Impact of Food Diversification on the Status of Fat-Soluble Vitamins in School-aged Children in the Nawa Region (Côte d'Ivoire)

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Authors' contributions

This work was carried out in collaboration among all authors. Author DAJ designed the study. Authors AMJM and SKL performed the statistical analysis, wrote the protocol, managed the analyses of the study and wrote the first draft of the manuscript. Authors AAE, BL ,YHF and KC managed the literature searches. All authors read and approved the final manuscript

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ABSTRACT

Introduction: In Côte d'Ivoire, there is an imbalance between the dietary intake and the nutritional requirements of school-aged children. The objective of this study was to analyze the effect of food diversification, namely sweet potato, soya and cowpea, on vitamin A, D and E profiles among school-aged children in Côte d'Ivoire.
Methodology: This study was conducted over eight months (from October 2017 to May 2018). It included 240 school-aged children (6 - 12 years old) who were divided into four groups of 60 pupils. These children consumed food at school canteens in 12 localities of the Nawa region. Four types of

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meals were proposed: rice with fish (Group 1 control), sweet potato porridge accompanied by green soybean (Group 2), sweet potato porridge accompanied by white cowpea (Group 3), and sweet potato porridge accompanied by cowpea with soya balls (Group 4). Three blood samples were collected: Phase 0 (prior to the consumption of the meals), Phase 1 (sampling taken three months later) and Phase 2 (sampling taken six months later). Blood assay for vitamins A, D and E was performed using high performance liquid chromatography (HPLC).

Results: Before the children consumed food at the canteen (phase 0), a sufficient amount of vitamins A, D and E was observed, except for group 4 where a deficiency of vitamin D (<30 ng/mL) was noted. The levels of vitamins A and D decreased in groups 1, 2 and 3 from phase 0 to phase 2. However, they increased in children of group 4 from 0.5 to 0.8 mg/L and from 22 to 28 ng/mL respectively. The vitamin E level increased in all groups from phase 0 to phase 2. The improvement in vitamin E status was more remarkable in the children of group 2 and group 4 with levels varying from 8.5 to 11.8 mg/L and 8.3 to 10.6 mg/L respectively.

Conclusion: Improvements in vitamin A, D, and E status were more pronounced in children who ate sweet potato, soybean, and cowpea meal compared to their mean concentration at the beginning of the study. The sweet potato, soybean, and cowpea-based meal could be chosen as a means of food diversification in school canteens in order to improve the vitamin status of school-aged children.

1. INTRODUCTION

Malnutrition continues to be prevalent throughout the world, although hunger reduction is one of the Millennium Development Goals [1]. Malnutrition affects all age groups, but young children and women of reproductive age are among the groups at greatest risk [2]. Many children around the world, particularly those from low-income populations, begin school with stunted growth while being underweight and/or suffering from multiple micronutrient deficiencies [3].

In Côte d'Ivoire, malnutrition due to a lack of micronutrients is a public health problem because of its prevalence. It affects the capacity of school-aged children to learn and succeed academically [4]. In the agricultural sector, particularly in the Nawa region which is a cocoa-growing area, the prevalence of malnutrition among school-aged children is 18.36% [5]. In 2014, surveys conducted among cocoa-producing populations and some primary schools in the Nawa region revealed that 80% of households had very little variety of food, based mainly on tubers and cereals [6]. According to field surveys, in school canteens of this region, only one type of meal is served twice a week without variation, which is often rice. As a result, a strong imbalance appears between the food intake and the nutritional needs of these school-aged children. Therefore, the diets of school-aged children should be diversified by providing foods rich in micronutrients [7], such as sweet potato [8], soybean [9] and cowpea [10].

Food diversification means "Eat a variety of foods" based on the premise that consuming a wide variety of foods will ensure an adequate intake of essential nutrients and, in turn, will lead to better diet quality and optimal health outcomes [11]. The 2015–2020 Dietary Guidelines for Americans recommend choosing a variety of nutrient-dense foods across and within all food groups, with particular emphasis on variety of vegetables and protein sources [12]. The nutritional management of malnutrition is based on the optimal use of locally available nutrient-rich foods to improve the nutritional status of children and prevent malnutrition [13]. In fact, Agbo et al. [6] have revealed that, among cocoa producers of the Nawa region, sweet potatoes, soya bean and Cowpea are well known, but they are not in their eating habits. Thus, within the framework of the "Vision for change" project, sweet potatoes, soybeans and cowpeas cultivation was introduced in agricultural cooperatives in order to supply school canteens in the Nawa region. Sweet potato (*Ipomoea batatas* Lam) provides energy and is rich in vitamins A and C, minerals (mainly potassium), dietary fiber, and proteins [14]. Soybean (*Glycine max*) is classified in the category of oilseeds owing to the richness of its seeds in macronutrients (proteins, lipids and carbohydrates), micronutrients (minerals and vitamins) and secondary metabolites [9]. Cowpea

(*Vigna unguiculata* L. Walp) represents an important source of protein [15] and is rich in micronutrients [16], including ß-carotene and vitamin E [17].

Nutritionally, tubers have a great potential to provide economical sources of dietary energy, in the form of carbohydrates. In general the protein content of tubers is low ranging from 1 to 2% on a dry weight basis. Moreover, tubers are deficient in most other vitamins and minerals but contain significant amounts of dietary fiber. However, Tubers contain some vitamin C and β-carotene [18]. A growing body of evidence highlights the nutritional quality of legumes. They provide a rich source of energy, protein, dietary fiber, and slowly digested carbohydrate, with a low glycaemic index [19]. Legumes are a good source of B-vitamins, niacin, folic acid, thiamine, and riboflavin, as well as an array of minerals such as iron, zinc, calcium, magnesium, phosphorous, and copper [20].

Micronutrients like vitamins are essential to human health [21]. During malnutrition, strong disruption in vitamin A, D and E status have been noted in school-aged children [22]. Vitamin A deficiency is a major public health problem, especially in developing countries. It is one of the leading causes of morbidity and mortality among those with insufficient dietary vitamin A intake [23]. Since vitamin D is essential for the regulation of the absorption of calcium and phosphates and therefore for normal bone metabolism, its deficiency leads to rickets [24]. Vitamin E deficiency leads to hemolytic anemia, cardiac arrhythmia, or progressive chronic neurological deficit which results in impaired reflexes, peripheral neuropathy, and blindness [25].

Despite the 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 [26]. The same is true for the effect of dietary diversification on them. This study aims to analyze the impact of the consumption of sweet potatoes, soybeans, and cowpeas on vitamin A, D, and E profiles in school-aged children in Côte d'Ivoire.

2. MATERIAL AND METHODS

2.1 Study Population

This is a longitudinal study conducted over one school year (nine months). This study took place

in 12 localities involving four counties (Buyo, Gueyo, Meagui, and Soubré), all belonging to the Nawa region where the "Vision for change" project has established a cocoa rehabilitation program that integrates the assessment of the nutritional status of school-age children attending school canteens. To participate in the study, children needed to be aged between six and twelve years old. In addition, only students who provided their consent and that of their parents participated in the study. Pupils 0-5 years aged and those aged over 12 years, sick children and pupils with the refusal of parents were not included in this study. The general health of the children was certified by a health worker (nurse) of the health district of Soubré before the study was performed.

2.2 Determination of the Sample Size

The sample size was calculated using the Leslie Fischer formula below, considering the prevalence of chronic malnutrition as 18.36% among the children of this area [5].

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

$$n = \frac{(1,96)^2 X 0,1836 \, (1 - 0,1836)}{(0,05)^2}$$

where n = 230 samples,
n: minimum sample size for obtaining significant results at a fixed risk level,
z: confidence level (the typical value for the 95% of confidence level is 1.96),
p: proportion of children suffering from chronic malnutrition estimated at 18.36% in the area [5] and
i: margin of error or precision set at 5%.

Based on a 10% margin of error, the sample size interval is [207; 253]. Therefore, the study included 240 pupils.

2.3 Determination of Vitamins

The determination of vitamins A, D, and E was carried out using UV detection in high performance liquid chromatography (HPLC) (Waters®, France) after the extraction of soluble vitamins from hexane, under shelter from the sunlight, according to the methods of Zaman et al. [27] and Catignani et al. [28]. Thus, 300 μL of serum were taken and collected in hemolysis tubes that were previously wrapped in aluminum

foil, into which 300 µL of retinyl acetate (internal standard: 1 mg/L) were introduced. After the addition of 300 µL of absolute ethanol, the mixture (serum, internal standard, and absolute ethanol) was homogenized by vortexing for 30 to 40 seconds, and then, 1,200 µL of hexane was added thereto. The whole was vortexed again for 50 seconds. After centrifugation at 3,500 turn/min for 15 minutes, 900 µL of hexane supernatant containing the fat-soluble vitamins were evaporated under a stream of nitrogen at a pressure of 0.5 bar. The final residue was taken up in 300 µL of methanol and placed in the chromatograph to be injected. A C18 reverse phase column of Waters ODS 2 type (4.0 mm × 25 mm × 5 µm) was used as stationary phase. The mobile phase involved a methanol/water mixture (97/3; v/v) at a flow rate of 1 mL/min. The injection volume was set at 20 µL. Detection was carried out with UV-visible at a wavelength of 280 nm. Chromatographic data analysis was performed with Breeze 2 software.

The reference serum values for vitamins are as follows: Vitamin A (0.1- 0.5 mg/L) [29], vitamin D [Deficient (<20 ng/mL); Insufficient (20-29 ng/mL); Sufficient (30-100 ng/mL); Toxicity (>100 ng/mL)] [30], and vitamin E (7.8-12 mg/L) [31].

2.4 Sampling

A standardized questionnaire survey was carried out on the socio-demographic data of the 240 students from schools of 12 localities. The pupils were divided into four groups of 60 pupils per county. A total of three blood samples were taken from each participant.

Phase 0: phase concerning blood collection before food consumption;
Phase 1: phase concerning blood collection after three months of food consumption;
Phase 2: phase concerning blood collection after six months offood consumption.

2.5 Preparation of Meals

Ina school calendar year, the students ate different meals made up of rice, sweet potato, soybeans, and cowpeas at the school canteens. The meals were prepared as follows:

2.5.1 Rice with tomato stew and fish

A total of 5 kg of rice were cooked for 30 minutes in a saucepan containing tap water, oil, and onions. The tomato stew was prepared by roasting the onions, garlic, and tomato paste in a little oil, and the whole was allowed to simmer for 30 to 40 minutes with the addition of cooking salt, pepper, and nutmeg.

2.5.2 Sweet potato porridge accompanied by green soybeans

A total of 1 kg of green soybeans was soaked in hot water, then pre-cooked for 30 minutes in water with a little salt. Also, 10 kg of sweet potato were peeled and cut. The onions, tomato paste, and garlic were quickly fried in a little oil, to which the pre-cooked soybeans and water were added. The whole content was simmered for 20 to 30 minutes, followed by the addition of sweet potato. The whole was left to cook for another 30 minutes after being salted and seasoned with pepper and nutmeg.

2.5.3 Sweet potato porridge accompanied by white cowpea

A total of 1 kg of white cowpea was soaked in hot water, dehulled and then pre-cooked for 45 minutes in water with a little salt. Moreover, 10 kg of sweet potato were peeled and cut. The onions, tomato paste, and garlic were swiftly fried in a little oil, to which the recooked cowpea and water were added. The whole content was simmered for 20 to 30 minutes, followed by the addition of the sweet potato. The whole was left to cook for another 30 minutes after being salted and seasoned with pepper and nutmeg.

2.5.4 Sweet potato porridge accompanied by green soya and white cowpea

A total of 1 kg of green soybeans was soaked in hot water and then pre-cooked for 30 minutes in water with a little salt. Also, 1 kg of white cowpea was soaked in hot water, dehulled and then pre-cooked for 45 minutes in water with a little salt. Besides, 10 kg of sweet potato were peeled and cut. The onions, tomato paste, and garlic were quickly fried in a little oil, to which the pre-cooked cowpea and soybeans were added. The whole was simmered for 20 to 30 minutes, followed by the addition of the sweet potato. The whole content was left to cook for another 30 minutes after being salted and seasoned with pepper and nutmeg.

2.6 Meals Distribution

For six months, the different menus were consumed as lunch in the school canteen twice a week (on Monday and Thursday), in respect to

what is usually performed at the school canteens of the region. Each child received approximately 300 g to 500 g of food. Thus, four groups were formed with three schools per group:

- Group 1 (Control group): rice with tomato stew and fish. This meal is usually served in canteens;
- Group 2: sweet potato porridge accompanied by green soybeans;
- Group 3: sweet potato porridge accompanied by white cowpea; and
- Group 4: sweet potato porridge accompanied by green soybeans and white cowpeas.

2.7 Statistical Analyzes

Statistical analyzes were performed using Graph Pad Prism 5 Demo software. Students's test was used to compare the variances of the means. The relationships between data were assessed with the Pearson's Chi^2 test. A p value <0.05 was considered statistically significant. The data were presented as mean ± standard deviation of the mean.

3. RESULTS

The results of this study showed that the children's vitamin A, D, and E levels are above the standard reference level, except for those of group 4 whose vitamin D level was below the standard level (<30 ng/mL).

3.1 Vitamin A status of the Study Population

Before the children consumed food at the canteen (phase 0), the concentration of vitamin A was 1.0 ± 0.07 mg/L, 0.7 ± 0.06 mg/L, 0.8 ± 0.09 mg/L, and 0.5 ± 0.07 mg/L in children of groups 1, 2, 3, and 4 respectively. Three months after food consumption (phase 1), the vitamin A levels in pupils in groups 2 (0.6 ± 0.05 mg/L), 3 (0.7 ± 0.06 mg/L), and 4 (0.7 ± 0.10 mg/L) differed significantly (*P*<0.05) from that of the control group (group 1) (0.4 ± 0.05 mg/L). Six months later (phase 2), no variation in vitamin A level was observed among groups 1, 2, and 3. However, a significant difference was noted between the vitamin A level of pupils in group 4 (0.8 ± 0.10 mg/L) and the control group (Fig. 1).

Analysis by group showed that group 1 was characterized by a reduction in the concentration of vitamin A. This decrease was significant

(*P*<0.05) in phase 1 (0.4 ± 0.05 mg/L) and phase 2 (0.6 ± 0.04 mg/L) compared to phase 0 (1.0 ± 0.07 mg/L). In groups 2 and 3, the level of vitamin A also decreased from 0.7 to 0.6 mg/L and from 0.8 to 0.7 mg/L respectively. However, no significant difference was observed between the phases. In group 4, the vitamin A level increased from 0.5 to 0.8 mg/L. The level of vitamin A in phase 2 differed significantly from that of the other phases (Fig. 1).

3.2 Vitamin D status of the Study Population

Before the pupils consumed food at the canteen (phase 0), the concentration of vitamin D was normal in all groups except in group 4 where the vitamin D level (22 ± 2.92 ng/mL) was below the normal standard reference value and significantly different from other groups. However, in phase 1, an increase in vitamin D concentration was noted in groups 2, 3, and 4 compared to group 1 (21 ± 3.18 ng/mL). This increase in the concentration of vitamin D was significant in group 2 (41 ± 5.10 ng/mL), very significant in group 3 (43 ± 4.93 ng/mL), and not significant in group 4 (28 ± 3, 75 ng/mL). In phase 2, no significant difference in vitamin D levels was found among the groups (Fig. 2).

Analysis by group showed that group 1 was characterized by a reduction in the concentration of vitamin D from phase 0 to phase 1 and then by an increase in phase 2. This decrease was very significant in phase 1 (21 ± 3.18 ng/mL) and not significant in phase 2 (35 ± 4.37 ng/mL) compared to phase 0 (47 ± 4.66 ng/mL). On the other hand, in group 2, the vitamin D level increased insignificantly to 41 ng/mL from phase 0 to phase 1 and then decreased, still insignificantly (*P*>0.05), to 34 ng/mL in phase 2. In phase 1, (41 ± 5.10 ng/mL) and by a non-significant reduction in the concentration of vitamin D in phase 2 (34 ± 4.21 ng/mL) compared to phase 0 (47 ± 4.66 ng/mL). Likewise, group 3 was characterized by a non-significant increase in the concentration of vitamin D in phase 1 (43 ± 4.93 ng/mL) and by a non-significant decrease in phase 2 (29 ± 4.19 ng/mL) compared to phase 0 (35 ± 4.66 ng/mL). In children of group 4, there was a gradual increase in vitamin D concentration from 21 to 28 ng/mL. Vitamin D levels between phases did not differ significantly (Fig. 2).
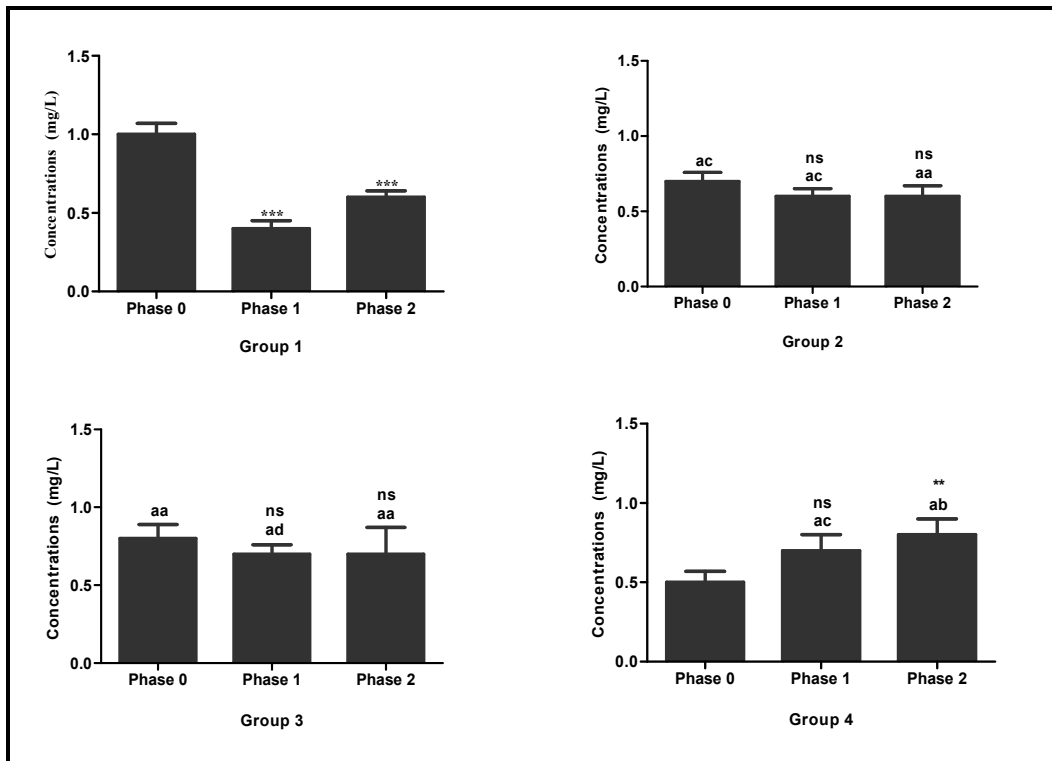
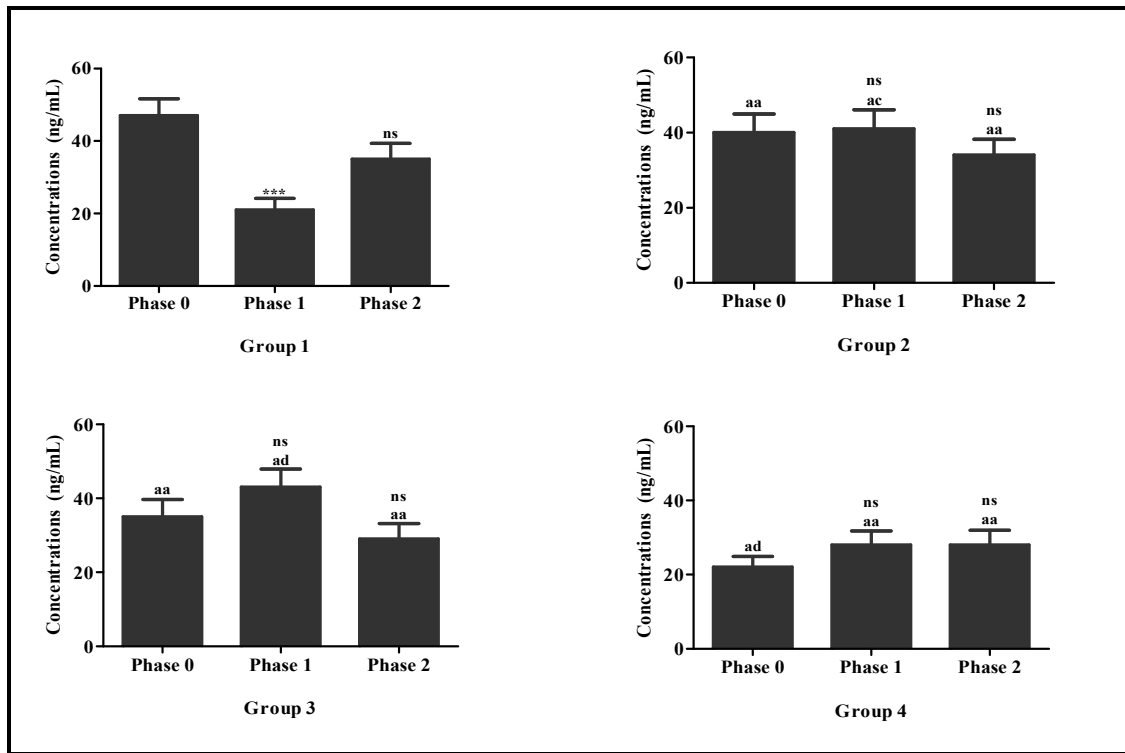**Fig. 1. Variation in vitamin A concentrations during the study**
*ns: not significant compared to phase 0 (P>0.05). * not very significant compared to phase 0 (P<0.05). ** significant compared to phase 0 (P<0.05). *** very significant compared to phase 0 (P<0.05).*^{aa} *not significant compared to group 1 (P>0.05).* ^{ab} *not very significant compared to group 1 (P<0.05).* ^{ac} *significant compared to group 1 (P<0.05).* ^{ad} *very significant compared to group 1 (P<0.05). Vitamin A (Ref: 0.1 - 0.5 mg/L)*

3.3 Vitamin E status of the Study Population

Before the pupils consumed food at the canteen (phase 0), the mean vitamin E concentration was normal in all groups 1 (9.1 ± 0.50 mg/L), 2 (8.5 ± 0.44 mg/L), 3 (10.2 ± 0.61 mg/L), and 4 (8.3 ± 0.34 mg/L). Three months after the meals were consumed, the average vitamin E concentration was still normal in all groups. However, the results showed a non-significant decrease in the concentration of vitamin E in group 1 (7.8 ± 0.44 mg/L) and a very significant increase in the concentration of vitamin E in group 2 (10.3 ± 0.54 mg/L) and 3 (11.6 ± 0.63 mg/L). Six months later, a non-significant decrease in vitamin E concentration was noted in group 3 (10.3 ± 0.55 mg/L) compared to an increase in groups 1 (9.8 ± 0.58 mg/L), 2 (11.8 ± 0.66 mg/L), and 4 (10.6 ± 0.56 mg/L) (Fig. 3).

The group analysis showed that in the pupils of group 1, the vitamin E level decreased from 9.1 to 7.8 mg/L from phase 0 to phase 1 and then increased to 9.8mg/L in phase 2. There was no significant difference between the vitamin E levels in each phase. On the other hand, for the students of group 2, there was an increase in the level of vitamin E from 8.5 to 11.8 mg/L from phase 0 to phase 2. The increase in phases 1 and 2 differs significantly in the level of vitamin E from phase 0. There was an increase in the level of vitamin E from 8.5 to 11.8 mg/L from phase 0 to phase 2. The increase in phases 1 and 2 differs significantly from the level of vitamin E in phase 0. With regard to group 3, the level of vitamin E increased from 10.2 to 11.6 mg/L from phase 0 to phase 1. But in phase 2, the level decreased to 10.3 mg/L. However, there is no significant difference in vitamin E levels among the three phases. Finally, group 4 was characterized by an increase in the concentration of vitamin E. This increase was not significant in phase 1 (8.9 ± 0.43 mg/L) but very significant in phase 2 (10.6 ± 0.56 mg/L) compared to phase 0 (8.3 ± 0.34 mg/L) (Fig. 3).
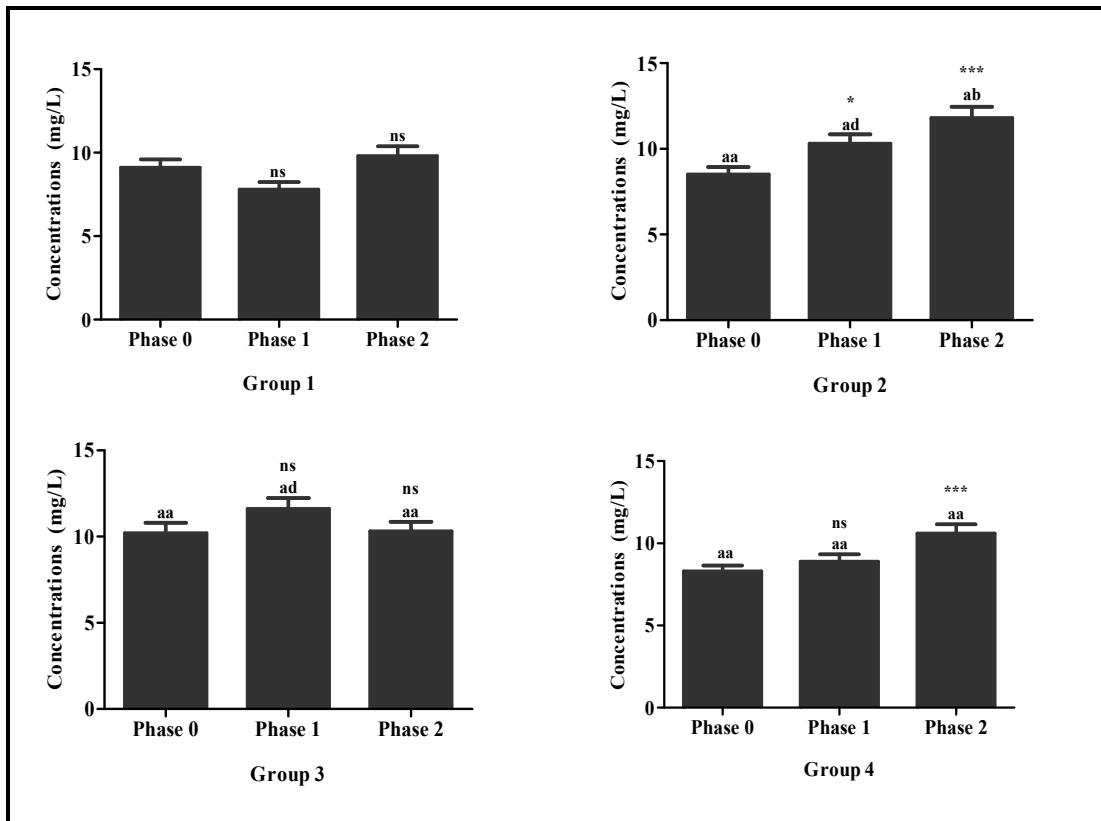
Fig. 2. Variation of vitamin D concentrations during the study

*ns: not significant compared to phase 0 (P>0.05). * not very significant compared to phase 0 (P<0.05). ** significant compared to phase 0 (P<0.05). *** very significant compared to phase 0 (P<0.05). aa not significant compared to group 1 (P>0.05). ab not very significant compared to group 1 (P<0.05). ac significant compared to group 1 (P<0.05). ad very significant compared to group 1 (P<0.05). Vitamin D [Deficient (<20 ng/mL); Insufficient (20-29 ng/mL); Sufficient (30-100 ng/mL); Toxicity (>100 ng/mL)].*

4. DISCUSSION

Vitamin A is one of the most important nutrients needed by children [32]. Before the children consumed food at the canteen (phase 0), their vitamin A level was within the normal standard (0.1 and 0.5 mg/mL), which suggests that there is no issue with vitamin A in these children at the beginning of this study. The follow-up on children in group 1, who consumed rice with tomato sauce and fish as a control food since they are consumed in most school canteens, revealed a decrease in the level of vitamin A in phases 1 and 2. Hence, a slightly varied diet, especially one that is not consumed at home, does not improve the micronutrient status in general and vitamin A concentration in particular. In addition, if the cereals consumed are not associated with vegetables that are rich in carotenoids as indicated by Agbo et al. [6], the risk of vitamin A deficiency is very high because the cereals are devoid of carotenoids [33]. In groups 2 and 3, the level of vitamin A decreased in phase 1 and stabilized in phase 2. The fact that the levels of

vitamin A remained stable may be due to the orange-fleshed sweet potato that contains. Indeed, tubers are rich in carotenoids [34]. This decrease in the level of vitamin A in these groups could be explained by its bioavailability [35] which is highly variable and influenced by factors related to food and diet [36]. Studies have shown that food matrices considerably affect the bioavailability of vitamin A [37]. In contrast, in group 4, the vitamin A level increased from phase 0 to phase 2, which could be due to the fact that the students in this group consumed sweet potatoes, soybeans, and cowpeas. The type of diet provided in this group could therefore be beneficial for children thanks to its main nutrients such as carbohydrates, proteins, fats, minerals, and vitamins [38]. The consumption of sweet potato associated with soy beans seems to be an important source of β-carotene [34]. Therefore, it is necessary to increase the consumption of plant-based foods [39] that are potentially rich in carotenoids [40] which, after ingestion, are converted into retinol (i.e. - say in vitamin A) [41].

Fig. 3. Variation of vitamin E concentrations in the study
ns: not significant compared to phase 0 (P>0.05). * not very significant compared to phase 0 (P<0.05). ** significant compared to phase 0 (P <0.05). *** very significant compared to phase 0 (P <0.05). [aa] not significant compared to group 1 (P >0.05). [ab] not very significant compared to group 1 (P <0.05). [ac] significant compared to group 1 (P <0.05). [ad] very significant compared to group 1 (P<0.05). Vitamin E (Ref: 7.8 - 12 mg/L)

Before the children consumed food at the canteen (phase 0), the concentration of vitamin D was normal in all groups except in group 4 where insufficiency was observed. Unlike other fat-soluble vitamins that have a food source, vitamin D's main source (Calciferol) is cutaneous thanks to ultra-violet solar rays [42]. Consequently, the children in groups 1, 2, and 3 had a good supply of vitamin D at the beginning of this study. The reduction in vitamin D concentration observed in group 1 from phase 0 to phase 1 could be due to the use of the vitamin D reserve to meet the physiological needs of children; the half-life of vitamin D in serum being 45 days [43]. Six months later, an improvement in vitamin D concentration was noted in group 1 from phase 1 to phase 2, which expresses a renewal of vitamin D reserves in the children of group 1. For the pupils of groups 2 and 3, there is an increase in the level of vitamin D in phase 1 but a decrease in phase 2 which may be due to a lack of synthesis of the vitamin [44] or its increased use

in erythropoiesis in individuals with inflammatory-type anemia. The association with inflammatory-type anemia is supported by studies that show that vitamin D could support erythropoiesis by reducing pro-inflammatory cytokines and increasing the proliferation of erythroid progenitor cells [45]. However, in the children of group 4, the vitamin D level increased from phase 0 to phase 2, which could be due to the fact that the food consumed could promote better synthesis of vitamin D.

An improvement in vitamin E status after food consumption in groups 2, 3, and 4 compared to group 1 (control group) was observed. This improvement was more pronounced in children who consumed the meal based on sweet potato, soya, and cowpea (Group 4). This increase corresponds to an intake of vitamin E from sweet potato [46], soybean [9] and cowpea [10]. The alpha-tocopherols contained in these foods are thought to improve the nutritional status of

children as essential nutrients and lipophilic antioxidants that prevent the oxidation of unsaturated fats from acids [47]. Lobo et al. [48] reported that increasing serum α-tocopherol concentrations promotes better growth and reduces morbidity in children. Vitamin E enhances the humoral and cell-mediated immune response, including the production of antibodies, phagocytic and lymphocyte responses, and resistance to viral and infectious diseases [49]. It controls the activity of blood platelets responsible for thrombosis and performs a protective action on red blood cells, which could prevent cardiovascular diseases of atheromatous origin [50].

5. CONCLUSION

In this study, the levels of vitamins A, D, and E were within the normal standard values, except in group 4 which was characterized by a low level of vitamin D. An improvement in the status of vitamins A, D, and E was more pronounced in the children who consumed the meal containing sweet potato, soya, and cowpea compared to their mean concentration at the beginning of the study. However, the vitamin D levels of children who consumed this meal remained below the normal standard level. The sweet potato, soybean, and cowpea-based meal could be used as a means of dietary diversification in school canteens in order to improve the vitamin status of school-aged children. However, further studies are required to determine the effect of this meal on the anthropometric, hematological, and biochemical parameters of these children.

CONSENT

An informed, written, and signed consent was obtained from each parent or guardian of the participating student after discussion of the purpose and benefits of the study and from each manager of each institution involved. The participants were informed of their volunteering and of their right to leave the interview at any time. A standardized questionnaire survey focusing on food and hygiene habits and medical history was conducted with each child. The confidentiality of the participants' information was also ensured. Only data in anonymity were submitted for statistical analysis.

ETHICAL APPROVAL

Before the data collection process was initiated, an ethical authorization was issued by the national research ethics committee (N / Ref: 009 // MSHP / CNER-kp). The authorities of each village and the school head teachers were contacted and informed before the start of the study in their localities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Pourafshar S, Rosentrater KA, Krishnan P. Malnutrition, a global problem; 2010.
    DOI: 10.1007/978-3-319-17169-2_44.
2. Unicef, World Health Organization, and The World Bank. Levels and trends in child malnutrition. Africa (Lond). 2012;35. Accessed: February 02, 2019.
    Available:http://www.who.int/nutgrowthdb/estimates2011/en/
3. World Health Organization. Global Report UNAIDS report on the global AIDS epidemic, 2016-2021. Geneva 27, Switzerland; 2016.
    Accessed: February 02, 2019.
4. Bleyere MN, Kokore BA, Konan AB, Yapo PA. Prevalence of child malnutrition through their anthropometric indices in school canteens of Abidjan (Côte d'ivoire). Pak. J Nutr. 2013;12(1):60-70.
    DOI: org/10.3923/pjn.2013.60.70.
5. N'go P, Azzaoui F, Ahami A, Aboussaleh Y, Lachheb A, Hamrani A. Déterminants socioéconomiques, environnementaux et nutritionnels de l'échec scolaire: cas des enfants résidant en zone cacaoyère de Soubré (Côte d'Ivoire). Antropo. 2012;28: 63-70.
6. Agbo AE, Mahyao A, Konan AD, Coulibaly L, Kouassi A, Kehlenbeck K, et al. Production, consumption, and nutrition survey in a cocoa farming area in the Nawa region. Report. ICRAF, Abidjan. 2014;137.
7. Agbo AE, Kouamé C, N'Doua ND, Kouassi

A, Brou K. Assessment of cocoa producers' children nutritional status in the Nawa Region, Côte d'Ivoire. J. Food Nutr. Res. 2017;5(8):606-613.
DOI: 10.12691/jfnr-5-8-11.

8. Alam MK, Sams S, Rana ZH, Akhtaruzzaman M, Islam SN. Minerals, vitamin C and effect of thermal processing on carotenoids composition in nine varieties orange-fleshed sweet potato (*Ipomoea batatas* L.).J Food Compost Anal. 2020;92.
DOI.org/10.1016/j.jfca.2020.103582.

9. Lokuruka M. Soybean nutritional properties: The good and the bad about soy foods consumption-A review. African J. Food, Agric. Nutr. Dev. 2010;10(4).
DOI: org/10.4314/ajfand.v10i4.55335.

10. Owade JO, Abong G, Okoth M, Mwang'ombe AW. A review of the contribution of cowpea leaves to food and nutrition security in East Africa. Food Sci Nutr. 2020;8(1):36-47.
DOI: doi.org/10.1002/fsn3.1337.

11. US Department of Agriculture and US Center for Nutrition Policy and Promotion. The Food Guide Pyramid; 1992.
Accessed: February 15, 2021.
Available:https://www.cnpp.usda.gov/FGP.

12. De Oliveira Otto MC, Anderson CAM, Dearborn JL, Ferranti EP, Mozaffarian D, Rao G et al. Dietary diversity: Implications for obesity prevention in adult populations: A science advisory from the American Heart Association. Circulation. 2018;138: 160–168.
DOI: org/10.1161/CIR.0000000000000595.

13. WHO, UNICEF. Global strategy for infant and young child feeding. Fifthy-Fourth World Health Assembly, 2003;5(1).
Accessed: February 15, 2021.
Available:https://apps.who.int/iris/bitstream/handle/10665/42590/9241562218.pdf.

14. Sun H, Mu T, Xi L, Zhang M, Chen J. Sweet potato (Ipomoea batatas L.) leaves as nutritional and functional foods. Food Chem. 2014;156:380-389.
DOI: org/10.1016/j.foodchem.2014.01.079.

15. Frota KDMG, Lopes LAR, Silva ICV, Arêas JAG. Nutritional quality of the protein of *Vigna unguiculata* L. Walp and its protein isolate. Rev Cienc Agron. 2017;48(5):792-798.
DOI: org/10.5935/1806-6690.20170092.

16. Dakora FD, Belane AK. Evaluation of Protein and Micronutrient Levels in Edible Cowpea (*Vigna unguiculata* L. Walp.)

Leaves and Seeds. Front Food Syst. 2019;3:70.
DOI: org/10.3389/fsufs.2019.00070.

17. Moloto MR, Phan ADT, Shai JL, Sultanbawa Y, Sivakumar D. Comparison of Phenolic Compounds, Carotenoids, Amino Acid Composition, in Vitro Antioxidant and Anti-Diabetic Activities in the Leaves of Seven Cowpea (*Vigna unguiculata*) Cultivars. Food. 2020;9(9): 1285.
DOI: org/10.3390/foods9091285.

18. Food and Agriculture Organization (FAO), Roots, Tubers, Plantains and Bananas in Human Nutrition, vol. 24 of Food and Nutrition Series, Food and Agriculture Organization, Rome, Italy, 1990;9–14.
Accessed: February 15, 2021.
Available:http://www.fao.org/docrep/T0207E/T0207E08.htm.

19. Kouris Blazos A, Belski R. Health benefits of legumes and pulses with a focus on Australian sweet lupins. Asia Pac. J. Clin. Nutr. 2016;25(1):1-17.
DOI: 10.6133/apjcn.2016.25.1.23.

20. Venter CS, Vorster HH, Ochse R, Swart R. Eat dry beans, split peas, lentils and soya regularly: A food-based dietary guideline. S. Afr. J. Clin. Nutr. 2013;26(3):36–45.

21. Awuchi CGI, Ikechukwu VSA, Echeta CK. Health Benefits of Micronutrients (Vitamins and Minerals) and their associated deficiency diseases: A systematic review. Int. J. Food. Sci. 2020;3(1):1-32.

22. Herrador Z, Sordo L, Gadisa E, Buño A, Gómez-Rioja R, Iturzaeta JM, et al. Micronutrient deficiencies and related factors in school-aged children in ethiopia: A cross-sectional study in Libo Kemkem and Fogera Districts, Amhara Regional State. PLoS One. 2014;9(12):112858.
DOI: org/10.1371/journal.pone.0112858

23. Stevens GA, Bennett JE, Hennocq Q, Lu Y, De-Regil LM, Rogers L, et al. Trends and mortality effects of vitamin A deficiency in children in 138 low-income and middle-income countries between 1991 and 2013: A pooled analysis of population-based surveys. Lancet Glob. Heal. 2015;3(9):528-536.
DOI: org/10.1016/S2214-109X(15)00039-X.

24. Civitelli R, Ziambaras K. Calcium and phosphate homeostasis: Concerted interplay of new regulators. J. Endocrinol. Investig. 2011;34(7):3–7.
DOI: 10.1080/07853890701689645.

25. Raizman JE, Cohen A, Theodoro Morrison T, Wan B, Chan M, Wilkenson C, et al. Pediatric reference value distributions for vitamins A and E in healthy community children: Establishment of new age-stratified reference intervals from a CALIPER cohort. Clin. Chem. 2014;47(9): 812-815.
DOI:org/10.1016/j.clinbiochem.2014.06.03 1

26. Armecin G, Behrman J, Duazo P, Ghuman S, Gultiano S, King E, et al. Early childhood development through an integrated program: Evidence from the Philippines. World Bank Policy Res. Work. Pap. 2006;3922.

27. Zaman Z, Fielden P, Frost PG. Simultaneous determination of vitamins A and E and carotenoids in plasma by reversed-phase HPLC in elderly and younger subjects. Clin Chem. 1993;39 (11):2229–2234.

28. Catignani GL, Bieri JG. Simultaneous determination of retinol and alpha-tocopherol in serum or plasma by liquid chromatography. Clin Chem. 1983;29(4): 708–712.

29. World Health Organization. Global prevalence of vitamin A deficiency in populations at risk 1995-2005: WHO global database on vitamin A deficiency. World Health Organization; 2009.
Available:https://apps.who.int/iris/handle/1 0665/44110.

30. Holick MF. Vitamin D deficiency. N Engl J Med. 2007;357(3):266–281.
DOI: 10.1056/NEJMra070553.

31. Boyvin L, M'Boh G, Aké Edjeme A, Soumahoro Agbo M, Séri Kipré L, Djaman J. Serum level of two antioxidant vitamins (A and E) in Ivorian (Côte d'Ivoire) people living with human immunodeficiency virus. Ann. Biol. Res. 2013;4(11):48–54.

32. Imdad A, Yakoob MY, Sudfeld C, Haider BA, Black RE, Bhutta ZA. Impact of vitamin A supplementation on infant and childhood mortality. BMC Public Health. 2011;11(3): 20.
DOI: 10.1186/1471-2458-11-S3-S20.

33. Bohn T. Carotenoids, chronic disease prevention and dietary recommendations. Int. J. Vitam. Nutr. Res. 2017;87(3-4):121-130.
DOI:10.1024/0300-9831/a000525.

34. Tatarowska B, Milczarek D, Wszelaczyńska E, Pobereżny J, Keutgen N, Keutgen AJ, et al. Carotenoids variability of potato tubers in relation to genotype, growing location and year. Am. J. Potato Res. 2019;96:493-504.
DOI: 10.1007/s12230-019-09732-9.

35. Van Het Hof KH, Tijburg LBM, Pietrzik K, Weststrate JA. Influence of feeding different vegetables on plasma levels of carotenoids, folate and vitamin C. Effect of disruption of the vegetable matrix. Br. J. Nutr.1999;82(3):203-212.
DOI: 10.1017/s0007114599001385.

36. Castenmiller JJM, West CE. Bioavailability and bioconversion of carotenoids. Annu Rev Nutr. 1998;18:19-38.
DOI: 10.1146/annurev.nutr.18.1.19.

37. Burri BJ, Chang JST, Neidlinger TR. βcryptoxanthin- and α-carotene-rich foods have greater apparent bioavailability than βcarotene-rich foods in Western diets. Br. J. Nutr. 2011;105(2):212-9.
DOI: 10.1017/S0007114510003260.

38. Fahlman MM, Dake JA, McCaughtry N, Martin J. A pilot study to examine the effects of a nutrition intervention on nutrition knowledge, behaviors, and efficacy expectations in middle school children: Research article. J. Sch. Health. 2008;78(4):216-22.
DOI:10.1111/j.1746-1561.2008.00289.x.

39. Sterling SR, Bowen SA. The potential for plant-based diets to promote health among blacks living in the United States. Nutrients. 2019;11:2915.
DOI: 10.3390/nu11122915.

40. Winkvist A, Hultén B, Kim J, Johansson I, Torén K, Brisman J, et al. Dietary intake, leisure time activities and obesity among adolescents in Western Sweden: A cross sectional study. Nutr. J. 2016;15:41.
DOI: 10.1186/s12937-016-0160-2.

41. Trono D. Carotenoids in cereal food crops: Composition and retention throughout grain storage and food processing. Plants. 2019;8:551.
DOI:10.3390/plants8120551.

42. Gil Á, Plaza Diaz J, Mesa MD. Vitamin D: Classic and novel actions. Ann. Nutr. Metab. 2018;72(2): 87–95.
DOI: 10.1159/000486536.

43. Jones KS, Assar S, Harnpanich D, Bouillon R, Lambrechts D, Prentice A, et al. 25(OH)D2 half-life is shorter than 25(OH)D3 half-life and is influenced by DBP concentration and genotype. J. Clin. Endocrinol. Metab. 2014;99(9): 3373–3381.
DOI: 10.1210/jc.2014-1714.

44. Holick MF. Vitamin D: A D-lightful solution for health. J Investig Med. 2011;59(6):872–880.
    DOI: 10.2310/JIM.0b013e318214ea2d.
45. Smith EM, Tangpricha V. Vitamin D and anemia: Insights into an emerging association. Curr Opin Endocrinol Diabetes Obes. 2015;22:432–438.
    DOI: 10.1097/MED.0000000000000199.
46. Chukwu O, Nuwachukwu NG. Effects of Cooking and Frying on Antioxidants Present in Sweet Potatoes (Ipomoea Batatas). Acad. Res. Int., 2012;2(2):104-109.
47. Ahsan H, Ahad A, Siddiqui WA. A review of characterization of tocotrienols from plant oils and foods. J Chem Biol. 2015;8: 45–59.

    DOI: 10.1007/s12154-014-0127-8.
48. Lobo LMC, Schincaglia RM, Peixoto MDRG, Hadler MCCM. Multiple micronutrient powder reduces vitamin e deficiency in brazilian children: A pragmatic, controlled clinical trial. Nutrients 2019;11(11).
    DOI: 10.3390/nu11112730.
49. Lewis ED, Meydani SN, Wu D. Regulatory role of vitamin E in the immune system and inflammation. IUBMB Life. 2019;71(4):487-494.
    DOI: 10.1002/iub.1976.
50. Anuj Y, Rewa K, Ashwani Y, Mishra JP, Seweta S, Shashi P. Antioxidants and its functions in human body. Res Environ Life Sci. 2016;9(11):1328-1331.

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