Assessment of the Nutritional Quality of Meals Served at the Abidjan Penitentiary Center: Implications for Inmate Health

Abstract

The nutritional quality of meals served in prisons is crucial for inmate health. However, it is often overlooked in developing countries like Côte d'Ivoire. This study aims to assess the nutritional value of meals served at the Abidjan Penitentiary Center (PPA). Standard biochemical analyses determined the macro- and micronutrient content of cooked meals served to male inmates in January and July. The average weekly nutritional intake of each nutrient was then calculated. The results reveal that two meals are served daily at PPA, in accordance with national regulations. These meals were often monotonous, especially in July. Breakfasts were low in calories, while most lunches were hypercaloric. However, the meals were insufficient in both quantity and quality. Most (73%) daily intakes of macro- and micronutrients did not meet half of the nutritional recommendations. Significant deficits in calories, lipids, potassium, and vitamin B1 were also observed, exposing inmates to risks of nutritional deficiencies and associated diseases. In conclusion, the diet at PPA is inadequate, necessitating a revision of food policies to ensure optimal nutrition. Diversifying menus and increasing portion sizes should be priority actions to improve inmate health.

Keywords: Prison food, Nutritionaldeficiencies, Inmatehealth, Pôle Pénitentiaire d'Abidjan, Côte d'Ivoire.

1. Introduction

The global prison population has significantly increased, rising from 8 million inmates in 2000 to over 11 million in 2021 **(Penal Reform International and Thailand Institute of Justice, 2021**), representing a 24% increase. In Africa, the number of prisoners has grown by 32%. While incarceration rates vary from country to country, Côte d'Ivoire stands above the median rate for West African countries (85/100,000 compared to 44.5/100,000), nearly doubling the median rate, yet remains below the global average of 144/100,000 inhabitants **(Fair and Walmsley, 2021**).

In 2021, the Ivorian prison administration counted an average of 25,121 inmates, with the majority being men (93.53%), for a capacity estimated at 7,885 inmates. This corresponds to an occupancy rate of 318.59% (**CNDH, 2022**). Overcrowding and poor nutrition are common issues in African prisons (**Cook *et al.*, 2015**).

In Côte d'Ivoire, the daily cost of feeding an inmate is 200 FCFA (**CNDH, 2022**), equivalent to approximately 0.33 USD/0.31 EUR. This amount is insufficient to ensure optimal nutrition for inmates. An inadequate diet can lead to chronic and deficiency-related diseases **(Bennett and Coninx, 2005; Ahoua *et al.*, 2007; Mathenge *et al.*, 2007**). Adequate nutrition plays a crucial role in the reintegration process of inmates, as certain nutrients are involved in maintaining responsible behavior (**Meyer *et al.*, 2015**). Indeed, vitamin and mineral supplementation has been shown to reduce aggressive behavior, while hypoglycemia is strongly linked to episodes of aggression (**Benton, 2007**).

Food, being a fundamental human need and a key determinant of behavior, must be provided optimally in the prison environment, as inmates rely entirely on prison meals to meet their nutritional needs.

Several reports have highlighted the poor quality of meals provided in Ivorian prisons (**CNDH, 2022**). However, there is no data evaluating the quality and nutritional value of these meals in Côte d'Ivoire, unlike in some African prisons (**Agyapong *et al.*, 2018; Kalonji *et al.*, 2021**). To inform the food and nutrition policy of prison authorities, a study was conducted to assess the nutritional intake of the meals provided to inmates in Côte d'Ivoire's largest prison, the Abidjan Penitentiary Center (in French, PôlePénitentiaired'Abidjan (PPA)).

2. Materials and Methods

2.1. Materials

The meals consumed during the day by the inmates of the Abidjan Penitentiary Center (PPA) were used for biochemical analyses. Only the meals provided by the PPA's standard prison rations were analyzed.

2.2. Methods

2.2.1. Data Collection

2.2.1.1. Gathering Information on Consumed Meals

The menu registers for the second weeks of January and July 2022 were consulted to obtain detailed information on the usual diet of the PPA inmates. This allowed verification that the food ingredients supplied to the kitchen by the storekeeper corresponded to the meals prepared and served to the inmates.

The collection of information focused on the two daily prison meals provided to the male inmates: breakfast and lunch, served respectively at 7 a.m. and 9 a.m. It is important to note that this collection did not include food that inmates could purchase from private prison vendors or receive from relatives. It also excluded food provided to female inmates, as they received and prepared their meals independently.

2.2.1.2. Determination of the Nutritional Value of Consumed Meals

The daily meals were collected in 30*20 cm ADF aluminum bags with self-forming insulation. They were then stored in coolers to maintain freshness until reaching the laboratory. At the laboratory, the meal samples were stored in a freezer at -18°C for subsequent analyses. In this study, a total of 16 meals or menus were analyzed (**Table I**).

The analyses focused on evaluating 15 parameters of the food rations: moisture, total proteins, total lipids, available carbohydrates, dietary fiber, energy value, ash, sodium, potassium, calcium, phosphorus, magnesium, iron, zinc, and vitamin B1.

Moisture, total protein, total lipid, dietary fiber, and ash contents were determined using the triple trial method (**Yépié*et al.*, 2021**). The ash obtained was used to determine the mineral profile (sodium, potassium, calcium, phosphorus, magnesium, iron, and zinc) using a Scanning Electron Microscope equipped with an X-ray detector (OXFORD Instruments). The available carbohydrate content was estimated by differential calculation (**FAO/INFOODS, 2015a**). The energy value was calculated using the metabolizable energy conversion factors known as Atwater's general factors (**FAO/INFOODS, 2015b**). Vitamin B1 was analyzed using the fluorometric method outlined by the AOAC (1990), procedure number 953.17 for vitamin B1, which involves extraction with 0.1N HCL for 1 hour, autoclaving (20 min/109°C), centrifugation (20 min/3500 rpm), oxidation, and fluorescence measurements of the thiochrome compound.

2.2.2. Nutritional Analysis of the Meals

A food survey conducted among male inmates determined the average portions consumed by individuals for each meal. These portions, representing the quantity of food consumed, were estimated using plastic cups of 15, 20, and 30 cL. The number of cups used was based on the number of inmates occupying a cell.

To obtain the nutritional intake for each meal, the nutritional value of each dish obtained in section 2.2.1.2 was multiplied by the quantity consumed as determined by the survey.

2.2.3. Determination of Weekly Nutritional Intake of Inmates

The nutritional intake from the two daily meals for each inmate was summed to obtain their total daily nutritional intake. The sum of daily intakes was then divided by 7 to obtain the average weekly nutritional intake. This was then compared to the recommended values for the 15 parameters mentioned above to assess whether the nutritional needs of the inmates were met.

The average energy requirement of the inmates was calculated by multiplying the basal metabolic rate (BMR) by the physical activity level (PAL). The BMR was determined using the Harris-Benedict equation, taking into account the median age, height, and weight of the inmates, which were 32 years, 174 cm, and 64 kg, respectively. A PAL of 1.2 was adopted since the majority had little or no physical activity.

The recommended daily intakes of nutrients were calculated based on the age group 18-50 years using the Nutrisurvey 2007 software, as the majority (76.2%) of male inmates in Côte d'Ivoire were aged 18 to 40 years.

2.2.5. Statistical Analyses

The collected data were first entered into Excel 2013. Then, statistical analysis was performed using GraphPad Prism version 8.4.3. The results are expressed as mean ± standard error. The comparison of means was conducted using either t-tests (for two means) or Tukey's test (for three or more means), following a one-way ANOVA at a 5% significance level.

2.4. Ethical Considerations

Authorization for the study was granted by the Directorate of Prison Administration of Côte d'Ivoire (No. 101 MJDH/DAP) prior to data collection in the PPA.

3. Results and Discussion

3.1. Menus Served During Two Periods of the Year

The meals consumed throughout the day by inmates at the Abidjan Penitentiary Center (PPA) were used for biochemical analyses. Only the dishes provided by the PPA's penal ration were analyzed (**Table I**).

It was observed that the breakfast menus during both study periods were monotonous. In January, maize porridge was exclusively consumed every day of the week. In July, although rice porridge was the main breakfast served during the week, it was often sweetened, specifically two days out of seven.

Regarding the lunch menus, they varied during the two periods and were mainly composed of a main dish (sauce, etc.), a side dish (rice, yam, etc.), and a protein source (meat, beans, etc.) (**Table I**). The main dish in July consisted of various sauces, while in January, it alternated between sauce and paste. The side dish varied in January (rice, yam, attiéké) but was monotonous in July (rice). Both animal proteins (beef, fish) and plant proteins (soybean, beans) were served during the two periods. Additionally, rice was the main ingredient in both breakfast and lunch menus during the entire week of July. This monotony could lead to nutritional deficiencies, particularly in micronutrients.

Table I: Weekly menus served to inmates in January and July at the PPA

Periods (Months)	Days	Breakfast		Lunch	
		Codes	Description	Codes	Description
January	1	PD1	Maize porridge	DEJ1	Boiledyam + Fish paste
	2	PD1	Maize porridge	DEJ2	Rice + Peanut-okra sauce + Beef
	3	PD1	Maize porridge	DEJ3	Beans + Fish
	4	PD1	Maize porridge	DEJ4	Jollofrice + Fish
	5	PD1	Maize porridge	DEJ5	Attiéké (cassava couscous) + Fish paste
	6	PD1	Maize porridge	DEJ6	Jollofrice + Beef
	7	PD1	Maize porridge	DEJ7	Soybeans + Fish Soja + poisson
July	8	PD2	Rice porridge	DEJ8	Rice + Okra sauce + Beans
	9	PD3	Sweetenedrice porridge	DEJ9	Rice + Peanut sauce + Beef leg
	10	PD2	Rice porridge	DEJ10	Rice + Eggplant sauce + Beans
	11	PD2	Rice porridge	DEJ11	Rice + Dried okra sauce + Fish

12	PD2	Rice porridge	DEJ12	Rice + Peanut sauce + Beans + Fish
13	PD3	Sweetenedrice porridge	DEJ13	Rice + Eggplant sauce + Beans + Fish
14	PD2	Rice porridge	DEJ14	Rice + Dried okra sauce + Beans + Fish

3.2. Biochemical Analysis of breakfast Menus

The biochemical analysis of the breakfast porridges (**Table II**) showed that the rice porridge with sugar was statistically more energetic (62.62 ± 0.10 kcal) than the sugar-free rice (50.80 ± 0.07 kcal) and maize porridges (49.57 ± 0.08 kcal). However, the maize porridge was the most nutritious as it was richer in protein, lipids, and minerals, with the exception of calcium.

Table II: Nutritional Values (per 100 g) of Breakfast Menus Served at PPA

Parameters	PD1	PD2	PD3
Energy (kcal)	49.57 ± 0.08^{c}	50.80 ± 0.07^{b}	62.62 ± 0.10^{a}
Water (g)	86.77 ±0.32^{a}	87.14 ± 0.00^{a}	84.22 ±0.01^{b}
Total Proteins (g)	1.26±0.01^{a}	1.03±0.00^{b}	0.99 ± 0.01^{c}
Total Lipids (g)	0.49±0.01^{a}	0.13±0.00^{b}	0.13 ±0.00^{b}
Available Carbohydrates (g)	10.01 ±0.01^{c}	11.35 ±0.06^{b}	14.37±0.01^{a}
Dietary Fiber (g)	1.02± 0.00^{a}	0.15±0.00^{b}	0.15 ± 0.00^{b}
Ash (g)	0.22 ± 0.01^{a}	0.16 ± 0.01^{b}	0.15 ± 0.00^{b}
Sodium (mg)	2.64 ± 0.01^{a}	2.38 ± 0.00^{b}	2.37 ± 0.01^{b}
Potassium (mg)	29.39 ± 0.13^{a}	18.32 ± 0.05^{b}	18.13 ±0.01^{b}
Calcium (mg)	8.29 ±0.01^{c}	10.92 ±0.03^{a}	10.56±0.02^{b}
Phosphorus (mg)	22.34 ±0.01^{a}	17.24 ±0.02^{b}	16.66±0.00^{c}
Iron (mg)	0.48 ±0.02^{a}	0.26 ± 0.02^{b}	0.27±0.02^{b}
Zinc (mg)	0.32 ± 0.01^{a}	0.25 ± 0.05^{ab}	0.21 ± 0.01^{c}
Magnesium (mg)	13.91 ± 0.06^{a}	5.44 ± 0.02^{b}	5.29 ± 0.01^{c}
Vitamin B1 (mg)	0.05 ± 0.02^{a}	0.02 ± 0.00^{b}	0.02 ± 0.00^{b}

Each value represents the mean ± standard error (n = 3 repetitions). After one-way ANOVA, mean comparisons were performed using Tukey's test at the 5% threshold. In a given row, values with different superscript letters differ significantly ($p < 0.05$).

3.3. Biochemical Analysis of Lunch Menus

For the lunches, the biochemical analysis revealed varying levels of different parameters (**Table III**). DEJ1, DEJ2, DEJ4, DEJ5, and DEJ6 were the most caloric, with values ranging from 136.9 ± 0.00 to 152.2 ± 4.87 kcal, and were also the richest in carbohydrates (19.62 ± 0.41 to 29.35 ± 3.91 g), except for DEJ2 (16.34 ± 1.14 g). In terms of proteins, DEJ3, DEJ6, and DEJ7 were the highest, with levels ranging from 9.54 ± 0.25 to 10.73 ± 0.36 g. Lipids were particularly high in DEJ2 (6.60 ± 0.80 g) and DEJ7 (5.53 ± 0.20 g). DEJ7 also recorded the highest fiber content of 10.42 ± 0.41 g and, along with DEJ1, the highest ash content, with values of 2.53 ± 0.20 g and 2.91 ± 0.21 g, respectively.

Overall, the lunches served in January were the most caloric and nutrient-dense due to the rich sauces provided in the July menus. Consequently, the July menus were more hydrating, with water content ranging from 71.20 ± 0.03 g (DEJ12) to 75.98 ± 0.26 g (DEJ9).

Regarding micronutrients, the January lunches were also the richest. DEJ7 was particularly high in potassium (600.4 ± 0.25 mg), iron (2.83 ± 0.21 mg), magnesium (97.54 ± 0.29 mg), and thiamine (0.17 ± 0.02 mg), while DEJ6 was the richest in calcium (299.4 ± 0.30 mg), phosphorus (273.6 ± 0.11 mg), and zinc (1.58 ± 0.38 mg) (**Table IV**).

Table III: Nutritional Values (per 100 g) in Macronutrients of Lunch Menus Served at the PPA

Parameters	Energy (kcal)	Water (g)	Total Proteins (g)	Total Lipids (g)	Available Carbohydrates (g)	Fibers (g)	Ashes(g)
DEJ1	140.2 ± 3.66 ^{ab}	59.42 ± 0.60 ^{e}	7.44 ± 0.95 ^{c}	2.10 ± 0.32 ^{d}	22.90 ± 0.76 ^{b}	5.24 ± 0.13 ^{b}	2.91 ± 0.21 ^{a}
DEJ2	152.2 ± 4.87 ^{a}	64.03 ± 0.80 ^{d}	6.86 ± 0.57 ^{c}	6.60 ± 0.80 ^{a}	16.34 ± 1.14 ^{c}	4.45 ± 0.40 ^{c}	1.72 ± 0.18 ^{c}
DEJ3	117.7 ±0.35 ^{c}	66.69 ± 0.08 ^{c}	9.54 ± 0.25 ^{ab}	1.41 ± 0.36 ^{de}	16.44 ± 0.31 ^{c}	3.89 ± 0.10 ^{c}	2.19 ± 0.17 ^{b}
DEJ4	136.9 ± 0.00 ^{b}	65.33 ± 0.13 ^{cd}	7.59 ± 0.37 ^{c}	2.49 ± 0.37 ^{d}	21.51 ± 0.46 ^{b}	1.61 ± 0.23 ^{f}	1.67 ± 0.15 ^{c}
DEJ5	145.3 ± 12.25 ^{a}	61.62 ± 2.82 ^{de}	3.53 ± 0.42 ^{d}	1.54 ± 0.19 ^{de}	29.35 ± 3.91 ^{a}	2.44 ± 0.25 ^{e}	1.53 ± 0.23 ^{c}
DEJ6	150.9 ± 0.10 ^{a}	62.78 ± 0.08 ^{d}	10.73 ± 0.36 ^{a}	3.46 ± 0.39 ^{c}	19.62 ± 0.41 ^{bc}	1.53 ± 0.37 ^{f}	2.33 ± 0.28 ^{b}
DEJ7	116.8 ± 0.02 ^{c}	64.46 ± 0.07 ^{cd}	10.52 ± 0.09 ^{ab}	5.53 ± 0.20 ^{b}	6.61 ± 0.35 ^{d}	10.42 ± 0.41 ^{a}	2.53 ± 0.20 ^{ab}
DEJ8	84.68 ± 1.32 ^{e}	75.59 ± 0.24 ^{a}	2.33 ± 0.00 ^{f}	0.91 ± 0.03 ^{f}	16.80 ± 0.41 ^{c}	3.14 ± 0.09 ^{d}	1.24 ± 0.04 ^{c}
DEJ9	96.17 ± 0.78 ^{d}	75.98 ± 0.26 ^{a}	2.88 ± 0.03 ^{e}	2.08 ± 0.09 ^{de}	16.50 ± 0.42 ^{c}	1.66 ± 0.02 ^{f}	0.91 ± 0.03 ^{cd}
DEJ10	90.13 ± 1.07 ^{de}	75.49 ± 0.23 ^{a}	2.48 ± 0.01 ^{e}	0.89 ± 0.03 ^{f}	18.06 ± 0.35 ^{c}	2.09 ± 0.04 ^{ef}	1.00 ± 0.03 ^{cd}
DEJ11	94.54 ± 0.86 ^{d}	72.85 ± 0.11 ^{b}	3.11 ± 0.04 ^{e}	1.00 ± 0.04 ^{f}	18.27 ± 0.34 ^{c}	3.44 ± 0.10 ^{cd}	1.33 ± 0.05 ^{c}
DEJ12	115.2 ± 0.10 ^{c}	71.20 ± 0.03 ^{b}	4.15 ± 0.09 ^{d}	2.76 ± 0.12 ^{d}	18.45 ± 0.33 ^{c}	2.27 ± 0.05 ^{e}	1.16 ± 0.04 ^{c}
DEJ13	102.5 ± 0.49 ^{d}	73.44 ± 0.14 ^{ab}	3.37 ± 0.05 ^{de}	1.81 ± 0.07 ^{de}	18.21 ± 0.34 ^{c}	2.12 ± 0.04 ^{ef}	1.06 ± 0.04 ^{cd}
DEJ14	92.38 ± 0.96 ^{d}	73.48 ± 0.14 ^{ab}	2.93 ± 0.03 ^{e}	0.86 ± 0.03 ^{f}	18.23 ± 0.34 ^{c}	3.26 ± 0.10 ^{cd}	1.25 ± 0.04 ^{c}

Each value represents the mean ± standard error (n = 3 repetitions). After a one-factor ANOVA, means were compared using Tukey's test at a 5% significance level. In the same column, values with different superscript letters represent significant differences ($p < 0.05$).

Table IV : Nutritional Values (per 100 g) in Micronutrients of Lunch Menus Served at the PPA

Parameters	Na (mg)	K (mg)	Ca (mg)	P (mg)	Fe (mg)	Zn (mg)	Mg (mg)	Vit B1 (mg)
DEJ1	290.0 ± 53.26 ^{a}	424.4 ± 4.03 ^{b}	195.4 ± 31.81 ^{b}	183.6 ± 24.29 ^{b}	2.11 ± 0.10 ^{b}	1.25 ± 0.11 ^{a}	25.78 ± 1.09 ^{f}	0.03 ± 0.00 ^{d}
DEJ2	290.3± 35.92 ^{a}	226.4 ± 24.02 ^{d}	61.80 ± 7.05 ^{d}	94.31 ± 5.13 ^{d}	1.10 ± 0.06 ^{d}	1.28 ± 0.10 ^{a}	53.91 ± 4.83 ^{c}	0.07 ± 0.01 ^{b}
DEJ3	280.3± 0.23 ^{a}	328.2 ± 0.29 ^{c}	28.31 ± 0.08 ^{e}	143.3 ± 0.11 ^{c}	2.36 ± 0.27 ^{b}	1.41 ± 0.28 ^{a}	64.60 ± 0.30 ^{b}	0.06 ± 0.00 ^{b}
DEJ4	315.8± 0.22 ^{a}	131.2 ± 0.09 ^{f}	196.5 ± 0.25 ^{b}	196.6 ± 0.28 ^{b}	1.55 ± 0.33 ^{c}	1.22 ± 0.06 ^{a}	22.58 ± 0.22 ^{fg}	0.04 ± 0.00 ^{d}
DEJ5	317.5± 66.64 ^{a}	196.8 ± 31.59 ^{de}	17.61 ± 2.27 ^{e}	42.01 ± 7.56 ^{f}	0.90 ± 0.15 ^{d}	0.24 ± 0.04 ^{c}	12.23 ± 1.66 ^{h}	0.04 ± 0.00 ^{d}
DEJ6	301.5± 0.48 ^{a}	154.6 ± 0.36 ^{f}	299.4 ± 0.30 ^{a}	273.6 ± 0.11 ^{a}	1.81 ± 0.18^{bc}	1.58 ± 0.38 ^{a}	24.35 ± 0.19 ^{f}	0.04 ± 0.00 ^{d}
DEJ7	238.8± 0.20 ^{a}	600.4 ± 0.25 ^{a}	112.6 ± 0.29 ^{c}	162.5 ± 0.34 ^{c}	2.83 ± 0.21 ^{a}	1.46 ± 0.29 ^{a}	97.54 ± 0.29 ^{a}	0.17 ± 0.02 ^{a}
DEJ8	195.8± 9.09^{b}	165.1 ± 6.16^{ef}	45.79 ± 1.90 ^{d}	57.82 ± 0.22^{ef}	0.79 ± 0.01 ^{d}	0.53 ± 0.00 ^{b}	38.17 ± 1.08 ^{e}	0.03 ± 0.00 ^{d}
DEJ9	230.9± 10.72 ^{a}	54.73 ± 1.01 ^{h}	12.20 ± 0.34 ^{e}	51.43 ± 0.07^{ef}	0.53 ± 0.00 ^{e}	0.46 ± 0.00 ^{b}	19.58 ± 0.21 ^{g}	0.04 ± 0.00 ^{d}
DEJ10	197.6± 9.17^{b}	123.3 ± 4.21 ^{f}	11.37 ± 0.30 ^{e}	51.73 ± 0.06^{ef}	0.92 ± 0.01 ^{d}	0.46 ± 0.00 ^{b}	18.19 ± 0.15 ^{g}	0.03 ± 0.00 ^{d}
DEJ11	196.6± 9.12^{b}	186.8 ± 7.17^{ef}	47.16 ± 1.97 ^{d}	69.82 ± 0.78 ^{e}	0.96 ± 0.02 ^{d}	0.64 ± 0.01 ^{b}	43.66 ± 1.34 ^{d}	0.04 ± 0.00 ^{d}
DEJ12	275.1± 12.78 ^{a}	95.33 ± 2.91 ^{g}	15.20 ± 0.48 ^{e}	70.63 ± 0.82 ^{e}	0.77 ±0.01 ^{d}	0.62 ± 0.01 ^{b}	28.65 ± 0.64 ^{f}	0.05 ± 0.00 ^{c}
DEJ13	197.7± 9.17^{b}	143.6 ± 5.16 ^{f}	13.26 ± 0.39 ^{e}	62.52 ± 0.44^{ef}	1.00 ± 0.02 ^{d}	0.49 ± 0.00 ^{b}	20.02 ± 0.23 ^{g}	0.03 ± 0.00 ^{d}
DEJ14	189.3± 8.78 ^{b}	175.2 ± 6.63^{ef}	45.60 ± 1.89 ^{d}	67.54 ± 0.68 ^{e}	0.90 ± 0.01 ^{d}	0.62 ± 0.01 ^{b}	41.70 ± 1.25 ^{de}	0.03 ± 0.00 ^{d}

Each value represents the mean ± standard error (n = 3 repetitions). After a one-factor ANOVA, means were compared using Tukey's test at a 5% significance level. In the same column, values with different superscript letters represent significant differences ($p < 0.05$).

3.3. Average Weekly Nutrient Intake of Meals Served in January and July

The average weekly nutrient intake of meals served in January and July at the PPA is detailed in Table V. It is evident that the menus provided in July (637.3 ± 13.31 kcal) are more caloric than those of January (590.8 ± 14.47 kcal), although no statistical difference is observed. Additionally, the July menus are statistically higher in water (622.7 ± 9.78 g vs 463.7 ± 3.71 g) and carbohydrates (124.2 ± 3.42 g vs 92.21 ± 3.18 g). In contrast, the January menus are statistically richer in proteins (29.07 ± 0.73 g vs 17.97 ± 0.18 g), lipids (11.74 ± 0.14 g vs 7.62 ± 0.15 g), fiber (16.27 ± 0.4 g vs 13.08 ± 0.08 g), and minerals (7.51 ± 0.25 g vs 6.05 ± 0.09 g). Regarding minerals, except for sodium, the January menus are statistically richer in potassium, calcium, phosphorus, iron, zinc, magnesium, and vitamin B1.

Furthermore, the menus provided during both periods do not meet the nutritional needs of the detainees. Indeed, these menus cover less than half of the recommended nutritional intake for energy and macronutrients, except for the fiber in the January menus, which meets slightly more than half of the recommendations (54.23%). The same is true for micronutrient recommendations, which were not met by either menu. However, certain nutrients, namely Na from the July menu, Fe and Mg from the January menu, and P from both menus, met more than half of the recommendations, with respective rates of 52.4%, 68.19%, 50.14%, 79.44%, and 50.6%.

Table V: Average Weekly Nutritional Intake of Meals Served in January and July at the PPA

Parameters	RNP	Menus Provided in January		Menus Provided in July	
		M ± SD	% RNP	M ± SD	% RNP
Energy (kcal)	2004.3	590.8 ± 14.47[a]	29.48	637.3 ± 13.31[a]	31.8
Water (g)	2600	463.7 ± 3.71[b]	17.83	622.7 ± 9.78[a]	23.95
Total Proteins(g)	59.2	29.07 ± 0.73[a]	49.10	17.97 ± 0.18[b]	30.35
Total Lipids(g)	68	11.74 ± 0.14[a]	17.26	7.62 ± 0.15[b]	11.21
Available Carbohydrates (g)	286.1	92.21 ± 3.18[b]	32.23	124.2 ± 3.42[a]	43.41
Dietary Fiber (g)	30	16.27 ± 0.4[a]	54.23	13.08 ± 0.08[b]	43.6
Ashes(g)		7.51 ± 0.25[a]		6.05 ± 0.09[b]	
Sodium (mg)	2000	944 ± 57.97[a]	47.2	717.6 ± 10.75 [a]	52.4
Potassium (mg)	3500	1040 ± 32.33[a]	29.71	717,6 ± 10,75[b]	20.50
Calcium (mg)	1000	435.4 ± 18.28[a]	43.54	166.2 ± 3.04[b]	16.62
Phosphorus(mg)	700	556.1 ± 19.50[a]	79.44	354.2 ± 4.51[b]	50.6
Iron(mg)	10	6.82 ± 0.19 [a]	68.19	4.87 ± 0.04 [b]	48.7
Zinc (mg)	10	4.63 ± 0.09[a]	46.31	3.32 ± 0.04[b]	33.2
Magnesium (mg)	350	175.5 ± 3.85[a]	50.14	163.6 ± 1.11[b]	46.74
Vitamin B1 (mg)	1.2	0.34 ± 0.02 [a]	28.33	0.24 ± 0.00[b]	20

Each value represents the mean ± standard error (n = 3 repetitions). Means comparison is performed by the t-test at the 5% threshold. In the same row, values with different superscript letters show significant differences between them ($p < 0.05$). M:mean; SD: standard deviation; RNP: nutritionalrecommendation.

3.4. Discussion

This study, which examines the nutritional content of meals served in Côte d'Ivoire's largest prison (PPA), highlights numerous deficiencies in the quality of the menus offered. These shortcomings can be attributed to the strict nutritional standards imposed on correctional institutions. Indeed, in Côte d'Ivoire, Decree No. 1/MJDHLP/DAP of 07/09/2015, which sets the daily food ration and the provision of hygiene and maintenance products for civilian detainees, states in its first article that: "*Every detainee has the right to receive from the prison, daily and at regular hours, good quality food with sufficient nutritional value to maintain their health and strength, equivalent to at least 2400 kcal per day...*" **(CNDH, 2022)**. Despite this provision, no previous study has verified or validated the nutritional value of meals served in Côte d'Ivoire's prisons.

The menus offered at the PPA included two meals, as stipulated by Article 3 of the aforementioned decree **(CNDH, 2022)**. These meals consist of breakfast and lunch, served at 7 a.m. and 9 a.m., respectively. The close timing of these two meals may force detainees who rely solely on them to endure prolonged fasting periods of up to 20 hours before receiving another meal the next day. This could lead to periods of hypoglycemia, which are strongly linked to episodes of aggression (**Benton, 2007**), commonly observed in overcrowded prisons.

The food items offered in these two daily meals were limited in variety and repetitive, particularly the breakfast options, which were repeated throughout the week. Additionally, the quantities of raw food provided to the kitchen were insufficient. On average, 2600 kg of raw food is supplied daily to the kitchen by the storekeeper. However, according to Article 2 of the decree, the composition of the daily food ration per detainee should include 5 to 6 components: (i) cereals (400g) or tubers (800g); (ii) legumes (130g) or legumes (100g) + animal proteins (30g); (iii) oil (65g) or oil (15g) + oilseeds (50g); (iv) fruits and vegetables (200g); (v) salt and pepper (6g each); and (vi) various spices, sugar, herbs, bread, milk... (optional) **(CNDH, 2022)**. Consequently, a detainee should receive between 807 and 1207g of raw food weight to ensure an adequate diet. This corresponds to a total of 3222 detainees for 2600 kg of raw food. However, during the survey conducted in both periods, an average of 8400 detainees were recorded at the PPA, of which 8113 were men. Thus, each male detainee would receive only about 320g of raw food weight, amounting to an almost insignificant diet.

Moreover, the biochemical analysis of the meals served shows that all breakfasts (PD1, 2, and 3) were low in calories (< 1 kcal/100g). On the other hand, the majority of lunches (9/14 or 64.29%) were high in calories, meaning their consumption could meet the nutritional needs of detainees. However, the small quantities consumed prevent detainees from obtaining adequate nutritional intake. Indeed, the menus for January and July provided an average of only 590.8 ± 14.47 kcal/day (29.48% of the recommended intake of 2004.3 kcal) and 637.3 ± 13.31 kcal/day (31.8%), respectively. As a result, a daily caloric deficit ranging from 1367 to 1413.5 kcal (cumulatively 9569 to 9894.5 kcal per week) would be observed. Therefore, detainees must find additional food sources to meet their caloric needs.

The results of this study contrast with those reported in Ghana by **Agyapong *et al.,* (2018)**, who found that inmates received an energy content exceeding the recommendations. However, that study evaluated nutrient intake using raw ingredients without accounting for the loss from cooking processes. It is therefore likely that the actual nutrients provided were lower than reported. In contrast, the analyses conducted in the present study are based on cooked meals.

Macronutrients were provided in quantities corresponding to at least one-third of the recommendations, except for lipid content (**Table V**). For this under-supplied nutrient, the menus provided to detainees met only 11.21% (July) and 17.26% (January) of the recommendations. This nutrient was under-supplied, yet it contributes a substantial amount of energy to the menu, as 1g provides 9 kcal.

Regarding micronutrients, most (sodium, calcium, phosphorus, iron, zinc, magnesium) were also provided in quantities corresponding to at least one-third of the recommendations, with the exception of potassium and vitamin B1 (**Table V**). For these under-supplied nutrients, the January menus met only 29.71% (potassium) and 28.33% (vitamin B1) of the recommendations, while the July menus met 20.50% (potassium) and 20% (vitamin B1). These results are almost identical to those of **Collins and Thompson, (2012),** who reported that calcium, magnesium, and potassium intakes were below two-thirds of the recommendations.

In this study, all macronutrients and micronutrients were below the recommended levels. Therefore, it is clear that male detainees are at risk of nutritional deficiencies. Deficiency diseases such as beriberi and anemia could arise, as has been the case in several African prisons (**Ahoua *et al.*, 2007; Agyapong *et al.,* 2018**). Indeed, it is very difficult to meet vitamin B1 requirements when consuming less than 1200, or even 1400 kcal per day(**Souccar, 2012**).

Moreover, an insufficient level of calcium was noted in the menus for both periods, with a more pronounced deficiency in the July menus, which provided only 166.2 ± 3.04 mg or 16.62% of the recommendations. **Gould *et al.* (2013)** indicated that a very low calcium intake (137 mg) was correlated with the absence of dairy products in prison meals. Similarly, insufficient intake of this mineral was reported by **Cook *et al.*(2015)**. However, the January menus had a statistically higher calcium content, likely due to the presence of cruciferous vegetables (cabbage) in the meals. Indeed, their calcium is particularly well absorbed, ranging from 40% to 60% (approximately 30% for milk) (**Souccar and Houlbert, 2023**).

However, given the high phosphorus content, the menus analyzed in January and July were characterized by a Ca:Pratio of 0.78 and 0.47, respectively. An unfavorable ratio (< 0.7) could lead to calcium loss in urine (**Yépié *et al.*, 2021**), arterial calcification, and bone loss (**Adatorwovor *et al.,* 2015)**. The correct ratio between these two minerals is estimated to be around 1.5:1 **(Calvo and Tucker, 2013**).

To conclude, the results indicate that Ivorian prisons, particularly the largest one, are facing a shortage of nutrients. This makes them more vulnerable and food insecure. Stakeholders should therefore focus on improving the supply of nutrients in prisons.

3.5. Limitations

It is important to note that the present results are based solely on the analysis and consumption of prison meals and do not include foods that inmates may cook, buy, and/or receive from their families. Another limitation of the findings is the lack of knowledge regarding whether all prisoners consume the same meal portions. This is related to the complexity of prison hierarchy and confinement in cells. Further research is therefore needed to deepen our understanding of prisoners' diets and their impact on the nutritional status and health of inmates.

Conclusion

Good nutrition is essential for health. The findings of this study suggest that the food provided to inmates is inadequate and insufficient. The menus, often repeated throughout the week, lacked variety. The nutrient intake from these menus was below the recommended levels. This could lead to nutritional deficiencies and even chronic diseases in the long term. These consequences represent a burden for governments, especially in developing countries like Côte d'Ivoire. Therefore, providing optimal nutrition should be a priority in the prison system. This includes diversifying the menu, increasing the quantities of all food groups, particularly fruits, vegetables, and oil. However, improving the nutritional quality of inmates' diets may prove challenging due to the low financial expenditure allocated for food purchases.

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