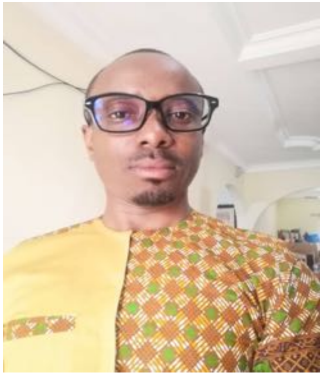
ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 1
January 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Afr. J. Food Agric. Nutr. Dev. 2023; 23(1):22088-22116 https://doi.org/10.18697/ajfand.116.22930

DIET MODELLING IN THE DEVELOPMENT OF A HEALTHY DIET FOR THE GHANAIAN POPULATION

Azupogo F[1]*, Agbemafle I[2], Owusu R[2], Wijesinha-Bettoni R[3], Addy P[4] and R Aryeetey [5]



Fusta Azupogo

*Corresponding author email: fazupoko@uds.edu.gh

[1]Department of Family and Consumer Sciences, Faculty of Agriculture, Food and Consumer Sciences, University for Development Studies, Box TL 1882, Tamale, Ghana

[2]Fred N. Binka School of Public Health, University of Health and Allied Sciences, Hohoe PMB 31, Ho, Ghana

[3]Food and Nutrition Division, Food and Agriculture Organization of the United Nations, Italy

[4]Ministry of Food and Agriculture, Accra, Ghana

[5]School of Public Health, University of Ghana, Legon, Accra

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 1
January 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

ABSTRACT

Diet modelling is one of the important steps in developing food-based dietary guidelines (FBDGs). However, this component remains uncommon in the FBDGs of many low-and middle-income countries. A diet modelling package (DietSolve) provided by the Food and Agriculture Organization (FAO) was used to formulate a healthy diet based on estimating the daily proportions of food groups that best meet the dietary goals established for the FBDGs for Ghana. Input data for the modelling included a list of commonly eaten foods across the agreed food groups, nutrient and energy content of the foods, current energy and nutrient consumption, and energy and nutrient constraints linked to the dietary goals, as determined by the FBDG multi-Sectoral Technical Task Team (MTTT). The modelling was based on assumptions and constraints including a total daily dietary energy target of 2000 kcal/day; the percentage contribution (energy targets) of the macronutrients as follows: carbohydrates (55-70%), protein (10-20 %), and fat (20-30%) to the total energy target; and calcium (1100 mg/day), iron (20 mg/day), and zinc (11 mg/day) constraints. The situation analysis and evidence review carried out as a prior step guided the diet modelling constraints. Energy contributions were also set for a serving of each food group. The final recommendations were based on food groups with each food group consisting of a variety of commonly consumed foods. The total weight of the optimized diet was estimated at 1514 g/day, including 144g/day of animal-source foods, 41.5g/day of discretionary choices, 226g/day of fruit, 227g/day of vegetables, 6g/day of healthy fats and oil, 198g/day of legumes, nuts, and seeds, and 672g/day of staples. This food group composition will provide an estimated 2639 kcal/day, a deviation of about 32% above the energy target set, made up of ~59% from carbohydrates, ~15% from protein and ~25% from fat, and meeting/exceeding the micronutrient targets set. The Optimised diet is healthier compared to the present dietary patterns of the population; its lower ASF component is known to impact less on the environment.

Key words: Food-based dietary guidelines, linear programming, diet modelling, healthy diet, infood-graphic, Ghana

https://doi.org/10.18697/ajfand.116.22930

INTRODUCTION

Consuming healthy diets throughout the life-course helps to prevent malnutrition in all its forms [1]. However, the current food system in Ghana does not ensure adequate and healthy food intake. The country is presently experiencing an increasing triple burden of malnutrition (coexistence of protein-energy undernutrition, overweight and obesity and micronutrient deficiencies) and diet-related chronic diseases [2–4]. Close to 43% of Ghanaian adults are either overweight or obese and the trend of overweight and obesity is increasing; women have a higher prevalence of overweight (27.8% vs 21.8%) and obesity (21.9% vs 6.0%) compared with men [4]. A recent systematic review and meta-analysis reported that 19% of children and adolescents in Ghana are either overweight or obese [5]. Depending on the classification system used, the prevalence of metabolic syndrome, in presumably healthy Ghanaian adults ranges between 6% and 21% [3].

The triple burden of malnutrition, coupled with diet-related chronic diseases is a serious public health issue. Undernutrition has intergenerational effects on foetal development limitation, which eventually leads to small gestational age and low birth weight for babies [6]. Overweight and obesity are also associated with diabetes, hypertension, stroke, ischemic heart, and obstructive sleep apnoea in later life [7]. Obese women are at higher risk of gestational diabetes, as well as giving birth to babies who are either overweight or obese and are more likely to become obese or prone to non-communicable diseases in later life [8,9]. Available evidence indicates that non-communicable diseases account for 43% of all deaths in Ghana [10].

The triple burden of malnutrition and diet-related chronic diseases may be attributed to increased consumption of highly processed foods and rapid urbanization accompanied by a shift in dietary patterns, persistent food insecurity, and an increasingly sedentary lifestyle [11–13]. Dietary habits in Ghana are evolving away from traditional foods towards more refined foods, ready-to-eat foods, that are low-nutrient and energy-dense. These dietary habits are characterised by low consumption of fruits and vegetables, especially in urban areas [12].

The local food environment increasingly offers highly processed packaged foods [12,14]. Fast-food franchises and restaurants are proliferating across the length and breadth of the country, particularly in major cities [15]. In a systematic review and meta-analysis, Rousham and colleagues [16] found that only a half of the population in Ghana and Kenya consume fruit and vegetables daily; a third consumed unhealthy foods, and more than a third consumed sugar-sweetened beverages daily. Those in low socioeconomic groups are more likely to consume cheaper processed energy-dense foods [17]. Ultra-processed food consumption has been cited for the rise of the triple-burden of malnutrition in Africa [18]. Besides the nutrition transition, sedentary lifestyle is increasing with the majority of Ghanaian adults minimally sedentary, especially in urban areas [19].

Food-based dietary guidelines (FBDGs) are an important tool for improving individual and population diets and promoting healthier lifestyles [20]. Food-based dietary guidelines are currently lacking in many African countries. This is because, the consultation process for formulating FBDGs can be difficult, time-consuming, and even biased [21]. Previous attempts to formulate FBDGs in Ghana have been limited to vulnerable population groups with limited geographical scope [22,23].

One important step in FBDG development is the situation analysis and evidence review (SAER), which provides information for diet modelling. Based on the SAER findings, diet goals and targets are set, to address the observed nutrition and diet-related problems. The diet modelling is used to obtain models of recommended daily dietary patterns which fulfil these diet goals, in addition to any other constraints set (for example acceptability and cost of the diet). The optimised diet model is also used to develop food selection guides for various population groups, in order to communicate the amounts (serve sizes and number of serves) and types of foods to consume each day. The food group proportions in the optimised diet model are used to develop a FBDG graphic for educating the general population. However, the use of diet modelling as part of the FBDGs development process is still uncommon in LMICs.

The School of Public Health of the University of Ghana partnered with the Ministry of Food and Agriculture to establish a national multi-Sectoral Technical Task Team (MTTT) with technical support from the Food and Agriculture Organization (FAO). The MTTT which included selected key stakeholders from government and non-government partner institutions, and academic and research institutions spearheaded the development of FBDGs for Ghana. The present study reports the process followed to develop an optimized daily dietary pattern for the Ghanaian population, which met diet goals set to address observed nutrition and diet-related problems in the country while being culturally acceptable and feasible for consumers to follow.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 23 No. 1 January 2023 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

MATERIALS AND METHODS

Study design

Input data for the modelling included a list of commonly eaten foods across the agreed food groups, nutrient and energy content of the foods, current energy and nutrient consumption, and energy and nutrient constraints linked to the dietary goals, based on the SAER and as agreed on by the FBDGs MTTT. The target population for the diet modelling included adolescents and the adult population in Ghana.

Definition of key terms

Portion size: The amount of food that is actually put on the plate that can be eaten at a sitting. A portion may be larger or smaller than a food guide serving.

Serving size: Serving size is a reference amount of food, usually expressed in terms of calories. In other words, it is the energy target per food group serving. For example, one slice of bread is about 40g and ~120kcal in energy.

Sentinel foods: Commonly consumed foods that are taken to represent each food group, to define the serving size (in calories). For example, if bread is the most commonly consumed food in the cereals group, it would be set as the sentinel food. It is possible to have more than one sentinel food per food group.

Input data requirements and preparation

In this paper, a diet modelling package (DietSolve) [24] provided by the FAO was used for diet modelling. The package was developed by a service provider, MS-Nutrition [25], in close cooperation with the FAO. The purpose of the modelling was to generate an optimal diet for persons living in Ghana based on food groups (which contained foods that are typically consumed within each group) and the relative proportions of consumption across the groups. The FAO DietSolve was a Microsoft Excel application which used linear programming to search for diet solutions using a set of decision variables (Box 1). The modelling works within agreed constraints such as nutrient thresholds (that is energy target, percentage contribution from the various macronutrients to total caloric energy intake, and micronutrient targets), acceptability constraints (upper and lower limits of food in grams to include from each food group), and cost constraints. It was also possible to specify the energy contribution from a "discretionary choices" food group which contained foods that are commonly consumed but not recommended for daily/frequent consumption. The optimization process either minimizes or maximizes a function of the decision variables while meeting the constraints, linearly. It determines the weight (or the number of servings) of each food group necessary to meet the specified nutritional requirements within the set constraints.

The FAO DietSolve requires data on representative foods and their relative percentage contribution (by weight) to the respective food group, in terms of population-level consumption. Since national food consumption data is lacking for Ghana, a food list was generated (Table S1) and was based on data from dietary intake studies conducted among diverse population groups in the country [22,26]. Descriptive statistics such as frequencies and percentages were used to summarise the dietary intake data. The MTTT reviewed the food list based on a priori knowledge of the Ghanaian food culture and the list of foods was generated; for instance, additional food items were added based on nutrient density even when consumption data was not available. Likewise, the relative percentage contribution (by weight) of foods to their food group was revised based on the MTTT's a priori knowledge of the customary diet in Ghana.

Box 1: Input data included in the Diet modelling

- Food list with nutrient values (from food composition table).
- Population dietary energy goals and Acceptable Macronutrient Distribution Ranges (AMDRs) for percentage energy from protein, fats and carbohydrates (Determined by MTTT).
- Population micronutrient goals for problem micronutrients and reference values to use, for example FAO/WHO Recommended Nutrient Intakes (RNIs).
- Food groups (determined by MTTT).
- Representative foods in each food group, with relative percentage contribution of the food (by wight) to the food group, according to consumption (obtained from review of dietary data and MTTT recommendation).

An average dietary energy target of 2000kcal/day was specified for Ghanaians, based on a systematic review of energy intake among apparently healthy adolescents and adults in Ghana [16]. Energy intake of 2000kcal/day was expected to minimise the risk of the increasing burden of overweight and obesity in the Ghanaian population and meet caloric needs. The percentage energy contribution (targets) of the macronutrients were determined by the MTTT as: carbohydrates (55-70%), protein (10-20%) and fat (20-30%) in conformity with the FAO/WHO/UNU recommendations [27]. The minimum and maximum percentage contributions of discretionary choices to the energy target were set between 1%

https://doi.org/10.18697/ajfand.116.22930

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 23 No. 1 January 2023 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

and 10%, respectively based on the MTTT's recommendations. Micronutrient constraints were included for calcium (1100 mg/day), iron (20 mg/day), and zinc (10 mg/day) based on the WHO/FAO recommendations for 15% iron bioavailability, and a moderate bioavailability of zinc [28]; these micronutrients were found to have public health significance for Ghana, based on the SAER and the MTTT's recommendations. The constraint for iron reflects the recommended nutrient intake (RNI) for menstruating females while that of zinc corresponds with the RNI for pregnant women in their third trimester; these requirements are the highest in the population.

The Food composition table (FCT) was based mainly on the 2012 West African Food Composition Table [29], which is the default table with the FAO Diet Solver Package. This was supplemented with data on additional foods using the Ten2Twenty-Ghana FCT [30], with care being taken to ensure the data were compatible. From December 2020 to June 2021, monthly meetings of the MTTT were held to discuss the food list and constraints and obtain consensus decisions where evidence was lacking; this approach was utilized throughout the modelling process. Food items were classified into seven groups based on recommendations from the MTTT. These included staples, animal-sourced foods (ASFs), fruits, vegetables, legumes, nuts and pulses, healthy fats and oil and discretionary choices. The discretionary choices food group included nutrient-poor, energy-dense snacks and beverages, such as biscuits and pastries, as well as sugar-sweetened beverages and sweets. The staples group included cereals, grains, roots, tubers and plantain.

One of the first steps involved selecting "sentinel foods" for each food group. When setting these, the typical portion sizes (that people consume in one sitting), were also taken into consideration. For example, a cooked fermented maize dumpling popularly called "Banku" in Ghana was the sentinel food in the staples food group, as it was the most commonly consumed food in the group. The first three food items with the highest weighting (percentage weight) in each food group were selected after sorting the foods in descending order (highest to lowest weight) except for the legumes, pulses and nuts food group, in which 6 foods with equal or highest weighting were selected; these foods were assessed based on the SAER to have a similar consumption weighting in the population. Subsequently, energy intake from a single serving of a food group corresponding to a typical household measure [31] of the food item in the Ghanaian population was estimated, using the FAO DietSolve. The household measures included small tomato puree tin size (TT. Sz), small tomato puree tin round full (TT rd.), full cream evaporated milk tin (E.T.Sz), dessert/tablespoon round full (dsp.rd), dessert/tablespoon level full (dsp

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 23 No. 1 January 2023 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

L), soup spoon/ladle (Sp.Sp.L), teaspoon level full Level (TT.L), average orange size (Org. Sz), sardine tin (peeled) (Srd. T. Sz), and stewing spoon round full (St. Sp. Rd) [31].

The average energy of typical servings of the sentinel foods in the group was then used as the energy from one serving of that food group. Table 1 shows the selected sentinel foods and the estimated energy target, by food group. In the Solver, the weight of each food was then adjusted to obtain the energy target set for a serving from that food group. For example, 128g of macaroni, boiled will provide ~200kcal, which corresponds to the serving size (in energy) set for staples.

Diet modelling approach
The FAO DietSolve has 6 sheets (layers); sheet 1 (input food composition) is the input interface for the FCT. Sheet 2 (food selection) is used to define the food list, food grouping, weighting and serving size for each listed food. Sheet 3 is for defining food group energy contributions (that is energy contribution from a serving size of each food group). Sheet 4 is used for setting constraints for energy and nutrients, as well as the acceptability constraints, that is, minimum and maximum servings/day for each food group. There is also an option to set a constraint for cost, which was not used in the current modelling because of the unavailability of cost data. Optimization of the modelling is performed in sheet 5. The unit of variation for the modelling was set as half (0.5) of the serving size; this meant that the resulting solution could be expressed in terms of either whole units or 0.5 units of the handy measure quantity. The optimization function used was to minimize the deviation from the energy target. The optimized results were interpreted in both sheets 5 and 6 of the Solver. Sheet 5 produced the optimized serving sizes of each food group and the contribution of food groups to energy and nutrient intake. Sheet 6 produced a visualisation of the contribution of each food group to the total amount of calories/day in the model. In discussions and meetings with the diet modelling team and the MTTT, several optimized models were compared; revisions in model parameters were made until the modelling team and MTTT observed that the optimized models satisfied most of the specified constraints.

RESULTS

Only the final optimized diet model is presented in this paper. The estimated energy intake/day in the selected optimized diet was 2638.9 kcal/day, about 32% higher than the energy target of 2000 kcal/day. The total mass of food proposed in the final optimized model was roughly 1500 g/day, as shown in Table 1. The optimized diet included 144g/day of ASFs, which is approximately 1.5 servings

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 23 No. 1 January 2023 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

daily or around 2 small tomato puree tin size servings of beef or chicken thigh per day. The optimised diet also included an average of half a serving of discretionary choice daily (42g). This is equivalent to 2 dessert spoons of sugar. Fruit and vegetable averaged 225.7g and 227.3g per day, respectively in the optimised diet. The daily fruit servings were equivalent to 1.5 average orange-sized servings, while the daily vegetable servings were equivalent to 7.5 servings (stewing spoon) of shredded raw cabbage or 4.5 servings (stewing spoons) of boiled cocoyam leaves (kontomire).

The proposed optimised diet's average daily intake of healthy fats and oil was 6.2g, which is similar to 1 dessert spoon level full serving/day of healthy fats and oil. The model also contained roughly 200g of legumes, nuts, and seeds per day, which equated to about 2 full-cream evaporated milk tin serves of legumes (for example white beans/cowpeas) daily or about 4 small tomato puree tin sizes of dried nuts (for example roasted groundnuts) per day. Furthermore, the average daily staple intake (672g) was similar to 4 full-cream evaporated milk tin servings of banku or around 38 dessert spoon round full serves of polished rice daily.

Figure 1a demonstrates that staples accounted for about 44% of total intake (g/day), whereas legumes, pulses, and nuts accounted for 13%. In addition, fruits and vegetables each contributed around 15% of total daily intake, while ASFs contributed about 10%. Discretionary choices made up roughly 2.7% of total daily intake (g/day), whereas healthy fats and oils made up only 0.4 % of the total daily intake (g/day). When examining the contribution of each food group to overall energy intake per day (Figure 1b), staples accounted for about half (49%) of the total, while legumes, nuts, and seeds accounted for nearly a quarter (24%). ASFs represented around a tenth of total daily calorie consumption, whereas fruits and vegetables each contributed 6% and 4.4% respectively, being low in energy. In addition, discretionary choices accounted for around 5% of total energy consumption, with healthy fats and oils accounting for about 2% of total energy intake per day. Table 3 demonstrates that the optimized diet model met the calcium, iron, and zinc restrictions, as well as the energy constraints for carbohydrates, fats, and protein.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 23 No. 1 January 2023 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

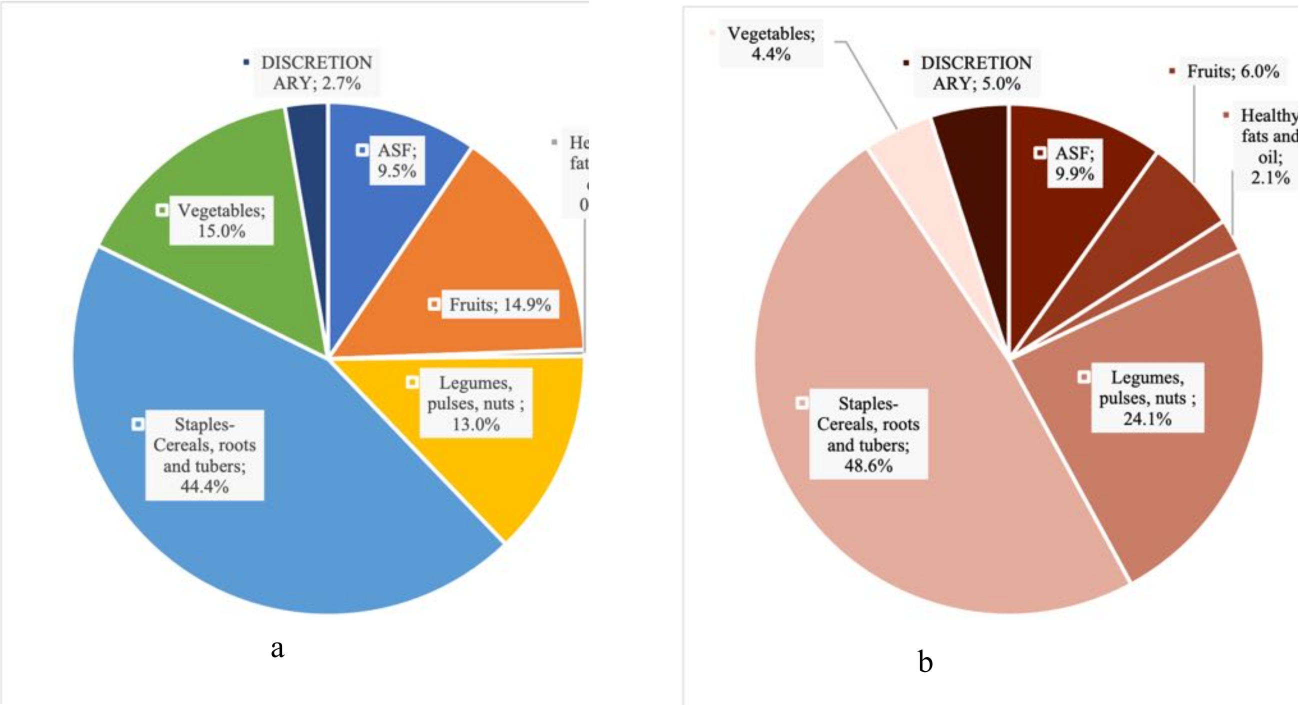


Figure 1: (a) Visualisation showing the percentage contribution of each food group to the estimated total amount intake (g); (b) Visualization showing the estimated percentage of energy intake from each food group; ASF, animal sourced-foods

DISCUSSION

Diet modelling was conducted diet modelling to obtain recommended daily dietary patterns for Ghana's FBDGs. The optimized diet determined the proportions of food groups that were depicted in the FBDGs food guide/graphic for Ghana. The diet modelling provided a basis for the recommendation of amounts of foods to consume based on food groups rather than specific food items which may be more difficult to adhere to. Food group recommendations allow for the consumption of more varied food items, which is known to improve nutrient adequacy and health [32,33]. Although the daily energy intake in the optimised diet was about 32% above the energy target, it remained within the plausible energy intake limit for women (500–3,500 kcal/day) and men (800–4,000 kcal/day) [34]. Moreover, the estimated daily energy intake of the proposed diet was similar to the average daily energy intake in the Ghanaian population [35] and about 139kcal/day (~ 5.6%) above the daily calorie target for a planetary healthy diet (2500kcal/day) as

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 1
January 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

proposed by the EAT-Lancet commission [36]. Importantly, the constraints for carbohydrates, fats and protein were fulfilled in the optimized diet and the diet also ensured nutrient adequacy for iron, calcium and zinc. Although a 15% bioavailability for iron was assumed, the optimized diet meets the requirements of dietary patterns with even a 10% iron bioavailability. Overall, the optimized diet when adhered to would ensure nutrient adequacy, thereby reducing the risk of micronutrient deficiencies while also limiting the risk of overweight and obesity, and their resultant consequences.

In conformity with the dietary patterns in Ghana [35,37], the proportion of staples remains highest in the diet although lower than the prevailing population pattern. The share of staples in the proposed diet also conforms with the recently developed Ethiopia FBDGs [38]. The EAT-Lancet Commission recommends that about one-third of the total daily calorie intake should come from whole grains [36]; however, such a dietary pattern would deviate greatly from the population pattern as staples, which primarily provide calories, account for around two-thirds of most Ghanaians' dietary intake [12,37]. This would possibly make the FBDGs unrealistic and difficult to adhere to. Root tubers and their products (that is yam, cassava, cocoyam, tarrow, 'gari'-fermented roasted cassava), plantains, and cereals and their products (that is rice, maize, millet, sorghum) are commonly consumed staples in Ghana. Wheat and wheat products are also increasingly popular among Ghanaians.

Within the given constraints for the contribution of carbohydrates to energy intake, staples provided nearly a half of total dietary intake (gram), and close to a half of daily calorie intake in the optimal diet model. Both high- and low-carbohydrate diets are linked to an increased risk of death, with the lowest risk found around 50–55 % carbohydrate intake [39]. Therefore, the aim was to minimise the share of staples in the overall dietary intake, which was achieved in the optimised diet by increasing the quantity of legumes, nuts and seeds consumed. The increased consumption of plant proteins, primarily from legumes, nuts, and seeds compensates for any possible deficit in the total protein requirements of the population from ASFs. In the optimized diet, legumes, nuts, and seeds accounted for nearly a quarter of total daily calorie intake. Consumption of legumes and nuts is an important aspect of a dietary strategy for the primary prevention of cardiovascular disease [40] and energy consumption that favours plant-derived protein and fat from sources such as vegetables and nuts is linked to lower mortality [39].

The optimized diet proposes that fruits and vegetables should make up one-third of the daily diet. While this falls short of the EAT-Lancet recommendation that a

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 23 No. 1 January 2023 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

planetary healthy diet should contain about half of a plate of fruits and vegetables by volume [36], it represents an improvement in terms of Ghana's current consumption patterns of fruits and vegetables [35]. More so, the total intake of fruits and vegetables (453 g/day) in the optimized model was slightly higher than the recommended [41] daily intake of fruits and vegetables for the prevention of cancer and cardiovascular diseases by the population. In reality, because the intake of fruits and vegetables in Ghana [42] is slightly below the optimized level, our results are aspirational, and seek to promote increased consumption of fruits and vegetables, as these foods are known to have beneficial effects in reducing overweight and obesity and improving cardiovascular health [43]. Fruits and vegetables are high in fibre, vitamins, minerals and other phytochemicals and evidence from systematic reviews indicates that a dietary pattern rich in fruits and vegetables ensures adequate micronutrient intake which enhances health [43, 44].

The aim was for an optimized diet which considers the independent contribution of vegetables and fruits to the daily energy and nutrient intake, informing the decision to have separate food groups for fruits and vegetables. Although the independent effects of fruits and vegetables on weight are inconclusive in the literature, it was anticipated that, compared to fruits, a higher vegetable intake may in the short to long-term reduce the prevalence of overweight and obesity, thereby reducing the burden of diet-related chronic diseases. A higher proportion of energy consumed as vegetables was associated with a significantly higher weight loss after 3 months, among overweight and obese Australian adults [45]. In the dietary model, for instance, the average energy content per 100g of fruits was 108.5 ± 105.0 kcal (range 29.0-332.8 kcal) while that for vegetables was 60.1 ± 70.1 kcal (range 15-296.0 kcal). However, customary cooking methods may rather increase energy intake with increased vegetable intake; among Chinese adults, for example, increased intake of vegetables was associated with a higher risk of obesity due to the use of oil for stir-frying vegetables, highlighting the importance of choosing the right cooking methods [46].

Fruit consumption in Ghana is low compared to vegetables [47] as consumers are more likely to spend on vegetables than fruits [48]. Although the preference for vegetables is partly attributed to the high cost of fruits [48,49], it also relates to the customary dietary patterns of consuming starchy staples with vegetable soups and stews [50]. Including fruits as a separate food group, therefore, ensures that specific recommendations which promote the consumption of fruits are made.

Animal-sourced foods are a good source of high-quality proteins, and they help to prevent micronutrient deficiencies [51]; however, ASFs are also high in saturated

https://doi.org/10.18697/ajfand.116.22930

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 1
January 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

fats, which have been linked with an increased risk of cardiovascular and other chronic diseases. Animal-sourced foods contributed about 10% of total calorie intake. Importantly, dairy products were combined with meat, fish and eggs as ASFs in the modelling; while this may limit the consumption of dairy products, it conformed with the customary dietary pattern in Ghana as there is low consumption of dairy products in the population compared to fish, meat and eggs [12,16,22]. The recommendation, however, includes consuming a variety of foods from animal sources. The main limitation is that in Ghana, ASFs are relatively more expensive compared to other foods [52], limiting the ability of most households to consume adequate amounts, especially in rural parts of the country.

In the optimized diet, healthy fats and oil were limited to no more than 1 dessert spoon full as a serving per day but this does not include fats and oil from other food groups such as ASFs, legumes, nuts and seeds. Unsaturated fats are preferred to saturated fats because they are associated with a lower risk of cardiovascular morbidity [1]. Red palm oil and numerous types of pre-packaged vegetable cooking oils are among the most regularly consumed oils in Ghana. However, there is a need to raise public awareness and education about low-fat cooking methods and recipes. In most Ghanaian recipes requiring oil or fat, the oil/fat is usually heated to a high temperature, which increases the consumption of saturated and trans-fats. Steaming or boiling should be promoted over frying to reduce fat and oil consumption. Substituting polyunsaturated fats such as soybean, canola (rapeseed), corn, safflower, and sunflower oils for butter, lard, and ghee; consuming reduced-fat dairy foods and lean meats; or removing visible fat from meat are some of the suggested methods for reducing fat intake. Furthermore, limiting fried foods, as well as pre-packaged snacks and foods that contain industrially-produced trans-fats (for instance doughnuts, cakes, pies, cookies, biscuits, and wafers), has also been suggested as a way of reducing saturated fat and industrially-produced trans-fat intake [1].

The optimized diet discriminated against the consumption of discretionary choices with an average intake of half a serving which was equivalent to two dessert spoons of sugar (~ 42 g/day). Although it is healthier to exclude discretionary choices from the diet, the consumption of these foods in the population is common, notably, bakery products, deep-fried snacks, sugar, sweets, and sugar-sweetened beverages [16]; excluding discretionary choices would consequently be a deviation from the customary or usual dietary pattern of the population. It was recommended in the FBDGs that discretionary choices should be consumed infrequently which is similar to the EAT-Lancet commission's recommendation on a low amount of added sugar.

Although the food list was not based on a national food survey, it included a comprehensive list of the commonly consumed foods from different studies across the country [22,26,35], validated by the MTTT. In the FAO DietSolvePackage, a food item with a higher percentage weighting contributes more to the energy and nutrient profile of its food group. However, the percentage weighting of foods was based on limited dietary intake studies. Thus, the estimates based on the food list may not adequately represent the population's behaviour. For that reason, the main limitation of the optimized diet was the percentage weighting assigned to foods in each food group. This limitation can only be addressed by gathering consumption data from a comprehensive nationally-representative survey.

The cost of adhering to the optimized diet model was not estimated due to constraints in accessing food price data. However, it is presumed the cost of adhering to the optimized diet is feasible since ASFs which are the most expensive contributed only a tenth of the total dietary and calorie intake. It is also reasonable to speculate that the cost of adhering to the proposed FBDGs would be relatively cheaper compared to the Eat-Lancet diet which cost about $2.84 (~ GHc24) daily [53] since the proposed FBDGs contain lesser quantities of the more costly fruits and ASF. Future modelling should include data based on a comprehensive market survey to inform the cost data in the modelling process.

Lastly, there is a low likelihood that the optimized diet model has been influenced by the quality of the FCT data; the energy and nutrient estimates in the FAO DietSolve included the 2012 edition of the West African FCT [29] and likewise the data from the Ten2Twenty-Ghana study [30]. The FCT data also accounted for the cooking process and retention factors. All newly included FCT data in the Package were peer-reviewed by nutrition specialists with expertise in using the FAO DietSolve. The Ghana FCT was last updated in 1992, informing the decision to exclude it from the energy and nutrient intake data.

There are only a few countries in sub-Saharan Africa which have developed FBDGs, and even fewer have included diet modelling. The involvement of the MTTT, which included representatives from several public sector agencies such as health, education, agriculture, and others as well as representatives from civil society, academia, and UN agencies in the decisions that informed the modelling for the FBDG enhanced the validity of the results.

CONCLUSION

In the present paper, the recommended daily dietary patterns for Ghana's FBDGs were obtained in a diet modelling approach. The optimized diet determined the proportions of food groups that constituted an optimal diet. The diet modelling ensures the feasibility of the technical recommendations and qualitative estimates of what should be consumed; the findings give consumers a practical guide to choosing foods that would help them stay healthy. Adherence to the optimized diet by the population would ensure nutrient adequacy for iron, calcium and zinc which are of public health relevance in Ghana while also following the recommended energy intake from each of the macronutrients, thereby limiting the risk of malnutrition in all its forms and diet-related chronic diseases. The recommended diet is healthier compared to the present dietary patterns of the population; its lower ASF component is known to impact less on the environment. Given the important role of agricultural diversification, food insecurity, poverty, and sensitization and education in dietary quality, it would be important to consider these as a fundamental part to promote the proposed FBDGs based on the optimised diet in the present study.

ACKNOWLEDGEMENTS

The dietary modelling was carried out as part of the food-based dietary guidelines development process in Ghana, which was technically and financially supported by the Food and Agricultural Organisation (FAO) of the United Nations. The contribution of the Ghana multi-sectorial technical task team (MTTT) to the modelling is acknowledged.

Ethical approval and consent to participate: Consent for participation was not necessary for the modelling process. No Human Subjects data gathering was employed in this study.

Consent for publication: Not applicable

Authors' contributions: Conception: RW-B, PA and RA. Design: FA, IA, RW-B, PA and RA. Analysis and interpretation of data: FA, IA, RO, RW-B, PA and RA. Drafting of the article: FA and RA. Critical revision for important intellectual content: IA, RO, RW-B, PA and RA and final approval of the version to be published: FA and RA.

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT Volume 23 No. 1 January 2023 PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST ISSN 1684 5374

Table 1: Selected sentinel foods and the estimated energy contribution from a serving, by the food group

Food Group	Food item	Description of portion, using household units	Weight of Serving (gram)	Edible Portion size (gram)	Estimated energy (Kcal)	Average energy (Kcal) for 1 serving of the food group (rounded up)
Animal-sourced food	Chicken, thigh, meat & skin, fresh, fried	1 TT. Sz	51.8	51.8	135.8	150.0
	Egg, chicken, whole, fried	2 Egg Size	103	103.0	161.7	
	Beef, medium fat, fresh, boiled	1 TT. Sz	50.7	50.7	148	
Staples	Banku, fermented maize dough boiled	1* E.T.Sz	170.3	170.3	183.9	200.0
	Rice, white, polished, boiled	9* dsp.rd	157.5	157.5	204.75	
	Yam tuber, boiled* (without salt)	2.5* TT. Sz	148.25	148.25	199.4	
Discretionary choices	Sugar	2* dsp. rd.	28.4	28.4	113.6	110.0
	Creamer non-dairy powder	3*dsp.rd.	21	21	112.5	
	Biscuits, basic recipe, baked	1/2*Small size pack	25	25	111.5	
Fruits	Orange, raw	Org. Sz	218.1	163.6	72.7	75.0
	Mango, pale flesh, raw	Org. Sz	160	144	75.5	
	Watermelon, fruit, raw	2.5*Srd. T. Sz.	275	275	80.3	
Vegetables	Other green leaves, fresh, raw	2 *St. Sp. rd.	80.74	80.74	27.5	30.0
	Okro fruit raw boiled	4 *TT rd.	108	108	35.6	
	Carrots, fresh, raw	2 *St. Sp. rd. (cut up, raw)	34	34	33.1	
Legumes, pulses, nuts[1]	Beans, white, boiled* (without salt)	1* ET L	113.4	113.4	140.3	140.0
	Cowpeas, dried, boiled	1* ET L	113.4	113.4	131.5	
	Groundnuts, dried, roasted	1/2 * TT Sz	27	27	158	
	Groundnuts, paste, raw *boiled*	3.5*TT.L	24.885	24.885	147	
	Melon seeds, slightly salted, raw	2*dsp. L	25.2	25.2	149.4	
	Neri (wrewre) roasted and boiled	1/2*Sp.Sp.L	30.45	30.45	130.5	
Healthy fats and oil	Vegetable oil, unspecified brand, raw	dsp L	6	6	53	55.0
	Palm oil, refined	dsp L	6.3	6.3	55.7	
	Coconut oil	dsp L	6	6	54	

TT. Sz, Small tomatoes puree tin size; E.T.Sz, Full cream evaporated milk tin; dsp.rd, dessert/tablespoon round full; Org. Sz, Average orange size; Srd. T. Sz., Sardine tin (peeled); St. Sp. rd., Stewing spoon round full; TT rd., Small tomato puree tin round full; ETL, Full cream evaporated milk tin level; TT.L, Teaspoon level full Level; dsp. L, Dessert/tablespoon level full; Sp.Sp.L, Stewing spoon level full; [1]For legumes, nuts and seeds, 6 food items with equal highest weighting were used and the average computed

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 1
January 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table 2: Food group amounts (g/d) and frequencies

Food Group	Serving Size (g)	Amount (g/d)	Number of servings /day
Animal-sourced foods	96.1	144.2	1.5
Discretionary choices	83.1	41.5	0.5
Fruits	150.4	225.7	1.5
Vegetables	90.9	227.3	2.5
Healthy fats and oil	6.2	6.2	1
Legumes, pulses, nuts	65.9	197.6	3
Staples- Cereals, roots and tubers	134.4	671.8	5
Total		1514.2	

Table 3: Total optimized intake for the macronutrients and selected micronutrients

Nutrient	Constraints specified	Content in Optimized model
Ca (mg/day)	1100.0	1105.6
Fe (mg/day)	20.0	34.8
Zn (mg/day)	10.0	15.0
Protein (% energy)	10-20	14.7
Fat (% Energy)	20-30	25.3
Carbohydrate (% Energy)	55-70	59.0

REFERENCES

1 **WHO.** Healthy Diet. Key facts. 2020;1–8. https://doi.org/10.1007/978-3-319-69892-2_126-1

2 **Ministry of Health [MoH].** National Policy for the Prevention and Control of Chronic Non-Communicable Diseases in Ghana. Accra, Ghana: 2012. https://www.iccp-portal.org/sites/default/files/plans/national_policy_for_the_prevention_and_control_of_chronic_non-communicable_diseases_in_ghana(1).pdf *Accessed 22 April 2022.*

3 **Ofori-Asenso R, Agyeman AA and A Laar** Metabolic Syndrome in Apparently "Healthy" Ghanaian Adults: A Systematic Review and Meta-Analysis. *Int J Chronic Dis* 2017;2017:1–9. https://doi.org/10.1155/2017/2562374

4 **Ofori-Asenso R, Agyeman AA, Laar A and D Boateng** Overweight and obesity epidemic in Ghana - A systematic review and meta-analysis. *BMC Public Health* 2016;**16**. https://doi.org/10.1186/s12889-016-3901-4

5 **Akowuah PK and E Kobia-Acquah** Childhood Obesity and Overweight in Ghana: A Systematic Review and Meta-Analysis. *J Nutr Metab* 2020;1–11. https://doi.org/10.1155/2020/1907416

6 **Prentice AM, Ward KA., Goldberg GR, Jarjou LM, Moore SE, Fulford AJ and A Prentice** Critical windows for nutritional interventions against stunting. *Am J Clin Nutr* 2013;**97:**911–8. https://doi.org/10.3945/ajcn.112.052332

7 **Inge TH, King WC, Jenkins TM, Courcoulas AP, Mitsnefes M, Flum DR, Wolfe MB, Pomp A, Dakin GF, Khandelwal S, Zeller MH, Horlick M, Pender JR, Chen JY and SR Daniels** The Effect of Obesity in Adolescence on Adult Health Status. *Paediatrics* 2013;**132:**1098–104. https://doi.org/10.3390/ijerph15020212

8 **Miao M, Dai M, Zhang Y, Sun F, Guo X and G Sun** Influence of maternal overweight, obesity and gestational weight gain on the perinatal outcomes in women with gestational diabetes mellitus. *Sci Rep* 2017;**7**:1–8. https://doi.org/10.1038/s41598-017-00441-z

9 **Ardlç C, Çolak S, Uzun K, Sall G, Aydemir T and G Telatar** Maternal Gestational Diabetes and Early Childhood Obesity: A Retrospective Cohort Study. *Child Obes* 2020;**16:**579–85. https://doi.org/10.1089/chi.2020.0183

10 **WHO.** Noncommunicable Diseases. Country Profiles 2018. Geneva, Switzerland:World Health Organization 2018. https://apps.who.int/iris/handle/10665/274512 *Accessed 14 April 2022.*

11 **Popkin BM, Corvalan C, and LM Grummer-Strawn** Dynamics of the double burden of malnutrition and the changing nutrition reality. *Lancet* 2020;**395:**65–74. https://doi.org/10.1016/S0140-6736(19)32497-3

12 **Ecker O and P Fang** Economic development and nutrition transition in Ghana: Taking stock of food consumption patterns and trends. In: Covic N, Hendriks SL, eds. Achieving a nutrition revolution for Africa: The road to healthier diets and optimal nutrition. Washington D.C, USA: International Food Policy Research Institute (IFPRI) 2016. 28–50. https://doi.org/10.2499/9780896295933_04

13 **WFP.** Comprehensive Food Security and Vulnerability Analysis (CFSVA) GHANA. Accra, Ghana: 2020. https://reliefweb.int/attachments/1667668a-280e-39d7-8fb1-9faacf079908/WFP-0000137744.pdf *Accessed 5 July 2022.*

14 **Andam KS, Tschirley D, Asante SB, Al-Hassan RM and X Diao** The transformation of urban food systems in Ghana: Findings from inventories of processed products. *Outlook Agric* 2018;**47:**233–43. https://doi.org/10.1177/0030727018785918

15 **Omari R, Essegbey GO, Frempong G, Jongerden J and G Ruivenkamp** Fast Food in the Greater Accra Region of Ghana. *Food Stud An Interdiscip J* 2013;**1**:29–44. https://doi.org/10.18848/2160-1933/cgp/v01i04/40531

16 **Rousham EK, Pradeilles R, Akparibo R, Aryeetey R, Bash K, Booth A, Muthuri SK, Osei-Kwasi H, Marr CM, Norris T and M Holdsworth** Dietary behaviours in the context of nutrition transition: A systematic review and meta-analyses in two African countries. *Public Health Nutr* 2020;**23:**1948–64. https://doi.org/10.1017/S1368980019004014

17 **Pechey R and P Monsivais** Socioeconomic inequalities in the healthiness of food choices: Exploring the contributions of food expenditures. *Prev Med (Baltim)* 2016;**88**:203–9. https://doi.org/10.1016/j.ypmed.2016.04.012

18 **Reardon T, Tschirley D, Liverpool-Tasie LSO, Awokuse T, Fanzo J, Minten B, Vos R, Dolislager M, Sauer C, Dhar R, Vargas C, Lartey A, Raza A and BM Popkin** The processed food revolution in African food systems and the double burden of malnutrition. *Glob Food Sec* 2021;**28**. https://doi.org/10.1016/j.gfs.2020.100466

19 **Mensah D** Evidence on Physical Activity and Sedentary Behaviour in Ghana: A Rapid Scoping Review. *Afr. J. Food Agric. Nutr. Dev.* 2022;**22:**19583–601. https://doi.org/10.18697/ajfand.107.21805

20 **Herforth A, Arimond M, Álvarez-Sánchez C, Coates J, Christianson K and E Muehlhoff** A Global Review of Food-Based Dietary Guidelines. *Adv Nutr* 2019;**10**:590–605. https://doi.org/10.1093/advances/nmy130

21 **Ferguson EL, Darmon N, Briend A and IM Premachandra** Food-based dietary guidelines can be developed and tested using linear programming analysis. *J Nutr* 2004;**134**:951–7.

22 **Brouwer ID, Jager I de, Borgonjen K, Azupogo F, Rooij M, Folson G and AR Abizari** Background Technical Report. Development of Food-Based Recommendations using Optifood - Ghana. Development of food-based dietary recommendations for children, 6-23 months old, in Karaga District and Gomoa East District, Ghana. Wageningen: 2017. http://www.gainhealth.org/wp-content/uploads/2018/03/Ghana-Development-of-Food-based-Dietary-Recommendations-Using-Optifood-Karaga-and-Gomoa-Districts.pdf *Accessed 19 April 2018.*

23 **Nykänen EPA, Dunning HE, Aryeetey RNO, Robertson A and A Parlesak** Nutritionally optimized, culturally acceptable, cost-minimized diets for low-income Ghanaian families using linear programming. *Nutrients* 2018;10. https://doi.org/10.3390/nu10040461

24 **FAO.** FAO diet modelling package for food-based dietary guidelines (draft). Rome, Italy: 2020.

25 **MS_Nutrition.** A Team at the Heart of Human Nutrition Research. 2021. https://ms-nutrition.com/en/#presentation Accessed 30 Jun 2022.

26 **Owusu JS, Colecraft EK, Aryeetey R, Vaccaro JA and FG Huffman** Nutrition intakes and nutritional status of school-age children in Ghana. *J Food Res* 2017;**6:**20–1. https://doi.org/10.5539/jfr.v6n2p11

27 **FAO/WHO/UNU.** Expert Consultation. Energy and protein requirements. Geneva, Switzerland: WHO 1985. https://apps.who.int/iris/bitstream/handle/10665/39527/WHO_TRS_724_(chp1-chp6).pdf;jsessionid=1612413F35A69FDD2924BF1C83729626?sequence=1 *Accessed 8 June 2022.*

28 **WHO /FAO.** Vitamin and mineral requirements in human nutrition. Second edition. Second. Bangkok, Thailand: 2004. https://apps.who.int/iris/handle/10665/42716 *Accessed 18 March 2022.*

29 **FAO**. West African Food Composition Table (B. Stadlmayr, U. R. Charrondiere, V. N. Enujiugha, R. G. Bayili, E. G. Fagbohoun, B. Samb, P. Addy, I. Barikmo, F. Ouattara, A. Oshaug, I. Akinyele, G. A. Annor, K. Bomfeh, H. Ene-Obong, I. F. Smith, I. Thiam, & B. Burlingame (eds.)). FAO. 2012. https://www.fao.org/3/i2698b/i2698b.pdf *Accessed 29 November 2018.*

30 **Azupogo F, Abizari A-R, Osendarp SJM, Feskens EJ and ID Brouwer** Ten2Twenty-Ghana: Study Design and Methods for an Innovative Randomised Controlled Trial with Multiple-Micronutrient Fortified Biscuits Among Adolescent Girls in North-Eastern Ghana. *Curr Dev Nutr* 2021;**5**:1–20. https://doi.org/10.1093/cdn/nzaa184

31 **Owusu AA, Ankrah MY, Boateng GP and G Anteh** Food weights/handy measures tables. Cantonments, Accra: 1994.

32 **Arimond M, Wiesmann D, Becquey E, Carriquiry A, Daniels MC. Deitchler M Fanou-fogny N, Joseph ML, Kennedy G and Y Martin-prevel** Simple Food Group Diversity Indicators Predict Micronutrient Adequacy of Women ' s Diets in 5 diverse, resource-poor settings. *J Nutr* 2010;**140**:2059s-2069s. https://doi.org/10.3945/jn.110.123414.2059S

33 **Ruel MT** Is dietary diversity an indicator of food security or dietary quality? A review of measurement issues and research needs. FCND Discussion Paper No. 140, IFPRI, Washington D.C; 2003. https://www.ifpri.org/publication/dietary-diversity-indicator-food-security-or-dietary-quality *Accessed 29 November 2018.*

34 **Willet W** Nutritional Epidemiology. Monographs in Epidemiology and Biostatstics. Third. Oxford University Press, USA 2012.

35 **Galbete C, Nicolaou M, Meeks KA, Aikins ADG, Addo J, Amoah SK, Smeeth L, Owusu-Dabo E, Klipstein-Grobusch K, Bahendeka S, Agyemang C, Mockenhaupt F P, Beune EJ, Stronks K, Schulze MB and I Danquah** Food consumption, nutrient intake, and dietary patterns in Ghanaian migrants in europe and their compatriots in Ghana. *Food Nutr Res* 2017;61. https://doi.org/10.1080/16546628.2017.1341809

36 **The Eat-Lancet Commission.** Healthy Diets From sustainable food systems. Summary Report of the EAT-Lancet Commission. Lancet 2019;32.

37 **Ghana Statistical Service (GSS)/Ghana Health Service (GHS)/ICF International**. Demographic and Health Survey 2014. Accra, Ghana and Rockville, Maryland, USA; 2015. http://www.dhsprogram.com/pubs/pdf/FR307/FR307.pdf *Accessed 14-09-2019.*

38 **Federal Government of Ethiopia, Ministry of Health EPHI Ethiopia**. Food-Based Dietary Guidelines – 2022. Addis Ababa: 2022. https://ephi.gov.et/wp-content/uploads/2021/02/FBDG_MotherDocument_WebVersion.pdf *Accessed 09 June 2022.*

39 **Seidelmann SB, Claggett B, Cheng S, Henglin M, Shah A, Steffen LM, Folsom AR, Rimm EB, Willett WC and SD Solomon** Dietary carbohydrate intake and mortality: a prospective cohort study and meta-analysis. *Lancet Public Heal* 2018;**2667**:1–10. https://doi.org/10.1016/S2468-2667(18)30135-X

40 **Marventano S, Izquierdo Pulido M, Sánchez-González C, Godos J, Speciani A, Galvano F and G Grosso** Legume consumption and CVD risk: a systematic review and meta-analysis. *Public Health Nutr* 2017;**20:**245–54. https://doi.org/10.1017/S1368980016002299

41 **World Cancer Research Fund/American Institute for Cancer Research.** Food, Nutrition, Physical Activity and the Prevention of Cancer: a Global perspective. Washington, DC: AICR: 2007. https://www.researchgate.net/publication/315725512_Food_Nutrition_Physical_Activity_and_the_Prevention_of_Cancer_A_Global_Perspective_Summary#fullTextFileContent

42 **Ruel MT, Minot N and L Smith** Patterns and determinants of fruits and vegetable consumption in sub-Saharan Africa: a multi-country comparison. Background paper for the joint FAO/WHO Workshop on Fruit and Vegetables for Health, 1-3 September 2004, Kobe, Japan. Washington D.C, USA: 2004.

43 **Slavin J and B Lloyd** Health Benefits of Fruits and Vegetables. *Adv Nutr* 2012;**3**:506–16. https://doi.org/10.3945/an.112.002154.506

44 **Castro-Quezada I, Román-Viñas B and L Serra-Majem** The Mediterranean diet and nutritional adequacy: A review. *Nutrients* 2014;**6:**231–48. https://doi.org/10.3390/nu6010231

45 **Tapsell LC, Batterham MJ, Thorne RL, O'Shea JE, Grafenauer SJ and YC Probst** Weight loss effects from vegetable intake: A 12-month randomised controlled trial. *Eur J Clin Nutr* 2014;**68:**778–85. https://doi.org/10.1038/ejcn.2014.39

46 **Shi Z, Hu, X, Yuan B, Hu G, Pan X, Dai Y, Byles JE and G Holmboe-Ottesen** Vegetable-rich food pattern is related to obesity in China. *Int J Obes* 2008;**32:**975–84. https://doi.org/10.1038/ijo.2008.21

47 **Amo-Adjei J and A Kumi-Kyereme** Fruit and Vegetable Consumption By Ecological Zone and Socioeconomic Status in Ghana. *J Biosoc Sci* 2015;**47:**613–31. https://doi.org/10.1017/S002193201400025X

48 **Meng T, Florkowski WJ, Sarpong D, Chinnan M and VA Anna** Expenditure on Fresh Vegetables, Fresh Fruits, and Peanut Products in Urban Ghana: Does Location Matter? Selected Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meeting, Dallas, TX, February 1-4, 2014. 2014. 1–20. http://ageconsearch.umn.edu/record/162427

49 **Florkowski WJ, Chinnan MS, Resurreccion AVA and D Sarpong** Fruit and vegetable consumption frequency by urban households in Ghana - implications for postharvest handling. Acta Hortic 2013; 1387–92. http://agris.fao.org/agris-search/search.do?recordID=US201400148908#.WypyD1YaHiU.mendeley *Accessed 20 Jun 2018.*

50 **Gamor G, Akoto-Danso EK, Karg H and T Chagomoka** Traditional Recipes from the Northern Region of Ghana. Tainan 74199 Taiwan: AVRDC – The World Vegetable Center 2015.

51 **Zhang Z, Goldsmith PD and A Winter-Nelson** The Importance of Animal Source Foods for Nutrient Sufficiency in the Developing World: The Zambia Scenario. *Food Nutr Bull* 2016;**37**:303–16. https://doi.org/10.1177/0379572116647823

52 **Colecraft E, Marquis GS, Aryeetey R, Sakyi-Dawson O, Lartey A and B Ahunu** Constraints on the Use of Animal Source Foods for Young Children in Ghana: A Participatory Rapid Appraisal Approach. *Ecol Food Nutr* 2006;45:351–77. https://doi.org/10.1080/03670240600985464

53 **Hirvonen K, Bai Y, Headey D and WA Masters** Affordability of the EAT–Lancet reference diet: a global analysis. *Lancet Glob Heal* 2020;*8*:e59–66. https://doi.org/10.1016/S2214-109X(19)30447-4

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 1
January 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

Table S1: The food list and its food grouping, weighting and portion size for the modelling

No	Food Item	Weighted percentage consumption	Portion size (g)	Energy (Kcal)
	Animal source foods (ASF)			
1	Chicken, Drumstick, Meat & Skin, Fresh, RTboiled	18.0	75.0	153.0
2	Egg, Chicken, Whole, RTfried	11.0	95.0	149.2
3	Beef, Medium Fat, Fresh, RTboiled	8.0	51.0	148.4
4	Fish, Nile Perch (Type3), Fresh, RTroasted	7.2	129.0	150.9
5	Goat, Medium Fat, Fresh, Raw RTboiled	7.0	135.0	147.2
6	Milk, Cow, Canned, Evaporated	5.0	110.0	149.2
7	Milk, Cow, Powder, Whole	5.0	30.0	148.3
8	Anchovy, Fillet, RTgrilled* (Without Salt and Fat)	5.0	95.0	151.1
9	Shrimp/Prawn, RTboiled	5.0	151.0	149.5
10	Fish, Nile Perch (Type3), Fresh, RTboiled	4.3	158.0	148.5
11	Egg, Chicken, Whole, RTboiled	4.0	97.0	150.4
12	Tuna, RTgrilled (Without Salt and Fat)	4.0	85.0	150.1
13	Fish, Nile Perch (Type3), Fresh, RTfried	4.0	128.0	149.8
14	Sardines In Oil, Canned (Drained Solids with Bone)	2.5	68.0	149.8
15	Tilapia, Steamed*(Without Salt)	2.5	128.0	150.0
16	Pork, Medium Fat, Fresh, Raw RTboiled	2.0	75.0	150.0
17	Mackerel, Boiled* (Without Salt)	2.0	80.0	150.1
18	Chicken, Gizzard, Fresh, RTboiled	2.0	72.0	110.9
19	Fish, Silver Fish (Mukene), Dried, RTboiled	1.0	75.0	151.5
20	Chicken, Thigh, Meat & Skin, Fresh, RTfried	0.5	57.0	149.3
	Discretionary choices			
1	Biscuits, Basic Recipe, RTbaked	8.0	24.0	107.0
2	Sugar White, Brown	7.1	27.0	108.0
3	Creamer Non-Dairy Powder	6.5	20.0	107.2
4	Sausage, Beef Reduced Fat, RTfried	6.5	40.0	107.6
5	Soda (Coca, Fanta Etc.)	5.4	271.0	108.4
6	Cake, Basic Recipe, RTbaked	5.0	30.0	107.1
7	Candy	5.0	28.0	108.9
8	Honey	5.0	34.0	110.8
9	Pito Beverage Recipe	5.0	220.0	107.8
10	Chocolate Drink Powder (Chocolate)	5.0	26.0	106.6
11	Cheese Raw RTfried	4.0	39.0	109.6
12	Ice Cream	4.0	53.0	109.7
13	Sobolo Beverage Recipe	4.0	182.0	109.2

https://doi.org/10.18697/ajfand.116.22930

14	Zinkom Beverage Recipe	4.0	74.0	109.5
15	Maasa Recipe	4.0	26.0	107.6
16	Soya Khebab Recipe	4.0	23.0	109.3
17	Kulikuli Recipe	3.5	18.0	102.4
18	Doughnut, Basic Recipe, RTfried	3.0	25.0	106.5
19	Sausage, Wiener (Beef, Pork, Chicken) Canned	2.2	48.0	109.0
20	Short Bread	2.0	21.0	105.4
21	Coffee, Liquid	2.0	800.0	16.0
22	Sugar Cane Immature	2.0	400.0	108.0
23	Wheat Flour, Refined, Raw *RTfried*	1.9	41.0	109.1
24	Coffee, Instant Powder	1.0	31.0	110.1
	Fruits			
1	Orange, Raw	11.3	170.0	75.5
2	Mango, Pale Flesh, Raw	10.7	144.0	75.5
3	Pineapple, Pulp, Raw	8.4	140.0	76.3
4	Papaya, Fruit, Ripe, Raw	8.1	215.0	77.0
5	Watermelon, Fruit, Raw	8.0	260.0	75.9
6	Banana, Yellow Flesh, Raw	6.3	70.0	74.1
7	Fruit, Unspecified, Fresh, Raw	6.3	128.0	76.8
8	Avocado, Pulp, Raw	5.5	40.0	61.7
9	Guava, Fruit, Raw	5.0	135.0	76.9
10	Grapefruit, Pulp, Raw	5.0	230.0	76.6
11	Tangerine, Fresh, Raw	5.0	145.0	76.9
12	Cashew Apple, Pulp, Raw	4.0	135.0	75.1
13	Apple, With Skin, Raw	3.3	144.0	76.7
14	Shea Fruit Pulp, Raw	3.0	75.0	73.4
15	Melon Yellow Fresh	3.0	255.0	74.0
16	Tamarind, Dried, Raw	2.0	26.0	71.5
17	Blackberries Fresh	2.0	210.0	79.8
18	African Locust Bean, Flour from Fruit, Pulp	1.0	22.0	73.2
19	Dates, Dried	1.0	23.0	70.4
20	Baobab, Fruit/Monkey Bread, Pulp, Raw	1.0	20.0	60.4
	Healthy Fats and Oil			
1	Vegetable Oil, Unspecified Brand, Raw	20.0	6.3	55.7
2	Palm Oil, Refined	15.0	6.0	54.0
3	Coconut Oil	12.0	6.0	54.0
4	Soya Oil	12.0	6.0	54.0
5	Margarine, Fortified	10.0	7.0	51.1
6	Palm Oil, Red	10.0	6.0	54.0
7	Animal Fat, Cow Ghee (Muzigo), Raw	8.0	6.0	52.6

ajfand SCHOLARLY, PEER REVIEWED
AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 1 January 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

8	Groundnut Oil	7.0	6.0	54.0
9	Shea Butter	5.0	6.0	54.0
10	Butter, From Cow's Milk (Without Salt)	1.0	8.0	57.6
	Legumes, Pulses and Nuts			
1	Beans, White, RTboiled(Without Salt)	9.5	112.0	138.5
2	Cowpeas, Dried, RTboiled	8.5	120.0	139.2
3	Groundnuts, Paste, Raw RTboiled	8.0	20.0	117.6
4	Groundnuts, Dried, RTroasted	7.0	20.0	117.0
5	Melon Seeds, Slightly Salted, Raw	7.0	20.0	118.5
6	Neri Roasted RTboiled	7.0	33.0	141.2
7	Koose RTfried	7.0	90.0	139.5
8	Pigeon Pea, RTboiled* (Without Salt)	7.0	125.0	139.1
9	Coconut, Immature Kernel, Fresh, Raw	6.0	86.0	139.0
10	African Yam Bean, RTboiled* (Without Salt)	6.0	120.0	138.0
11	Bambara Groundnut, Combined Varieties, Dried, RTboiled(Ghana)	6.0	38.0	140.2
12	Sesame Seeds Roasted RTboiled	6.0	20.0	115.2
13	Soya Bean, Combined Varieties, RTboiled* (Ghana) (Without Salt)	5.0	80.0	143.8
14	Tiger Nut, Raw	5.0	46.0	139.8
15	Africa Locust Bean (Dawadawa) Dried RTboiled	3.0	24.0	106.8
16	Cashew Nut, Dried, RTroasted	2.0	20.0	114.8
	Staples-Cereals, Roots and Tubers			
1	Rice, White, Polished, RTboiled	11.5	155.0	201.5
2	Banku, Fermented Maize Dough Boiled	8.8	185.0	199.8
3	Yam Tuber, Boiled* (Without Salt)	7.0	149.0	200.3
4	Maize Flour, White Variety, Unrefined, Raw RTboiled	5.7	56.0	202.2
5	Cassava Flour, Raw RTboiled	5.6	64.0	201.0
6	Kenkey (Ga)	5.6	177.0	203.6
7	Cassava, Fresh, RTboiled	5.4	178.0	199.4
8	Banana, Matooke, Green, Fresh, RTboiled	5.0	171.0	198.4
9	Cocoyam (Bukupa), Fresh, Raw RTboiled	4.5	177.0	198.2
10	Rice Local Brown Unpolished Raw RTboiled	4.4	58.0	204.2
11	Cassava, Flour, Raw RTFried	4.4	64.0	201.0
12	Maize, Yellow, Soft Porridge* (Without Salt)	3.5	415.0	198.8
13	Plantain, RTfried	3.3	90.0	200.7
14	Bread, Wheat, Refined Flour, RTbaked	3.1	75.0	199.5
15	Millet, Whole Grain, RTboiled Without Salt)	3.1	140.0	199.4
16	Sweet potato, Yellow, Wo/Skin, Fresh, RTboiled	2.0	175.0	199.5
17	Oats RTboiled	2.0	48.0	204.0

18	Porridge, Maize and Guinea Corn Recipe	2.0	57.0	46.7
19	Maize On Cob, Yellow Variety, Fresh, RTroasted	2.0	90.0	201.6
20	Macaroni, Boiled* (Without Salt)	1.6	128.0	200.1
21	Bread, Wheat, Bun, Refined Flour, Type 1, RTbaked	1.6	75.0	199.5
22	Wheat, Whole Grains, Raw	1.2	62.0	201.9
23	Baby Cereal, Mixed Cereal, Dry, Tom Brown	1.0	55.0	199.7
24	Osino Kenkey With Sugar	1.0	155.0	198.4
25	Maize On Cob, White Variety, Fresh, RTboiled	1.0	96.0	198.7
26	Maize On Cob, White Variety, Fresh, RTRoasted	1.0	90.0	201.6
27	Maize On Cob, Yellow Variety, Fresh, RTboiled	1.0	97.0	199.8
28	Millet Flour, Raw RTboiled	0.9	53.0	198.2
29	Bread/Rolls, White	0.7	76.0	201.0
30	Rice, White, Polished, RTfried	0.3	114.0	200.6
	Vegetables			
1	Other Green Leaves, Fresh, Raw	4.8	90.0	30.6
2	Okro Fruit Raw RTboiled	4.5	90.0	29.7
3	Carrots, Fresh, Raw	4.1	79.0	32.4
4	Cabbage, Green, Fresh, RTfried	4.0	70.0	30.1
5	Tomato, Ripe, Red, Fresh, RTboiled	4.0	165.0	29.7
6	Tomato, Ripe, Fresh, Raw *RTfried*	4.0	165.0	29.7
7	Onion, Large Bulb, Fresh, Raw	4.0	74.0	29.6
8	Cocoyam, Leaves, RTboiled (Without Salt)	4.0	80.0	29.1
9	Lettuce, Raw	4.0	165.0	29.5
10	Roselle Leaves, RTboiled (Without Salt)	4.0	72.0	30.2
11	Okro Soup	3.5	72.0	31.0
12	Jute (Bush-Okra) Leaves, RTboiled (Without Salt)	3.5	50.0	30.9
13	Spinach, RTboiled (Without Salt)	3.3	110.0	31.7
14	Amaranth Leaves, Fresh, Raw RTboiled	3.0	125.0	28.8
15	Tomato, Ripe, Fresh, Raw	3.0	165.0	29.7
16	Pumpkin Leaves, RTboiled (Without Salt)	3.0	105.0	30.3
17	Bitter Leaf, Fresh RTboiled (Veronica Leaves)	3.0	53.0	30.7
18	Ayoyo Leaves Raw, RTboiled	3.0	50.0	29.5
19	Ginger Fresh RTboiled	3.0	39.0	31.6
20	Pepper, Sweet, Red, RTboiled (Without Salt)	2.5	80.0	30.7
21	Baobab Leaves, Dried RTboiled	2.5	11.0	29.9
22	Eggplant, Thick &Short (Type3), W/Skin, Fresh, RTboiled	2.5	120.0	28.8
23	Cucumber, Raw	2.3	195.0	29.2
24	Pepper, Sweet, Green, Raw	2.1	112.0	28.7
25	Pepper, Sweet, Orange, Raw	2.0	115.0	29.4
26	Baobab, Leaves, RTboiled (Without Salt)	2.0	43.0	31.9

ajfand SCHOLARLY, PEER REVIEWED AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT
Volume 23 No. 1 January 2023
PUBLISHED BY AFRICAN SCHOLARLY SCIENCE COMMUNICATIONS TRUST
ISSN 1684 5374

27	Cassava, Leaves, RTboiled (Without Salt)	2.0	30.0	30.4
28	Dandelion Leaves Raw, RTboiled	2.0	65.0	30.6
29	Okro Leaves Dried, RTboiled	2.0	15.0	44.4
30	Okro Leaves Raw, RTboiled	2.0	75.0	30.0
31	Cowpea, Leaves, RTboiled (Without Salt)	2.0	67.0	29.2
32	Turkey Berries Raw, RTboiled	2.0	100.0	30.0
33	Moringa Leaves, Fresh, Raw RTboiled	1.5	86.0	29.2
34	Okro Fruit Dried Powder, RTboiled	1.0	12.0	30.1

RT, retention factor