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Research Article

Impact of Dietary Diversification on the Anthropometric and Vitamin Status of School-Age Children in the Nawa Region (Cote d'Ivoire)

Mousso Jean Maurel Allico[1, *], Adou Koffi Kunindjani[1], Gninfanni Silvere Ouattara[2], Adouko Edith Agbo[3, 4], Christophe Kouame[4], Allico Joseph Djaman[5, 6]

[1]Nutrition Research Centre, National Institute of Public Health, Abidjan, Cote d'Ivoire
[2]Department of Biochemistry and Genetics, Peleforo Gon Coulibaly University, Korhogo, Cote d'Ivoire
[3]Food Science and Technology Department, Nangui ABROGOUA University, Abidjan, Cote d'Ivoire
[4]Agricultural Science, International Center of Agroforestry Research, Abidjan, Cote d'Ivoire
[5]Health and Biology, Félix Houphouët-Boigny University, Abidjan, Cote d'Ivoire
[6]Fundamental and Medical Biochemistry, Pasteur Institute of Cote d'Ivoire, Abidjan, Cote d'Ivoire

Abstract

In Cote d'Ivoire, there is a disparity between dietary intake and nutritional needs among school-age children. Studies have shown that dietary diversification could offer a solution. A study was therefore conducted to assess the impact of dietary diversification on the anthropometric and vitamin profiles of students in school cafeterias in the Nawa region. This study took place from October 2017 to May 2018 in school cafeterias in 12 localities in the Nawa region. It included 240 school-aged children aged 6 - 12, divided into four groups of 60 students. Four types of meals were offered to the four groups: rice with tomato sauce and fish, sweet potato stew enriched with green soybeans, sweet potato stew enriched with white cowpeas, and sweet potato stew enriched with cowpeas and soybean balls. Anthropometric measurements were based on the standardized method of the World Health Organization and the United Nations Children's Fund. Concurrently, blood samples were collected before meal consumption (Phase 0), three (3) months later (Phase 1), and six (6) months later (Phase 2). Blood levels of vitamin A were measured using high-performance liquid chromatography (HPLC). In this study, the mean age ranged from 8.62 to 10.25 years, with a significant difference ($p < 0.01$) between Group 2 (10.25 years) and Group 1 (8.60 years). An increase in the children's weight, height, and body mass index was observed six months after food consumption. Before the children began eating school meals (phase 0), adequate vitamin A levels were observed. Vitamin A levels decreased in groups 1, 2, and 3 from phase 0 to phase 2. However, they increased in children in group 4 from 0.5 to 0.8 mg/L. In this study, an increase in weight, height, and body mass index was observed among children who consumed the various meals in the study. Furthermore, an improvement in vitamin A status was more pronounced among children who consumed the meal based on sweet potato, soybeans, and cowpeas. This dish could be selected as a suitable option for dietary diversification in school cafeterias.

*Correspondence: Mousso Jean Maurel Allico (allico87@gmail.com)

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Keywords

Dietary Diversification, West Africa, School Cafeteria, Vitamin

1. Introduction

Malnutrition remains a widespread problem worldwide, even though reducing hunger is one of the Millennium Development Goals [1]. Indeed, it affects all age groups, but young children and women of childbearing age are the most vulnerable [2]. Furthermore, it is worth noting that many children worldwide, particularly those from low-income populations, start school with stunted growth, low weight, and/or multiple micronutrient deficiencies due to an unbalanced diet [3].

In Cote d'Ivoire, micronutrient deficiency malnutrition is a public health problem due to its high prevalence. It affects the learning and cognitive abilities of school-age children [4]. In the NAWA region, the prevalence of malnutrition among school-age children was 18.36% [5]. In 2014, surveys conducted among rural populations and in certain primary schools in the region revealed that 80% of households had a diet with little variety, consisting mainly of tubers and grains [6]. Furthermore, field surveys in school cafeterias in this region revealed that only one type of meal was served-namely, rice and fish-alternating on different days of the week with no variation in the menu. Thus, there appears to be an imbalance between dietary intake and the nutritional needs of these school-age children. It is therefore necessary to diversify their diet by introducing foods rich in micronutrients [7]. Foods that can provide these nutrients and are readily available in this area include sweet potatoes, soybeans, and cowpeas [7]. The nutritional value of these foods has been proven [8]. Indeed, the sweet potato (Ipomoea batatas Lam) is energy-dense and rich in vitamins (A, C), minerals, dietary fiber, and protein [9]. As for soybeans (Glycine max) is classified as an oilseed and protein crop due to the high content of macronutrients, micronutrients, and secondary metabolites in its seeds [10]. As for cowpeas (Vigna unguiculata L. Walp), they represent an important source of protein for populations [11]. It is also rich in micronutrients, particularly betacarotene and vitamin E [12].

Furthermore, it should be noted that during this period of nutritional deficiency, variations in body composition (anthropometry) were observed, depending on nutritional needs and caloric intake [13]. These variations are believed to be associated with dietary habits and an imbalance between caloric intake and energy expenditure [14]. Consequently, this leads to underweight conditions and stunted growth during childhood, which are much more clearly observed in adulthood [15].

Micronutrients such as vitamins are essential to human health [16]. During periods of malnutrition, significant disturbances in vitamin A status have been observed among school-age children [17]. Vitamin A deficiency is a major public health problem, particularly in low-income countries. It is one of the leading causes of morbidity and mortality among those with an insufficient dietary intake of vitamin A [18].

Today, despite advocacy for health and nutrition services in primary schools, there is a clear lack of data on the actual nutritional status of children in this age group in developing countries, particularly in Cote d'Ivoire [19]. Few studies address the effect of dietary diversification on anthropometric and vitamin status [20].

Thus, given the importance of these parameters in nutritional balance, an assessment among these children could better contribute to the prevention of malnutrition-related diseases.

The objective of this study is therefore to examine the impact of consuming a variety of dishes made from sweet potatoes, soybeans, and cowpeas on anthropometric and vitamin status in school-age children in Cote d'Ivoire, specifically in the Nawa region (southwest).

2. Materials and Methods

2.1. Materials

2.1.1. Study Population

The study population consisted of students aged 6 to 12 years enrolled in twelve (12) public schools in twelve different localities across four departments (Buyo, Gueyo, Meagui, and Soubre) in the Nawa region of southwestern Cote d'Ivoire.

2.1.2. Ethical Approval

Before beginning data collection, ethical approval was obtained from the National Research Ethics Committee (Ref: 009//MSHP/CNER-kp). Village authorities and school principals were contacted and informed prior to the study's commencement in their respective communities. Similarly, informed, written, and signed consent was obtained from each parent or legal guardian of the student after explaining the purpose and benefits of the study.

2.2. Methodology

2.2.1. Determination of Sample Size

The sample size was calculated using the Leslie-Fischer

formula, based on the prevalence of chronic malnutrition (18.36%) among children in this area [5].

$$n = \frac{z^2 p(1-p)}{i^2}$$

z: confidence level (standard value for a 95% confidence level 1.96).

p: proportion of children suffering from chronic malnutrition estimated at 18.36% in the area.

i: margin of error or precision set at 5%.

n: minimum sample size for obtaining statistically significant results.

2.2.2. Sampling of Subjects

Sampling was carried out following a survey using a standardized questionnaire covering the socio-demographic data of children from the 12 localities, with 20 students per school.

2.2.3. Inclusion and Exclusion Criteria

This study included children aged 6 to 12 years. The students' general health was assessed by a health worker prior to the study. Students with chronic illnesses or a family history of medical conditions were excluded.

2.2.4. Meal Preparation

For the preparation of the meals, rice, fish, sweet potato, soybeans, and cowpea were used. The meals were prepared according to the following method:

1) Meal 1: Boiled rice with tomato sauce and fish
2) Meal 2: Sweet potato stew enriched with green soybeans
3) Meal 3: Sweet potato stew enriched with white cowpea
4) Meal 4: Sweet potato stew with green soybeans enriched with white cowpeas

The students consumed the different meals prepared over the course of a school year in the school cafeterias. The different menus were eaten as lunch in the school cafeteria two days a week (Monday and Thursday), in accordance with their usual eating habits during this period.

School canteens in the region were visited over a six-month period. Each child received between 300 and 500 grams of food. Four groups were formed, with three schools per group:

1) Group 1 (Control): The children were served rice with tomato sauce and fish (staple dish typically served in school cafeterias)
2) Group 2: received sweet potato stew enriched with green soybeans
3) Group 3: received sweet potato stew enriched with white cowpeas
4) Group 4: received sweet potato stew enriched with green soybeans and white cowpeas.

2.2.5. Anthropometric Measurements

Anthropometric measurements were based on the standardized method of the World Health Organization (WHO) and the United Nations Children's Fund [21].

Height was measured using a SECA 206 (FRANCE) adult wall-mounted tape measure graduated in centimeters and affixed to the wall.

Weight (kg) was measured using a mechanical bathroom scale, model M 309800 (GERMANY), in the morning on an empty stomach, followed by emptying the bladder.

Body mass index (BMI) was calculated based on the simple ratio of weight to the square of height

$$\text{BMI} = \text{Weight} / (\text{Height})^2$$

$$\begin{cases} \text{BMI} < 18.5\ \text{kg/m2: underweight} \\ 18.5 < \text{BMI} < 25\ \text{kg/m2: normal} \\ \text{BMI} \geq 25\ \text{kg/m2: over weight} \end{cases}$$

2.2.6. Sampling

The blood draw required a sample to be taken early in the morning between 8 and 9 a.m. A total of three samples were collected at different time points. Before the study, a sample was collected from the children (Phase 0). After three (3) months of consuming the various meals, another sample was collected (Phase 1). And six (6) months after consuming the meals, a final sample was taken (Phase 2). Thus, whole blood at each phase was collected in a dry (red) tube and sent to the laboratory. After centrifugation at 3,000 rpm for five (5) minutes, the serum was aliquoted for the vitamin test (vitamin A).

2.2.7. Vitamin A Assay

The vitamin A assay was performed using UV detection in high-performance liquid chromatography (HPLC) (Waters®, France), following extraction of the fat-soluble vitamin with hexane in the dark according to the methods of Zhang et al. [22]. Thus, 300 µL of serum were sampled and collected in hemolysis tubes previously wrapped in aluminum foil, into which 300 µL of retinyl acetate (internal standard: 1 mg/L) were added. After adding 300 µL of absolute ethanol, the mixture (serum, internal standard, and absolute ethanol) was homogenized by vortexing for 30 to 40 seconds, then 1200 µL of hexane was added. The mixture was vortexed again for 50 seconds. After centrifugation at 3,500 rpm for 15 minutes, 900 µL of hexane supernatant containing the fat-soluble vitamin was evaporated under a stream of nitrogen at a pressure of 0.5 bar. The final residue was dissolved in 300 µL of methanol and placed in the chromatograph for injection. A Waters ODS 2 C18 reverse-phase column (4.0 mm × 25 mm × 5 µm) was used as the stationary phase. The mobile phase consisted of a methanol/water mixture (97/3; v/v) at a flow rate of 1 mL/min. The injection volume was set to 20 µL. Detection was performed in the UV-visible range at a wavelength of 280 nm.

Chromatographic data analysis was performed using Breeze 2 software. The reference range for serum vitamin A is 0.1–0.5 mg/L [23].

2.3. Statistical Analyses

Statistical analyses were performed using GraphPad Prism 5 Demo software. Student's t-test was used to compare the variances of the means. Relationships between the data were assessed using Pearson's chi-square test. A p-value of <0.05 was considered statistically significant. Data are presented as mean ± standard deviation.

3. Results and Discussion

3.1. Anthropometric Profiles of the Children in the Study

In this study, the mean age ranged from 8.62 to 10.25 years, with a significant difference ($p < 0.01$) between Group 2 (10.25 years) and Group 1 (8.60 years) (Table 1). Among children in all groups, a weight increase was observed that was not statistically significant ($p > 0.05$), rising from 25.78 to 31.45 kg compared to Group 1 (Table 1). Furthermore, the group of children who consumed the meal based on sweet potato, soybeans, and cowpeas (Group 4) showed a non-significant ($P > 0.05$) increase in weight gain (4.60 ± 0.30 kg) compared to Group 1 (control) (Figure 1). With regard to height, an increase was also observed in the mean height of the children across the entire study, which ranged from 1.32 to 1.42 m. This increase was significant ($P < 0.05$) at the start of the study in Group 2 (Table 1). Furthermore, children who consumed the meal based on sweet potato, soy, and cowpeas (Group 4) showed a non-significant ($P > 0.05$) increase in height compared to the control group (Figure 2).

In this study, the children's body mass index increased in all groups, with a significant difference ($P < 0.01$) six months after consuming the meals, compared to Group 1 (control) (Table 1).

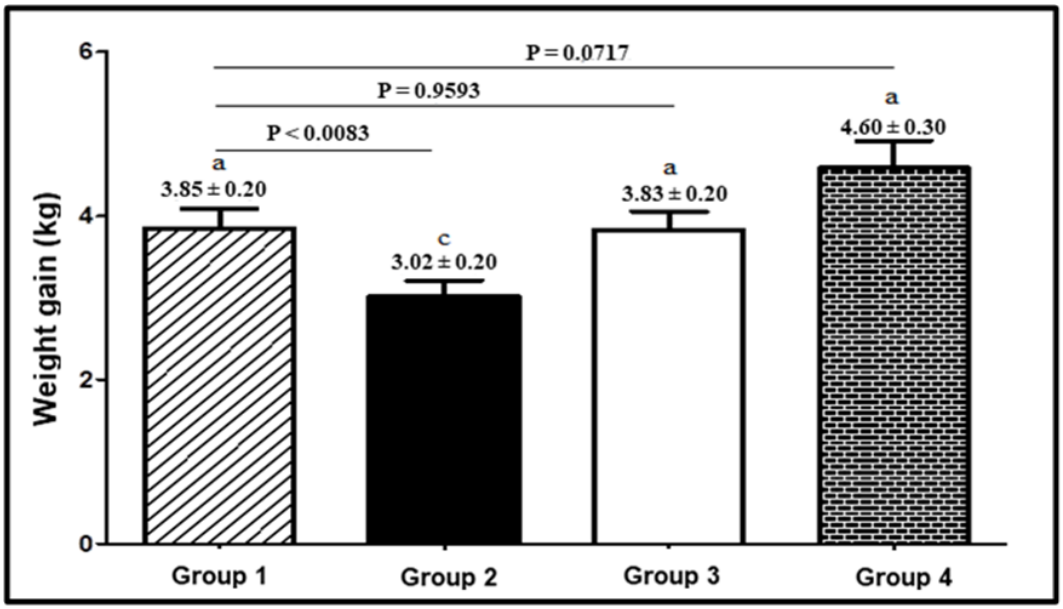


Figure 1. *Comparison of weight gain in the study population.*

Group 1 (Control) = Rice + sauce; Group 2 = Sweet potato + Soybeans; Group 3 = Sweet potato + Cowpeas; Group 4 = Sweet potato + Soybeans + Cowpeas; P value a: Group 1 vs. Group 2; The difference is significant for $P < 0.05$ (Student's t-test). a Not significant compared to Group 1 ($P > 0.05$); b Slightly significant compared to Group 1 ($P < 0.05$); c Significant compared to Group 1 ($P < 0.05$); d Highly significant compared to Group 1 ($P < 0.05$).

Table 1. *Mean values of anthropometric parameters for the study population.*

Parameters	Phases	Group 1 (n = 60)	Group 2 (n = 60)	Group 3 (n = 60)	Group 4 (n = 60)
Age (years)		8.62 ± 0.32 ^{ns}	10.25 ± 0.24**	9.43 ± 0.26 ^{ns}	9.23 ± 0.25 ^{ns}
Weight (kg)	P0	25.78 ± 1.30^{ns}	28.45 ± 0.98 ^{ns}	27.15 ± 1.07^{ns}	25.95 ± 0.9 ^{ns}
	P1	28.22 ±1.45 ^{ns}	30.18 ± 1.03 ^{ns}	29.08 ±1.15 ^{ns}	29.13 ±0.94 ^{ns}

Parameters	Phases	Group 1 (n = 60)	Group 2 (n = 60)	Group 3 (n = 60)	Group 4 (n = 60)
Height (m)	P2	29.63 ±1.39 ^{ns}	31.45 ± 1.05 ^{ns}	30.98 ±1.16 ^{ns}	30.55 ±1.00 ^{ns}
	P0	1.32 ± 0.02 ^{ns}	1.38 ± 0.02*	1.34 ± 0.02 ^{ns}	1.31 ± 0.01 ^{ns}
	P1	1.35 ± 0.02 ^{ns}	1.40 ± 0.02 ^{ns}	1.36 ± 0.02 ^{ns}	1.35 ± 0.01 ^{ns}
	P2	1.38 ± 0.02 ^{ns}	1.42 ± 0.02 ^{ns}	1.37 ± 0.02 ^{ns}	1.37 ± 0.01 ^{ns}
BMI (18,5-25 kg/m2)	P0	14.12 ±0.28 ^{ns}	20.35 ±0.50**	19.90 ±0.52 ^{ns}	14.82 ±0.25 ^{ns}
	P1	14.82 ±0.36 ^{ns}	21.25 ± 0.49**	20.95 ± 0.55*	15.80 ± 0.23*
	P2	15.09 ±0.27 ^{ns}	21.89 ± 0.50**	22.18± 0.56**	16.08± 0.24**

The difference is significant at P < 0.05 (Student's t-test). ns: Not significant compared to group 1 (P > 0.05); * Slightly significant compared to group 1 (P < 0.05); ** Significant compared to group 1 (P < 0.05); *** Highly significant compared to group 1 (P < 0.05).

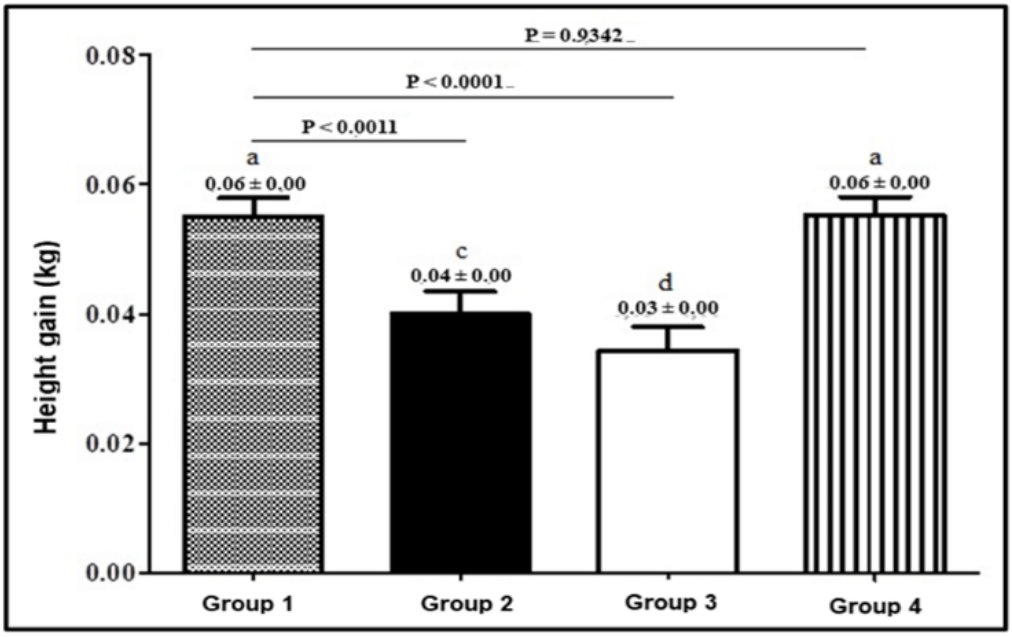


Figure 2. *Comparison of height gain in the study population.*

Group 1 (Control) = Rice + sauce; Group 2 = Sweet potato + Soybeans; Group 3 = Sweet potato+ Cowpeas; Group 4 = Sweet potato + Soybeans + Cowpeas; P value a: Group 1 vs. Group 2; The difference is significant at P < 0.05 (Student's t-test). a Not significant compared to Group 1 (P > 0.05); b Slightly significant compared to Group 1 (P < 0.05); c Significant compared to Group 1 (P < 0.05); d Highly significant compared to Group 1 (P < 0.05)

3.2. Vitamin A Status of the Study Population

Before consuming meals in the cafeteria (phase 0), vitamin A concentrations were 1.0 mg/L, 0.7 mg/L, 0.8 mg/L, and 0.5 mg/L, respectively, among children in groups 1, 2, 3, and 4. Three months after consuming the meals (phase 1), vitamin A levels in children in group 2 decreased significantly ($p < 0.05$) from 0.7 to 0.6 mg/L, while group 4 showed a significant increase ($p < 0.05$) from 0.5 to 0.7 mg/L, compared to group 1 (control). No change was observed in group 3 (0.8 mg/L). Six months later (phase 2), no change in vitamin A levels was observed among groups 1, 2, and 3. However, a significant difference in children's vitamin A levels was noted in group 4 (0.8 mg/L) compared to the control (Table 2). Analysis by group showed that groups 1, 2, and 3 were characterized by a reduction in vitamin A concentration. This decrease was significant ($p < 0.05$) in phase 1 (0.4 mg/L) compared to phase 0 (1.0 mg/L). In Group 4, the vitamin A level increased from 0.5 to 0.8 mg/L. The vitamin A level in Phase 2 differed significantly from that in the other phases (Table 2).

Table 2. Vitamin A status of the study population.

Phases	Group1 (n = 60)	Group 2 (n = 60)	Group 3 (n = 60)	Group 4 (n = 60)
P0	1.0 ± 0.07^{ns}	$0.7 \pm 0.06^{*}$	0.8 ± 0.09^{ns}	$0.5 \pm 0.07^{***}$
P1	0.4 ± 0.05^{ns}	$0.6 \pm 0.05^{**}$	$0.8 \pm 0.18^{*}$	$0.7 \pm 0.10^{**}$
P2	0.6 ± 0.04^{ns}	0.6 ± 0.07^{ns}	0.7 ± 0.17^{ns}	$0.8 \pm 0.10^{*}$

Group 1 (Control) = Rice + sauce; Group 2 = Sweet potato + soybeans; Group 3 = Sweet potato + cowpeas; Group 4 = Sweet potato + soybeans + cowpeas. Phase 0: initial phase without consumption; Phase 1: phase after three months of meal consumption; Phase 2: phase after six months of meal consumption. Vitamin A (0.1-0.5 mg/L). The difference is significant for $P < 0.05$ (Student's t-test). ns: Not significant compared to Group 1 ($P > 0.05$); * Slightly significant compared to group 1 ($P < 0.05$); ** Significant compared to group 1 ($P < 0.05$); *** Highly significant compared to group 1 ($P < 0.05$).

4. Discussion

In this study, the average ages obtained range from 8 to 10 years. This is consistent with the guidelines of the United Nations Educational, Scientific and Cultural Organization (UNESCO), which since 1972 has considered the 6 -11 age range to be primary school age and the 12 -17 age range to be secondary school age. These age averages are relatively high compared to those obtained by Akpole et al. [24] in two school cafeterias in the municipality of Cocody, Cote d'Ivoire. In contrast, our results are similar to those of children in the same age group enrolled in Ghanaian school cafeterias, where the average age was 10 years [25], and to those of Karki et al. [26] in Nepal, with an average age of 9 years. In Guinea-Bissau, a survey of primary school students on malnutrition revealed that the average age ranged from 6 to 11 years [27].

In this study, an increase in children's body weight and height was observed after consuming various foods. Indeed, dietary diversification is essential for providing children with important nutrients [28].

In terms of weight, the results were lower than those reported by Amidu et al. [25], with average weights ranging from 25.78 kg to 31.45 kg, but were broadly similar to those reported by Akpole et al. [24], who found an average body weight of 27.39 kg.

Regarding height, the results obtained are consistent with those of Amidu et al. [25], who found an average height of 1.30 m among children in public elementary schools aged 6 to 12 years. This led to a significant increase in body mass index among the children. Thus, a varied diet allows children to receive adequate amounts of energy and nutrients, which contributes to a body mass essential for maintaining health [28].

As for vitamin A, it is one of the most important and essential nutrients for children [29].

Before eating meals in the cafeteria (phase 0), vitamin A levels were normal (0.1 and 0.5 mg/mL). This suggests that there is no vitamin A deficiency among these children. Children in the control group (Group 1), who consumed rice with sauce, showed a decrease in vitamin A levels in Phases 1 and 2. This suggests that a diet lacking in variety, especially if this is also the case at home, does not improve micronutrient status in general and vitamin A status in particular.

Children who consumed sweet potatoes with soybeans (Group 2) and sweet potatoes with cowpeas (Group 3), respectively, showed decreased vitamin A levels in Phase 1, which stabilized in Phase 2. This decrease could be related to the diet, as the Dietary matrices significantly affect the bioavailability of vitamin A [30]. As for the stabilization of vitamin A levels, this is likely due to sweet potatoes, which are rich in carotenoids [31]. If the cereals consumed are not combined with carotenoid-rich vegetables, as noted by Agbo et al. [6], the risk of vitamin A deficiency would be high because cereals lack carotenoids [32].

In contrast, among children fed sweet potatoes combined with soybeans and cowpeas (Group 4), vitamin A levels increased from the beginning to the end (Phase 2). This could be due to the children's diversified diet (dietary diversification). This is because dietary diversification provides a variety of foods (sweet potatoes, soybeans, and cowpeas) to ensure a balanced intake of nutrients essential for the body's proper functioning. Our results corroborate those of Verger et al. [33], who found that consuming a variety of foods helps meet nutritional needs for vitamins and minerals, thereby contributing to the maintenance of physiological balance and the prevention of nutritional deficiencies. For this reason, it is necessary to increase consumption of this combination namely sweet potatoes, soybeans, and cowpeas-which, after ingestion, are converted into retinol via vitamin A [34].

5. Conclusions

This study demonstrated improvements in weight, height, body mass index, and vitamin A status among children who received the various meals tested in the study. This improvement was most pronounced among children who received the meal made with sweet potatoes, soybeans, and cowpeas. This dish could be selected as a suitable option for diversifying school cafeteria menus to promote children's growth.

These findings open up a new avenue of research into the

long-term effects of this meal on children's growth and nutritional status.

Abbreviations

BMI	Body Mass Index
WHO	World Health Organization
UNICEF	United Nations Children's Fund
COBAS c311	Comprehensive Biochemical Analysis Clinical 311
Mm	Millimeter
Kg	Kilogram
µL	Microliter

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Author Contributions

Mousso Jean Maurel Allico: Conceptualization, Writing – original draft

Adou Koffi Kunindjani: Data curation, Software

Gninfanni Silvere Ouattara: Formal Analysis, Writing – review & editing

Adouko Edith Agbo: Investigation, Methodology

Christophe Kouame: Resources, Supervision

Allico Joseph Djaman: Project administration, Validation

Conflicts of Interest

The authors declare no conflicts of interest.

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