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Assessment of Macro-mineral Content of Restaurant-prepared Lunch Meals on a University Campus in Ghana

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ABSTRACT

Inadequate dietary intake of potassium, calcium, and magnesium, combined with excessive sodium consumption, is a well-established risk factor for cardiovascular diseases, including hypertension. Recent studies have reported increasing prevalence of hypertension among university students and staff in Ghana. Because restaurant-prepared food is a major source of lunch meals for this population, it is imperative to assess the macro-mineral composition of these meals. Therefore, this study assessed the sodium, potassium, magnesium and calcium contents of restaurant-prepared lunch meals served on a university campus in Ghana. Fifteen different lunch meals, five from each of three restaurants (A, B and C) were purposively sampled on a university campus in Kumasi, Ghana. Atomic absorption spectrophotometry was performed to analyze the macro-mineral contents of homogenized and chemically digested food samples. Banku with grilled tilapia dish from restaurant C had the highest sodium content (174.40 mg). Fufu and groundnut soup dish from restaurant A had the highest potassium content (212.50 mg). In the present study, Jollof rice with chicken dish from restaurant A had the highest calcium content (165.74 mg). Levels of magnesium were high across the three restaurants. Except for magnesium, the macro-mineral contents of the meals were considerably lower than the recommended dietary allowance. There were no statistically significant differences in the macro-mineral contents of the food samples across the three restaurants ($p > 0.05$). This study found that restaurant-prepared lunch meals had low amounts of sodium, potassium and calcium, and high amounts of magnesium. Findings from this study could inform campus food policy decisions to improve the health of the university community and curb the rising prevalence of hypertension among university students and staff in Ghana.

Keywords: *Macro-minerals, mineral analysis, restaurant-prepared meals, University campus, cardiovascular disease, Ghana*

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INTRODUCTION

Cardiovascular diseases (CVDs) are among the leading causes of death globally (WHO, 2021). In sub-Saharan Africa (SSA), the prevalence of CVDs increased by 132% between 1990 and 2019 while the number of deaths from the disease doubled within the period (Alhuneafat *et al*., 2024). According to Zhou *et al*., (2021), the prevalence of hypertension in SSA was 48% and 34% in women and men respectively. In Ghana, the prevalence of hypertension in adults ranges between 27% to 30% with the highest prevalence rates occurring in the more urbanized parts of the country (Atibila *et al*., 2021; Bosu and Bosu, 2021). Rising prevalence of hypertension is an emerging health challenge across university campuses in Africa (Akintunde *et al*., 2014; Alinaitwe *et al*., 2024), including Ghana (Aryeetey and Ansong, 2011; Gyamfi *et al*., 2018). Aryeetey and Ansong (2011) reported a hypertension prevalence of 34% among university staff in a Ghanaian university. A relatively low hypertension prevalence of 2.2% was reported by Gyamfi *et al*., (2018) among undergraduate students in a Ghanaian university, however the 26.1% prevalence of pre-hypertension among the young students is very alarming.

Unhealthy diet and lifestyle practices have been implicated in the rise of hypertension in sub-Saharan Africa contexts including Ghana (Gafane-Matemane *et al*., 2024). This has been attributed to the dramatic shift from a traditional dietary pattern, which is predominantly plant-based with high fibre, low added salt, low sugars and low saturated/trans-fat content, to a more refined westernized dietary pattern high in sodium, sugars and saturated/trans-fat (Aliyu and Amadu, 2017; Ndong *et al*., 2022). Macro-minerals are a class of essential minerals required in larger quantities for optimal human health. Sodium, potassium, magnesium and calcium are important macro-mineral nutrients naturally occurring in food in varied amounts (Gupta and Gupta, 2014). Plant-based foods are typically high in potassium and magnesium. Although sodium is naturally present in food, levels are typically high in processed foods due to high quantities of salt added for preservation and taste enhancement (Calliope and Samman, 2020; Hutton, 2002; Jachimowicz-Rogowska and Winiarska-Mieczan, 2023). Dairy products are major sources of dietary calcium in most regions of the world. In the Ghanaian diet, anchovies, small fish typically consumed with the bones, are a significant source of dietary calcium (Agyei-Mensah *et al*., 2023; Litaay *et al*., 2023). The recommended dietary allowance (RDA) for sodium for adults is less than 2g sodium (2000 mg)/day equivalent to 5 g (one teaspoon) salt per day (WHO, 2025). The average RDA for magnesium for adults is 240 mg/day for both men and women (260 mg/day (men) and 220 mg/day (women)) (FAO/WHO, 2002). The requirement for potassium is 3500 mg per day for adults (WHO, 2013). The recommended calcium intake for adults is 1000 mg calcium per day (FAO/WHO, 2002). Sodium, potassium, magnesium and calcium are key the minerals emphasized in the popular Dietary Approaches to Stop Hypertension (DASH) diet (Sacks *et al*., 2001). The DASH dietary pattern promotes high intake of potassium, calcium and magnesium, and low intake of sodium, refined sugars and saturated fats to lower blood pressure and improve cardiovascular health (Sacks *et al*., 2001). According to the WHO the mean dietary intake of sodium is 10.78 g/day which is more than twice the recommended sodium intake of < 5 g/day (WHO, 2025). The majority (~ 75%) of sodium consumption is from processed foods with the remainder from naturally occurring sodium (~15%) and added salt (~15%) (Jachimowicz-Rogowska and Winiarska-Mieczan, 2023). Excessive sodium tends to inactivate endothelial nitric oxide synthase, decreasing the synthesis of the vasodilator nitric oxide thereby increasing plasma levels of dimethyl L- arginine, an inhibitor of nitric oxide, resulting in high blood pressure (Fujiwara *et al*., 2000).

High dietary potassium has been shown to hyperpolarize endothelial cells through vascular smooth muscle cells which causes vasodilation and low blood pressure (Chan *et al*., 2024). Additionally, Chan *et al*., (2024) indicated that potassium also causes negative sodium balance thereby blunting out the sodium effects on blood pressure. Adequate dietary consumption of calcium has also been shown to reduce high blood pressure (Sacks *et al*., 2001). Low calcium intake has been suggested to stimulate levels of calcitriol hormone which increases influx into vascular smooth muscle cells leading to vasoconstriction and elevated blood pressure (Villa-Etchegoyen *et al*., 2019). Magnesium stimulates the production of nitric oxide and prevents the influx of calcium ions into the cells of the vascular tissue by acting as a natural calcium channel blocker (Kostov and Halacheva, 2018).

Both staff and students on university campuses in Ghana tend to patronize out-of-home restaurant-prepared foods and other convenient fast foods on campus, especially at lunchtime, due to proximity, convenience and time constraints resulting from high academic workload and other responsibilities. Studies elsewhere indicated that meals vended by small food retailers tend to be high in at least one negative nutrient (Li *et al*., 2022) especially sodium (Jachimowicz-Rogowska and Winiarska-Mieczan, 2023). In light of the rising hypertension prevalence among university populations in Ghana (Aryeetey and Ansong, 2011; Gyamfi et al., 2018), it is crucial to assess the macro-mineral content of commonly consumed campus meals. Therefore, this study aimed to determine the levels of sodium, potassium, magnesium, and calcium in restaurant-prepared lunch meals on a university campus in Ghana.

METHODOLOGY

Study design

This study employed a cross-sectional design to assess

Table 1: Food samples collected across the three restaurants.

Food samples* by Restaurant					
Restaurant A	**Weight (g)**	**Restaurant B**	**Weight (g)**	**Restaurant C**	**Weight (g)**
Plain boiled rice, tomato stew with fried chicken	500	Jollof rice, fried fish, *shito* (hot fried pepper sauce) and sautéed salad (cabbage, carrots, green peppers)	673	Chips and grilled chicken, sautéed vegetables (cabbage, carrots, green peppers), ketchup, *shito* (hot fried pepper sauce)	570
Banku (boiled fermented corn balls), Okra soup and fish	1,159	Plain rice, chicken, tomato stew and sautéed salad (cabbage, carrots, green peppers)	708	Fried rice and fried chicken, *shito* (hot fried pepper sauce)	650
Fufu (pounded cassava and plantain), Groundnut soup and fish	1,217	*Fufu* (pounded cassava and plantain), light soup and goat meat	886	*Banku* (boiled fermented corn balls) with grilled tilapia, vegetables (green pepper, carrots, onions, tomatoes), *shito* (hot fried pepper sauce), ketchup and ground red pepper	1,046
Jollof rice, fried chicken and salad (cabbage, carrots)	697	*Banku* (boiled fermented corn balls) with grilled tilapia, vegetables (green pepper, carrots, onions, tomatoes), *shito,* ketchup and ground red pepper	1,046	*Ampesi* (boiled yam and plantain) with *Palava* sauce and fried fish	958
Ampesi (boiled yam and plantain) with *Palava* (garden eggs) sauce and fried fish	958	*Red-red* (cooked beans stew and fried plantain) with grilled chicken	1,022	*Fufu* (pounded cassava and plantain), light soup and goat meat	886

*The constituent of the dishes in the local name are defined in parenthesis.

macro-mineral content in restaurant-prepared lunch meals between January to May, 2019.

Study site

The study was conducted at Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana, where three restaurants were randomly selected from a total of five on campus. For ethical reasons, identifying information about the restaurants has been withheld; hence, they are referred to as Restaurants A, B, and C.

Sample collection

Purposive sampling technique was used to purchase a total of fifteen (15) restaurant-prepared lunch meals. The meals were purchased anonymously to prevent bias in their preparation. The five restaurants had different foods on their daily menu. The purposive sampling method was employed because it afforded an easy selection of foods from the different foods on the restaurants' menu to ensure samples reflect the foods on the menu (Table 1).

Sample preparation and analysis

Food samples collected from various restaurants were homogenized to ensure that the subsample used for analysis was representative of the bulk. The food samples were homogenized in the Food Science laboratory of the Department of Food Science, KNUST. Wet digestion procedure was performed to dissolve organic matter components of the homogenized food samples in the laboratory of the Department of Chemistry, KNUST. Atomic absorption spectrophotometry was performed in duplicate samples to determine the macro-mineral (sodium, potassium, magnesium and calcium) concentrations at the Central laboratory, KNUST.

Wet digestion

Wet digestion followed a triple acid method. Two grams (2 g) of each homogenized food sample were weighed using a calibrated analytical balance (Ohaus Ranger 3000, China) and transferred into 50 mL digestion tubes. One milliliter of distilled water was added to each tube and mixed thoroughly. A 1:1 mixture (v/v) of 4 mL HCl/HNO_3 and 5 mL H_2SO_4 was added. The tubes were incubated at 200 °C for 30 minutes in a Biobase BJPX-2102X incubator (China) and then cooled at room temperature for another 30 minutes. After cooling, the digests were diluted to a final volume of 50 mL with deionized water and filtered. Filtrates were used for the mineral analysis in accordance with the AOAC guidelines (AOAC, 2023).

Atomic absorption spectrophotometry

The atomic absorption spectrophotometer Model Nov AA 400P (Germany) was used to quantitatively measure the sodium, potassium, magnesium, and calcium concentrations of the resultant solutions according to the wavelengths of 589nm, 766.5nm, 285.2nm, and 422.7nm (Chekri *et al*., 2010).

Statistical analysis

Data were processed using Microsoft Excel (2016).

Table 2: Macro-mineral content per 100g of food samples from Restaurant A

Food Samples	Macro-mineral contents per 100 g of Sample			
	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)
Plain rice, stew and chicken	13.71	11.37	0.48	13.26
Banku, Okra soup and fish	14.47	13.47	1.38	62.25
Fufu, Groundnut soup and fish	12.74	17.46	1.50	73.50
Jollof rice and chicken, salad (cabbage, carrots), ketchup	15.95	12.63	23.78	120.44
Ampesi (boiled yam and plantain) with *Palava* sauce and fried fish	13.61	17.42	2.41	182.14

Table 3: Macro-mineral content per 100g of food samples from Restaurant B.

Food Samples	Macro-mineral contents per 100 g of Sample			
	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)
Jollof rice and fried fish, *shito*, salad (sautéed cabbage, carrots, green pepper)	15.91	10.33	5.82	29.76
Plain rice and Chicken, tomato stew, salad (sautéed cabbage, carrots, green pepper)	16.17	14.07	4.51	50.22
Fufu, light soup and goat meat	11.87	12.92	0.69	35.77
Banku with Grilled Tilapia, vegetables (green pepper, carrots, onions, tomatoes*), shito,* ketchup and ground red pepper	14.21	12.56	0.92	35.93
Red-red (cooked beans and fried plantain) with Grilled chicken	8.55	12.01	0.36	77.58

Results were expressed as means ± standard deviations. One-way ANOVA was conducted to assess mean differences between the macro-mineral content of foods across the three restaurants, with statistical significance set at $p < 0.05$

RESULTS

Macro-mineral contents of food samples in each of the three restaurants

Table 2 presents the macro-mineral content per 100g of food samples from Restaurant A. The results show that *Ampesi* (boiled yam and plantain) with *palava* sauce and fried fish had the highest magnesium content (182.14 mg). *Jollof* rice, fried chicken and salad had the highest sodium (15.95 mg) and calcium (23.78 mg) contents respectively. *Fufu* with groundnut soup and fish had high potassium content (17.46 mg). Plain rice, stew and chicken had the lowest concentrations of magnesium (13.27 mg), calcium (0.48 mg) and potassium (11.37 mg) while *fufu* with ground nut soup and fish had low sodium concentration (12.74 mg).

From Table 3, the macro-mineral content per 100g of food samples from Restaurant B showed that *Red-red* with grilled chicken had the highest magnesium content (77.58 mg). Plain rice, chicken, tomato stew and salad had the highest sodium (16.17 mg) and potassium (14.07 mg) contents respectively. *Jollof* rice with fried fish, *shito* and salad had the highest concentrations of calcium (5.82 mg) and lowest concentrations of magnesium (29.76 mg) and potassium (10.33 mg). *Red-red* with grilled chicken had the lowest sodium (8.55 mg) and calcium (0.36 mg) contents correspondingly. Results on the macro-mineral contents of food samples from Restaurant C are shown in (Table 4).

The results show that *Ampesi* (boiled yam and plantain) with *palava* sauce and fried fish had the highest magnesium (124.04 mg) and calcium (2.75 mg) contents. Potato chips with grilled chicken and sautéed vegetables had high the highest potassium content (18.47 mg). *Banku* with grilled tilapia had the highest sodium concentration (16.67 mg). Fried rice with fried chicken and sautéed vegetables had the lowest levels of magnesium (30.63 mg), potassium (11.13 mg) and sodium (11.51 mg) whereas potato chips and grilled chicken with sautéed vegetables (0.56 mg) had the lowest calcium levels.

Average macro-mineral contents of food sample across the three restaurants

Table 5 shows the average macro-mineral content per 100g food sample across the three restaurants. Across the three restaurants, mean sodium, calcium and magnesium contents of the food samples were highest in restaurant A with 14.10 mg, 5.91 mg and 90.32 mg respectively. Potassium content was highest in restaurant C with 14.92 mg. There were no significant differences ($p > 0.05$) in the mean macro-mineral contents of foods analyzed across the three restaurants.

Macro-mineral contents of whole food samples

The total macro-mineral contents of the whole food samples, as obtained from each restaurant, were compared to one-third of the recommended dietary allowance for each of the macro-minerals. Table 6 presents the macro-mineral content of the whole food samples analyzed from restaurant A. Plain rice with stew and chicken had the lowest sodium (68.56 mg), potassium (56.85 mg), calcium (2.40 mg) and magnesium (66.28 mg) contents. *Banku* with okra soup and fish had the highest sodium content (167.70 mg). *Fufu* with groundnut soup and fish had the highest amount of potassium (212.50 mg). *Jollof* rice with fried chicken and salad had the highest levels of calcium (165.74 mg). *Ampesi* (boiled yam and plantain) with *palava* sauce and fried fish had the highest amount of magnesium (1744.90 mg).

Table 4: Macro-mineral content per 100g of food samples from Restaurant C.

Food Samples	Macro-mineral contents per 100 g of Sample			
	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)
Chips and grilled chicken, sautéed vegetables (cabbage, carrots, green pepper), ketchup, *shito*	15.14	18.45	0.56	75.25
Fried rice with fried chicken, sautéed vegetables (cabbage, carrots, green pepper), shito	11.51	11.13	1.69	30.27
Banku and grilled tilapia, vegetables (green pepper, carrots, onions, tomatoes), *shito*, ketchup, ground red pepper	16.67	14.93	1.15	102.31
Ampesi (boiled yam and plantain) with *Palava* sauce and fried fish	12.56	15.94	2.75	124.04
Fufu, light soup and goat meat	14.60	14.12	1.43	112.19

Table 5: Average macro-mineral content per 100g of food sample by restaurant.

	Macro-mineral contents per 100 g of Sample			
Macro-mineral (mg)	**A** Mean±SD	**B** Mean±SD	**C** Mean±SD	**p- values**
Sodium	14.60±1.20	13.34±3.18	14.60±2.06	0.837
Potassium	14.47±2.81	12.38±1.37	14.91±2.67	0.237
Calcium	5.91±10.01	2.46±2.52	1.52±0.81	0.494
Magnesium	90.32±63.93	45.86±19.27	88.81±37.35	0.236

Table 6: Macro-mineral contents per total weight (g) of food samples from Restaurant A.

Food Samples	Macro-mineral contents per total weight (g) of Sample			
	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)
Plain rice, stew and chicken	68.56	56.85	2.90	66.28
Banku, Okra soup and fish	167.70	156.09	15.98	721.48
Fufu, Groundnut soup and fish	154.99	212.50	18.23	894.50
Jollof rice with chicken, salad (cabbage, carrots), ketchup	111.18	88.04	165.74	839.45
Ampesi (boiled yam and plantain) with *Palava* sauce and fried fish	130.36	166.91	23.10	1744.90

Table 7: Macro-mineral contents per total weight (g) of food samples from Restaurant B

Food Samples	Macro-mineral compositions per total weight (g) of Sample			
	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)
Jollof rice and fried fish, *shito*, salad (sautéed cabbage, carrots, green pepper)	107.04	69.52	39.19	200.29
Plain rice and Chicken, tomato stew, salad (sautéed cabbage, carrots, green pepper)	114.46	99.60	31.94	355.59
Fufu, light soup and goat meat	105.15	114.48	6.08	317.06
Banku with grilled tilapia, vegetables (green pepper, carrots, onions, tomatoes), *shito*, ketchup and ground red pepper	148.67	131.41	9.59	375.80
Red-red (cooked beans and fried plantain) and Grilled chicken	87.34	122.71	3.68	792.86

Table 8: Macro-mineral contents per whole food samples from Restaurant C.

Food Samples	Macro-mineral contents per total weight (g) of Sample			
	Sodium (mg)	Potassium (mg)	Calcium (mg)	Magnesium (mg)
Potato Chips and grilled chicken, sautéed vegetables (cabbage, carrots, green pepper), ketchup, *shito*	86.29	105.14	3.19	428.90
Fried rice with fried chicken, sautéed vegetables (cabbage, carrots, green pepper), *shito*	74.80	72.36	11.00	196.74
Banku and grilled tilapia, vegetables (green pepper, carrots, onions, tomatoes), *shito*, ketchup and ground red pepper	174.40	156.15	12.04	1070.12
Ampesi (boiled yam and plantain) with Palava sauce and fried fish	120.31	152.70	26.33	1188.33
Fufu, light soup and goat meat	129.33	125.09	12.67	994.01

Table 7 shows that in Restaurant B, *Banku* with grilled tilapia, had the highest sodium (148.67 mg) and potassium (131.41 mg) content. *Red-red* with grilled chicken had the highest levels of magnesium (792.86 mg) while *Jollof* rice with fried fish, and salad had the highest calcium content (39.19 mg). *Red-red* with grilled chicken had the lowest levels of sodium (87.34 mg) and calcium (3.68 mg). The lowest levels of potassium (69.52 mg) and magnesium (200.29 mg) levels were found in *Jollof* rice with fried fish and salad. From Table 8 it was observed that in restaurant C sodium (174.40 mg) and potassium (156.15 mg) contents were highest in *Banku* with grilled tilapia while calcium (26.33 mg) and magnesium (1188.33 mg) levels were highest in *Ampesi* (boiled yam and plantain) with *palava* sauce and fried fish. Fried rice with fried chicken and sautéed vegetables had the lowest levels of sodium

Table 9: Average macro-mineral content of the whole food samples across the three restaurants.

Macro-mineral (mg)	$\frac{1}{3}RDA$	Macro-mineral content of whole food samples			
		A Mean±SD	**B** Mean±SD	**C** Mean±SD	**p-value**
Sodium	666.67	126.54 ±36.10	112.53±22.52	117.03 ±39.31	0.810
Calcium	333.33	45.09 ±67.80	18.10 ±16.29	13.04 ±8.35	0.601
Potassium	1166.67	136.08 ±62.80	106.94±24.27	123.01 ±34.88	0.432
Magnesium	80	852.72±598.66	408.32±225.45	775.62±435.91	0.281

(74.80 mg), potassium (72.36 mg) and magnesium (196.74 mg) respectively. Potato chips with grilled chicken and sautéed vegetables (3.19 mg) had the lowest calcium levels.

Average macro-mineral content of the whole food samples across the three restaurants

Table 9 shows that the mean sodium (126.54 ±36.10 mg), potassium (136.08 ±62.80 mg), calcium (45.09±67.80 mg) and magnesium (852.72±598.66 mg) contents between the three restaurants were highest in restaurant A. Average sodium, potassium and calcium contents in all three restaurants were below one-third the RDA while magnesium levels exceeded one-third of the RDA. There were no significant differences ($p > 0.05$) in the average macro-mineral contents of foods across the three restaurants.

DISCUSSION

Mineral content of food products can differ depending on the source and quality of raw ingredients, processing methods and conditions used (Gupta and Gupta, 2014). The results show that sodium content was generally low in all meals analyzed. The WHO recommends less than 2 000 mg of total sodium intake per day for adults (WHO, 2025). Because this study focused on lunch meals, it is expected that the sodium content of the meals would contribute to one-third of the recommended RDA for sodium. Among all foods sampled from each restaurant, the plain rice dish had the lowest sodium content while the *Banku* with grilled tilapia dish had the highest sodium content but was still considerably lower than the RDA for sodium. There was no significant difference in the sodium content of meals across the three restaurants. Food items included in the meals, such as beans, fresh or frozen vegetables, fresh poultry and fish amongst others are generally low in sodium. This could partially explain the low sodium levels observed in the restaurant meals in this present study. Ghanaian cuisines are typically cooked from scratch and tend to have prolonged cooking/preparation times including soaking, boiling/steaming, frying and stewing. In a low-resourced setting like Ghana, where access to cold storage facilities is limited, these cooking methods tend to serve as protective measure against microbial proliferation. However, it could lead to a loss of essential micronutrients. Prolonged cooking could potentially have contributed to the reduction in sodium levels in the restaurant meals analyzed in this study through leaching during cooking (Bethke and Jansky, 2008). All the meals from the three restaurants had significantly low sodium content compared to the RDA for sodium. The low amounts of sodium in all the meals from the three restaurants are desirable since sodium reduction in the diet is recommended to prevent hypertension and cardiovascular disease (Sacks *et al*., 2001; WHO, 2025). The restaurant operators on KNUST campus should be encouraged to maintain the low sodium content of their dishes as part of strategies to curb the high risk of hypertension reported among students and staff (Gyamfi et al., 2018).

Unlike sodium, loss of potassium through leaching because of the cooking methods is not a desirable effect. This is because potassium is an essential mineral required for controlling blood pressure (Chan *et al*., 2024). It would be expected that high potassium levels would be observed in the lunch meals from the three restaurants because they include potassium-rich foods like potatoes and vegetables like tomatoes used in preparing the salads, stew, *shito* (hot fried pepper sauce), and soups. However, the potassium levels of the meals were generally low with no significant differences across the three restaurants. *Fufu* and groundnut soup dish from restaurant A had the highest amount of potassium which was still far lower than one-third of the RDA for potassium. The groundnut component of the *fufu* dish could have influenced the relatively high potassium content since groundnuts are a rich source of potassium. All the rice dishes had the lowest levels of potassium, with the plain boiled dish having the lowest potassium level. This is not surprising because rice is known to contain small amounts of potassium. Food vended from food outlets tends to contain small portions of vegetables (Todd *et al*., 2010) which would not have had a significant effect on the potassium content of the whole rice dish. Additionally, processing methods like prolonged soaking of corn for preparing *Banku* and boiling and decanting off excess water during preparation of *Ampesi* (plantain and yam) and *Fufu* (plantain and cassava) could drastically reduce the potassium content of the dishes. This could potentially explain the low potassium levels observed in all the dishes, even though they include potassium-rich food ingredients. The low potassium

content of the meals across the three restaurants does not align with the DASH dietary recommendation for high dietary potassium to lower blood pressure (Sacks *et al*., 2001). Since processing could lower the potassium content of the food samples in this study, the portion of potassium-rich uncooked vegetables could be increased to help consumers meet their potassium requirements.

In the present study, *Jollof* rice with chicken dish from restaurant A had the highest calcium content while the plain rice dish from restaurant A had the lowest calcium content. The levels of calcium in the meals were lower than one-third of the RDA. There was no significant difference in the calcium content of meals across the three restaurants. The main sources of dietary calcium are milk and dairy cereals, legumes, fish, vegetables and dried fruits. Milk and dairy products are by far the best sources of calcium (Miller *et al*., 2001) which were not common in the food samples analyzed in this present study. Low calcium content of the dishes in this present study could be attributed to the low calcium components. The relatively high levels of calcium in the Jollof rice and chicken dish could be attributed to the chicken. The restaurant operators should be encouraged by campus food policy makers to adopt innovative recipes to increase the calcium content of their dishes to align with the DASH dietary recommendation (Sacks *et al*., 2001) to lower the prevalence of high blood pressure among the university community (Gyamfi et al., 2018).

Magnesium is the only mineral that exceeded the RDA in this present study. The levels far exceeded the 220-260 mg/day required. High magnesium values were recorded in the *fufu* with groundnut soup, *Ampesi* with *palava* sauce, and *Red-red* dishes. No significant differences were observed in the magnesium content of meals across the three restaurants. The high magnesium levels observed in these dishes could be due to the presence of good sources in dishes - groundnut in the *fufu* dish, vegetables (cocoyam leaves) in the *Ampesi* dish and beans (cowpea) in the *Red-red* dish. The low levels of magnesium in some of the dishes (cereal-based dishes) could also be attributed to the removal of the germ and outer layers of cereal grains which account for more than 80% loss in magnesium (Oghbaei and Prakash, 2016). Although the high magnesium content across the three restaurants is desirable in the context of the DASH diet, the excessive amounts above the RDA could be counter-effective due to the potential to competitively inhibit absorption and bioavailability of calcium.

This present study focused on the macro-mineral content of the restaurant-prepared dishes. However, several factors can affect the bioavailability of the macro-minerals in the dishes. For instance, the bioavailability of magnesium and calcium in the predominantly plant-based meals sampled across the three restaurants could be influenced by different factors including presence of inhibitors like oxalates/phytates and competition with other divalent mineral ions like iron. Because calcium, magnesium and iron use similar transport mechanisms for intestinal absorption, their bioavailability could be inhibited by high levels of one of the three. In the context of this present study, the high magnesium levels could competitively inhibit calcium absorption. Future studies should include assessment of phytate content and potential competitive inhibition by other divalent minerals on the bioavailability of calcium and magnesium (Costello et al., 2021).

In summary the sodium, potassium and calcium contents across the three restaurants were below one-third of the RDA while magnesium far exceeded one-third of the RDA. There were no statistically significant differences in all the macro-mineral contents of the meals vended across the three restaurants in this present study. The low potassium and calcium levels are not appropriate for cardiovascular risk protection, especially against hypertension. However, the low sodium levels and high magnesium levels in the meals are desirable for optimal cardiovascular health.

Strengths and limitations of the study

The focus of this study on the analysis of macro-mineral content of foods patronized by a population with rising prevalence of hypertension is a strength. Findings from this study could inform campus food policy decisions to improve the health of students and staff and curb the rising prevalence of hypertension among the university community in Ghana. The use of atomic absorption spectrophotometry is also a strength as it affords analytical precision. However, there are some limitations that could limit the generalizability of the study findings. The food samples were sampled from restaurants within a single university campus in Ghana. Additionally, different recipes, cooking methods and sources of food ingredients in each of the restaurants could potentially influence the macro-mineral content of the food samples. In view of these, future studies should include greater variability of foods, cooking methods as well as the sources of the foods to enhance generalizability.

Conclusion

The restaurant-prepared lunch meals analyzed in this study had low amounts of sodium, potassium and calcium, and high amounts of magnesium. The levels of sodium, potassium, and calcium in the meals were lower than the RDA, while magnesium content exceeded the RDA. Only sodium and magnesium levels are desirable for cardiovascular health. The cooking methods used during the meal preparation process could have contributed to significant leaching of the macro-mineral contents. Future studies should investigate the impact of the cooking methods on the macro-mineral content of the meals.

Authors' contributions

CAA was involved in the study conception, study design,

literature research, supervision of data collection, data analysis, write up and critical review of the manuscript. PA was involved in the study design, literature search, data collection, data analysis and write-up. FEA was involved in the write up and critical review of the manuscript. ES was involved in the write-up and critical review of the manuscript. All authors approved the final manuscript.

Competing interests

The authors declare no competing interest.

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