Nutritional Adequacy of the Planetary Health Diet Improved by More Nutrient-Rich Foods: Analyses of the FAO Food Composition Tables for Western Africa

Hannah Sanders

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Adam Drewnowski
Didier Alia

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Abstract

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Hannah Sanders

Chair of the Supervisory Committee:
Adam Drewnowski
Food Systems, Nutrition, and Health

The EAT-Lancet planetary health diet (PHD) was designed to meet nutritional needs while staying within planetary boundaries. This study tested nutrient adequacy of the PHD using the Food and Agriculture Organization Food Composition Tables for Western Africa (WAFCT). WAFCT food items (n=596) were aggregated into PHD categories (n=21). Median energy, protein and micronutrient content were calculated for each category. Protein amounts were corrected using the Protein Digestibility Corrected Amino Acid Score (PDCAAS). Priority micronutrients were iron, zinc, calcium, vitamin A, vitamin B12 and folate. Nutrient density of food categories was assessed by the Nutrient Rich Food Index. Median nutrient values were multiplied by food amounts to estimate PHD's nutritional value. Energy was estimated at 2,516 kcal/day. Total protein was estimated at 87 g/day before and 62 g/day after PDCAAS correction. The proposed amounts of calcium vitamin A and zinc were insufficient based on nutrient reference values. Folate, iron, and vitamin B12 were sufficient. Increasing suggested amounts of nutrient-rich beef and chicken livers, small dried fish, and pulses, while reducing whole grains and tree nuts led to a food plan that achieved reference values.

1. Introduction:

1.1 Nutrition concerns in West Africa

Despite recent progress toward the United Nations Sustainable Development Goal of ending all forms of malnutrition by 2030 (United Nations Department of Economic and Social Affairs, 2024), micronutrient deficiencies and protein inadequacy in West African countries remain a concern for public health nutrition (Chadare et al., 2022; Ritchie & Roser, 2017; Stevens et al., 2022). Protein and micronutrients are essential for optimal physiologic function and are particularly important for growth and development. Insufficient nutrient intake contributes to nearly a third of children under five in West Africa being stunted (UNICEF/WHO/World Bank, 2023). Diets in West Africa tend to be based around cereals, grains, and starchy roots (Food and Agriculture Organization of the United Nations, 2024b), deriving most of their protein from plant sources (Afshin et al., 2019; Vissamsetti et al., 2023). Micronutrients that may be insufficiently consumed in West African are iron, zinc, calcium, vitamin A, vitamin B12 and folate (Beal et al., 2017). Furthermore, the total micronutrient density of the food supply in West Africa is reported to have declined since 1990 (Beal et al., 2017).

1.2 EAT-Lancet Planetary Health Diet

The impact of climate change on the food system may exacerbate these nutrition challenges, while combatting malnutrition through current food production methods may further impact the climate (Swinburn et al., 2019). In light of this dilemma, the EAT-Lancet Commission designed the Planetary Health Diet (PHD) (Willett et al., 2019) to meet nutrient requirements, prevent diet-related chronic disease, and minimize the environmental and climate impacts of food production (Willett et al., 2019). Driven by evidence indicating plant-based foods are more environmentally sustainable than animal-based foods, the Commission recommends the PHD be predominantly comprised of plants. While limiting meat and dairy, the universal PHD encourages the consumption of whole grains, vegetables, fruits, and nuts. Since its release, the PHD has become a model for proposed plant-forward diets, notably in high-income countries such as Italy (Tucci et al., 2021) and Denmark (Lassen et al., 2020).

1.3 Concerns about nutritional adequacy in the context of regional food supplies

Despite their minimal environmental impact of producing plant protein sources (Willett et al., 2019), they may lack some essential amino acids and are considered to be lower quality compared to meat, milk and eggs (Ferrari et al., 2022; Schaafsma, 2000; van Vliet et al., 2015). The PHD has a high plant protein to animal protein ratio, and the amount of available high-quality protein is unspecified (Willett et al., 2019). The differential availability of animal and plant proteins protein quality can be assessed through the Digestible Indispensable Amino Acid Score (DIAAS) and the Protein Digestibility Corrected Amino Acid Score (PDCAAS) (FAO Expert Consultation, 2013; Schaafsma, 2000). Both tools are equations designed to determine the proportion of dietary amino acids digested, with the former evaluating ileal amino acid digestibility and the latter determined by fecal nitrogen excretion. Though the FAO has determined DIAAS to be the more accurate and the preferred method of determining protein quality (FAO Expert Consultation, 2013), assessing fecal nitrogen of foods is more feasible thus leading to the more complete databases on PDCAAS of foods. Neither method of accounting for protein quality is included in the PHD.

Another concern with the PHD is its potential deficiency in key micronutrients. An analysis using a custom compiled food database found the PHD to be deficient in vitamin B12, zinc, iron, and calcium for all adults and women of reproductive age (Beal et al., 2023). The study proposed an increase in the amount of animal-source foods by adding nine specific food groups (some overlapping with the original PHD food groups) in the PHD as a solution to achieve micronutrient sufficiency through diet (Beal et al., 2023).

1.4 West African Context and Study Aims

Potential low protein quality and micronutrient inadequacy of the PHD raise concern about its merit in West Africa where combatting stunting, wasting, and hidden hunger are national priorities for nearly all countries (Global Nutrition Report, 2022). There is a gap in the literature testing the contextualization of the PHD to different global regions through exclusive use of regional databases. In light of this gap, this study aimed to assess protein content before and after PDCAAS correction and to estimate priority micronutrient content of the PHD in order to determine its nutrient adequacy using the FAO/INFOODS Food Composition Table for Western Africa 2019 (WAFCT) (Vincent, 2020). A secondary aim, building on the work of Beal et al. (2023), was to determine whether micronutrient adequacy could be improved by including locally available and nutrient-rich food groups. To our knowledge, there are no analyses of potential PHD performance exclusively using the WAFCT to reflect the regional food supply. Therefore, the goal was to assess the performance of the PHD in the context of West Africa using regional food composition tables.

2. Methods

2.1 The FAO Food Composition Table for Western Africa

The FAO/INFOODS Food Composition Table for Western Africa 2019 (Vincent, 2020) lists 1,028 foods and beverages, their names in English and French, along with their energy and nutrient content. All nutrient values are listed per 100 grams, edible portion. The version of WAFCT downloaded from INFOODS website (FAO, 2022) had multiple missing nutrient values for some items. Missing energy and nutrient values of raw foods or their equivalents were obtained from the USDA Food and Nutrient Database for Dietary Studies 2017-18 (FNDDS 2017-18) nutrient composition database (U.S. Department of Agriculture, 2018). Foods with substantial missing values were excluded from analyses (n=116). Added sugar content was calculated based on WAFCT recipes provided. The final analytical database included 912 foods, classified into food groups, categories, and subcategories using published schemes.

2.2 WAFCT food groups, categories and subcategories

The original WAFCT food groups, as coded by FAO, were grains and cereals (n=169), meat and poultry (n=118), legumes (n=115), vegetables (n=113), fish and seafood (n=106), starchy roots and tubers (n=89), fruits (n=44), fats and oils (n=35), soups and sauces (n=5), nuts and seeds (n=30), milk and dairy (n=25), eggs (n=14), beverages (n=24), and miscellaneous foods (n=28).

2.2.1 PHD categories

The 912 WAFCT foods were manually coded into 21 categories using the published PHD categorization scheme (Beal et al., 2023; Willett et al., 2019). Items not captured in PHD categories such as powdered milks, infant formula, spices, sugary beverages, refined grains (n=56) and processed fortified foods (n=47) were excluded. Following published PHD definitions led to additional exclusions. For example, the PHD specifies dry weights of grains and pulses (Willett et al. 2019); therefore, cooked grains and legumes (n=134) were excluded as their high water content reduces energy and nutrient density. The PHD suggests 250 g milk or equivalent amounts of dairy products per day. For simplicity, we used 250 g of whole milk (3.5% dairy fat) and did not base calculations on cheese, yogurt or cream (n=22), therefore, these items were excluded. In the absence of defined criteria for PHD categories, such as red and orange vegetables, we applied the closest related FAO Minimum Dietary Diversity for Women food group criteria (FAO, 2021). The PHD recommendations also do not specify whether weights are based on raw or cooked forms for other categories other than grains and legumes. Therefore, in the absence of PHD guidance, all forms available in the WAFCT were retained, most notably for vegetables and tubers or starchy vegetables. No retention factors for micronutrients were applied. The number of items in each 21 PHD categories ranged from 1 (dairy foods) to 118 (vegetables). Each of the PHD categories was represented in the WAFCT except for lard or tallow (set at 5 g/day). Applying the PHD exclusion criteria yielded an analytical sample of 596 foods.

2.2.2 Priority micronutrients categorization scheme (Beal & Ortenzi)

Beal et al. (2023) added nine additional food categories to the original 21 PHD subcategories because of their high micronutrient content (Beal & Ortenzi, 2022). All 596 food items in the WAFCT database were manually coded to identify separate subcategories of beef (n=17), organ meats (n=27), seeds (n=10), fresh fish (n=20), small dried fish (n=1), canned fish with bones (n=5), crustaceans (n=3), and bivalves (n=7). Refined grains (n=56) were also coded, but not included in the analysis. All other items remained in their PHD subcategories.

2.2.3 Nutrient density categorization scheme (Sanders et al.)

The present categorization scheme built on Beal et al. (2023) by disaggregating some categories still further (Beal et al., 2023). For example, whole grains (n = 43) were divided into their respective grains (e.g., millet), cassava was separated from tubers and starchy vegetables, red and orange flesh fruit (e.g., mango) were separated from other fruits, meat categories were specified by animal (e.g., goat), and organs were separated by animal (chicken vs. beef and lamb) and by organ (liver vs. other organs). Some of these food groups have exceptionally high content of priority micronutrients as described by Beal and Ortenzi (2022) which motivated the further subclassification.

The three categorization schemes and inventory are summarized in **Table 1**.

Table 1. PHD, Beal & Ortenzi, and Sanders et al. WAFCT food item categorization scheme and inventory

PHD Category	PHD Subcategory	Beal & Ortenzi Subcategory	Sanders et al Subcategory	Count
Whole grains (rice, wheat, corn and other)	Whole grains (rice, wheat, corn and other)	Whole grains	Millet	16
			Maize	12
			Rice	4
			Wheat	4
			Sorghum	3
			Fonio	2
			Oat	1
			Teff	1
		Refined grains	Refined grains (excluded)*	56
Total				**43**
Tubers or starchy vegetables (potatoes and cassava)	Tubers or starchy vegetables (potatoes and cassava)	Tubers or starchy vegetables	Cassava	11
			Plantain	20
			Potato	5
			Sweet Potato	4
			Yam	31
			Other starchy vegetables	9
Total				**80**
Legumes	Dry beans, lentils, and peas	Dry beans, lentils, and peas	Dry beans, lentils, and peas	25
	Soy foods	Soy foods	Soya bean	6
Total				**31**
Vegetables	Dark green leafy vegetables	Dark green leafy vegetables	Dark green leafy vegetables	64
	Red and orange vegetables	Red and orange vegetables	Red and orange vegetables	19
	Other vegetables	Other vegetables	Other vegetables	35
Total				**118**
Fruits	All fruit	All fruit	Red and orange flesh fruits	5
			Other fruits	39
Total				**44**
Nuts	Peanuts	Peanuts	Peanuts	12
	Tree nuts	Tree nuts	Tree nuts	8
		Seeds	Seeds	10
Total				**30**
Beef, lamb and pork	Beef and lamb	Beef and lamb	Lamb/mutton	4
			Goat	8
			Other meat	14

		Beef	Beef	17
		Organs (e.g., liver, spleen, kidney, and heart)	Beef and lamb organs (e.g., liver, spleen, kidney, and heart)	11
			Beef and lamb liver	8
	Pork	Pork	Pork	12
Total				**74**
Chicken and other poultry	Chicken and other poultry	Chicken and other poultry	Chicken and other poultry	25
		Organs (e.g., liver, spleen, kidney, and heart)	Chicken organs (e.g., liver, spleen, kidney, and heart)	4
			Chicken liver	4
Total				**33**
Eggs	Eggs	Eggs	Eggs	14
Total				**14**
Fish	Fish	Fish	Prepared fish	60
		Fresh fish	Fresh fish	20
		Small dried fish	Small dried fish	1
		Canned fish with bones	Canned fish with bones	5
		Crustacean	Crustacean	13
		Bivalves	Bivalves	7
Total				**106**
Dairy foods (whole milk or equivalents)	Dairy foods (whole milk or equivalents)	Whole milk or derivative equivalents	Whole milk	1
Total				**1**
Unsaturated oils	Unsaturated oils	Unsaturated oils	Unsaturated oils	8
Total				**8**
Saturated 14 oils	Palm oil	Palm oil	Palm oil	4
	Dairy fats (included in milk)	Dairy fats (included in milk)	Dairy fats (included in milk)	3
	Lard or tallow	Lard or tallow	Lard or tallow	0
Total				**7**
All sugars	All sugars	All sugars	All sugars	3
Total				**3**
Grand Total				**596**

*Refined grains are included in the Beal et al. (2023) analysis but are excluded here because they are not included in the original PHD

2.3 Constructing the PHD

The published recommendation of the PHD provided ranges (minimum - maximum) and suggested mean intake values for each food category. For example, beef and pork were limited to 7 g/day each (range 0-14 g/day), whereas the amount of chicken was set at 29 g/day (Willett et al., 2019). The present goal was to construct energy and nutrient density profiles for each food category based on WAFCT data. Other than dairy foods, WAFCT data provided multiple items within each category which enable use of descriptive statistics (see **Table 1**). For example, energy and nutrient profiles for chicken and poultry were based on 33 items, and for fish on 106 items. To profile the nutrient density per 100g of each PHD subcategory, we calculated median values of all items in the subcategory. Using medians instead of means avoided excessive influence by outliers. For example, the mean vitamin A density of chicken and poultry is 1567 µg/100g, while the median is only 22 µg/100g because of the few dense organ meats included in this category.

Similar energy and nutrient density profiles were constructed for each subcategory in the other two categorization schemes. This approach followed that used by Beal et al. (2023) in calculating micronutrients in the PHD, with a difference being that this analysis excludes cooked grains, beans, lentils and peas.

2.4 Protein, priority micronutrient, and energy measures

Protein was the nutrient of primary interest. The analysis measures unadjusted protein and adjusted protein in grams. To adjust protein for quality, PDCAAS values for specific food items were obtained from the literature and were applied to WAFCT individual foods and food categories (see **Appendix A**). PDCAAS correction values were applied to 578 of the 596 food items. Unadjusted protein in grams was multiplied by PDCAAS values for a final adjusted protein content for each item. The remaining 18 items include oils and sugars that contain little to no protein; therefore, PDCAAS is not applicable, so unadjusted and adjusted protein values are the same.

The priority micronutrients of interest were calcium, zinc, vitamin B12, iron, folate, measured in dietary folate equivalents (DFE), and vitamin A, measured in retinol activity equivalents (RAE), given the high prevalence of deficiency in West Africa (Beal et al., 2017; Gebremedhin, 2021; Rohner et al., 2014). Daily energy was measured in kilocalories (kcal) for each subcategory.

2.5 Nutrient adequacy standards

Nutrient reference values (NRV) for daily intake of protein and micronutrients were taken from the FAO Codex Alimentarius for adult populations (Lewis, 2019). The values used for zinc and iron are based on 22% and 10% dietary absorption, respectively, in a cereal-based, low animal protein diet (Lewis, 2019). The NRVs used are shown in **Supplemental Table 2.**

Individual energy needs are highly variable based on differences in body size, body composition, age, activity level, disease status, and growth needs. This analysis aligns with the PHD's specified average of 2500 kcal/day which is estimated to meet the daily energy expenditure of a 70kg male and 60kg female with a moderate to active level of physical activity.

2.6 Nutrient profiling methodology

Nutrient density was tested using the well-established Nutrient Rich Food (NRF) score for priority micronutrients (Drewnowski, 2010; Fulgoni et al., 2009), which essential calculated the nutrients to calories ratio. The Nutrient Rich Food Index 6.3 (NRF6.3) is composed of two subscores: the positive NR6 subscore based on nutrients to encourage and the negative LIM subscore based on 3 nutrients to limit. The six priority nutrients to encourage were iron, zinc, calcium, vitamin A, vitamin B12, and folate. The three nutrients to limit were saturated fat, sodium, and added sugar. Percent daily values (%DV) for each nutrient were calculated per 100 kcal using the NRV and were capped at 100%. The NRF6.3 score was the sum of %DV for the six nutrients to encourage minus the sum of %DV for the three nutrients to limit. NRF6.3 scores were used to identify the most nutrient rich food categories in the WAFCT.

2.7 Plan of analysis

The median values (per 100g in weight) were multiplied by the PHD recommended grams of daily intake of the subcategory to produce daily amounts for each nutrient within each food group. We matched the weights (in grams) of the PHD because studies that measure diet adherence compare quantity of food consumed in weights (Ali et al., 2022; Stubbendorff et al., 2021). Alternatively, Beal et al. (2023) modeled their diet by matching the food group intake on energy in kcals. We applied this method for comparison, and the results are not meaningfully different **(Supplemental Table 1).**

Energy, protein, PDCAAS-adjusted protein, and priority micronutrients for each PHD subcategory were summed to determine the PHD-WAFCT total daily intake for every nutrient. Nutrient intakes were compared against their respective NRV, and the difference was used to determine nutrient sufficiency (positive values) or deficiency (negative values).

Isocaloric modifications to the PHD were proposed by adding selected WAFCT subcategories that were nutrient rich and adjusting the recommended intake quantity of each food group. Modifications built the earlier work of Beal et al. (2023) to meet the NRV while minimizing deviation from the original PHD. The proposed adjustments were guided by the micronutrient density of WAFCT food groups based on the NRF6.3 and priority micronutrient rich foods globally (Beal & Ortenzi, 2022).

3. Results

3.1 Energy and protein in the PHD

Table 2 shows the subcategory specific daily intake and energy of the PHD reference (Willett et al., 2019) compared to the energy and protein content of the WAFCT when the PHD intake values are applied. First, estimated daily energy based on median values by food group was 2,516 kcal/day, which is nearly identical to the original PHD calculations of 2,503 kcal/day. Second, 86% of calories in the PHD came from plant-source foods and only 14% came from animal-source foods. The WAFCT is similar, showing 88% of calories came from plant-source foods and 12% of daily calories came from animal-source foods.

The PHD does not provide protein estimates and does not address protein quality. The present calculations estimated unadjusted protein intake from plant and animal sources was 87 g/day. Based on present analyses, 60 g/day (68.8%) of protein (by weight) came from plant sources and 27 g/day (31.2%) came from animal-source foods. After the PDCAAS correction, the estimated amount of digestible protein dropped by 29% to 62 g/day. After the PDCAAS correction, 36 g/day or 58% of protein (by weight) came from plant sources and 26 g/day (42%) came from animal-source foods. Whole grains, dry beans, lentils, and peas, and peanuts were the subcategories whose protein contribution was most reduced after adjusting for digestibility.

Table 2. Daily weight and energy of the original PHD compared to daily energy, protein and PDCAAS-adjusted protein of the PHD using median values from the WAFCT

PHD Category	PHD Subcategory	PHD-Original (g/d)	PHD-Original (kcal/d)	PHD-WAFCT (kcal/d)	PHD-WAFCT (kcal/100g)	PHD-WAFCT Protein (g/d)	PHD-WAFCT PDCAAS Protein (g/d)
Whole Grains	Whole grains (rice, wheat, corn)	232	811	812	350	21.81	9.54
Tubers or Starchy Vegetables	Tubers or starchy vegetables (potatoes and cassava)	50	39	68	135	0.90	0.67
Vegetables	Dark green leafy vegetables	100	23	46	46	4.25	3.11
	Other vegetables	100	25	36	36	1.40	0.80
	Red and orange vegetables	100	30	56	56	1.50	1.11
Fruits	Fruits	200	126	141	71	1.90	1.13
Dairy Foods	Dairy foods (whole milk)	250	153	160	64	8.25	8.25
Protein Sources	Beef and lamb	7	15	13	184	1.81	1.70
	Pork	7	15	25	354	1.48	1.45
	Chicken and poultry	29	62	44	153	7.40	6.95
	Eggs	13	19	23	180	1.66	1.66
	Fish	28	40	33	119	6.52	6.13
	Dry beans, lentils, peas	50	172	161	321	10.40	7.18
	Soy foods	25	112	96	383	8.76	7.97
	Peanuts	25	142	144	575	5.60	2.63
	Tree nuts	25	149	137	548	3.55	1.67
Added Fats	Palm oil	6.80	60	61	900	0	0
	Unsaturated oils	40	354	360	900	0	0
	Dairy fats (in milk)	0	0	0	743	0	0
	Lard or tallow	5	36	0	0	0	0
Added Sugar	All sugars	31	120	101	326	0.12	0.12
Plant-Source Total (%)		985 (74)	2,163 (86)	2,217 (88)		60.19 (69)	35.92 (58)
Animal-Source Total (%)		339 (26)	340 (14)	299 (12)		27.12 (31)	26.15 (42)
Grand Total		**1,324**	**2,503**	**2,516**		**87.32**	**62.07**

3.2 Priority micronutrients in the PHD

Table 3 shows the priority micronutrient content of the PHD based on median values from the WAFCT, broken down by subcategory. Estimated daily amount of vitamin A in the form of RAE was 466.63 µg, which is insufficient compared to the NRV of 800 µg. Dark green leafy vegetables and red and orange vegetables were the largest contributors to vitamin A intake, supplying 210.0 µg and 127.0 µg, respectively. Estimated daily calcium was 864.81 mg, which is inadequate as it is 135mg shy of the NRV of 1,000 mg. The largest contributors to calcium intake were dairy foods and dark green leafy vegetables, contributing 297.5 mg and 249.0 mg, respectively. Estimated daily zinc amount was 13.89µg and considered inadequate compared to the NRV of 14µg. The whole grains subcategory was the largest contributor to zinc intake by supplying 5.10µg.

Estimated amounts of some priority micronutrients (folate, iron, and vitamin B12) met the adult NRV for adequate daily intake. Estimated daily folate measured in dietary folate equivalents (DFE) was 641.43 µg, which is substantially above the NRV of 400 µg. The largest contributors to folate intakes were dry beans, lentils and peas, and whole grains which contribute 170 µg and 164.72 µg, respectively. Estimated daily iron was 27.67 mg which is nutritionally sufficient compared to the NRV of 22 g in a high phytate diet. The high iron content of the median item in the whole grains category (12.06 mg/day) is responsible for the sufficient iron intake. Estimated daily vitamin B12 was 2.83 µg, which is greater than the NRV of 2.4µg. Despite the low quantity of animal source foods, the sufficiency of vitamin B12 was driven by the 250 g of dairy foods. Whole milk contributed over half (1.48 µg) of daily requirement.

Table 3. Micronutrient content of PHD based on median values from the WAFCT

			WAFCT Totals					
PHD Category	**PHD Subcategory**	**PHD (g/d)**	**Folate, DFE (µg/d)**	**Iron (mg/d)**	**Calcium (mg/d)**	**Vitamin B12 (µg/d)**	**Zinc (µg/d)**	**Vitamin A, RAE (µg/d)**
Whole Grains	Whole grains (rice, wheat, corn)	232	164.72	12.06	53.36	0	5.10	0
Tubers or Starchy Vegetables	Tubers or starchy vegetables (potatoes and cassava)	50	8.00	0.48	7.50	0	0.22	1.50
Vegetables	Dark green leafy vegetables	100	64.00	3.60	249.00	0	0.69	210.00
	Other vegetables	100	20.00	1.00	30.00	0	0.28	7.00
	Red and orange vegetables	100	15.00	1.30	33.00	0	0.30	127.00
Fruits	Fruits	200	29.00	1.30	43.00	0	0.30	9.00
Dairy Foods	Dairy foods (whole milk)	250	20.00	0.25	297.50	1.48	1.58	105.00
Protein Sources	Beef and lamb	7	0.60	0.22	1.26	0.17	0.25	0.60
	Pork	7	0.21	0.15	0.98	0.03	0.14	0.14
	Chicken and other poultry	29	1.45	0.41	3.77	0.11	0.59	6.38
	Eggs	13	8.45	0.27	9.17	0.22	0.20	15.47
	Fish	28	2.38	0.42	16.80	0.83	0.31	3.92
	Dry beans, lentils, and peas	50	170.00	2.30	37.00	0	1.20	0.50
	Soy foods	25	95.00	1.73	51.75	0	1.20	0
	Peanuts	25	27.50	0.86	12.63	0	0.65	0.50
	Tree nuts	25	14.50	1.13	14.63	0	0.82	0.13
Added Fats	Palm oil	6.8	0	0.01	0.07	0	0	0
	Unsaturated oils	40	0	0.01	0	0	0	0
	Dairy fats (included in milk)	0	0	0	0	0	0	0
	Lard or tallow	5	0	0	0	0	0	0
Added Sugar	All sugars	31	0.62	0.19	3.41	0	0.06	0
Grand Total			**641.43**	**27.67**	**864.81**	**2.83**	**13.89**	**487.13**
Nutrient Reference Value (Lewis, 2019)			400	22	1000	2.4	14	800
Difference Between Nutrient Content and NRV (% difference)			**+241.43 (160%)**	**+5.67 (126%)**	**-135.19 (86%)**	**+0.43 (118%)**	**-0.11 (99%)**	**-312.87 (61%)**

3.3 Assessing the nutrient density of the WAFCT

Table 4 displays the results of performing nutrient profiling on the PHD subcategories of the WAFCT. Three additional groups, chicken liver, beef and lamb liver, and small dried fish were also profiled based on their exceptional scores in other analyses (Beal & Ortenzi, 2022). The subcategories with the highest NRF6.3 scores are chicken liver (391.24), beef and lamb liver (307.22), dark green leafy vegetables (203.33), small dried fish (200.80) and fish (140.78). The subcategories with the lowest NRF6.3 scores were palm oil (-37.11), all sugars (-35.08), dairy fats (-23.19), unsaturated oils (-11.23) and tree nuts (8.01).

Table 4. Nutrient density of the PHD categories based on WAFCT median values for each category

PHD Category	PHD Subcategory	NR6 (SD)	LIM (SD)	NRF6.3 (SD)
Whole Grains	Whole grains (rice, wheat, corn and other)	29.23 (12.15)	1.35 (1.32)	27.88 (11.95)
Tubers or Starchy Vegetables	Tubers or starchy vegetables (potatoes and cassava)	21.73 (20.68)	2.71 (4.81)	19.02 (21.94)
Vegetables	Dark green leafy vegetables	207.26 (84.53)	3.93 (2.94)	203.33 (83.44)
	Other vegetables	61.12 (33.51)	2.34 (1.70)	58.78 (33.23)
	Red and orange vegetables	80.72 (31.98)	5.53 (12.91)	75.19 (32.83)
Fruits	Fruits	24.72 (16.20)	2.09 (7.07)	22.63 (18.72)
Dairy Foods	Dairy foods (whole milk)	88.46 (0)	19.54 (0)	68.92 (0)
Protein Sources	Beef and lamb	112.52 (47.16)	16.81 (11.73)	95.71 (51.11)
	Beef and lamb liver	315.25 (25.92)	8.03 (0.90)	307.22 (26.04)
	Pork	28.67 (7.96)	15.43 (3.07)	13.24 (10.81)
	Chicken and other poultry	106.38 (104.04)	9.35 (8.63)	97.03 (104.96)
	Chicken liver	398.84 (3.73)	7.60 (0.50)	391.24 (3.30)
	Eggs	109.03 (33.45)	13.86 (1.48)	95.16 (33.45)
	Fish	149.65 (55.37)	8.86 (9.46)	140.78 (54.54)
	Small dried fish	207.52 (0)	6.72 (0)	200.80 (0)
	Dry beans, lentils, and peas	50.18 (15.32)	1.54 (0.83)	48.65 (15.96)
	Soy foods	67.54 (2.60)	3.15 (0.31)	64.39 (2.61)
	Peanuts	19.19 (7.46)	7.55 (1.53)	11.64 (8.96)
	Tree nuts	21.84 (8.57)	13.83 (14.97)	8.01 (22.00)
Added Fats	Palm oil	0.10 (0.06)	37.21 (11.86)	-37.11 (11.91)
	Unsaturated oils	0.12 (0.16)	11.35 (6.37)	-11.23 (6.24)
	Dairy fats (included in milk)	14.52 (1.66)	37.71 (2.94)	-23.19 (2.34)
	Lard or tallow	N/A	N/A	N/A
Added Sugar	All sugars	2.03 (1.76)	37.12 (22.00)	-35.08 (22.17)

3.4 Improving nutrient density of the PHD

Table 5 shows potential improvements on the PHD to meet the recommended micronutrient values, while staying within the 2,500 kcal/day energy target, based on the WAFCT. These improvements include reducing whole grains by 32 g and tree nuts by 15 g, increasing dry beans, lentils, and peas by 50 g, and adding small amounts of nutrient rich chicken liver (2 g), beef and lamb liver (2 g), and small dried fish (7 g). After applying these isocaloric revisions, the unadjusted protein intake was 97.74 g/day, while the PDCAAS-adjusted protein intake was 71.61 g/day, both increased from the original PHD. The percentage of unadjusted animal protein increased to 33% while that PDCAAS-adjusted animal protein increased to 44%. The ratio of overall animal to plant source energy remained the same in the revised PHD.

Table 5. Energy and protein content of the revised PHD based on median values from the WAFCT

				Revised WAFCT Totals		
PHD Category	**PHD Subcategory**	**Net Change (g)**	**Revised PHD Composition (g/d)**	**Revised Energy (kcal/d)**	**Revised Protein (g/d)**	**Revised PDCAAS Protein (g/d)**
Whole Grains	Whole grains (rice, wheat, corn)	-32	200	700	18.80	8.22
Tubers or Starchy Vegetables	Tubers or starchy vegetables (potatoes and cassava)	0	50	68	0.90	0.67
Vegetables	Dark green leafy vegetables	0	100	46	4.25	3.11
	Other vegetables	0	100	36	1.40	0.80
	Red and orange vegetables	0	100	56	1.50	1.11
Fruits	Fruits	0	200	141	1.90	1.13
Dairy Foods	Dairy foods (whole milk)	0	250	160	8.25	8.25
Protein Sources	Beef and lamb	0	7	14	1.94	1.82
	Beef and lamb liver	+2	2	4	0.50	0.47
	Pork	0	7	25	1.48	1.45
	Chicken and other poultry	0	29	44	7.48	7.03
	Chicken liver	+2	2	3	0.47	0.44
	Eggs	0	13	23	1.66	1.66
	Fish	0	28	33	6.52	6.13
	Small dried fish	+7	7	22	4.23	3.97
	Dry beans, lentils, and peas	+50	100	321	20.80	14.35
	Soy foods	0	25	96	8.76	7.97
	Peanuts	0	25	144	5.60	2.63
	Tree nuts	-15	10	55	1.42	0.67
Added Fats	Palm oil	0	6.8	61	0.00	0.00
	Unsaturated oils	0	40	360	0.00	0.00
	Dairy fats (included in milk)	0	0	0	0.00	0.00
	Lard or tallow	0	5		0.00	0.00
Added Sugar	All sugars	0	31	101	0.12	0.12
Plant-Source Total (%)			992.80 (76)	2,184 (87)	65.46 (67)	40.78 (56)
Animal-Source Total (%)			345.00 (14)	328 (13)	32.54 (33)	31.24 (44)
Grand Total			**1338.80**	**2512**	**97.99**	**72.02**

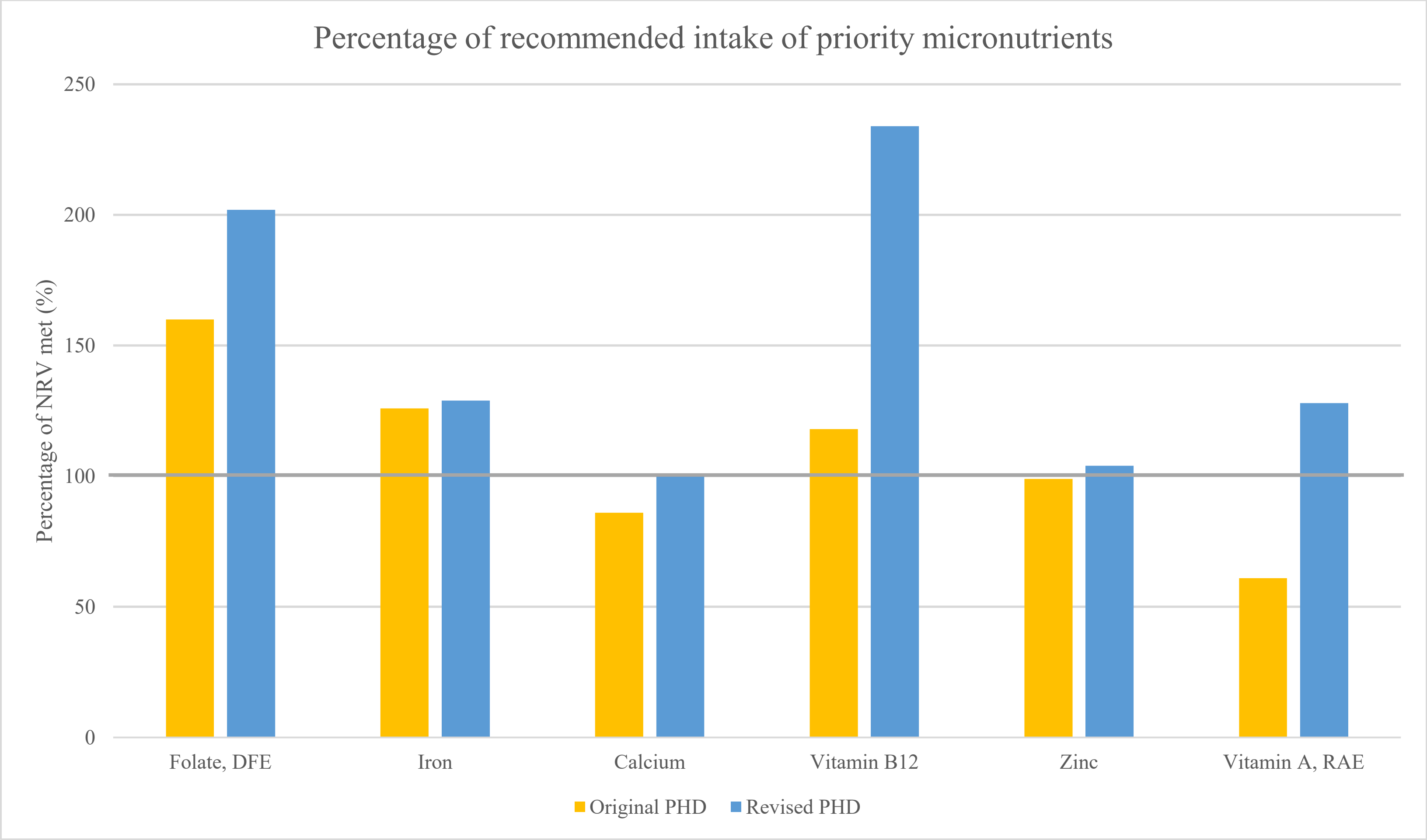
Table 6 shows that all micronutrients evaluated meet their respective NRV. Increased legume intake contributes to zinc adequacy since legumes have the highest zinc content of any PHD category (7.67 µg/d). Chicken liver and beef and lamb liver are extremely dense in vitamin A; therefore, including these categories separately from their respective meat contributes to nutritionally sufficient vitamin A (see **Table 4** and **Supplemental Table 3**). Small dried fish are dense in calcium, with a median of nearly 2,000 mg per 100 g. Therefore, including this category in the diet leads to adequate calcium intake. Though vitamin B12 was sufficient in the original PHD model, daily intake more than doubled with the 11 g increase in animal-source products. The differences between micronutrient intake in the original and revised PHD are visualized in **Figure 1.**

Table 6. Micronutrient content of the revised PHD based on median values from the WAFCT

				Revised WAFCT Totals					
PHD Category	**PHD Subcategory**	**Net Change (g)**	**Revised PHD Intake (g/d)**	**Folate, DFE (µg/d)**	**Iron (mg/d)**	**Calcium (mg/d)**	**Vitamin B12 (µg/d)**	**Zinc (µg/d)**	**Vitamin A, RAE (µg/d)**
Whole Grains	Whole grains (rice, wheat, corn)	-32	200	142.00	10.40	46.00	0	4.40	0
Tubers or Starchy Vegetables	Tubers or starchy vegetables (potatoes and cassava)	0	50	8.00	0.48	7.50	0	0.22	1.50
Vegetables	Dark green leafy vegetables	0	100	64.00	3.60	249.00	0	0.69	210.00
	Other vegetables	0	100	20.00	1.10	30.00	0	0.28	7.00
	Red and orange vegetables	0	100	15.00	0.90	33.00	0	0.30	127.00
Fruits	Fruits	0	200	29.00	1.30	43.00	0	0.30	9.00
Dairy Foods	Dairy foods (whole milk)	0	250	20.00	0.25	297.50	1.48	1.58	105.00
Protein Sources	Beef and lamb	0	7	0.42	0.23	1.09	0.16	0.24	0.49
	Beef and lamb liver	+2	2	4.80	0.25	0.43	2.00	0.08	366.00
	Pork	0	7	0.21	0.15	0.98	0.03	0.14	0.14
	Chicken and other poultry	0	29	1.16	0.35	3.77	0.09	0.51	4.06
	Chicken liver	+2	2	20.00	0.24	0.14	0.45	0.07	162.20
	Eggs	0	13	8.45	0.27	9.17	0.22	0.20	15.47
	Fish	0	28	2.38	0.42	16.80	0.83	0.31	3.92
	Small dried fish	+7	7	3.22	0.52	135.73	0.35	0.54	9.87
	Dry beans, lentils, and peas	+50	100	340.00	4.60	74.00	0	2.40	1.00
	Soy foods	0	25	95.00	1.73	51.75	0	1.20	0
	Peanuts	0	25	27.50	0.86	12.63	0	0.65	0.50
	Tree nuts	-15	10	5.80	0.45	5.85	0	0.33	0.05
Added Fats	Palm oil	0	6.8	0	0.01	0.07	0	0	0
	Unsaturated oils	0	40	0	0.01	0	0	0	0
	Dairy fats (included in milk)	0	0	0	0	0	0	0	0
	Lard or tallow	0	5	0	0	0	0	0	0
Added Sugar	All sugars	0	31	0.62	0.19	3.41	0	0.06	0
Grand Total				**805.56**	**28.32**	**1,021.80**	**5.61**	**14.51**	**1,023.20**
Nutrient Reference Value (Lewis, 2019)				400	22	1,000	2.4	14	800

Difference Between Nutrient Content and NRV (% difference)	**+405.56 (202%)**	**+6.32 (129%)**	**+11.80 (102%)**	**+3.21 (234%)**	**+0.51 (104%)**	**+223.20 (128%)**

Figure 1. Percentage of recommended intake of priority micronutrients in original and revised PHD



4. Discussion

4.1 Summary of results

This study was the first of its kind to test the nutritional adequacy of the PHD in the context of West Africa. The analysis leveraged the FAO WAFCT (Vincent, 2020), downloaded from INFOODS (FAO, 2022) that provides nutrient composition of foods commonly consumed in the Western Africa Region. Analyzing the nutritional sufficiency of the PHD using regionally available food is important to support policymakers and public health nutritionists in deciding how and to what extent promoting food consumption in greater alignment with the PHD is contextually appropriate. These findings may also support national dietary guideline development for countries represented by the WAFCT.

Our analyses used the median energy and micronutrient values for each PHD subcategory. Energy estimates using the WAFCT were remarkably close to those calculated for the PHD (2,516 vs 2,503 kcal). Using the WAFCT, 88% of energy came from plants which aligns closely with the PHD estimate of 86%. Though PDCAAS corrections have been applied to PHD-based vegan diets (Rojas Conzuelo et al., 2022), to our knowledge, PDCAAS corrections have not been applied to the original PHD. The estimated intake of PHD foods in the protein category is 209g, with 125g (60%) coming from plant protein foods and 84g (40%) from animal protein foods. By only providing weight intake recommendations by food group, the EAT-Lancet Commission did not provide protein intake in grams of protein, protein quality, or indispensable amino acids. Therefore, we built on the PHD by assessing protein quality. Our results show the PHD provides 87g/day, which is sufficiently greater than the 50 g/day recommendation (Lewis, 2019). When adjusted for PDCAAS, daily intakes of high-quality protein dropped to 62 g/day, which is marginally sufficient. The PHD demonstrated inadequacy in the critical micronutrients of calcium, zinc and vitamin A. We showed how the shortfall can be ameliorated through small additions of nutrient dense foods. Therefore, aligning consumption with the PHD recommendations without revisions may not meet all nutritional needs of those eating West African foods.

Our results demonstrating the PHD's micronutrient shortfalls are consistent with past reports that combined several regional databases (Beal et al., 2023), however the lacking micronutrients are different. In contrast to Beal et al (2023), our analysis showed vitamin A insufficiency and complete adequacy for iron. These differences may be driven in part by using different food database and nutrition reference values for a different population in the analysis. Additionally, Beal et al. (2023) included foods in their consumed form (i.e., cooked), while our analysis included foods in the form specified by the EAT-Lancet Commission or in both raw and cooked form, if unspecified. We corrected the PHD's nutrient inadequacies of calcium, zinc and vitamin A by adding small amounts of liver and small dried fish and replacing some whole grains with dry beans, lentils and peas. Through these changes, we maintained 14% animal source foods, while Beal et al. (2023) recommended nearly doubling animal intake to meet the reference values.

Of note, these conclusions were drawn based on a target energy intake of 2,516 kcal/day, which is higher than general energy requirements for children under five (Koletzko, 2008). This population is a priority for nutrition interventions in Western Africa and may only require 50% of the energy needs of the PHD. Scaling down the PHD by a factor based on energy requirement might lead to protein and micronutrient inadequacies for this population.

4.2 Protein source ratios

The unadjusted ratio of plant to animal protein in the PHD based on our analysis was 69:31, which is less than the current average ratio consumed in Western Africa of 83:17 (Food and Agriculture Organization of the United Nations, 2023). This difference indicates that West Africans would need to increase their average animal protein intake for greater adherence to the PHD. The ratio of plant to animal protein generally decreases as gross domestic product (GDP) per capita increases (Drewnowski, 2023). For example, Niger is the West African country with the lowest GDP per capita and consumes roughly 78 g of protein/capita/day with a plant to animal ratio of 89:11 (Food and Agriculture Organization of the United Nations, 2023). In contrast, the average ratio of high-income countries is 37:63 (Food and Agriculture Organization of the United Nations, 2023). The plant to animal protein ratio of the PHD in our analysis aligns most closely with that of lower-middle income countries (72:28). The disparities in optimal protein source ratios that may contribute to nutrient deficiency have motivated efforts to increase animal protein consumption in low-income countries. Of particular relevance, the FAO's Africa Sustainable Livestock 2050 initiative to scale up animal-source food production includes Burkina Faso and Nigeria as West African country participants (Food and Agriculture

Organization of the United Nations, 2024a). In addition to increasing intake of high-quality protein, increasing animal source foods may also improve food, nutrition and economic security (FAO, 2023). Furthermore, the close positive correlation between animal-source food consumption and GDP may suggest that replacement of plant-source protein for that of animals may be a natural externality of economic development (Drewnowski, 2023). The EAT-Lancet Commission (Willett et al., 2019) and other entities who promote a reduction in animal protein consumption for environmental sustainability should also support opportunities for low-income communities, such as those located in West Africa, to bolster the sustainable production and consumption of livestock and poultry in addition to supporting economic development.

4.3 Challenges to accurately accounting for micronutrient bioavailability

Recommending a diet for planetary and human health must also consider digestibility and absorbability of micronutrients. The literature on sustainable diets raises concern about micronutrient deficiency due to decreased intake and absorption of priority nutrients (Beal, 2024; Leonard et al., 2024). In our analysis, folate, iron, and vitamin B12 content of the PHD exceeded the NRV, indicating nutritional sufficiency. However, iron bioavailability varies widely between the animal-source derived heme iron and plant-derived non-heme iron (van Wonderen et al., 2023). In our analysis, over 93% of the iron is non-heme, which poses major implications for bioavailability. Additionally, over 12 g of the 27 g of daily iron is coming from the whole grains due to the high median whole grain iron density of 5.2g/100g. The database includes 16 iron-rich pearl millet items from Burkina Faso that drive up the median value despite marginal contribution to daily iron intake in a limited geographic region (Hama-Ba et al., 2019). The high median may not be reflective of dietary consumption in that the iron density of maize and rice is less than 4g/100g.

Calcium and zinc are also highly susceptible to variable bioavailability (Gibson et al., 2010; Platel & Srinivasan, 2016), and neither met the recommended intake in the PHD based on the WAFCT. Dark green leafy vegetables, soy foods and dry beans have a much lower fractional rate of absorbable calcium than milk (Shkembi & Huppertz, 2021) yet contribute over a third of the dietary calcium requirement in this analysis. Despite the variance in the absorption rates of calcium depending on the source, food matrix, and presence of phytates and oxalates (Guéguen & Pointillart, 2000; Shkembi & Huppertz, 2021), calcium has no alternate NRV for those who consume plant-based diets (Lewis, 2019). Though the NRV does provide a blanket adjustment for iron and zinc requirements in high-phytate diets based on lower absorption factors of 10% and 22%, respectively, this does not provide sufficient insight into bioavailability that varies widely by source food. Therefore, food or food group specific bioavailability adjustments for minerals with variable absorption factors, similar to PDCAAS and DIAAS, would be advantageous for more accurately assessing the nutrient sufficiency across a range of diets (Beal & Ortenzi, 2022; van Wonderen et al., 2023).

4.4 Applying micronutrient dense food groups to the PHD

Much effort has been devoted to fortification (World Food Programme, 2022; World Health Organization Executive Board, 2023) and alternative food processing and preparation methods (Egounlety & Aworh, 2003; Elliott et al., 2022) as strategies to close the micronutrient gap for those consuming plant-based diets. However, the PHD seeks to develop a diet containing whole, minimally processed foods that do not include fortification (Willett et al., 2019). Therefore, ensuring micronutrient adequacy of the PHD based on the WAFCT requires the addition of intrinsically nutrient dense food groups at the minimum quantity necessary. Building on the work of Beal & Ortenzi (2022), we defined chicken liver, beef and lamb liver, and small dried fish to be the only sub-categorical additions needed given they are outliers of nutrient density within their respective subcategories. Similar to Beal et al. (2023), we proposed a reduction in whole grains as they are lower in nutrient density and food supply and consumption patterns are shifting away from cereals. However, we also did not separate seeds from the tree nut subcategory and instead proposed an overall reduction in tree nut consumption since nutrient density is low. Our analysis did not necessitate an increase in the proportion of animal-source foods (fish, beef, bivalves, crustaceans, etc.) to the extent Beal et al. (2023) proposed. This may be due in part to Beal et al.'s (2023) substitution of whole grains for more nutrient-poor refined grains and lower energy intake target used in addition to the micronutrient gap variance between our analyses. Instead, we opted for increasing dry beans, lentils and peas given their affordability and acceptability in region, despite their phytate content. Though this analysis did not account for the non-communicable disease risk or environmental impact of proposed diet revisions, increasing animal source protein consumption and production may be associated with less favorable outcomes (Willett et al., 2019), thus motivating our goal of proposing the smallest possible increase. However, inclusion of animal liver and small dried fish may be important subgroups to highlight in future iterations of the PHD to achieve nutritionally sufficient diets in the absence of fortification.

4.5 Strengths

This study exhibits several strengths. This is the first analysis of its kind to leverage the WAFCT in isolation, which allows for a more representative insight into the PHD's applicability in the West African context, rather than attempting to draw conclusions using a global food database. Using a regional database also minimizes the inevitable inconsistencies in micronutrient density given that the nutrient content of locally available foods was measured for the manner in which they are normally cultivated and prepared. Additionally, the analysis included nearly 600 food items with multiple items in each category, which increased its validity. Our novel application of the PDCAAS adjustments at the food and food-group specific level helps understand the PHD's protein quality. These methods solidify the path for future research to perform similar analyses leveraging similar food databases from other regions.

4.6 Limitations

The project was completed in the context of several key limitations. Importantly, there is extensive heterogeneity both within and between West African countries represented in the WAFCT. These differences in cuisine, dietary patterns and food availability are not captured in the WAFCT or in this analysis, thus limiting the applicability of these results to specific subpopulations. Also, the original WAFCT has several missing data that were updated with USDA values or excluded. This limits the accuracy of the data specific to West Africa given that nutrient composition may vary in different regions and food environments, and the direction of this bias is unknown. The exclusion of items with missing values also restricts the comprehensiveness of the database.

The use of medians to represent an entire subcategory also limits the validity. In some subcategories, significant variation exists such that nutritional sufficiency may be impacted depending on which foods within the group are consumed. Also, the midpoints used in the analysis are not weighted by frequency of food consumption. Therefore, this study's estimates are not intended to make conclusions about the adequacy of an entire population's dietary intake.

Additionally, there is currently no consistent method for determining estimated mineral absorption for each food subcategory, comparable to the PDCAAS method of adjusting for protein digestibility. Therefore, the analysis did not adjust for specific and individual mineral needs based on the food sources in which they are consumed and the quantity of phytates in the diet. We also did not apply retention factors to the micronutrient values in the database when using the raw form of food due to the PHD guidance on form of consumption varying across food groups. Given the mixed instructions on using raw versus cooked foods, we determined application of retention factors was beyond scope of this analysis.

These results only report the nutritional composition of the foods included in PHD. This necessitated the exclusion of all refined, processed, and fortified foods that were included in the WAFCT, despite their availability in the West African food supply. These results must be interpreted considering the extent to which the EAT-Lancet Diet currently aligns with dietary consumption. Both FAO Food Balance Sheets and survey data report adherence to the PHD recommendations may be low in this region (Ali et al., 2022; Food and Agriculture Organization of the United Nations & EAT-Lancet Commission, 2021).

Finally, the proposed revisions to the PHD consider only micronutrient and protein sufficiency, not sustainability or affordability of the diet. Data on other dimensions of the diet are not available in the WAFCT yet should be considered before commissioning future versions of the PHD.

4.7 Conclusions and public health impact

This study tested the universality of the EAT-Lancet Commission's PHD by assessing its protein and micronutrient sufficiency using foods documented in the WAFCT. While the protein intake was sufficient, the PDCAAS-adjusted protein was only marginally adequate. Folate, iron, and vitamin B12 met the recommended intakes while calcium, zinc and vitamin A were less than the recommended intake. Adding small amounts of nutritionally dense foods can alleviate the micronutrient inadequacies of the PHD when applied to foods consumed in West Africa.

The food supply, and consequently, food consumption patterns in West African countries are not currently aligned with the PHD (Ali et al., 2022; Food and Agriculture Organization of the United Nations & EAT-Lancet Commission, 2021). This may be due in part to the unaffordability of the diet (Drewnowski, 2020). A 2020 analysis estimated that consumption of the PHD in Sub-Saharan Africa may cost $2.50 per day, which is greater than the daily income per capita of five West Africa countries (Hirvonen et al., 2020). Therefore, daily PHD consumption may be unrealistic in the absence of economic growth and food system transformation. Reducing the cost of environmentally sustainable and nutritionally adequate diets remains a global challenge; however, policymakers should give priority to regions where protein and micronutrient deficiencies are greatest.

West African countries that have not yet developed a national dietary guideline may consider using a revised PHD in light of the low calcium, zinc and vitamin A intake based on the WAFCT analysis. They should also account for protein digestibility and micronutrient bioavailability in the context of the whole diet proposed. Countries should consider investing in the promotion of intrinsically micronutrient dense foods as part of their strategies to alleviate deficiencies since they are available in the food supply and may be already consumed. This study provides evidence to suggest the need to support regional adaptations of the PHD based on the food supply. Additionally, future iterations of the PHD should consider inclusion of the most micronutrient dense food groups as additional categories to encourage initiatives that bolster their accessibility and affordability in the food supply.

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6. Appendix

Appendix A. Specific PDCAAS values for foods and food groups

Food group	**Foods**	**PDCAAS Values**	**Source**
Legumes and pulses	Black beans	0.61	A
	Brown beans	0.61	A
	Kidney beans	0.61	A
	White beans	0.61	A
	Navy beans	0.61	A
	Pinto beans	0.61	A
	Red beans	0.61	A
	Cowpeas	0.38	A
	Lentils	0.52	A
	Soybeans	0.91	B
	Peas	0.69	A
	Cooked peas	0.6	C
	Pigeon pea	0.78	A
	Bambara bean	0.78	A
	Legumes and peas	0.7	A
	Legumes	0.74	D
Nuts and seeds	Nuts and seeds	0.47 (mean)	D
Grains	Corn	0.47	E
	Corn flour	0.44	D
	Cornmeal	0.37	F
	Pearl Millet	0.2	F
	Oats	0.66	F
	Breakfast cereal	0.8	G
	Rice	0.81	H
	Cooked Rice	0.62	C
	Rice, brown	0.61	D
	Sorghum flour	0.46	D
	Wheat	0.46	E
	Wheat bread	0.37	F
	Wheat bran	0.67	D
	Wheat flour	0.47	D
	Other cereals	0.69	D
Milk, dairy and eggs	Milk	1	I
	Milk Cream	0.8	F
	Cheese	0.99	J
Egg	Egg	1	D
Meat and poultry	Beef/ tripes/ giblets	0.94	D
	Chicken	0.94	D
	Pork	0.98	F

	Sausage	0.94	D
	Other meats (Ostrich, crocodile, camel)	0.94	D
	Insects (cricket)	0.76	K
	Termites	0.9	K
	Mixed dishes with beef	0.83 (mean)	J
Fish and seafood	Sardine	1	F
	Shrimp/ crab/ sea snail/ tilapia/ clams	0.94	D
	Mackerel	0.94	F
	Tilapia	0.94	D
	Tuna	1	F
	Other fish	0.94	D
Vegetables	Cabbage	0.62	D
	Amaranth	0.73	D
	Potato	0.81	F
	Eggplant	0.55	D
	Spinach	0.75	D
	Lettuce	0.16	D
	Cucumber	0.3	D
	Tomato	0.39	D
	Pumpkin	0.29	D
	Onion	0.39	D
	Carrot	0.74	D
	Other tubers	0.74	D
	Other leaves and vegetables	0.73	D
	Orange	0.42	D
Fruits	Watermelon	0.46	D
	Banana	0.75	D
	Apple	0.72	D
	Grape	0.27	D
	Other fruit	0.64	D
	Date	0.31	D
	Avocado	0.71	D
	Dried fruits	0.48	D

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Supplemental Table 1. Energy, protein and micronutrient intake of the PHD when matching energy intake by food group, based on WAFCT medians

				WAFCT Totals								
PHD Category	**PHD Subcategory**	**Mass intake of WAFCT adj for PHD kcal (g/d)**	**PHD kcal/day**	**Energy (kcal/d)**	**Unadjusted Protein (g/d)**	**Adjusted Protein (g/d)**	**Folate, DFE (µg/d)**	**Iron (mg/day)**	**Calcium (mg/d)**	**Vitamin B12 (µg/d)**	**Zinc (µg/d)**	**Vitamin A, RAE (µg/d)**
Whole Grains	Whole grains (rice, wheat, corn and other)	232	811	811	21.78	9.52	164.52	12.05	53.29	0.00	5.10	0.00
Tubers or Starchy Vegetables	Tubers or starchy vegetables (potatoes and cassava)	30	39	39	0.52	0.38	4.84	0.30	4.53	0.00	0.14	1.51
Vegetables	Dark green leafy vegetables	50	23	23	2.13	1.55	32.00	1.80	124.50	0.00	0.34	105.00
	Other vegetables	64	25	25	0.97	0.56	12.82	0.64	19.23	0.00	0.18	4.49
	Red and orange vegetables	85	30	30	0.80	0.59	10.99	0.80	19.44	0.00	0.21	89.15
Fruits	Fruits	179	126	126	1.70	1.01	25.91	1.16	38.43	0.00	0.27	8.04
Dairy Foods	Dairy foods (whole milk or equivalents)	239	153	153	7.89	7.89	19.13	0.24	284.48	1.41	1.51	100.41
Protein Sources	Beef and lamb	8	15	15	2.11	1.98	0.69	0.26	1.47	0.20	0.29	0.69
	Pork	4	15	15	0.90	0.88	0.13	0.09	0.59	0.02	0.09	0.08
	Chicken and other poultry	41	62	62	10.33	9.71	2.03	0.57	5.27	0.15	0.82	8.92
	Eggs	11	19	19	1.35	1.35	6.88	0.22	7.46	0.18	0.17	12.59
	Fish	34	40	40	7.86	7.39	2.87	0.51	20.25	1.00	0.37	4.73
	Dry beans, lentils, and peas	54	172	172	11.15	7.69	182.18	2.46	39.65	0.00	1.29	0.54
	Soy foods	29	112	112	10.26	9.34	111.27	2.02	60.61	0.00	1.40	0.00
	Peanuts	25	142	142	5.54	2.60	27.19	0.85	12.48	0.00	0.65	0.49

	Tree nuts	27	149	149	3.86	1.82	15.78	1.22	15.92	0.00	0.89	0.14
Added Fats	Palm oil	7	60	60	0	0	0	0.01	0.07	0.00	0.00	0.00
	Unsaturated oils	39	354	354	0	0	0	0.01	0.00	0.00	0.00	0.00
	Dairy fats (included in milk)	0	0	0	0	0	0	0	0	0	0	0
	Lard or tallow	0	36	0	0	0	0	0	0	0	0	0
Added Sugar	All sugars	37	120	120	0.06	0.15	0.74	0.22	4.05	-	0.07	-
Plant Source Total		857	2,163	2,163	58.77	35.21						
Animal Source Total		336	340	304	30.45	29.21						
Grand total after matching energy			2,503	2467	89.22	64.43	619.96	25.44	711.73	2.95	13.78	336.78

Supplemental Table 2. FAO Codex Alimentarius nutrient reference values for protein and priority micronutrients (Lewis, 2019)

Nutrient	**Daily NRV**
Protein	50 g
Calcium	1000 mg
Folate (DFE)	400 µg
Iron	22 mg
Vitamin A (RAE)	800 µg
Vitamin B12	2.4 µg
Zinc	14 µg

Supplemental Table 3. Micronutrient density of additional subcategories of revised PHD and their respective parent categories

PHD Subcategory	**Folate (µg)**	**Iron (mg)**	**Calcium (mg)**	**Vitamin B12 (µg)**	**Zinc (µg)**	**Vitamin A (RAE) (µg)**
Chicken and other poultry	4.00	1.20	13.00	0.31	1.77	14.00
Chicken liver	1,000.00	11.85	7.00	22.50	3.69	8,110.00
Beef	11.00	1.80	20.00	1.80	4.76	10.0
Beef and lamb liver	240.00	12.50	21.50	100.00	4.14	18,300.00
Fish	8.50	1.50	60.00	2.95	1.11	14.00
Small dried fish	46.00	7.40	1939.00	5.00	7.67	141.00