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Research article

Potassium, sodium, calcium and magnesium levels of commonly consumed foods and estimates of dietary intakes of selected Nigerian adults

Olutayo Sunday Shokunbi [a,b,c,1,*], Oladejo Thomas Adepoju [b], Isaiah David Ipfani Ramaite [a], Oluwatosin Sarah Shokunbi [d], Paul Eanas Lesedi Mojapelo [a], Isaac Olaolu Akinyele [b]

[a] Department of Chemistry, School of Mathematical and Natural Sciences, University of Venda, Limpopo Province, South Africa
[b] Department of Human Nutrition and Dietetics, Faculty of Public Health, College of Medicine, University of Ibadan, Ibadan, Nigeria
[c] Department of Biochemistry, School of Basic Medical Sciences, Babcock University, Ilishan-Remo, Ogun State, Nigeria
[d] Department of Basic Sciences, School of Science and Technology, Babcock University, Ilishan-Remo, Ogun State, Nigeria

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ABSTRACT

Micronutrient deficiency is a public health challenge globally, as it affects both people and the economy. In Nigeria, most micronutrients, especially minerals are lost during food processing. The study was carried out to determine the potassium, sodium, calcium and magnesium composition of foods commonly eaten by Nigerian adults and to estimate the average adults' daily intake of these macrominerals. The contents of these minerals in 141 food items collected 'as consumed' from 10 locations in Federal Capital Territory, Abuja and Ogun State, Nigeria, were quantified by digesting the foods through dry ashing and analysed using flame atomic absorption spectrometer. The levels (mg/100 g fresh weight) of potassium, sodium, calcium and magnesium in the various foods ranged from 2.92 to 1520, 1.46 to 30,700, 1.35 to 1280 and 1.16 to 416, respectively. Recovery values were within the range of 95–110%. Adults' mean mineral intakes (mg/person/day) of the analysed foods were 1970 ± 780, 2750 ± 1100, 423 ± 300 and 389 ± 130 for potassium, sodium, calcium and magnesium, respectively. Mean sodium intake was higher while potassium and calcium intakes were lower compared with international recommendations (mg/person/day) of 1500, 2300–3400 and 1000–1300, respectively; indicating the need to enlighten consumers. The snapshot data from this study are useful to update the Nigerian Food Composition Database.

1. Introduction

Minerals, though required in minute quantities for growth and proper function of human body tissues; contribute to optimal

* Corresponding author. Department of Biochemistry, School of Basic Medical Sciences, Babcock University, Ilishan-Remo, Ogun State, Nigeria.
E-mail addresses: osshokunbi@gmail.com, shokunbio@babcock.edu.ng (O.S. Shokunbi), tholadejo@yahoo.com, tadepoju@com.ui.edu.ng (O.T. Adepoju), Isaiah.Ramaite@univen.ac.za (I.D.I. Ramaite), shokunbiol@babcock.edu.ng (O.S. Shokunbi), Paul.Mojapelo@univen.ac.za (P.E.L. Mojapelo), olu_akins@yahoo.com (I.O. Akinyele).
[1] Phone Number: +2348030689633.

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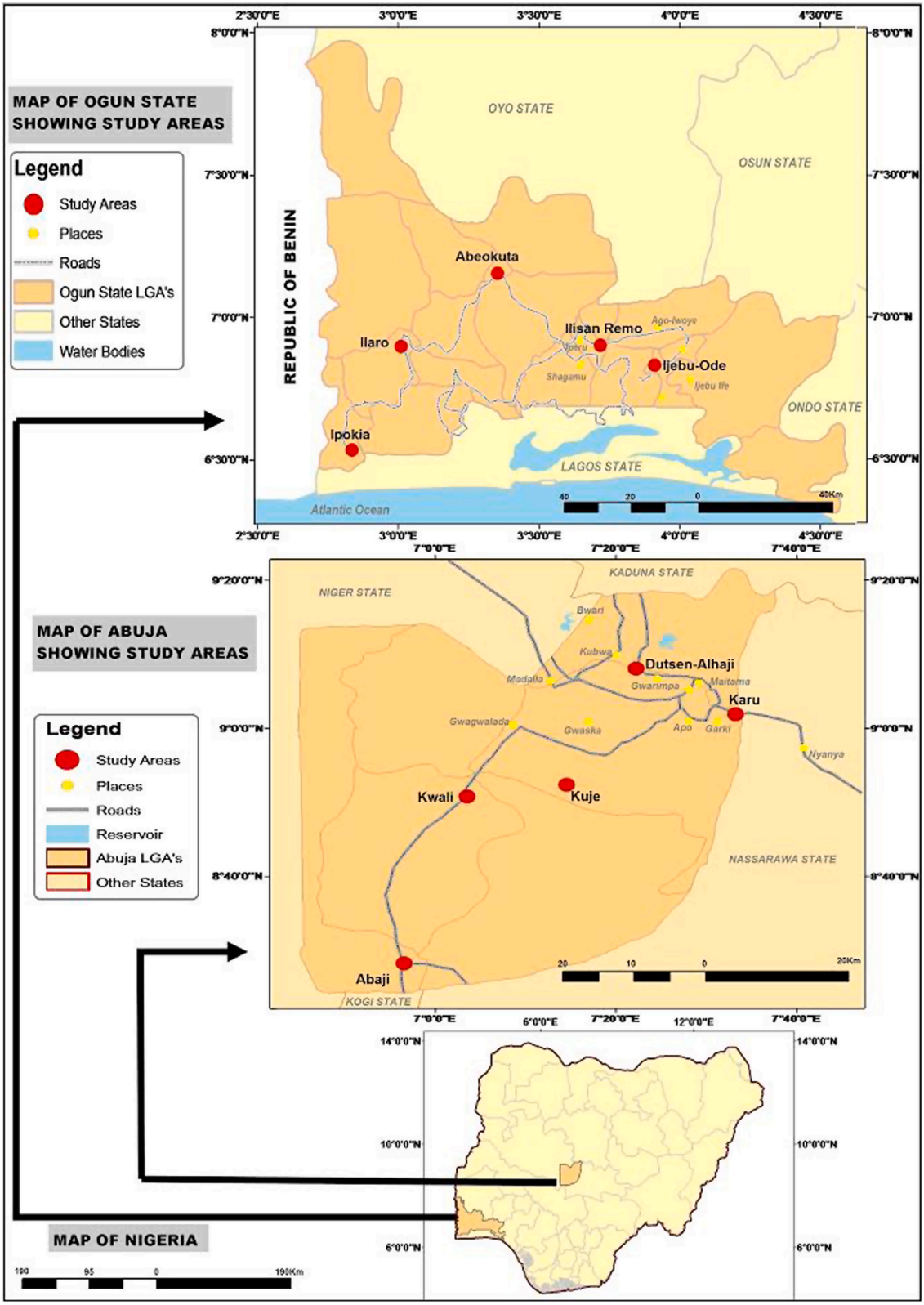

Fig. 1. Study sites in federal capital territory (FCT), abuja and Ogun state [6].

Table 1
Characteristics of the food samples collected for metal analyses.

Food group	Scientific name	Common name and preparation mode	Food name in local language
Tubers, starches and their products	*Manihot esculenta*	Cassava (white, fermented, sieved, cooked)	*Fufu* (Y)
	Ipomoea batatas	Potato (sweet, yellow, peeled, fried)	*Odukun* (Y)
	Dioscorea rotundata	Yam (parboiled, sundried, grind, powder, cooked into paste)	*Amala dudu* (Y)
	Dioscorea rotundata	Yam (white, boiled, pounded)	*Iyan* (Y), *Sokwara* (H), *Usong abia* (Ib/Ef), *Inniji/Itaraji* (I)
	Dioscorea rotundata	Yam (white, fried)	*Dundu*
	Dioscorea rotundata	Yam (white, boiled)	
	Dioscorea rotundata	Poundo yam (powder, cooked into paste)	Pando (Y)
	Dioscorea rotundata	Yam pottage (white, boiled with pepper, salt and palm oil)	*Asaro* (Y)
	Dioscorea alata	Yam cake (water yam, grated, mixed with salt, pepper and fried with vegetable oil)	*Ojojo* (Y)
	Manihot esculenta	Cooked garri (cassava, white, grated, fermented, dewatered, roasted and cooked into paste)	*Eba* (Y)
	Artocarpus altilis	Bread fruit (pulp, boiled)	*Gbere* fruit (Y), *Bire fuut* (Ib), *Ukwa Oyibo* (I)
	Musa paradisiaca	Plantain (mature ripe, fried with vegetable oil)	*Dodo* (Y)
	Musa paradisiaca	Plantain chip (mature unripe, fried with vegetable oil)	*Igbekere* (Y)
Cereals and cereal products	*Oryza sativa*	Rice (Long grain, white, boiled)	*Iresi* (Y), *Shinkafa* (H), *Osikapa* (I)
	Oryza sativa	Rice (Short grain, white, boiled)	
	Oryza glaberrima	Local rice (boiled)	
	Oryza sativa	Jollof rice (rice, white, cooked with tomato paste, tomatoes, onions, spices, with vegetable oil)	
	Oryza sativa	Fried rice (rice, white, cooked with diced carrot, green peas, green beans and spices with vegetable oil)	
	Oryza sativa	Rice cake (rice, white, soaked, ground, add yeast, baking powder, pinch of salt, sugar, fried with vegetable oil)	*Masa* (H)
	Oryza sativa and Vigna unguiculata	Rice (white, boiled), beans (white, boiled) with fresh sauce prepared from dry pepper, salt, bullion cube, onions and vegetable oil	*Garogaro* (H)
	Zea mays	Maize (yellow, mature, whole kernel, roasted)	
	Zea mays	Maize (yellow, mature, whole kernel, boiled)	
	Zea mays	Maize (white, mature, whole kernel, roasted)	
	Zea mays	Maize pudding (white maize, dried, ground, powder, cooked into paste)	*Tuwo* (Y), *Tuwo masara* (H)
	Oryza sativa	Rice pudding (white rice, dried, ground, powder, cooked into paste)	*Tuwo shinkafa* (H)
	Triticum aestivum	Bread (wheat, white flour)	White bread
	Triticum aestivum	Bread (whole wheat flour)	Brown bread
	Triticum aestivum	Bread (wheat, white flour, malt, mixed fruit)	Malt bread
	Zea mays	Moulded maize (white maize, fermented gruel, cooked, moulded)	*Eko* (Y), *Agidi* (I)
	Zea mays	Cornmeal (white maize, dried, ground, powder, sugar, pinch of salt, fried with vegetable oil)	*Kokoro* (Y)
	Triticum aestivum	Wheat pudding (white, powder, cooked into paste)	Semovita, semolina
	Zea mays and *Arachis hypogaea*	Maize (corn meal from roasted corn), groundnut powder, ground chili pepper, sugar, groundnut oil	*Tanfirin*, *Donkwa* (H)
	Pennisetum glaucum	Millet flour, ginger powder, ground pepper, pinch of salt	*Fura* (H)
	Avena sativa	Oat (cooked into paste)	
	Zea mays	Custard (cooked into paste)	
	Triticum aestivum, *Arachis hypogaea* and *Cocos nucifera*	Granola (whole wheat flour, white flour, groundnut, coconut, honey, sugar, banana, nutmeg, pinch of salt, vegetable oil, baked)	
	Zea mays	Cornflakes	
	Triticum aestivum	Spaghetti (boiled, drained)	
	Triticum aestivum	Jollof spaghetti (spaghetti, cooked with tomato paste, tomatoes, onions, spices, with vegetable oil)	
	Triticum aestivum	Noodles (plain, boiled with accompanying spice)	
	Triticum aestivum	Noodles (boiled with accompanying spice, along with steamed or fried egg) 1 medium sized egg (60 g) per 140 g dry noodle pack (s)	
	Arachis hypogaea and Oryza sativa	Groundnut milk and rice gruel (groundnut and rice soaked separately, ground and sieved, small rice portion boiled, cook further with groundnut and rice milk obtained previously)	*Kunu gyada* (H)
Legumes and legume products	*Vigna unguiculata*	Bean pottage (White bean, boiled with dry pepper, salt and palm oil)	*Ewa alaropo* (Y)
	Vigna unguiculata	Bean (Drum, plain, boiled with salt)	*Ewa woro* (Y)
	Vigna unguiculata	Bean (White, plain, boiled with salt)	*Ewa woro* (Y)
	Vigna unguiculata	Bean (Olo 2, plain, boiled with salt)	*Ewa woro* (Y)
	Vigna unguiculata	Bean (Pewu, plain, boiled with salt)	*Ewa woro* (Y)

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Table 1 (*continued*)

Food group	Scientific name	Common name and preparation mode	Food name in local language
	Vigna unguiculata	Bean cake (White bean, soaked, dehulled, ground along with pepper and onion, mixed with salt, fried with vegetable oil)	*Akara olororo* (Y), *kosai* (H)
	Vigna unguiculata	Bean cake (Pewu bean, soaked, dehulled, ground along with pepper and onion, mixed with salt, fried with vegetable oil)	*Akara olororo* (Y), *kosai* (H)
	Vigna unguiculata	Bean cake (Drum bean, soaked, dehulled, ground along with pepper and onion, mixed with salt, fried with vegetable oil)	*Akara olororo* (Y), *kosai* (H)
	Vigna unguiculata	Bean pudding (White bean, soaked, dehulled, ground along with pepper and onion, mixed with salt and vegetable oil, steamed into mould)	*Moi-moi olororo* (Y), *Ole* (Y), *allele da moi* (H)
	Vigna unguiculata	Bean pudding (Olo 2 bean, soaked, dehulled, ground along with pepper and onion, mixed with salt and vegetable oil, steamed into mould)	*Moi-moi olororo* (Y), *Ole* (Y), *allele da moi* (H)
	Vigna subterranea	Bambara nut (plain, boiled with salt)	*Okpa* (I)
	Vigna subterranea	Bambara nut pudding (Bambara nut, soaked, dehulled, ground along with pepper and onion, mixed with salt and palm oil, steamed into mould)	*Okpa* (I)
	Glycine max	Tofu pie (white wheat flour, soybean (milled, sieved, cooked with coagulant, drained into mould)	
	Glycine max	Tofu (soybean, milled, sieved, cooked with coagulant, drained into mould, cut to pieces and fried with vegetable oil)	*Wara* (Y), *awara* (H)
Fruits	*Musa sapientum, Musa acuminate*	Banana (ripe, peeled, raw)	*Ogede* (Y), *ayaba* (H), *unere* (I), *mboro* (Ib)
	Citrus sinensis	Orange (all commercial varieties)	*Osan* (Y), *lemu* (H), *olama* (I)
	Carica papaya	Pawpaw (peeled, ripe)	*Ibepe* (Y), *gwanda* (H), *okwurebekee* (I)
	Ananas comosus	Pineapple (pulp, peeled)	*Ope oyinbo* (Y), *abarba* (H), *nkwu abaa* (I)
	Citrullus lanatus	Water melon (edible portion, fruit without seed, without peel)	*Eso-bara* (Y), *kankana* (H)
	Cucumis melo	Golden melon (edible portion, with skin epicarp)	
	Psidium guajava	Guava (ripe, edible portion, without seeds)	*Gurofa* (Y), *guaiba* (H)
	Phoenix dactylifera	Date (mature, edible portion)	*Debino* (H)
	Malus domestica	Apple (wine, raw, with skin)	*Apu pupa* (Y)
	Malus domestica	Apple (green, raw, with skin)	*Apu gireeni* (Y)
	Malus domestica	Apple (wine/green, raw, with skin)	
	Pyrus communis	Pear apple (European pear, raw, with skin)	
	Citrus tangerine	Tangerine (peeled, raw, edible portion)	*Tangarin* (Y), *lemu zaki* (H)
	Prunus 'Black Amber'	Plum (raw, with skin)	
Vegetables and vegetable products	Solanum melongena	Garden egg (light yellow, raw, with skin)	*Igba* (Y), *yalo* (H), *mkpuru anara* (I)
	Solanum melongena	Garden egg (green, raw, with skin)	
	Solanum melongena	Garden egg (reddish, raw, with skin)	
	Solanum melongena	Garden egg (lemon, raw, with skin)	
	Capsicum annuum Group	Green bell pepper (raw)	
	Pisum sativum	Green peas (raw)	
	Phaseolus vulgaris	Green bean (raw)	
	Brassica oleracea var. *capitate*	Cabbage (raw)	*Gabeeji* (Y), *danyen kabaji* (H)
	Brassica oleracea var. *capitate*	Cole slaw	
	Daucus carota subsp. *Sativus*	Carrot (fresh, raw)	*Karooti* (Y), *danyen karas* (H)
	Cucumis sativus	Cucumber (fresh with peel, raw)	*Gulli da bavo* (H)
	–	Stew (for rice, with vegetable oil)	*Obe ata din din* (Y)
	–	Stew (for tunwo)	
	–	Stew (with palm oil)	*Obe ata din din* (Y)
	–	Stew (for masa)	
	–	Stew (for swallow)	*Omi obe* (Y)
	–	Stew (for local rice)	*Obe ata dudu* (Y)
	Gallus gallus domesticus	Egg stew	
	Arachis hypogaea	Groundnut soup	
	Vigna unguiculata	Bean soup	*Gbegiri* (Y)
	Irvingia gabonensis	African/wild mango soup	*Ogbono* (I), *apon* (Y)
	Telfairia occidentalis	Fluted pumpkin leaves (fried)	*Ugu* (I)
	Abelmoschus esculentus	Ladies' fingers (plain)	*Ila* (Y), *kubewa* (H), *okwuru* (I), *ikong etighi* (Ef)
	Abelmoschus esculentus	Ladies' fingers soup	
	Amaranthus hybridus	African spinach soup	*Tete* (Y), green, amaranthus
	Corchorous olitorius	Jute leaf (plain)	*Ewedu* (Y)
	Celosia argentea	Lagos spinach soup	*Soko* (Y), celosia
	Telfairia occidentalis, *Cucumeropsis mannii*	Fluted pumpkin leaves soup (with egusi)	*Ugu* (I), *ikong-ubong* (Ef/Ib)

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Table 1 (*continued*)

Food group	Scientific name	Common name and preparation mode	Food name in local language
	Amaranthus hybridus, *Cucumeropsis mannii*	African spinach soup (with egusi)	*Tete* (Y)
	Amaranthus hybridus	African spinach soup	*Efo riro – tete* (Y)
	Celosia argentea, *Cucumeropsis mannii*	Lagos spinach soup (with egusi)	*Soko* (Y)
	Talinum triangulare	Water leaf soup	*Gbure* (Y), *yakuwa* (H), *mbologi* (I)
	Talinum triangulare, *Telfairia occidentalis*	Water leaf (with Fluted pumpkin leaves) soup, without meat, fish, cow skin	*Edikang ikong* (Ef/Ib)
	Celosia argentea	Lagos spinach soup	*Efo riro – soko* (Y)
	Gnetum africanum, *Cucumeropsis mannii*	Wild African spinach soup (with egusi)	*Eru* (Y), *Okazi* (I), *afang* (Ib/Ef)
Condiments	Sodium chloride	Salt	*Iyo* (Y), *gishiri* (H), *nnu* (I)
	Parkia biglobosa	Locust bean (fermented)	*Iru woro* (Y), *dadawa* (H)
Milk and milk product	–	Powdered vegetable-fat milk (raw)	
	–	Powdered full-cream milk (raw)	
	–	locally fermented milk	*Nono* (H)
Meat, poultry and eggs	*Bos taurus indicus*	Beef (boiled, in stew)	*Eran malu* (Y)
	Bos taurus indicus	Beef (fried, in stew)	*Eran malu* (Y)
	Bos taurus indicus	Cow skin (raw)	*Ponmo* (Y)
	Gallus gallus domesticus	Chicken thigh (fried)	*Eran adiye* (Y), *kaza* (H), *anuokwuikwo* (I)
	Meleagris gallopavo	Turkey wing (fried)	*Eran Tolotolo* (Y)
	Gallus gallus domesticus	Egg (chicken, whole cooked, hard boiled)	*Eyin adiye* (Y), *kuwoiyi kaza* (H), *akwa okuko* (I), *nkwa unen* (Ib)
	Gallus gallus domesticus	Egg (chicken, whole cooked, hard boiled, put in stew before serving)	
Fish	*Clupea harengus*	Atlantic herring (fried)	*Shawa* (Y)
	Clupea harengus	Atlantic herring (tiny, fried)	*Shawa* (Y)
	Clupea harengus	Atlantic herring (smoked)	*Shawa* (Y)
	Trachurus trachurus	Atlantic horse mackerel (fried)	*Kote* (Y)
	Scomber scombrus	Atlantic mackerel (fried)	*Titus* (Y)
	Scomber scombrus	Atlantic mackerel (smoked)	*Titus* (Y)
		Folo (roasted)	*Folo* (Y)
	Clarias gariepinus	Cat fish (roasted)	*Ejaaro* (Y), *inagha* (Ef/Ib)
	Farfantepenaeus notialis	Cray fish (roasted)	*Ede* (Y), *ayiya* (I), *obuk* (Ef)
	Micromesistius poutassou	Blue whiting (roasted)	*Panla* (Y)
	Micromesistius poutassou	Blue whiting (fried)	*Panla* (Y)
	Stockfish	Stockfish	*Panla* (Y), *Oporoko* (I)
	Pseudotolithus senegalensis	West African croaker (roasted)	*Apo* (Y), *oniok* (Ef), *okhovo* (Ur)
		Palamu (roasted)	*Palamu* (Y)
Nuts and seeds	*Arachis hypogaea*	Ground nut (roasted)	*Epa* (Y), *jeda* (H), *opaoa* (I)
	Arachis hypogaea	Ground nut (boiled)	
	Anacardium occidentale	Cashew nut (roasted)	*Kasu* (Y), *kashu* (H), *kasu* (Ib)
	Juglans regia	Walnut (boiled)	*Ahusa* (Y), *asala* (Y), *irin goro* (H), *ukpa* (I)
	Cocos nucifera	Coconut (mature, kernel, fresh)	*Agbon* (Y), *kwakwa* (H), *aku oyibo* (I)
	Cyperus esculentus	Tiger nut (yellow, raw)	*Ofio* (Y), *aya* (H), *aki awusa* (I), *isip isong* (Ib)
	Cyperus esculentus	Tiger nut (brown, raw)	*Ofio* (Y), *aya* (H), *aki awusa* (I), *isip isong* (Ib)
	Citrullus lanatus	Water melon (seed only)	
Sugar and cocoa product	*Saccharum* spp.	Granulated sugar (raw)	*Suga* (Y), *sukari* (H), *oto biribiri* (I)
	Theobroma cacao	Cocoa product (raw)	

Note: Ef – Efik language, H – Hausa language, Ib – Ibibio language, I – Igbo language, Ur – Urobo language, Y – Yoruba language.

functioning of the whole system [1]. At least 16 minerals are known to be essential to human health, and have been broadly grouped into macro (or major) and micro (or trace) minerals. Macrominerals are needed by the body in the order of 100 mg or more on a daily basis, and they include potassium, sodium, calcium, magnesium, phosphorus, chloride and sulphur [1,2].

Potassium, sodium, calcium and magnesium, are involved in diverse biological and metabolic roles in humans such as fluid-electrolyte balance, maintenance of normal blood pressure, glucose uptake, muscle contraction, bone and teeth formation, nerve impulse transmission, certain enzyme regulations, regulation of parathyroid hormone level, protein synthesis and cellular growth and reproduction [1,3–5] are the focus of this report. Due to the important roles played by these macrominerals, a host of health-related anomalies can be ascribed to their inadequate intakes and deficiencies; hence, it is necessary to evaluate their levels in foods to

ascertain the dietary intakes by individuals or populations, for proper guidance towards optimal health.

Comprehensive information on food quality in relation to specific types and quantities of nutrients in several foods can be very helpful in strategizing toward ensuring nutrition security, especially in various developing countries, where budgets for foods are often inadequate [6]. The level of diet-related non-communicable diseases (NCDs) such as diabetes, coronary heart disease and hypertension is increasing in Nigeria as a result of rapid globalization, urbanization, lifestyle and dietary changes. Babalola et al. [7] reported nutrition transition in over 75% of farming households in Ogun State; while NCD prevalence of 32.8% was reported among adult population in the South-South region of Nigeria [8]. Over 75% of a population of civil servants in Ibadan, South-West Nigeria were reported to have at least two risk factors of NCDs [9]; and 64.4% prevalence of NCDs was reported among Nigerian adults that visited Federal Medical Centre, Nasarawa State in the North Central part of Nigeria [10]. This makes it very necessary to generate high-quality food composition data to enable easy nutrition guidance on food combinations for promotion of optimal health and reduction in prevalence of NCDs [11]. Availability of food composition data are highly useful in promoting nutrition-sensitive agriculture; improved food processing methods with optimal nutrient retention, and correct food labelling to help in consumers' preferences [12–14]. It is most likely that some of these could be the reasons why relevant agencies and government of countries around the world have provided appropriate funding for the generation of food composition data for several generations.

Majority of publications on macromineral contents of Nigerian foods are not so recent and they included relatively limited food varieties [15–18]. In recent times, the Food and Agriculture Organization of the United Nations (FAO) worked with some experts, especially within West Africa, to compile the composition for West African foods [19,20]. A national effort with the support of Nestle Nigeria Plc. and some other agencies also led to the production of the first version of the Nigeria Food Composition Table [21]. Most recently, Vincent et al. [14] reported the nutrient contents of several foods within West Africa; but due to availability of limited high-quality data, they advocated for further efforts to develop additional national Food Composition Table/Food Composition Database (FCT/FCDB). It was also recommended that efforts should be made to keep updating the existing FCT/FCDB with more recent analytical data, because many of them in Western Africa are being compiled from various data reported around the 1960s–1980s [14]. Thus, this research was designed to evaluate the potassium, sodium, calcium and magnesium composition of 141 individual foods from 11 food groups commonly consumed by Nigerian adults. The data obtained were then applied to determine their adult average daily intakes in comparison to international recommendations.

2. Materials and methods

2.1. Study locations

Federal Capital Territory (FCT), Abuja and Ogun State were purposively selected as representatives of North Central and South West geopolitical zones of Nigeria, respectively. Five cities/towns (Abaji, Dutsen Alhaji, Karu, Kuje and Kwali) from FCT Abuja and five cities/towns (Abeokuta-South, Ijebu-Ode, Ilaro, Ilisan and Ipokia) from Ogun State were randomly selected. Food samples were purchased from each of the ten cities/towns. The map showing the ten locations involved in this study is available in Fig. 1 [6].

2.2. Sample selection and collection

The food samples selection was fully dependent on the list of commonly consumed foods in Abuja and Ogun State. A food consumption survey was carried out for the generation of food list (data not published), which guided the sampling of food items being analysed. Highest priority was given to Nigerian staples. Thereafter, some foods were included to account for some diversity of foods across regions and seasonal variation. A total of 637 individual food samples including 141 different food items were collected from August to October 2014. Various foods were bought "as consumed" from two to 23 major food vendors (for every food item) through systematic random sampling from the major markets available within each of the ten sub-locations. The mean number of replicates of each individual food sampled was 4.5 (min: 2, max: 23 – Table 4). The differences in number of specific food samples collected from each market were based on availability and the size of the food item. The food groups of the foods purchased and analysed were tubers, starches and their products; cereals and cereal products; legumes and legume products; fruits; leafy and fruity vegetables; condiments, sauces and soups; dairy products; beef, poultry and eggs; fish; oil seeds; and sugar and cocoa product. A subsample of each food item was collected, and the edible portions "as consumed" were analysed. A detailed description of the 141 food items analysed is as presented in Table 1. The items were gathered from areas populated by various ethnic groups with much diversified food habits. These areas are provided with different food items produced from virtually all parts of Nigeria and some from oversea, hence the food items were representatives of those sold to consumers all over the country [6].

2.3. Food preparation

The purchased food samples were immediately transferred to the laboratory for fresh processing. The head, bone and skin of most fish samples were removed and excluded from further processing and analyses. Some fruits were washed with laboratory tap water and peeled; and shells of oil seeds such as coconuts and walnuts were removed and excluded from further processing. All food preparations involving cooking were done in the communities where they were collected and oven dried in the laboratory. All samples were dried at 100 °C using Gallenkamp hot air oven (Weiss Technik, Loughborough, England) and pulverised with Eurolex blender model GM 1153 (Eurolex, New Delhi, India). The pulverised samples were then stored separately in polyethylene bags at −20 °C for further analyses.

2.4. Sample digestion

The food processing (dry ashing) and macromineral analyses were carried out at the Departments of Agronomy and Chemistry of University of Venda, Thohoyandou, Limpopo province, South Africa. Modified method of AOAC [22] by Akinyele and Shokunbi [23] was used for the dry ashing. One gram of each dried food sample was measured into a porcelain crucible and ashed in the Carbolite muffle furnace (model S30 2AU, Bamford, Sheffield, England) by gradually raising the temperature up to 500 °C over 1 h and then allowing to ash at this temperature for the next 12 h. The ash was dissolved with 10 mL of 1 mol L^{-1} nitric acid (Merck, Germany – 67%, v/v), filtered into a 50 mL volumetric flask using Whatman filter paper (No. 41) and made up to mark with the dilute nitric acid (1 mol L^{-1}). Ultra-pure water (18 MΩcm) (Merck Milli-Q, Germany) was used throughout the processing. The blank digests were processed using the same protocol, one per batch of 15 food samples.

2.5. Analytical instruments for macromineral analyses

The levels of the four macrominerals in the food sample were evaluated through digests using Varian atomic absorption spectrometer (AA240FS series, California, USA), operated on air/acetylene flame. Operating parameters for the minerals evaluated were set according to the manufacturer's manual. Lanthanum (III) chloride heptahydrate solution (Merck KGaA, Darmstadt, Germany) was used as the matrix modifier for the flame AAS analyses, which were done at the most sensitive analytical spectral lines of the minerals. The details of the conditions of the instrument are available in Table 2. The limit of detection (LOD) and the limit of quantification (LOQ) were extrapolated in accordance with the NF EN 13804 [24] and specified respectively as 3 and 6 times the standard deviation of the mean of 21 independent blank tests. Appropriate corrections were also done based on the weight of sample (1 g) and the dilution (1:50). The blank samples were fully taken through the digestion and AAS determination techniques. The range of 0.160–0.251 mg/100 g and 0.320–0.502 mg/100 g edible portion were obtained for LOD and LOQ respectively (Table 4). The mean values obtained for the four minerals were on dry weight basis, and were then converted to their equivalent mean values "as consumed" being reported here using their moisture content per 100 g food sample.

2.6. Quality controls

The results of the four macrominerals analysed were validated by the quality control processes shown below:

1. Within every set of 15 individual food samples being dry-ashed, one blank sample was usually included for monitoring cross contamination or protocol memory effects. All sample values were presented after due subtraction of the mean of the blank values in the respective batch.
2. It was ensured that the calibration curves had very minimal outliers ($r^2 > 0.995$; four points) in the analyses of all these minerals. A re-calibration was done, whenever an outlier was observed. The standard solutions (mg L^{-1}), obtained from Merck, Germany, prepared in 10% (v/v) of 27 g L^{-1} lanthanum (III) chloride heptahydrate solution (Merck KGaA, Darmstadt, Germany), ranged from 0 to 0.8, 0 to 0.6, 0 to 1.6 and 0 to 0.4 for potassium, sodium, calcium and magnesium, respectively.
3. Recovery studies were carried out to determine the accuracy and reliability of the results by spiking fifteen different food samples before dry ashing and values read on the AA240FS. The concentrations of the spiked samples varied from 200 μg L^{-1} (1 mg/100 g) for sodium to 10,000 μg L^{-1} (50 mg/100 g) for potassium. The recoveries were within 95–110% (Table 3).

2.7. Estimation of selected adult mean daily intakes of potassium, sodium, calcium and magnesium

The Multiple-pass 24-hr dietary recall protocol designed by the USDA was used in assessing daily intakes of the macrominerals from the 141 food items analysed. Thirty trained Interviewers were employed to perform the 5-step dietary recall interview (Suppl. 1). A total of 732 apparently healthy consenting Nigerian adults (238 males and 494 females) aged 18–68 years (87% of contacted participants) and were not on special diet or medication were recruited from the 10 cities and towns used for the study. Three hundred and forty-nine (349) of the participants resided in Abuja, while 383 resided in Ogun State. The interviews were carried out on two non-consecutive days for each participant, including one week day and one weekend day. The trained interviewers made use of food models and standardised wordings to improve the certainty of the participants recalling all foods and drinks consumed, the previous day. The estimated weight of the different food items consumed were used to compute individual and mean daily macromineral intakes

Table 2
Instrumental conditions for Flame Atomic Absorption Spectrometer (FAAS) for the determination of macrominerals in food samples.

Element	Acetylene (L min^{-1})	Air (L min^{-1})	Wavelength (nm)	Slit width (nm)	Lamp current (mA)	Lamp mode
Potassium	2	13.5	766.5	1.0	5	NON-BGC[a]
Sodium	2	13.5	589.0	0.5	5	NON-BGC[a]
Calcium	2	13.5	422.7	0.5	10	NON-BGC[a]
Magnesium	2	13.5	285.2	0.5	4	BGC-D2[b]

[a] NON-BC, no background correction.
[b] BGC-D2, deuterium background correction.

Table 3
Recovery (%) of macrominerals from various food items.

Metal	Sample weight (g)	Concentrations of standard spiked (mg/L)	Volume of the standard solution spiked (μL)	Spiked concentration[a] (mg/100 g)	Mean Recovery concentration[b] (mg/100 g)	Mean Percentage recovery[b] (%)
K	1.00	1000	100	10.0	10.4 ± 0.7	104 ± 7
	1.00	1000	500	50.0	47.5 ± 2.3	95.0 ± 4.8
Na	1.00	100	100	1.00	1.1 ± 0.1	110 ± 8
	1.00	1000	100	10.0	10.0 ± 0.5	100 ± 5
Ca	1.00	1000	50	5.00	5.2 ± 0.2	104 ± 4
	1.00	1000	250	25.0	24.0 ± 1.1	96.0 ± 4.6
Mg	1.00	1000	100	10.0	9.5 ± 0.4	95.0 ± 4.2
	1.00	1000	400	40.0	42.4 ± 1.8	106 ± 4

[a] Corresponding to 20.0, 100.0, 200.0, 500.0, 800.0 and 1000.0 μg/100 mL respectively, for 1.0, 5.0, 10.0, 25.0, 40.0 and 50.0 mg/100 g spiked concentration, using a sample weight of 1.0 g and a final volume of 50 mL.
[b] Values represent mean ± standard deviation (SD).

of respondents, using a standardised nutrient calculator software built with Java programming language and customised for this study (unpublished). The potassium, sodium, calcium and magnesium levels in a number of foods and drinks in the participants' menu (about 5% of all food items) but not analysed in this study, were obtained from the Nigerian Food Composition Table [21].

2.8. Ethical considerations

The ethical approval was sought and obtained from University of Ibadan/University College Hospital Ethical Review Board (Approval No.: UI/EC/13/0053) for this work. All protocols were followed in line with the guidelines regulating studies on human participants from National Institute of Health, USA. After complete explanation of the research protocol to participating individuals, each of them was required to complete the informed consent form before being enrolled in the study and all their data were handled anonymously.

2.9. Data analyses and reporting

The individual food composition data is reported as mean of all duplicate samples analysed for each of the 637 individual foods (amounting to 141 different food items). The mean levels of the macrominerals on fresh weight basis are presented in mg per 100 g of edible portion. The upper bound mean concentrations were determined and reported at the food group levels, with values less than the LOD estimated as LOD values, and those less than LOQ estimated at the level of LOQ. Data analyses were carried out through the use of Statistical Package for Social Sciences (SPSS) version 21.0. The calculated mean concentrations of the various food groups were compared using one-way analysis of variance (ANOVA), while Least Significant Difference (LSD) was used to separate the means. Levels of significant differences were set at $p < 0.05$ and 0.001.

3. Results and discussion

3.1. Potassium, sodium, calcium and magnesium contents of food items "as consumed"

The moisture contents and mean levels of potassium, sodium, calcium and magnesium of 141 individual food items "as consumed" from Nigeria as well as the upper bound mean concentrations of the macrominerals at food group level are presented in Table 4. To the best of our knowledge, this report is the first most extensive data on these macrominerals in commonly consumed foods from Nigeria, within the last three decades. On fresh weight basis, the concentrations (mg/100 g) of potassium, sodium, calcium and magnesium in the foods analysed ranged from 2.92 to 1520, 1.46 to 30,700, 1.35 to 1280 and 1.16 to 416, respectively. Some of the values obtained for the four minerals in this study are similar to the values reported for yam products and cooked rice [25,26]. Many are also similar to those reported by Stadlmayr et al. [19] and Stadlmayr et al. [20] from West African food items. They were however higher than values reported by Morakinyo et al. [27] on some tubers and cereals of local dishes collected from household and restaurants in Lagos, Nigeria. The variation may be due to the differences in the food sources as well as preparation methods. Furthermore, the levels of calcium and magnesium reported for cereals, legumes and tubers in this study are within the range reported for some cereals, legumes and tubers in the literature [28,29]; though the potassium and sodium levels differ sharply. The differences in this case are likely due to the level of processing of the different food items, as processing such as boiling for consumption tends to reduce the potassium content, while simultaneously raising the sodium content.

The mean levels of potassium were lowest (2.92 mg/100 g) in cooked custard and highest (1520 mg/100 g) in "stockfish". The levels in the foods decreased from 1520 mg/100 g in "stockfish" to 1510 mg/100 g in "*folo*" fish and then to 1440 mg/100 g in powdered full-cream milk. Most fish samples from group contained very high levels of potassium. Fried plantain chips, cornflakes, fried bean cake of drum bean, date, water leaf soup, fried beef in stew, boiled walnut and cocoa product had the highest levels of potassium in the tubers, starches and their products; cereals and cereal product; legumes and legume products; fruits; vegetables and vegetable products; beef, poultry and eggs; oil seeds; and sugar and cocoa product groups, respectively. Comparing these data at the

Table 4
Moisture content (g/100 g), concentrations (mg/100 g edible portion on fresh weight basis) of macrominerals in some Nigerian foods 'as consumed' and upper bound[q] mean concentrations at food group level.

Food group	Individual food sample: local/common name	Number of samples (n)	Moisture	Potassium	Sodium	Calcium	Magnesium
	Limit of quantification (LOQ) (mg/100 g EP)		–	0.414	0.502	0.356	0.320
Tubers, starches and their products	*Fufu* (cooked)	12	67.8	53.4 (25.4–92.8)	5.02 (1.87–8.59)	20.6 (10.8–40.3)	19.5 (4.63–35.7)
	Sweet potato (fried)	4	53.0	404 (381–426)	162 (137–214)	30.9 (22.1–44.1)	28.9 (17.0–51.3)
	Amala dudu (cooked)	10	76.3	191 (121–254)	15.1 (7.15–28.5)	14.9 (7.45–32.7)	26.3 (10.3–41.4)
	Pounded yam	6	70.3	186 (142–269)	9.02 (2.84–15.8)	12.4 (6.11–20.0)	27.5 (10.4–45.1)
	Yam (fried)	8	54.5	313 (249–389)	214 (125–382)	20.6 (12.8–31.7)	38.7 (12.7–79.1)
	Yam (boiled)	3	64.2	161 (161–162)	336 (335–336)	27.0 (18.7–35.2)	72.2 (71.1–73.3)
	Poundo yam (cooked)	2	73.9	15.6 (14.8–16.4)	12.0 (11.7–12.4)	9.20 (9.05–9.35)	5.50 (4.00–7.00)
	Yam pottage (white yam)	2	68.8	247 (226–271)	236 (215–252)	10.9 (10.6–11.4)	14.8 (14.1–16.0)
	Cake (water yam, fried)	2	63.3	554 (542–566)	353 (345–360)	10.0 (9.98–10.1)	21.6 (20.8–22.4)
	Cooked *garri*	10	72.6	96.3 (35.7–181)	11.8 (4.92–18.9)	22.5 (12.9–33.5)	27.6 (10.9–43.8)
	Bread fruit (boiled)	2	79.5	221 (219–223)	12.2 (12.0–12.4)	18.1 (13.44–24.7)	44.3 (42.2–46.4)
	Plantain (mature ripe, fried)	6	43.3	448 (350–678)	12.8 (3.85–24.1)	5.01 (4.36–6.29)	58.1 (38.3–71.6)
	Plantain chip (mature unripe, fried)	4	1.95	969 (931–1050)	194 (105–280)	6.41 (5.68–7.12)	91.6 (84.0–98.3)
	[q]*Food group mean* ± SD	–	–	297 ± 260^{bc}	121 ± 130^{a}	16.0 ± 8.0^{a}	36.7 ± 24^{ab}
Cereals and cereal products	Rice (Long grain, boiled)	14	71.0	34.3 (18.7–51.4)	205 (100–355)	8.83 (3.59–15.3)	13.5 (2.40–36.3)
	Rice (Short grain, boiled)	4	71.7	11.3 (10.9–11.7)	333 (328–337)	11.5 (10.7–12.2)	19.9 (19.7–20.1)
	Local Rice (boiled)	4	71.9	49.6 (16.7–93.4)	158 (117–236)	10.5 (8.89–13.5)	36.2 (11.8–48.1)
	Jollof Rice	5	65.8	98.3 (74.0–130)	362 (326–409)	15.3 (11.2–18.9)	24.6 (16.3–31.0)
	Fried Rice	3	62.5	93.2 (81.1–106)	334 (257–469)	9.45 (9.18–10.0)	7.37 (6.96–8.22)
	Masa (rice cake, fried)	3	56.4	27.2 (16.0–48.9)	163 (146–197)	19.8 (12.0–27.2)	26.5 (12.4–51.8)
	Garogaro (rice, beans, boiled; along with fresh sauce)	2	67.1	76.2 (62.1–105)	180 (128–206)	32.2 (20.3–41.7)	48.8 (43.9–52.7)
	Maize (yellow, roasted)	6	42.8	211 (89.1–325)	8.73 (2.46–27.5)	12.7 (6.0–18.3)	71.9 (25.6–112)
	Maize (yellow, boiled)	3	72.7	195 (189–201)	7.54 (6.99–8.09)	9.1 (4.51–15.7)	47.2 (44.8–49.6)
	Maize (white, roasted)	2	54.6	126 (122–131)	35.7 (33.7–37.8)	11.6 (7.4–16.8)	93.6 (88.4–99.0)
	Tuwo (white maize, cooked)	4	77.9	60.3 (21.4–138)	28.9 (4.66–74.3)	9.67 (7.12–14.9)	32.6 (22.6–52.2)
	Tuwo (rice, cooked)	3	77.0	19.4 (12.5–30.5)	27.4 (12.5–49.3)	7.29 (4.11–11.9)	9.58 (5.02–17.2)
	Bread (white)	13	30.7	140 (75.6–216)	256 (120–335)	75.3 (40.5–158)	51.0 (14.7–99.5)
	Bread (whole wheat)	3	26.8	174 (153–196)	148 (128–167)	94.8 (83.2–96.8)	94.9 (82.0–108)
	Bread (malt)	2	28.3	220 (208–233)	116 (116–117)	91.5 (88.9–95.0)	24.4 (23.2–25.6)
	Maize, white, moulded gruel	10	86.4	25.6 (6.07–67.1)	5.28 (0.58–16.7)	2.98 (1.70–4.12)	11.5 (3.67–32.3)
	Cornmeal (white maize, powder, fried)	2	5.23	250 (233–260)	538 (516–580)	1.35 (0.892–1.72)	94.8 (88.3–98.5)
	Semovita (cooked)	9	76.2	47.1 (27.9–112)	5.06 (2.07–10.2)	6.63 (5.19–10.2)	14.3 (7.34–21.9)
	Donkwa (cooked)	2	18.0	325 (255–395)	219 (167–274)	101 (79.6–125)	181 (163–210)
	Fura (cooked)	2	57.5	119 (109–136)	8.09 (7.25–10.1)	13.1 (8.43–18.2)	49.6 (45.0–54.5)
	Oat (cooked)	2	89.0	36.8 (35.7–38.0)	3.56 (3.26–3.86)	4.79 (4.22–5.36)	4.04 (3.47–4.60)
	Custard (cooked)	2	91.0	2.92 (2.90–2.93)	92.8 (91.3–94.3)	2.64 (2.16–2.98)	18.0 (15.9–20.2)
	Granola	2	1.63	91.0 (81.9–99.5)	232 (182–304)	138 (127.5–155)	19.4 (14.0–29.7)
	Cornflakes	2	1.17	821 (811–831)	2.55 (1.80–3.30)	7.50 (6.00–9.42)	70.0 (65.0–75.0)
	Spaghetti (boiled)	2	63.5	156 (151–161)	53.6 (52.4–54.8)	2.70 (2.61–2.95)	14.7 (14.3–15.2)

(*continued on next page*)

Table 4 (*continued*)

Food group	Individual food sample: local/common name	Number of samples (n)	Moisture	Potassium	Sodium	Calcium	Magnesium
	Jollof spaghetti	2	67.0	130 (126–135)	317 (312–322)	3.01 (2.79–3.23)	18.2 (17.7–18.8)
	Noodles (plain, boiled)	6	61.0	69.9 (59.5–89.2)	589 (487–734)	2.15 (1.61–3.09)	9.76 (8.06–11.3)
	Noodles (boiled, with boled or fried egg)	3	59.4	73.0 (53.5–100)	594 (380–861)	4.43 (3.47–5.16)	10.3 (7.81–12.4)
	Kunu (*gyada*)	2	89.6	29.6 (28.8–30.3)	1.70 (1.62–1.78)	4.51 (3.87–4.96)	8.22 (7.37–9.06)
	[q]*Food group mean* ± SD	–	–	128 ± 160[a]	173 ± 180[a]	24.6 ± 36[a]	38.8 ± 39[ab]
Legumes and legume products	Bean pottage (White bean)	4	70.0	351 (274–480)	441 (377–576)	16.8 (12.7–21.4)	54.0 (49.2–59.5)
	Bean (drum, boiled)	8	64.2	331 (83.9–495)	282 (66.2–443)	18.5 (9.80–29.2)	59.9 (16.9–93.2)
	Bean (white, boiled)	2	60.9	433 (310–557)	297 (287–306)	20.2 (16.2–24.1)	63.7 (50.3–77.0)
	Bean (*olo* 2, boiled)	3	68.6	298 (269–335)	248 (233–262)	28.5 (25.2–32.7)	87.3 (76.5–102)
	Bean (*pewu*, boiled)	2	67.8	74.9 (74.8–75.1)	147 (137–158)	16.4 (16.3–16.5)	30.7 (26.2–35.2)
	Bean cake (white bean, fried)	3	53.3	349 (339–364)	362 (337–410)	28.3 (16.5–38.6)	76.9 (71.3–86.5)
	Bean cake (*pewu* bean, fried)	3	54.3	502 (443–599)	404 (262–488)	19.3 (18.9–19.9)	61.7 (55.3–64.6)
	Bean cake (drum bean, fried)	2	50.5	541 (387–696)	620 (619–622)	18.5 (18.0–19.2)	60.9 (54.4–67.4)
	Bean pudding moulded (white bean, cooked)	2	68.5	277 (207–314)	368 (335–386)	27.0 (25.1–29.1)	61.6 (59.2–66.2)
	Bean pudding moulded (*olo* 2 bean, cooked)	2	73.2	269 (261–276)	484 (344–623)	16.5 (16.3–16.7)	32.9 (29.0–36.7)
	Bambara nut (boiled)	2	59.6	266 (252–280)	516 (514–518)	16.8 (14.4–19.1)	71.7 (69.5–74.1)
	Bean pudding moulded (Bambara nut, cooked)	4	64.1	286 (244–336)	456 (427–486)	22.3 (19.6–26.9)	85.7 (72.1–98.7)
	Tofu pie	2	33.8	226 (215–236)	432 (428–436)	30.6 (30.0–31.2)	58.0 (56.3–59.6)
	Tofu (fried)	7	55.5	133 (109–184)	482 (435–579)	84.8 (80.9–91.1)	49.1 (40.5–55.5)
	[q]*Food group mean* ± SD	–	–	310 ± 130[bc]	396 ± 120[a]	26.0 ± 18[a]	61.0 ± 17[b]
Fruits	Banana (ripe)	15	75.1	263 (204–338)	7.14 (3.24–15.9)	4.38 (2.44–8.42)	41.7 (31.5–53.7)
	Orange	15	89.3	126 (83.3–199)	1.46 (nd-3.13)	33.6 (29.0–40.1)	13.7 (10.3–19.8)
	Pawpaw	9	89.5	109 (78.9–141)	3.19 (1.51–6.43)	18.5 (16.5–22.3)	11.8 (5.74–20.6)
	Pineapple	7	84.8	84.9 (52.1–109)	2.58 (1.07–5.53)	15.6 (11.5–20.6)	23.5 (16.4–29.0)
	Water melon (fruit without seed)	16	93.4	87.6 (61.0–121)	2.78 (1.13–5.89)	6.09 (5.10–7.99)	8.92 (5.20–15.1)
	Golden melon	2	93.5	144 (138–149)	1.53 (1.41–1.65)	8.91 (8.82–9.00)	14.7 (14.2–15.2)
	Guava	4	84.0	260 (177–380)	4.52 (3.16–7.34)	20.4 (13.7–24.8)	15.9 (11.3–23.4)
	Date	4	10.0	607 (565–644)	16.1 (10.5–26.7)	45.2 (33.3–54.4)	56.2 (48.1–74.9)
	Apple (wine)	6	83.8	85.2 (70.6–105)	3.29 (2.14–5.25)	6.63 (5.48–8.41)	9.11 (4.38–24.0)
	Apple (green)	13	84.7	76.4 (50.0–116)	3.32 (1.06–6.67)	4.71 (3.65–5.76)	6.59 (3.47–13.1)
	Apple (wine/green)	2	83.0	85.2 (84.9–85.4)	3.20 (3.04–3.35)	8.50 (8.00–9.00)	7.30 (5.78–8.82)
	Pear apple (European pear)	4	84.2	81.9 (69.0–105)	3.34 (2.41–4.86)	12.9 (9.00–14.1)	14.7 (10.8–21.9)
	Tangerine	4	89.8	144 (134–160)	2.85 (1.67–3.82)	30.1 (27.2–31.9)	13.0 (9.61–15.1)
	Plum	2	81.9	169 (167–172)	5.23 (4.91–5.55)	2.65 (2.61–2.72)	7.44 (7.07–7.81)
	[q]*Food group mean* ± SD	–	–	166 ± 140[ab]	4.32 ± 3.7[a]	15.6 ± 13[a]	17.5 ± 14[a]
Vegetables and vegetable products	Eggplant (light yellow)	7	92.9	151 (132–162)	2.24 (1.08–3.47)	9.29 (8.07–11.1)	16.0 (13.8–20.4)
	Eggplant (green)	7	91.8	159 (128–187)	3.16 (1.90–5.69)	9.33 (7.42–10.2)	20.6 (16.9–23.2)
	Eggplant (reddish)	2	91.7	141 (118–157)	7.75 (7.34–8.35)	8.73 (7.34–9.34)	24.9 (24.1–25.6)
	Eggplant (lemon)	2	92.5	131 (105–158)	2.41 (2.15–2.67)	7.92 (6.81–8.63)	14.3 (11.9–16.8)
	Green bell pepper (raw)	3	94.4	180 (163–189)	1.74 (1.45–2.01)	7.86 (5.60–10.9)	13.1 (11.4–14.9)
	Green peas (raw)	7	74.7	390 (266–554)	9.11 (3.43–15.6)	23.9 (19.1–31.2)	55.0 (33.6–65.8)
	Green bean (raw)	2	92.1	231 (181–282)	3.93 (3.23–4.62)	34.1 (32.3–35.9)	29.8 (25.7–33.8)
	Cabbage (raw)	7	93.1	204 (152–233)	4.00 (2.59–5.66)	30.6 (28.6–36.3)	14.7 (11.4–21.4)
	Cole slaw	3	81.1	203 (192–210)	142 (120–170)	28.1 (26.6–29.6)	18.0 (16.5–21.1)
	Carrot	3	88.1	312 (234–363)	11.2 (6.19–16.1)	24.3 (21.8–25.8)	18.6 (16.8–21.5)
	Cucumber	10	96.6	108 (86.3–150)	1.81 (0.78–4.06)	15.2 (14.7–15.6)	11.3 (7.39–17.1)

(*continued on next page*)

Table 4 (*continued*)

Food group	Individual food sample: local/common name	Number of samples (n)	Moisture	Potassium	Sodium	Calcium	Magnesium
	Stew (for rice, with vegetable oil)	23	71.5	273 (96.4–489)	786 (267–1580)	11.9 (7.90–26.7)	27.9 (11.5–50.3)
	Stew (for *tuwo*)	2	81.9	58.1 (57.3–58.9)	410 (408–411)	16.1 (14.2–18.0)	44.0 (42.8–45.3)
	Stew (with palm oil)	4	79.0	245 (199–296)	577 (401–706)	13.4 (8.65–22.2)	22.0 (13.6–30.8)
	Stew (for *masa*)	2	86.6	191 (190–191)	513 (479–546)	15.5 (14.4–16.7)	29.8 (29.0–30.6)
	Stew (for swallow)	2	76.1	217 (213–222)	484 (434–534)	7.83 (7.39–8.26)	16.7 (12.9–20.6)
	Stew (for local rice)	2	82.9	156 (138–167)	547 (480–585)	6.22 (6.11–6.28)	14.6 (13.9–15.3)
	Egg stew	2	65.4	301 (290–313)	986 (980–991)	31.7 (31.5–31.9)	22.8 (22.7–22.9)
	Groundnut soup	2	84.1	102 (96.0–107)	644 (634–654)	17.1 (16.3–17.9)	28.9 (28.8–29.0)
	Bean soup	2	71.3	209 (205–215)	421 (391–454)	21.7 (21.3–22.1)	38.0 (37.0–38.9)
	African/wild mango soup	2	70.3	109 (108–109)	679 (678–680)	48.7 (47.6–49.8)	42.5 (41.7–43.2)
	Fluted pumpkin leaves (fried)	2	72.2	226 (211–241)	400 (381–419)	49.6 (48.3–50.8)	93.6 (89.0–98.1)
	Ladies' finger (plain)	4	91.5	127 (118–137)	407 (374–436)	26.3 (21.9–39.2)	25.7 (18.2–33.6)
	Ladies' fingers soup	4	93.2	96.2 (89.0–118)	394 (331–484)	38.6 (28.7–57.4)	19.4 (18.3–21.0)
	African spinach soup	2	56.6	187 (177–197)	1170 (1140–1200)	39.8 (39.6–39.9)	113 (112–114)
	Jute leaf (plain)	7	93.5	97.5 (62.0–146)	316 (237–525)	30.8 (16.0–49.2)	23.8 (17.1–34.2)
	Lagos spinach soup	2	60.1	202 (199–206)	690 (661–719)	35.7 (35.6–35.8)	71.6 (70.2–73.0)
	Fluted pumpkin leaves soup (with *egusi*)	7	68.6	190 (153–290)	457 (344–637)	57.4 (41.2–94.4)	91.3 (64.8–133)
	African spinach soup (with *egusi*)	3	74.2	133 (105–171)	507 (384–639)	58.6 (45.9–73.1)	86.0 (70.7–105)
	African spinach soup (*efo riro*)	2	79.9	251 (226–277)	725 (608–843)	31.3 (25.3–37.3)	72.1 (64.7–79.5)
	Lagos spinach soup (with *egusi*)	2	70.2	237 (170–272)	697 (554–785)	44.6 (23.3–55.9)	155 (148–163)
	Water leaf soup	4	71.6	201 (183–217)	552 (526–580)	38.2 (30.1–48.8)	72.7 (59.8–87.1)
	Water leaf (with Fluted pumpkin leaves) soup	2	72.0	254 (249–258)	423 (416–429)	58.7 (52.4–65.1)	74.1 (72.5–75.7)
	Lagos spinach soup (*efo riro*)	3	73.9	199 (161–230)	721 (575–927)	39.8 (37.8–41.6)	76.2 (71.1–82.0)
	Wild African spinach soup (with *egusi*)	2	83.0	93.2 (92.2–94.2)	341 (326–356)	23.1 (22.2–24.1)	42.9 (41.9–44.0)
	[q]*Food group mean* ± SD	–	–	188 ± 72[ab]	401 ± 310[a]	27.5 ± 16[a]	44.0 ± 34[ab]
Condiments	Salt	4	2.3	207 (180–243)	30,700 (28,600–33300)	7.61 (5.56–8.78)	56.5 (29.4–87.6)
	Locust bean (boiled and fermented)	7	65.8	35.6 (15.7–51.8)	503 (103–957)	90.7 (73.3–110)	67.3 (49.8–101)
	[q]*Food group mean* ± SD	–	–	121 ± 120[ab]	15,600 ± 21000[b]	49.2 ± 59[ab]	61.9 ± 7.6[abc]
Milk and milk product	Powdered vegetable-fat milk (raw)	6	3.6	1430 (1400–1450)	249 (244–254)	694 (674–714)	91.8 (91.5–92.1)
	Powdered full-cream milk (raw)	4	3.9	1440 (1320–1550)	337 (294–400)	1280 (1240–1320)	95.0 (89.7–97.2)
	Nono (locally fermented milk)	2	92.3	106 (95.5–115)	22.5 (21.3–24.7)	51.6 (54.3–72.8)	16.7 (12.1–22.0)
	[q]*Food group mean* ± SD	–	–	992 ± 770[d]	203 ± 160[a]	675 ± 610[c]	67.8 ± 44[abc]
Meat, poultry and eggs	Beef (boiled, in stew)	12	65.5	201 (121–265)	494 (312–850)	18.8 (13.9–31.2)	35.0 (24.8–55.1)
	Beef (fried, in stew)	9	46.7	309 (231–418)	563 (352–840)	21.2 (14.8–27.6)	35.5 (29.2–46.9)
	Ponmo (raw)	6	79.0	6.95 (2.57–10.8)	15.7 (11.5–19.9)	5.85 (3.11–7.14)	6.51 (3.81–9.46)
	Chicken thigh (fried)	5	44.5	251 (178–291)	363 (153–573)	34.7 (28.0–43.9)	40.3 (29.1–56.8)
	Turkey wing (fried)	5	44.3	266 (241–305)	480 (268–869)	39.0 (31.6–45.8)	49.7 (39.6–64.7)
	Egg (boiled)	5	74.6	148 (96.8–177)	152 (135–170)	47.1 (38.8–58.3)	16.8 (14.3–19.7)
	Egg (boiled, in stew)	3	72.2	180 (138–228)	377 (216–470)	48.2 (44.8–50.1)	18.9 (16.9–20.7)
	[q]*Food group mean* ± SD	–	–	195 ± 99[ab]	349 ± 200[a]	30.7 ± 16[ab]	29.0 ± 15[ab]
Fish	Atlantic herring (fried)	6	40.9	684 (567–869)	320 (267–377)	71.9 (66.1–82.2)	69.4 (48.9–95.8)
	Atlantic herring (tiny, fried)	2	24.3	876 (867–886)	244 (240–248)	56.9 (55.0–67.7)	77.8 (77.0–78.6)
	Atlantic herring (smoked)	5	53.9	518 (427–560)	232 (159–263)	63.5 (38.4–82.1)	55.9 (47.4–66.9)
	Atlantic horse mackerel (fried)	5	52.6	382 (152–678)	438 (277–629)	96.1 (85.4–113)	53.2 (25.7–83.0)
	Atlantic mackerel (fried)	4	48.3	369 (333–453)	274 (133–430)	41.4 (38.5–46.6)	47.4 (38.1–57.7)

(*continued on next page*)

Table 4 (*continued*)

Food group	Individual food sample: local/common name	Number of samples (n)	Moisture	Potassium	Sodium	Calcium	Magnesium
	Atlantic mackerel (smoked)	2	45.3	455 (424–475)	276 (243–319)	32.5 (31.9–33.6)	54.0 (52.4–57.0)
	Folo (roasted)	2	22.3	1510 (1490–1540)	474 (463–485)	85.2 (83.0–87.2)	116 (111–122)
	Cat fish (roasted)	5	13.9	845 (434–1140)	303 (226–436)	78.4 (58.2–103)	133 (109–168)
	Cray fish (roasted)	4	11.4	859 (704–1090)	1080 (762–1410)	205 (162–256)	416 (358–492)
	Blue whiting (roasted)	5	61.3	464 (164–838)	455 (339–587)	56.9 (45.3–70.4)	124 (117–136)
	Blue whiting (fried)	3	40.1	623 (400–845)	659 (624–700)	51.6 (39.9–67.1)	108 (77–135)
	Stockfish	3	5.5	1520 (1510–1540)	585 (581–589)	396 (356–436)	229 (223–234)
	West African croaker (roasted)	3	10.4	1240 (1170–1300)	501 (479–526)	29.8 (26.9–35.7)	149 (136–173)
	Palamu (roasted)	4	6.5	1330 (1200–1430)	714 (645–766)	44.5 (39.8–50.0)	208 (183–248)
	[q]*Food group mean* ± SD	–	–	834 ± 410^{d}	468 ± 240^{a}	93.6 ± 97^{b}	131 ± 100^{c}
Nuts and seeds	Ground nut (roasted, salted)	7	3.11	717 (523–841)	377 (222–587)	50.8 (45.6–53.5)	272 (196–375)
	Ground nut (boiled, salted)	6	40.5	327 (258–394)	294 (110–447)	47.6 (43.6–54.5)	147 (114–209)
	Cashew nut (roasted)	2	4.78	554 (547–567)	45.5 (44.0–47.9)	52.4 (44.6–58.6)	326 (307–351)
	Walnut (boiled)	2	36.4	867 (849–885)	12.4 (12.1–12.6)	81.1 (74.7–85.1)	248 (242–254)
	Coconut (mature, kernel, fresh)	3	41.9	317 (170–398)	24.2 (16.5–36.4)	16.3 (10.2–24.0)	97.6 (75.5–132)
	Tiger nut (yellow)	2	47.5	302 (296–308)	10.6 (10.1–11.1)	27.6 (27.0–28.2)	54.8 (54.5–55.2)
	Tiger nut (brown)	3	14.5	473 (462–483)	8.54 (7.99–9.08)	26.2 (23.2–29.1)	74.5 (70.9–78.1)
	Water melon (seed)	2	53.2	266 (263–268)	13.9 (13.8–13.9)	6.26 (6.18–6.35)	143 (142–145)
	[q]*Food group mean* ± SD	–	–	478 ± 220^{c}	98.3 ± 150^{a}	38.5 ± 24^{ab}	183 ± 130^{d}
Sugar and cocoa product	Refined sugar (raw)	4	1.00	33.3 (30.0–39.1)	1.97 (1.56–2.62)	4.20 (2.80–5.80)	1.16 (0.900–1.60)
	Cocoa product (raw)	4	1.55	825 (784–867)	120 (113–127)	212 (202–226)	195 (191–200)
	[q]*Food group mean* ± SD	–	–	429 ± 560^{abc}	61.0 ± 84^{a}	108 ± 150^{ab}	98.1 ± 140^{bc}

Values are presented as mean (min.-max.); limit of detection (LOD); limit of quantification (LOQ); edible portion (EP). LOD = ½ LOQ.

[q] Estimate upper bound mean concentrations: all non-detected and non-quantified values were expressed at the level of LOD and LOQ, respectively. Food group mean values having different superscript alphabetical letter are significantly different from each other at $p < 0.05$.

food group level showed that the mean potassium levels of all food groups are significantly different ($p < 0.001$). Pairwise comparisons indicated that "milk and milk product" and "fish" food groups had significantly highest ($p < 0.05$) potassium levels, followed by "nuts and seeds", "sugar and cocoa product", "legume and legume products", and "tuber, starches and their products" groups. The wide range of distribution of potassium in Nigerian foods "as consumed" reported here is similar to several potassium contents of foods reported in some parts of the globe; though the data differ for some of the food items, when compared with previous reports [14,30,31]. The level of potassium in powdered milk reported here (14,400 mg/kg) is slightly higher than the value (12,800 mg/kg) reported by Gimou et al. [31]. However, the potassium content of the milk was still surpassed by that of some soft bony smoked fish such as "stockfish" and "*folo*" fish. Other rich sources of potassium include plantain chips, boiled walnut, cocoa product, cornflakes and date. These rich sources of potassium show that Nigerian foods are rich in biodiversity, which can provide possible dietary support in the management of hypertension among Nigerian consumers.

The mean sodium level was highest (30,700 mg/100 g) in table salt and least (1.46 mg/100 g) in orange. All the fruits, some fruity vegetables, most cereals and tubers normally prepared/eaten without addition of table salt had relatively low mean levels of sodium. Most items within the "legumes and legume products", cooked vegetables and "fish" groups had high mean levels of sodium. Food group level comparison portrayed a general significant difference ($p < 0.001$) among the 11 food groups. Two by two comparison revealed "condiments" group as having the highest mean sodium level that is significantly different ($p < 0.05$) from sodium contents of every other food group. This shows clearly why addition of condiments, especially table salt, to foods during or after food preparation tends to increase sodium content of such food; thereby making it unhealthy. Table salt is expected to be added in minimal quantity to foods during cooking, as most foods naturally contain some sodium. The lower levels of sodium in unprocessed foods than in processed food were also reported by Tanase et al. [32]. The myriads of foods analysed indicated that the mean levels of sodium in Nigerian prepared foods vary widely from location to location. The high levels of sodium in stews and soups from various food vendors and restaurants across the sub-locations make it very necessary to take extra caution while consuming foods outside the home. The low levels of sodium in the "fruits", some fruity vegetables, and most cereals and tubers normally prepared without addition of table salt also provide a wide pool for the selection of food items for appropriate management of elevated and or high blood pressure.

The mean levels of calcium were lowest (1.35 mg/100 g) in "*kokoro*" and highest (1280 mg/100 g) in powdered full-cream milk. Other rich sources of calcium (in descending order of concentrations) include powdered vegetable-fat milk, "stockfish", cocoa product, roasted cray fish, granola, "*donkwa*", fried Atlantic horse mackerel and whole wheat bread. Some other local food sources of calcium are locust bean, fried tofu and boiled walnut. General food group comparison also showed a significant difference ($p < 0.001$) across groups. "Milk and milk product" group had the highest mean calcium content that is significantly different ($p < 0.05$) from all other groups, while "sugar and cocoa product" group was the closest, though very far from the food group mean of "milk and milk product". This makes "milk and milk product" to be the best source of calcium among all the food groups. Apart from the "stockfish" that is very high in calcium content, indigenous foods like "*donkwa*", locust bean, fried tofu and boiled walnut are also rich sources of calcium and can be promoted especially at locations where they are available. The trend noticed here relative to milk and fish having high calcium contents was similarly reported by other studies [30,31]. This suggests the comparativeness of our data with previous works on the rich sources of calcium, especially within Nigerian food systems.

Magnesium mean concentration was lowest in refined sugar (1.16 mg/100 g) and highest in cray fish (416 mg/100 g). Other rich sources of magnesium (in descending order of concentrations) include roasted cashew nut, roasted groundnut, boiled walnut, "stockfish" and roasted "*palamu*" fish. A total comparison of the food groups indicated that they are significantly different ($p < 0.001$) from one another. Pairwise comparison portrayed that "nuts and seeds" group had the highest mean value of magnesium that is significantly higher ($p < 0.05$) than all other groups, followed by "fish", "sugar and cocoa product", "milk and milk product" and "condiments". The nuts and several fish in Nigerian dishes notably contain high levels of magnesium (Table 4). The magnesium levels reported are similar to those reported by other studies in the literature [30,33]. Groundnuts and cashew nuts were also reported to be high in magnesium content [34,35], as such, can be recommended to specific individuals that require higher intakes of the mineral and can be applied for supplementation or fortification when the need arises.

3.2. Participants' mean daily intakes of macrominerals

The mean daily macromineral intakes of the participants are as presented in Table 5. Their mean daily mineral intakes (mg/person/day) were 1970 ± 780, 2750 ± 1100, 423 ± 300 and 389 ± 130 for potassium, sodium, calcium and magnesium, respectively. The recommended daily intakes and the tolerable upper intake levels (ULs)/provisional tolerable daily intakes (PTDIs) are highlighted on the Table [36–38]. Based on the recommended daily intakes, the mean value of potassium is slightly below recommendation; that of calcium is far lower than the recommendation, while that of magnesium is within range. The mean daily intake of sodium is about double the recommendation. The daily intakes of calcium and magnesium however, are lower than the ULs/PTDIs. A disaggregated data indicated that the mean daily intake of sodium by participants in Ogun State was significantly higher ($p < 0.05$) than that of participants in Abuja. A reverse was the case for the mean calcium intakes at the two main locations. Majority of study group, especially from Ogun State consumed above the safe level of sodium. Most of the participants within Ogun State (potassium – 71.0%, calcium – 95.3%) and Abuja (potassium – 71.9%, calcium – 95.1%), consumed less than the required levels of potassium and calcium through the foods analysed (Table 6).

The dietary macromineral intake pattern of the selected 732 Nigerian adults studied showed that the set of commonly consumed foods analysed within this study incorporated majority (somewhat over 90%) of the types of foods consumed by the participants (Tables 1, 5, and 6). Most of the foods tend to supply the appropriate levels of minerals to majority of the participants, up to the recommended daily intake (RDI) levels. However, the amount of potassium intake is somewhat low compared with RDI as similarly

Table 5
Participants' mean daily macromineral intakes.

Metal	Mean ± SD (Min, Max)	Recommended Intake (AI/RDA)	UL/PTDI
MACROMINERAL	(mg/person/day)		
Potassium	1970 ± 780 (366, 8370)	2300–3400[a#]	ND[a]
Sodium	2750 ± 1100 (34.4, 9310)	1500[a#]	ND[a]
Calcium	423 ± 300 (40.7, 2270)	1000–1300[b##]	2000–3000[b]
Magnesium	389 ± 130 (126, 1080)	310–420[c##]	350[c*]

a – National Academies of Sciences, Engineering, and Medicine [36].
b – Institute of Medicine [37].
c – Institute of Medicine [38]; UL – Tolerable Upper Intake Level; PTDI – Provisional Tolerable Daily Intake; ND – no data.
* – applies only to supplemental magnesium for healthy adults.
# – Adequate Intake (AI).
– Recommended Dietary Allowance (RDA).

Table 6
Participants' mean daily macromineral intakes by locations compared with recommendations.

Metal	Ogun (n = 383)	Abuja (n = 349)	Recommended Intake (AI/RDA)	UL/PTDI
MINERAL	(mg/person/day)			
Potassium	2010 ± 780 (71.0, 24.4, 4.6)	1980 ± 710 (71.9, 25.2, 2.9)	2300–3400[a#]	ND[a]
Sodium	2980 ± 1100* (6.7, 0.3, 93.0)	2500 ± 940 (12.6, 0.3, 87.1)	1500[a#]	ND[a]
Calcium	400 ± 260 (95.3, 4.7, 0.0)	449 ± 330* (95.1, 4.9, 0.0)	1000–1300[b##]	2000–3000[b]
Magnesium	400 ± 140 (27.2, 33.4, 39.4)	387 ± 120 (29.2, 35.5, 35.3)	310-420[c##]	350[c§]

Values represent mean ± standard deviation (SD) (% consuming below recommendation, % consuming within recommendation and safe level, % consuming above recommendation/safe level).
* – Mean value is significantly higher (at $p < 0.05$) than that obtained from the other location; ND – no data.
§ – applies only to supplemental magnesium for healthy adults.
a – National Academies of Sciences, Engineering, and Medicine [36].
b – Institute of Medicine [37].
c – Institute of Medicine [38]; UL – Tolerable Upper Intake Level; PTDI – Provisional Tolerable Daily Intake.
– Adequate Intake (AI).
– Recommended Dietary Allowance (RDA).

reported in some other studies within [39] and outside Nigeria [40–42] on adult populations. This seems like a common trend in various parts of the world, especially those with dietary pattern closer to Western dietary pattern (with higher intakes of processed foods and lower intakes of fruits and vegetables). There is a need for well-planned and implemented strategies to slow down or reverse this trend among Nigerian adults.

Sodium intake by these adult populations is far beyond recommendation (especially for those in Ogun State) perhaps due to the increase in consumption of processed foods and sauces/stews, which have high sodium contents. Furthermore, the large proportion of participants (44.5%) patronizing restaurant services (a day prior to dietary recall data collection day – data not shown) can be a contributory factor; as most outlets often greatly spice their foods with bouillon cubes and similar items, in a stance to attract customers. Cardiovascular diseases including hypertension have been of major public health concern in developed countries and recently in developing countries, as it is one of the prominent risk factors for mortality, as well as stroke, heart and renal diseases [43,44]. High sodium consumption has been implicated as major risk factors for the development of hypertension [45,46]. This led to the WHO target of reducing mean population sodium intake by 30% on or before 2025 [47]. Furthermore, to enhance cardiovascular health, various organizations including the American Heart, Lung and Blood Institute and European Society of Hypertension have recommended intakes of diet low in sodium and fat, and high intake of fruits and vegetables [43,48]. This current finding of high sodium intake might be partly responsible for the alarming prevalence of hypertension among Nigerian Adults – 8%–46% by Ogah et al. [49], 28.9% by Adeloye et al. [50], 27.3% by Ajayi et al. [51] and 55% by Okubadejo et al. [52]. This situation of sodium intake pattern (especially for those in Ogun State) requires prompt public health attention for necessary education and advocacy to relevant stakeholders to reduce sodium and increase potassium intakes; for Nigeria to meet non-communicable disease targets of WHO by 2025, thereby enhancing cardiovascular health for adult population. This is similar to the passionate plea of Noubiap et al. [53] for a positive outcome in sub-Saharan Africa.

The low level of calcium intake by participants in this study is another major concern. It is assumed that this intake pattern does not exist for a prolonged period; otherwise, it can lead the population into a deficiency disease condition. Deficiency of calcium in adult could lead to the development of osteoporosis, a paediatric disease with geriatric consequences [1]. Though this single study may not be appropriate to conclude that Nigerian adults generally have low calcium intake, it is better to take caution by deliberately increasing dietary calcium intake within the adult population to forestall future national challenges on bone health. Hansen et al. [54] established that calcium absorption from small fish was comparable to that from skimmed milk. Thus, to ensure optimal intake of calcium by Nigerian adults, milk is recommended. However, other rich sources including the various fish, "*donkwa*", boiled walnut, locust beans and fried tofu can equally serve as alternatives. Calcium intake from water and perhaps some important sources were not captured in

these analyses and intake estimation, which could be a contributing factor to the low calcium intake estimated here. It is therefore suggested that further studies be carried out on the calcium intakes of more Nigerian adults to establish the true picture. This will enable the adoption of appropriate intervention strategies to ensure the optimal maintenance of bone health of Nigerian adults, and thereby avoid future geriatric consequences that could emanate from lack of necessary action(s).

The dietary intake of magnesium by the study participants is not of too much concern as reasonable percentage of them consumed amounts that were within recommended level. Furthermore, an excessive intake of magnesium is unlikely to yield toxicity, except in those with kidney disorders [55] or those regularly taking magnesium supplements. In most cases, a balanced intake of other macrominerals usually offset the appropriate magnesium need of individuals.

4. Conclusion and recommendations

The report has made available snapshot data on the composition of potassium, sodium, calcium and magnesium in individual food items from Nigeria "as consumed". Commonly consumed foods across Nigeria are highly rich in potassium, sodium, calcium and magnesium. This is the first most extensive data on these macrominerals in commonly consumed Nigerian foods in recent time. The levels of these minerals obtained in most of the food items are similar to those presented for similar foods across some other countries. The analysis and presentation of the data "as consumed" increases the possible use of the results for extrapolating macromineral contributions of these food items to consumer food record, and for estimations by Dietitians to respective patients. It is further envisaged to be useful in updating the data on the 2017 Nigerian Food Composition Table; though major stakeholders should still be encouraged to support the improvement of the Table for optimal content. Most of the participants had very high intakes of sodium and low intakes of potassium and calcium in their diets. Therefore, it is very necessary to educate the participants, especially those within Ogun State, on the need to modify their food choices and preferences in a way that will drastically lower sodium intakes and improve potassium and calcium intakes to enhance cardiovascular health and prevent osteoporosis.

Author contribution statement

Olutayo Sunday Shokunbi: Conceived and designed the experiments; Performed the experiments; Analysed and interpreted the data; Wrote the paper.

Oladejo Thomas Adepoju, Isaac Olaolu Akinyele: Conceived and designed the experiments; Wrote the paper.

Isaiah David Ipfani Ramaite, Oluwatosin Sarah Shokunbi, Paul Eanas Lesedi Mojapelo: Performed the experiments; Wrote the paper.

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Data availability statement

Data included in article/supp. material/referenced in article.

Declaration of interest's statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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