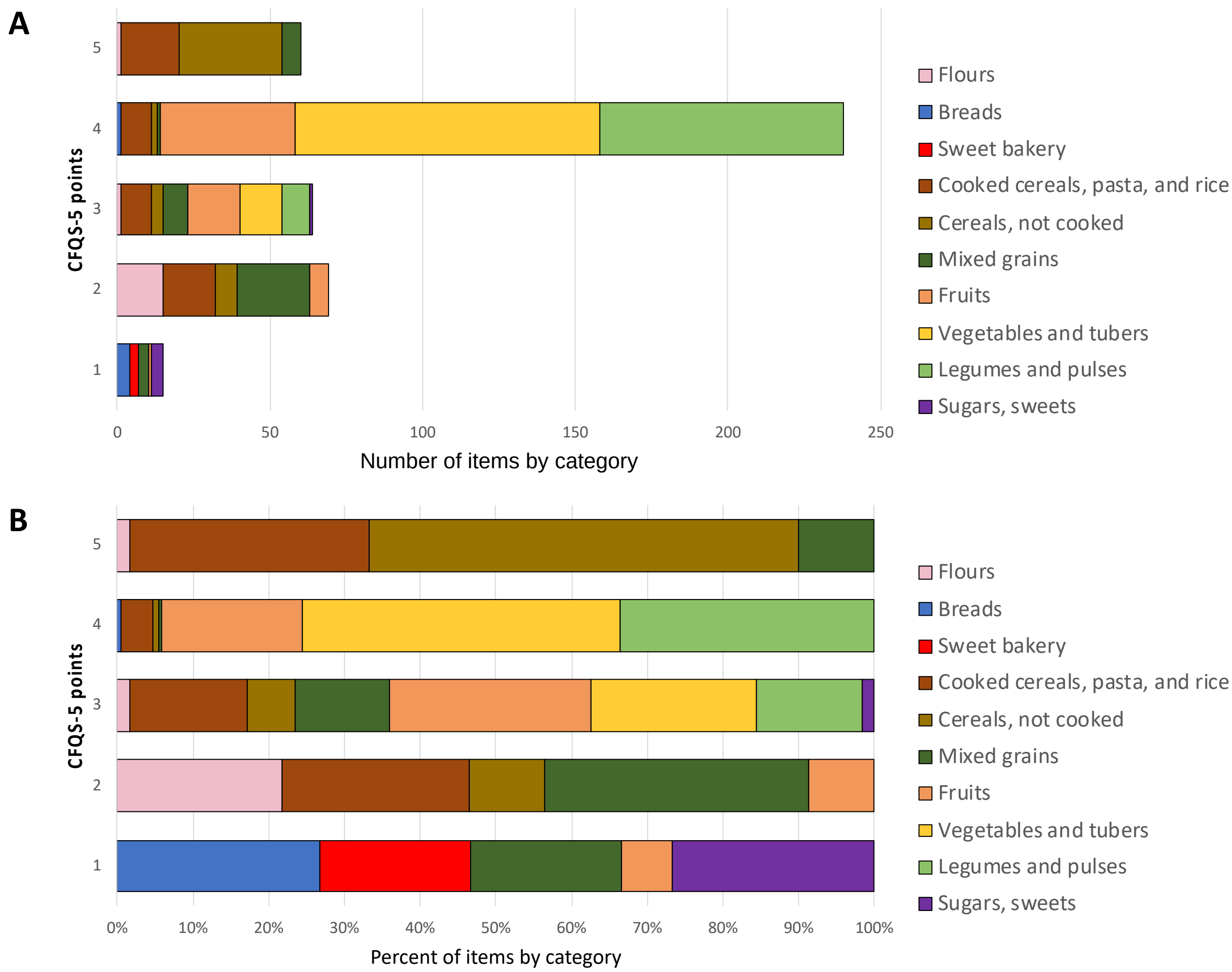

Figure 4. Distribution of CFQS-5 scores across food groups (N=446) shown as point values (A) and as percentages (B).

3.3.3.3 Carbohydrate Food Quality Scores (CFQS) of African Indigenous Grains (AIG)

The Carbohydrate Food Quality Scores (CFQS) were assessed for African indigenous grains (AIG) and compared to non-indigenous grains. In general, a greater proportion of AIGs were categorized as higher-quality carbohydrate foods in comparison to their non-indigenous counterparts, as shown in **Figure 5**. Among the AIGs, a total of 38 food items (69%) obtained 4 or more CFQS points, thereby attaining the classification of higher-quality carbohydrate foods. Conversely, 17 AIGs (31%) were classified as lower-quality carbohydrate foods. In contrast, within the non-indigenous grain category, 25 grains (45%) were designated as higher-quality carbohydrate foods, while 30 grains (55%) were identified as lower-quality carbohydrate foods.

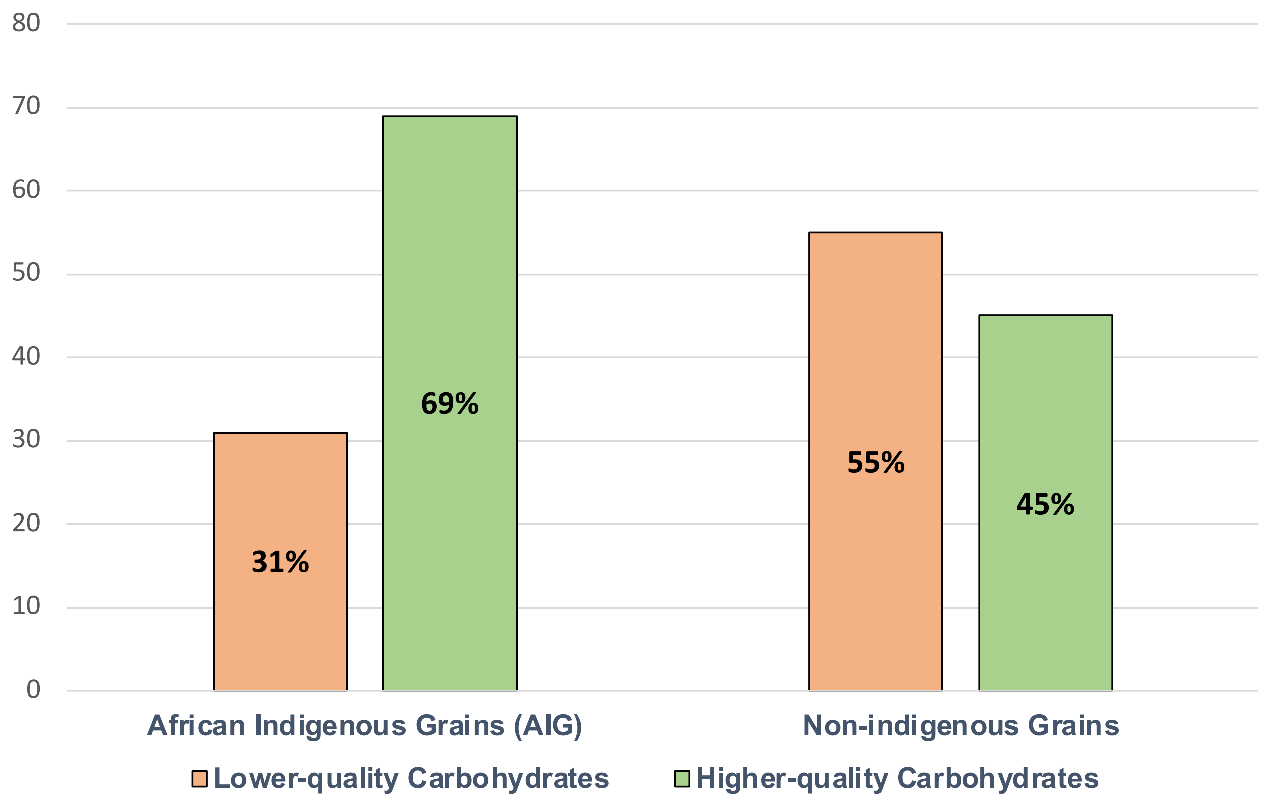

Figure 5. Carbohydrate Quality among African Indigenous Grains (AIG) (n=55) and non-indigenous grains (n=55). Higher-Quality Carbohydrates were those with CFQS scores of 4 or higher.

3.3.2.3 Carbohydrate Food Quality Scores (CFQS) and the Nutrient Rich Food (NRF) Index Models

The association between the CFQS-5 model scores and three different NRF scores is shown in **Figure 6**. The size of the circles indicates the number of higher-quality items per food category. Since no foods within the sweet bakery and sugars and sweets categories obtained a CFQS score of 4 or higher, those food groups are not included in the graph. The CFQS-5 model score vegetables and tubers, legumes and pulses, and fruits as higher-quality carbohydrate foods relative to NRF9.3 and NRF15.3. **Figure 6** shows how flours have a higher NRF6.3 score, but they are not among the highest CFQS-5 scores. The correlation between the CFQS-5 and NRF9.3 scores is 0.474 (p-value <0.001), the correlation between the CFQS and NRF6.3 scores is 0.370 (p-value <0.001), and the correlation between the CFQS-5 and NRF15.3 scores is 0.396 (p-value <0.001). The CFQS metric was moderately correlated with the different NRF metrics, having a higher correlation with the NRF9.3.

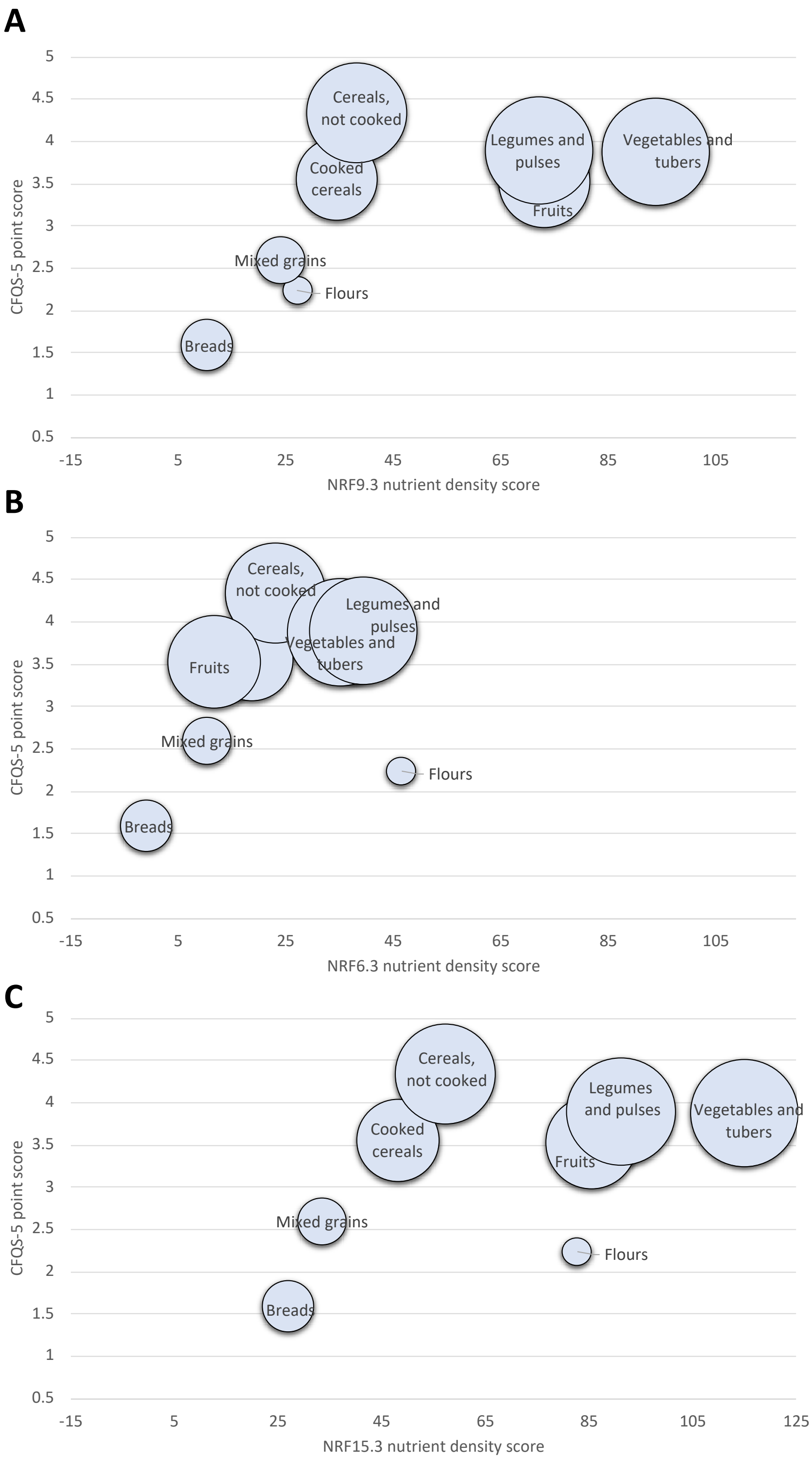

Figure 6. Relation between Carbohydrate Food Quality scores (CFQS) and the different NRF versions (N=446). (A) CFQS-5 vs. NRF9.3 Scores for Carbohydrate Food Categories, (B) CFQS-5 vs. NRF6.3 Scores for Carbohydrate Food Categories, (C) CFQS-5 vs. NRF15.3 Scores for Carbohydrate Food Categories (The size of the circles represent the percentage of higher-quality carbohydrate foods in each food category).

3.4 Protein quality

Table 11 lists energy density and protein content of the FAO/INFOODS Food Composition Table for Western Africa foods by the 14 food groups included in the WAFCT, separately for animal and plant proteins. Since most foods included in the WAFCT are minimally processed, only three (cereals, soups and sauces, and beverages) out of the 14 food groups contained a combination of both plant and animal proteins within the group itself. Food groups that contained the most animal protein per 100 g were meat and poultry; fish and seafoods; eggs; and milk and dairy. Food groups that contained the most plant protein were nuts and seeds, and legumes. Overall, the fat and oils, beverages and miscellaneous food groups contained limited amounts of protein.

Table 11. Energy density and total animal and plant protein content of 909 WAFCT 2019 foods aggregated into 14 food groups.

						Protein content in g/100 g by food group[1]			
		ED* kcal/100 g		Total protein		Animal-based		Plant-based	
WAFCT Food Groups	No. of foods	Mean	SEM*	Mean	SEM	Mean	SEM	Mean	SEM
Meat and poultry	118	211.29^{f}	9.53	24.86^{a}	0.71	24.86^{a}	0.71	0.00	0.00
Eggs	14	171.24^{e,f}	4.71	12.87^{b,c}	0.39	12.87^{b}	0.39	0.00	0.00
Fish and seafood	106	126.11^{c}	3.74	23.90^{a}	0.66	23.90^{a}	0.66	0.00	0.00
Milk and products	23	192.22^{e,f}	31.28	10.25^{c}	2.20	10.25^{b}	2.20	0.00	0.00
Cereals	169	224.11^{f,g}	9.52	5.79^{d}	0.28	1.20^{d}	0.00	5.82^{b}	0.28
Starchy roots, tubers	89	156.66^{d,e}	8.71	2.03^{f}	0.11	0.00	0.00	2.03^{c}	0.11
Legumes	115	177.25^{e}	9.54	12.23^{b,c}	0.75	0.00	0.00	12.23^{a}	0.75
Vegetables	113	72.57^{a,b}	7.36	4.50^{d}	0.49	0.00	0.00	4.50^{b}	0.49
Fruits	44	98.82^{b}	11.76	1.18^{g}	0.13	0.00	0.00	1.18	0.13
Nuts and seeds	30	499.93^{h}	24.57	17.04^{b}	1.81	0.00	0.00	17.04^{a}	1.81
Soups and sauces	34	130.97^{c,d}	10.41	4.53^{d}	0.28	4.76^{c}	0.29	3.20^{b}	0.60
Fats and oils	35	880.71^{i}	9.02	0.09^{h}	0.04	0.00	0.00	0.09^{e}	0.04
Beverages	12	52.67^{a}	7.03	1.36^{f,g}	0.49	3.80^{c}	0.10	0.54^{d}	0.31
Miscellaneous	7	288.29^{g}	70.79	1.29^{f,g}	0.72	0.00	0.00	1.29^{c,d}	0.72
P		<0.001		<0.001		<0.001		<0.001	

*ED: Energy Density; SEM: Standard Error of the Mean.

[1] Means annotated with same-letter superscripts are not significantly different from each other.

3.4.1 Protein Source and Nutrient Density

Figure 7 presents the proportion of animal-protein foods and plant-based protein foods within the top tertile of the different NRF versions. Within foods in the top tertile of NRF9.3 scores, 214 foods (71%) were plant-based protein sources, whereas 89 (29%) were animal protein foods. The proportion was different for the NRF6.3 and NRF15.3 versions, in which the top tertile contained a higher proportion of animal protein foods. A total of 180 foods in the top tertile of NRF6.3 score were animal protein foods, whereas 123 (41%) were plant-based protein foods. Results were similar with the top tertile of NRF15.3, where 174 foods (57%) were animal protein foods and 129 (43%) were plant-based protein foods.

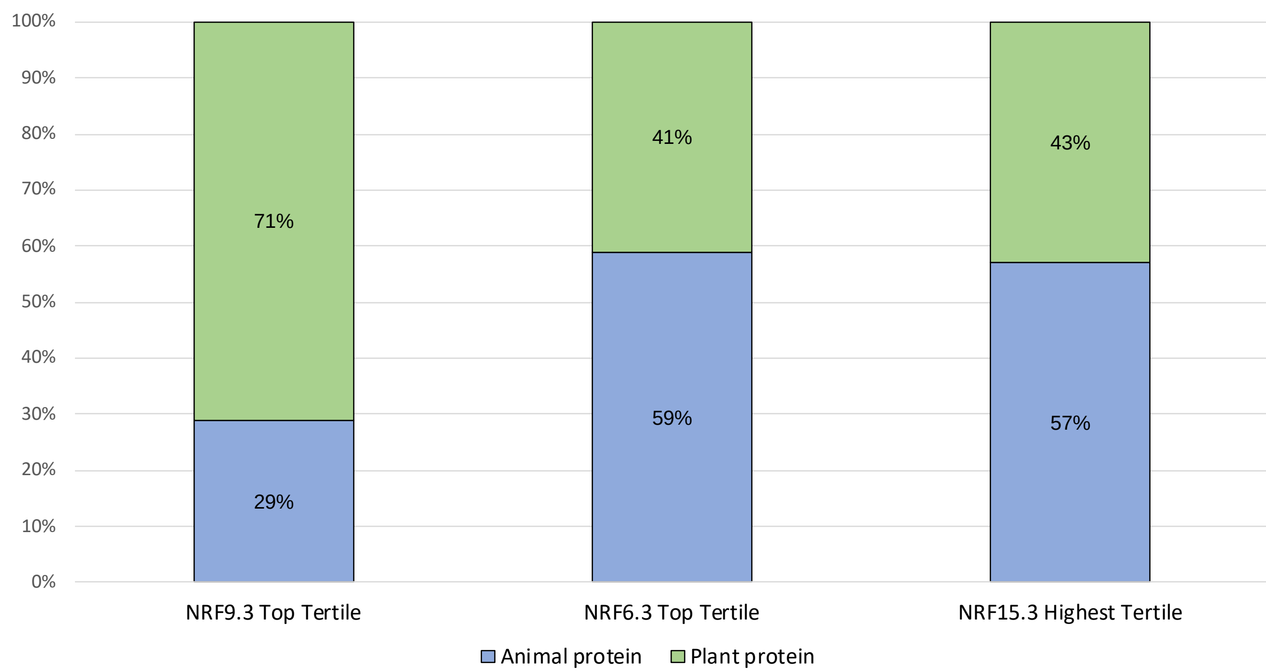

Figure 7. Top tertile of NRF scores and proportion of foods by protein type (N=303).

3.4.2 PDCAAS Adjustment

After PDCAAS adjustment, food groups had significant reductions in mean grams of protein per 100 grams of food. **Table 12** shows that the differences were most pronounced for nuts and seeds; cereals; starchy roots and tubers; legumes; vegetables; fruits; and soups and sauces. No differences were observed in the eggs category given that its PDCAAS value equals 1. Moreover, the difference observed in the milk category was not statistically significant.

Table 12. Protein grams per 100 grams for 862 WAFCT 2019 foods by food categories before and after PDCAAS adjustment.

Protein g per 100 g									
		Grams of protein per 100g of food		**Grams of protein per 100g of food after PDCAAS correction**		**95% CI of the difference**		**Paired samples test**	
WAFCT food groups	**No. of foods**	**Mean**	**SEM**	**Mean**	**SEM**	**5%**	**95%**	**t-test value**	**P-value**
Meat and poultry	118	24.86	0.71	23.30	0.64	1.33	1.80	13.42	<0.001
Eggs	14	12.87	0.39	12.87	0.39	-	-	-	NS
Fish and seafood	106	23.90	0.66	22.63	0.62	1.16	1.39	22.23	<0.001
Milk and products	23	10.25	2.20	10.16	2.19	0.02	0.16	2.73	0.12
Cereals	169	5.79	0.28	2.45	0.14	2.96	3.71	17.62	<0.001
Starchy roots, and tubers	89	2.03	0.11	1.52	0.08	0.46	0.58	17.93	<0.001
Legumes	115	12.23	0.75	8.22	0.65	3.46	4.55	14.65	<0.001
Vegetables	113	4.50	0.49	3.03	0.34	1.13	1.80	8.68	<0.001
Fruits	44	1.18	0.13	0.71	0.08	0.35	0.59	7.83	<0.001
Nuts and seeds	30	17.04	1.81	8.01	0.85	7.08	10.99	9.44	<0.001
Soups and sauces	34	4.53	0.28	3.71	0.24	0.72	0.91	17.27	<0.001
Beverages	7	0.66	0.40	0.51	0.38	0.01	0.29	2.71	0.035

NS: Not statistically significant.

Figure 8 shows a scatterplot of mean protein content (g/100 g) against energy density (kcal/100 g) by the 14 WAFCT food categories. **Figure 8A** shows the values as included in the WAFCT. Foods groups with more than 10 g of protein per 100 grams were mostly animal-sourced foods, including meat and poultry; fish and seafood; eggs; and milk and products. Only two food categories provided >10 g/100g of plant protein. Those were nuts and seeds (17.04 g protein/100 g), and legumes (12.23 g protein/100 g). **Figure 8B** shows the values for corrected protein after PDCAAS adjustment. Protein from food groups containing animal sources was minimally impacted by PDCAAS correction, and the same four food groups still contained >10 g protein/100 g after the adjustment. In contrast with animal food sources, no food group containing plant-based protein reached protein a content of >10 g/100 g after protein adjustment.

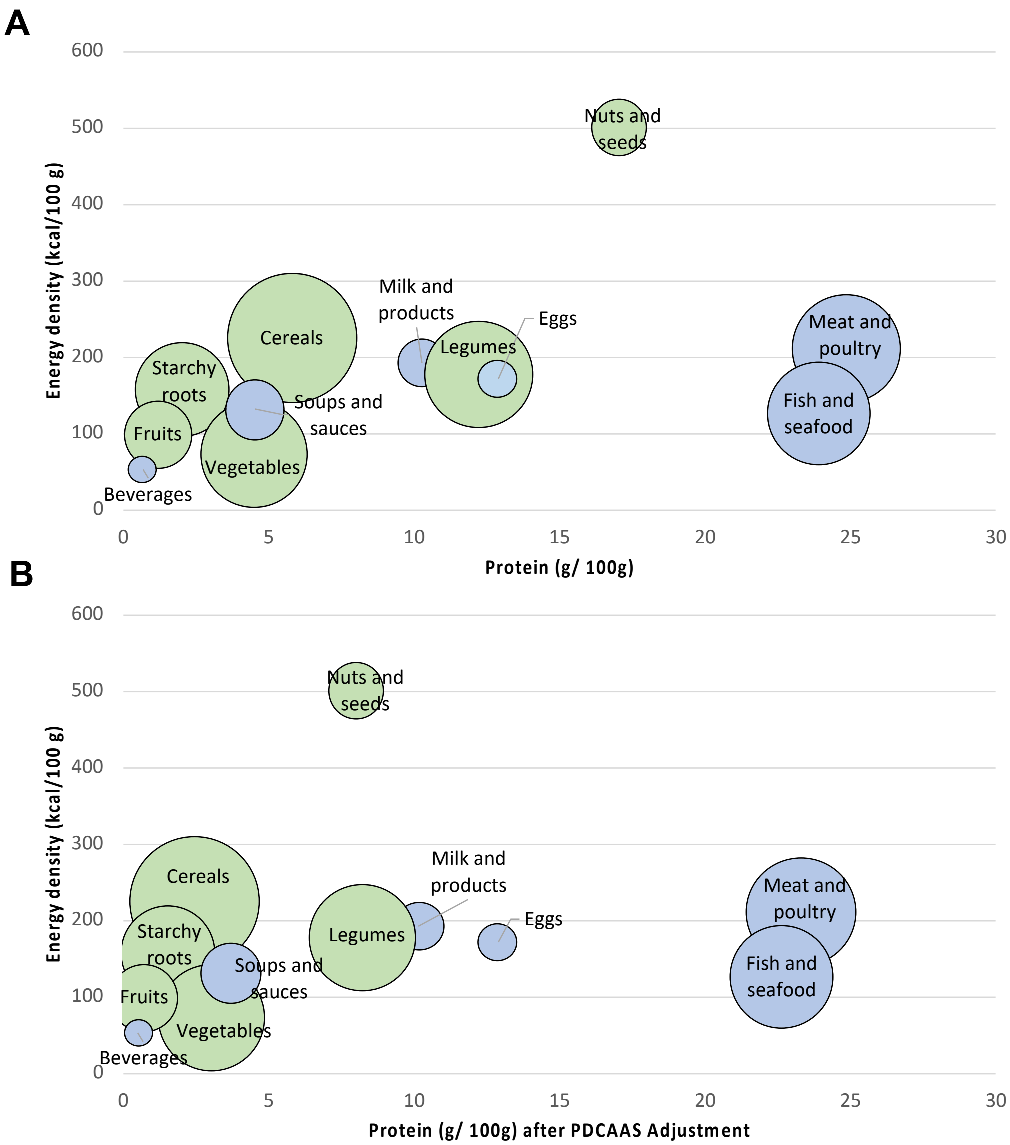

Figure 8 – Scatterplot of protein grams per 100 grams before (A) and after (B) PDCAAS correction by the 14 WAFCT categories. (The size of the circles represents the number of foods in each food category).

Table 13 shows the difference in grams of protein per 100 grams of food before and after PDCAAS adjustment by type of protein. Even though significant reductions were found in the meat and poultry protein; milk, eggs, and dairy protein; and fish and seafood protein categories, the difference after adjustment was most pronounced for plant protein, as expected.

Table 13. Protein grams per 100 grams for 862 WAFCT 2019 foods by type of protein.

		Protein g per 100 g							
		Grams of protein per 100g		PDCAAS correction		95% CI of the difference		Paired samples test	
Type of Protein	No. of foods	Mean	SEM	Mean	SEM	5%	95%	t-test value	P-value
Meat and poultry	126	23.59	0.79	22.07	0.74	1.30	1.74	13.74	<0.001
Milk, eggs, and dairy	38	10.94	1.37	10.89	1.37	0.01	0.10	2.586	0.014
Fish and seafood	127	20.74	0.84	19.54	0.81	1.09	1.30	23.35	<0.001
Plant-sourced foods	571	6.07	0.28	3.52	0.19	2.30	2.79	20.25	<0.001

Table 14 presents the correlation between grams of protein per 100g of food (before and after PDCAAS adjustment), and the different micronutrients analyzed in the study, stratified by protein type. The results show that animal protein was strongly associated with vitamin B3, potassium, zinc, vitamin B6, magnesium, iron, vitamin B1, and calcium. The nutrients that demonstrated no positive or significant associations with animal proteins were vitamin A, fiber, vitamin C, vitamin D, vitamin E, and folate. On the other hand, plant-based protein was strongly associated with potassium, fiber, magnesium, zinc, copper, vitamin B3, vitamin B1, folate, vitamin B2, vitamin B6, calcium, and iron. The nutrients that exhibited no positive or significant associations with plant-based protein were vitamin A, vitamin C, vitamin D, vitamin. E, and vitamin B12.

When comparing the association between grams of protein per 100g of food (after adjustment) and the various nutrients by type of protein, animal protein had a higher correlation with vitamin B3, vitamin B6, iron, vitamin B12, vitamin D compared to plant-based protein. Conversely, plant-based protein had a higher correlation with fiber, potassium, zinc, magnesium, vitamin B1, calcium, vitamin B2, copper, and folate compared to animal protein.

Table 14. Correlation between grams of protein and micronutrients by type of protein.

	Animal Protein		**Plant-Based Protein**	
	Protein g per 100 g	**Protein g after PDCAAS adjustment**	**Protein g per 100 g**	**Protein g after PDCAAS adjustment**
Fiber	-0.20**	-0.26**	0.67**	0.71**
Vitamin A	0.07	0.07	-0.15**	-0.10*
Vitamin C	-0.16**	-0.18**	-0.15**	-0.10*
Vitamin D	0.11	0.12*	-0.03	-0.01
Vitamin E	-0.04	-0.06	-0.02	-0.02
Calcium	0.21**	0.23**	0.33**	0.36**
Iron	0.37**	0.34**	0.38**	0.30**
Potassium	0.55**	0.53**	0.67**	0.72**
Magnesium	0.37**	0.38**	0.73**	0.67**
Zinc	0.54**	0.51**	0.78**	0.67**
Folate	0.02	0.02	0.66**	0.60**
Copper	0.13*	0.12*	0.72**	0.66**
Vitamin B1	0.23**	0.24**	0.71**	0.63**
Vitamin B2	0.22**	0.20**	0.40**	0.39**
Vitamin B3	0.74**	0.74**	0.79**	0.65**
Vitamin B6	0.47**	0.48**	0.40**	0.38**
Vitamin B12	0.15*	0.14*	0.06	0.03

*. Correlation is significant at the 0.05 level (2-tailed)
**. Correlation is significant at the 0.01 level (2-tailed)

3.4.3 Protein Adjustment and other Nutrient Profiling Tools: Nutri-Score

The protein points of the Nutri-Score were applied to each food (N=862) before and after PDCAAS adjustment. Before the adjustment, 57% of foods had 3 protein points or higher (for having >4.8 g protein/100 g); however, after the adjustment only 43% of foods had 4.8 g of protein per 100 grams or higher. Based on the points awarded by Nutri-Score, most plant-based protein food sources scores were greatly impacted by the PDCAAS correction. As many as 102 foods lost their 5-point protein scores, and 96 new foods scored zero after the protein correction. **Figure 9** shows the change in protein point-score distribution. The findings of this study demonstrate the potential impact of PDCAAS correction on the categorization outcomes of established nutrient profiling methods.

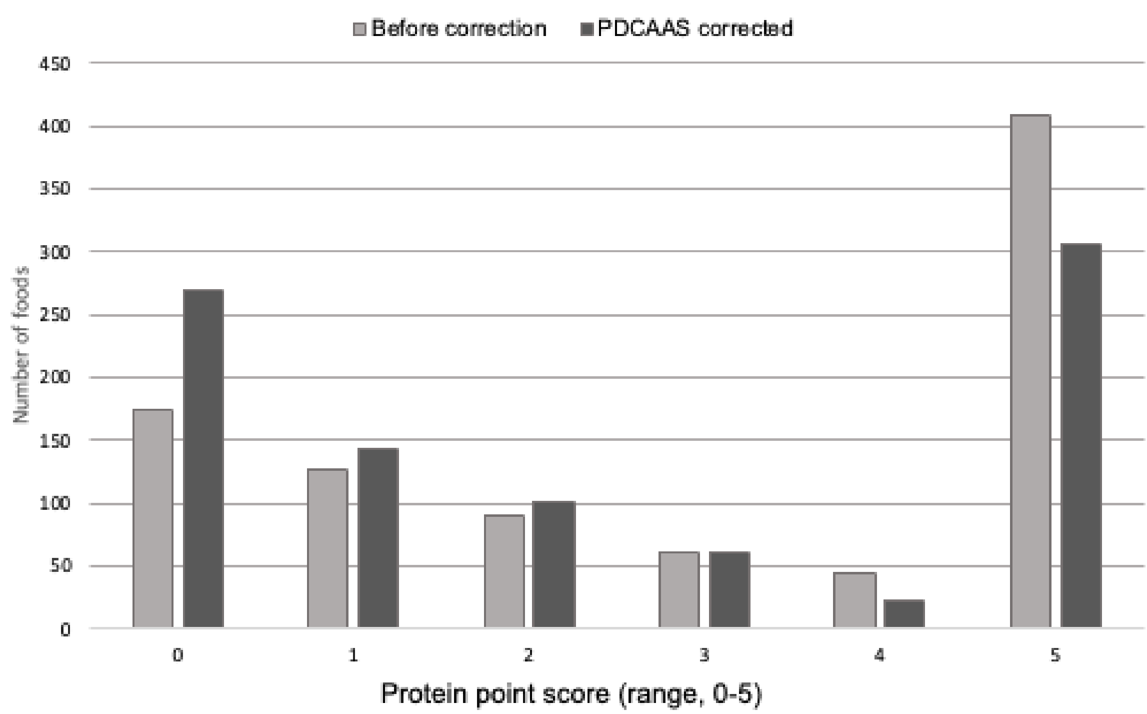

Figure 9 Point scores for protein content for 862 WAFCT component foods in the NutriScore before and after protein digestibility-corrected amino acid score (PDCAAS) correction.

4. Discussion

4.1 The WAFCT as proxy for the food supply

Having access to accurate local data is the first step in adapting nutrient profiling methods to the needs of LMICs (14). Historically, there has been a dearth of reliable data pertaining to food composition tables in Africa. These tables provide quantitative information on the nutrient and non-nutrient components present foods and beverages. Over the years, many food composition tables within African countries have suffered from outdated data, making them unreliable(27). The absence of nutrient composition databases containing branded processed foods remains a prevalent issue in the region.

The present study analyses relied on the Food and Agriculture Organization (FAO) and the International Network of Food Data Systems (INFOODS) and their updated Food Composition Table for Western Africa (28). This updated resource exhibits a significant expansion, featuring nearly three times the number of food entries and twice the quantity of nutrient components compared to its previous version, highlighting its profound significance (28). However, the analyses conducted in this study required complete data for the included food items, posing a challenge due to the presence of missing values in the published WAFCT. Consequently, significant additional efforts were undertaken to address these challenges, including the input of data, creation of variables, and the introduction of new classifications, subclassifications, and correction factors. These meticulous efforts resulted in a comprehensive dataset consisting of 909 food items with complete data.

The WAFCT 2019 classifies foods into 14 different food groups. The utilization of appropriate food grouping methodologies offers the advantage of simplifying dietary recommendations by focusing on food items rather than individual nutrients (29). Moreover, adopting comprehensive food grouping systems enables researchers to explore the associations between specific food groups and various health outcomes (30). In comparison to the 9 food groups utilized in the United States, based on the 1-digit code FNDDS classification, the 14-WAFCT categories aligned more closely with the Minimum Dietary Diversity for Women (MDD-W) Indicator developed by the FAO. The MDD-W aims to evaluate the proportion of women aged 15-49 years who have consumed a diverse diet the previous day, particularly in LMICs (19). This alignment suggests that the assessment of consumption patterns using the WAFCT 14-category food groups can be utilized in future research to evaluate dietary diversity among populations in Western Africa. The adoption of the WAFCT's 14-category food groups can serve as a standardized classification framework for the development of new food composition tables and research studies employing nutrient profiling models within the African region.

4.2 The role of nutrient profiling

The Western Africa region bears a substantial burden of malnutrition, affecting both children and adults (4). The prevalence of stunting in children under the age of 5 (30.9%) surpasses the global average of 22%, and adult obesity is on the rise (4). Furthermore, the region grapples with one of the highest rates of micronutrient deficiencies worldwide (3). The urgent need to combat these issues requires the identification, availability, and equitable access to nutrient-dense foods. Government interventions that increase availability and affordability of local nutrient-dense foods are needed to increase the population's physical and economic access to these foods (31). Additionally, the development and dissemination of population-level dietary guidelines can provide valuable guidance on appropriate dietary choices(32). These interventions can promote health, help the population to meet nutrient requirements, and prevent malnutrition and associated diseases (31).

The purpose of nutrient profiling is to help implement dietary guidance. Nutrient profiling models can help to identify and rank nutrient-rich foods and food groups, differentiating them from those with lower nutritional value (33). The FAO/INFOODS Food Composition Table for Western Africa (WAFCT) 2019 has served here as a proxy for the local food supply. Nutrient profiling methods can facilitate the identification of locally available nutrient-dense foods. Foods in the database were evaluated using a range of nutrient profiling models and were scored for nutrient density, carbohydrate quality, and protein quality.

To the best of our knowledge, this represents the first comprehensive assessment utilizing nutrient profiling models on the WAFCT 2019 dataset. Evaluations of nutrient density of Africa indigenous vegetables (AIV) (34,35) and Africa Indigenous Grains (AIG) (36) were of particular interest. Ensuring the integration of nutritional recommendations within the local context and culture, while simultaneously advocating for the consumption of local foods, can assist the development of strategies and programs aimed at addressing malnutrition in the Western Africa region.

4.3 Origins of nutrient profiling tools and their application to the WAFCT

At this time, most nutrient profiling models have primarily served the needs of high-income countries (14) where rising rates of obesity and diet-related noncommunicable diseases are the main health issue. The focus of existing nutrient profiling tools has centered on restricting dietary energy, sodium, total sugar, and saturated fat (12). However, nutrient priorities in LMICs often differ from those in high-income countries. For instance, while the United States identifies vitamin D, calcium, potassium, dietary fiber, and iron as nutrients of public health concern(37), LMICs commonly face deficiencies in iron, zinc, folate, vitamin A, calcium, and vitamin B12 (5). Consequently, many existing nutrient profiling tools may need to be adapted for use in LMICs, as highlighted by the World Health Organization (WHO) (13). To ensure appropriateness, it is necessary to adapt nutrient profiling models to local contexts, accounting for the specific nutrients of concern within the studied area.

The Nutrient-Rich Food (NRF) Index family of nutrient profiling models may be most suitable for this purpose (20)– since the scores include multiple nutrients to encourage as well as nutrients to limit. Multiple versions of the Nutrient-Rich Food (NRF) Index served to assess nutrient density in the WAFCT foods. The NRF9.3, which has been developed, applied and validated in high-income countries(38–40), was applied to the WAFCT. Acknowledging the significance of adapting nutrient profiling tools to the specific context of Western Africa, two other versions of the NRF model were employed in this study: the NRF6.3 (41), designed to evaluate priority micronutrients in LMICs (encompassing iron, zinc, calcium, vitamin A, vitamin B12, and folate) and the NRF15.3, which extended the assessment to include additional priority micronutrients (encompassing vitamin A, vitamin D, vitamin E, vitamin C, vitamin B1, vitamin B2, vitamin B3, vitamin B6, vitamin B12, folate, copper, calcium, iron, magnesium, and zinc).

Using the three different NRF versions, vegetables obtained the highest NRF scores among the various food groups. Analyses on African indigenous vegetables (AIV) revealed that these foods had higher nutrient density and protein content compared to non-indigenous vegetables. Moreover, within the vegetable group, dark green leafy vegetables exhibited significantly higher scores, followed by other vitamin A-rich vegetables and other vegetables. Various AIV were also classified as dark green leafy vegetables. These findings provide support for the FAO MDD-W food grouping, which differentiates dark green leafy vegetables and vitamin A-rich vegetables from other vegetables to evaluate dietary diversity as an indicator of micronutrient adequacy (19).

The novel Carbohydrate Foods Quality Score (CFQS) metric (11) was also employed to assess 446 carbohydrate containing foods. Given that the WAFCT predominantly consists of minimally processed foods, with a limited number of packaged foods included, most carbohydrate foods obtained their free sugar and sodium point by meeting the criteria of <10 g/ 100 grams of carbohydrate and <600 mg/ 100 grams of dry weight, respectively. Consequently, a considerable proportion of the analyzed foods (66.8%) fell into the category of higher-quality carbohydrate foods. Among the various food groups, vegetables and tubers, legumes and pulses, fruits, uncooked cereals, and cooked cereals, pasta, and rice contained the largest number of higher-quality carbohydrate foods.

When assessing only minimally processed grain foods, African Indigenous Grains (AIG) presented higher nutrient density scores than non-indigenous grains, especially when the non-indigenous grains were not fortified. AIG also had higher carbohydrate quality compared to their non-indigenous counterparts. Fortification of foods proved to be an important tool to increase nutrient density in a variety of foods commonly consumed by the population.

Furthermore, after the adjustment, significant reductions in the mean grams of protein per 100 grams of food were observed across various food groups, with the most prominent differences observed for nuts and seeds, cereals, starchy roots and tubers, legumes, vegetables, fruits, and soups and sauces. The application of PDCAAS correction had a substantial impact on plant-based protein sources when assessed using the Nutri-Score point system, while discernible differences were not observed for animal protein foods.

These findings suggest that adjusting for protein quality may have significant consequences in the protein content and the scoring system when using other nutrient profiling methods as well.

4.4 Adapting nutrient profiling tools to local context

Considering the importance of adapting nutrient assessments to local contexts, the present study not only adapted nutrient profiling models, but also gave a special focus on analyzing local foods. Previous studies have highlighted the prevalence of dietary patterns rich in grains, cereals, legumes, roots, tubers, and plantains among West African populations (42). Therefore, conducting analyses of carbohydrate foods in West African countries can be instrumental in identifying higher-quality options that align with local dietary recommendations. The application of a special focus on African Indigenous Grains (AIG) allowed us to identify these foods as higher-quality carbohydrate foods and as important sources of nutrients. The nutritional advantages of AIGs were previously documented in the existing literature several years ago (36), and more recent evidence indicates a growing interest in these foods (43–45).

Furthermore, by directing our attention towards African Indigenous Vegetables (AIV), we were able to ascertain that these foods were characterized by elevated levels of essential micronutrients. Other studies have also identified AIVs as a potential solution to malnutrition (46) and even as climate resilient foods due to their tolerance to high temperatures and precipitation (47). However, various challenges, such as inadequate progress in agronomic techniques and limited access to AIVs in the market place, have been identified (48). Therefore, governmental efforts are needed to increase year-round availability, access, and affordability. An increase in the consumption of AIVs could improve micronutrient deficiencies within at-risk populations in Western Africa.

In addition, the NRF models were customized to suit the Western African context by incorporating nutrients of public health concern in LMICs. This customization enabled a comparative analysis between the adapted versions and the original NRF9.3 model. The results of our study demonstrated the value of this adaptation. While the vegetable group consistently demonstrated the highest NRF scores across the three NRF models, the subsequent food groups with elevated scores varied depending on the specific NRF model employed and the micronutrients being assessed.

When utilizing nutrient profiling models that specifically address the micronutrients of concern in LMICs (the NRF6.3 and NRF15.3), food groups comprising animal-sourced foods attained higher rankings compared to those obtained using the NRF9.3 model. Moreover, among the foods in the top tertiles of the different NRF scores, the proportion of animal-sourced foods was significantly higher in the NRF6.3 and NRF15.3 versions compared to the NRF9.3. This may be explained by the correlations found between the grams of protein and various micronutrients stratified by type of protein. Priority micronutrients assessed in the NRF6.3 and NRF15.3 had moderate and strong correlations with both plant-based and animal proteins; however, nutrients assessed by the NRF9.3 had a higher correlation to protein in plant-based foods. The significance of animal-sourced foods was accentuated through the evaluation of protein quality, incorporating a Protein Digestibility-Corrected Amino Acid Score (PDCAAS) adjustment for diverse food items and food groups.

4.5 Animal-sourced foods in the WAFCT

The evaluation of nutrient density and protein quality in this study demonstrates that animal-sourced foods play a pivotal role in providing essential micronutrients that are of public health significance in LMICs. Nonetheless, the production and consumption of animal-sourced foods has been linked with higher greenhouse gas emissions and a negative planetary impact. Evidence indicates that global greenhouse gas emissions from animal-sourced foods are twice those of plant-based foods (49). Consequently, there has been a push to reduce the consumption of animal-sourced foods to mitigate the impacts of climate change (50–52) and even taxes on meat consumption have been suggested (53). While reducing meat consumption is advocated as a means of improving health and reducing the impacts of climate change, various dietary recommendations proposing moderate to low consumption of these food groups are predominantly based on evidence derived from high-income countries (54). Furthermore, the most substantial levels of greenhouse gas emissions associated with the production and consumption of meat predominantly originate from nations with high-income economies (49).

The consumption of animal-sourced foods may be of vital importance to prevent micronutrient deficiencies in West African countries and other LMICs. The findings of this study support the evidence recently published by FAO, which emphasize the importance of meat, eggs, and milk as critical sources of vital nutrients that are not readily obtainable from plant-based food sources (55). Furthermore, previous research has indicated that priority micronutrients in LMICs are predominantly found in organs, meats, dark green leafy vegetables, seafood, and eggs (5). The significance of fish and seafood in the global food system has also been underscored (56).

Assessing protein quality holds particular significance in LMICs, where it can be a concern based on the dietary composition of the population (6). For instance, in sub-Saharan Africa, maize, which is deficient in essential amino acids, serves as the primary source of energy intake, while cassava is the main source of dietary protein (57). The well-established difference in protein quality between animal and plant-based foods requires considering the inclusion of animal foods to meet protein requirements within the West African population.

Furthermore, evidence suggests that increased consumption of animal-source foods can lead to improved nutrient intake and reduced malnutrition among many populations in sub-Saharan Africa (58). Reducing meat consumption in LMICs could adversely affect the livelihoods of many low-income populations who rely on livestock, poultry, and fishing (59). Therefore, dietary recommendations in LMICs should carefully consider these trade-offs. Governments, public health institutions, and academic organizations in West Africa should acknowledge the high nutrient density and superior protein quality of animal foods. However, efforts to increase sustainability in meat production and reduce food loss and waste are also needed. Nutritional policies, interventions, and recommendations regarding the consumption of animal foods should be informed by local nutritional needs and risks.

4.6 Limitations and next steps

The present study encountered several limitations that warrant consideration. Firstly, the application of nutrient profiling models was contingent upon the availability of complete nutrient information for the analyzed foods. To mitigate this limitation, data from the United States Department of Agriculture (USDA) (18) was utilized to fill data gaps in nutrient composition. However, it is important to acknowledge that nutrient profiles of foods can vary across different regions (60). Secondly, as it has been mentioned before, the composition of the WAFCT database primarily consists of minimally processed, processed, and culinary ingredients. This is of high importance, as the current prevalence and consumption of ultra-processed foods is notable in Western Africa (61). Consequently, the analyzed foods represent only a subset of the frequently consumed items in Western Africa and do not encompass the wide array of packaged processed foods currently consumed by the population.

Additionally, the FAO has noted that PDCAAS values tend to overestimate the amount of amino acids absorbed and they recommended to use the Digestible Indispensable Amino Acid Score (DIAAS) as the preferred method to measure protein quality (24). The DIAAS is regarded as a more precise indicator of amino acid absorption occurring in the distal portion of the small intestine (62). Nevertheless, due to limited availability of DIAAS data pertaining to the various foods in the WAFCT, the present study relied upon adjustments based on PDCAAS values and protein digestibility measurements.

Moreover, despite more than 25 years of iodine fortification in Africa, the prevalence of iodine deficiency is still a public health concern in West African region (63). However, the WAFCT lacks information on iodine content, impeding its integration into the NRF models. Lastly, micronutrient deficiencies often stem from inadequate consumption of nutrient-dense foods due to their high cost, particularly in LMICs (41,64,65). Unfortunately, the present study was unable to assess the cost and affordability of such foods due to the absence of food price data in West Africa. Nonetheless, the findings of this study provide valuable evidence that can inform various stakeholders for the development of food and nutrition policies and programs, such as the development of dietary guidelines and the inclusion of local nutrient-dense foods in social and food assistance programs.

The present study emphasizes the importance of tailoring nutrient profiling models to the particular context in which the research is conducted. It is recommended that future studies utilizing nutrient profiling tools in LMICs replicate this approach and adapt the tools to the local context, taking into account epidemiological data and the available resources. Moreover, countries in Western Africa should persist in the formulation of their own dietary guidelines, following the recent example set by Ghana (32). Collaboration between ministries of health, academic institutions, and United Nations agencies is essential in utilizing the existing evidence and developing population-specific nutritional recommendations. Additionally, further research and efforts are needed for the development and update of food composition tables that include packaged processed foods.

Finally, in addition to protein content, further research should explore adjusting nutrient composition by their bioavailability. Animal foods possess higher concentrations and greater bioavailability of various other nutrients that hold significant public health implications. For instance, the absorption rate of iron from animal foods ranges from 15% to 35%, while it can be less than 10% in plant-based diets (66). Similarly, the bioavailability of calcium from animal sources surpasses that of plant-based foods (67). Moreover, dietary zinc absorption is hindered by phytates present in whole-grain cereals and legumes, whereas animal proteins enhance zinc absorption (68). Therefore, it is crucial for future research utilizing nutrient profiling models to explore the adjustment of iron, zinc, and calcium levels in food items, particularly in LMICs (25). Conducting such investigations will yield robust evidence that can inform dietary recommendations aimed at promoting nutrient-dense foods and diets to prevent and address micronutrient deficiencies.

5. Conclusion

The present study utilized and adapted a comprehensive set of nutrient profiling tools to evaluate nutrient density, carbohydrate quality, and protein quality in the foods listed in the FAO/INFOODS Food Composition Table for Western Africa (WAFCT) 2019. Three versions of the Nutrient Rich Food (NRF) Index were employed to assess nutrient density, including two models adapted to the LMICs context. Vegetable food groups consistently demonstrated the highest NRF scores across all models and African Indigenous Vegetables showed significantly higher nutrient density scores and had higher protein content compared to non-indigenous vegetables. A greater proportion of African Indigenous Grains were found in the higher-quality carbohydrate foods category, and they demonstrated higher nutrient density scores in comparison to non-indigenous grains.

When applying nutrient profiling models tailored to the micronutrients of concern in LMICs (NRF6.3 and NRF15.3), food groups containing animal-sourced foods obtained higher rankings compared to the ranking they had in the model originally developed within a high-income country context (NRF9.3). The evaluation of protein quality, incorporating Protein Digestibility-Corrected Amino Acid Score (PDCAAS) adjustments, revealed significant reductions in protein content, mainly across plant-based food groups. These findings emphasize the vital role of African indigenous vegetables and grains, and animal-sourced foods in providing essential micronutrients of public health significance in the Western Africa region. Governments, public health institutions, and academic organizations in the region should work together to recognize the nutrient density of these foods, increase their accessibility and affordability, and promote their consumption through appropriate policies and programs.

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7. Appendix 1

Specific PDCAAS values for foods and food groups.

Food group	Foods	PDCAAS values	Sources
Legumes and pulses	Black beans	.61	(A)
	Brown beans		
	Kidney beans		
	White beans		
	Navy beans		
	Pinto beans		
	Red beans		
	Cowpeas	.38	(A)
	Lentils	.52	(A)
	Soybeans	.91	(B)
	Peas	.69	(A)
	Cooked peas	.6	(C)
	Pigeon pea	.78	(A)
	Bambara bean	.78	(A)
	Legumes and peas	.70	(A)
	Legumes	.74	(D)
Nuts and seeds	Nuts and seeds	.47 (mean)	(D)
Grains	Corn	.47	(E)
	Corn flour	.44	(D)
	Cornmeal	.37	(F)
	Pearl Millet	.20	(F)
	Oats	.66	(F)
	Breakfast cereal	.08	(G)
	Rice	.81	(H)
	Cooked Rice	.62	(C)
	Rice, brown	.61	(D)
	Sorghum flour	.46	(D)
	Wheat	.46	(E)
	Wheat bread	.37	(F)
	Wheat bran	.67	(D)
	Wheat flour	.47	(D)
	Pasta	.43	(I)
	Other cereals	.69	(D)
Milk, dairy and eggs	Milk	1	(J)
	Milk Cream	.8	(F)
	Cheese	.99	(K)
	Egg	1	(D)
Meat and poultry	Beef/ tripes/ giblets	.94	(D)

	Chicken	.94	(D)
	Pork	.98	(F)
	Sausage	.94	(D)
	Other meats (Ostrich, crocodile, camel)	.94	(D)
	Insects (cricket)	.76	(L)
	Termites	.9	(L)
	Mixed dishes with beef	0.83 (mean)	(K)
Fish and seafood	Sardine	1	(F)
	Shrimp/ crab/sea snail/ tilapia/ clams	.94	(D)
	Mackerel	.94	(F)
	Tilapia	.94	(D)
	Tuna	1	(F)
	Other fish	.94	(D)
Vegetables	Cabbage	.62	(D)
	Amaranth	.73	(D)
	Potato	.81	(F)
	Eggplant	.55	(D)
	Spinach	.75	(D)
	Lettuce	.16	(D)
	Cucumber	.3	(D)
	Tomato	.39	(D)
	Pumpkin	.29	(D)
	Onion	.39	(D)
	Carrot	.74	(D)
	Other tubers	.74	(D)
	Other leaves and vegetables	.73	(D)
	Orange	.42	(D)
Fruits	Watermelon	.46	(D)
	Banana	.75	(D)
	Apple	.72	(D)
	Grape	.27	(D)
	Other fruit	.64	(D)
	Date	.31	(D)
	Avocado	.71	(D)
	Dried fruits	.48	(D)

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