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Research Article

Dietary Diversification Impact on Lipid and Carbohydrate Profiles of School-aged Children in Nawa Region (Cote d'Ivoire)

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Abstract

In Cote d'Ivoire, there is an imbalance between food intake and nutritional needs among school-aged children. Studies have indicated that dietary diversification could provide a solution. A study was therefore conducted to evaluate the impact of dietary diversification on the lipid and carbohydrate profiles of children in school canteens in the Nawa region. This study was conducted during October 2017 to May 2018 in school canteens of 12 localities in the Nawa region (Cote d'Ivoire). It included 240 school-aged children, 6 -12 years old, divided into four groups of 60. Four types of meals were offered, one for each of the four groups: rice with tomato sauce and fish, sweet potato stew enriched with green soybeans, sweet potato stew enriched with white cowpea, and sweet potato stew enriched with cowpea and soybeans. Blood samples were taken at the beginning, mid-term, and the end of the study. The blood tests measured were triglycerides, cholesterol (total, HDL, LDL), and blood glucose using the COBAS c311 analyzer. The results revealed that blood glucose (0.75 - 1.10 g/L), total cholesterol (1.06 - 2.50 g/L), and triglyceride (0.30 - 1.34 g/L) levels remained normal in children during the experimental period, with the exception of blood glucose in phase 2 of group 4. This value was significantly lower ($P < 0.05$), ranging from 0.72 to 0.68 g/L, compared to group 1 (control). In contrast, groups 2 and 3 experienced significant increases ($P < 0.05$) (from 0.75 to 0.79 g/L and from 0.83 to 0.85 g/L, respectively), compared to group 1 (control). Furthermore, in all children across the different groups, regardless of the sampling period, a decrease in HDL-c and LDL-c levels was observed, with the exception of the last sampling phase (P2) for group 4, which showed significantly increased HDL-c and LDL-c levels, respectively (from 0.29 to 0.65 g/L and from 0.63 to 1.47 g/L). A normalization of the lipid and carbohydrate profile was observed in the children who consumed the different meals offered during the study. The meal based on sweet potato, soybeans, and cowpea could be chosen as a means of dietary diversification in school canteens to improve school-aged children lipid and carbohydrate status.

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Keywords

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1. Introduction

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

In Cote d'Ivoire, for example, malnutrition due to micronutrient deficiency constitutes a public health problem due to its prevalence. It impacts the learning and academic performance of these school-aged children [4]. In the agricultural sector, particularly in the Nawa region, the prevalence of malnutrition among school-aged children was 18.36% [5]. In 2014, surveys conducted among rural populations and in some primary schools in this area revealed that 80% of households had a limited diet based primarily on tubers and cereals [6]. Furthermore, field surveys in school canteens in this region revealed that only one type of meal is served, namely rice with fish, and this is done on alternate days of the week without any variation in the menu. Thus, there appears to be a significant imbalance between the food intake and the nutritional needs of these school-aged children. It is therefore necessary to diversify their diet by providing foods rich in micronutrients. Foods that are likely to 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, sweet potatoes (Ipomoea batatas L.) are energy-rich with high level in vitamins (A, C) and minerals, dietary fiber, and protein [9]. Soybeans (Glycine max) are classified as oilseeds and protein crops due to the richness of their seeds in macronutrients, micronutrients, and secondary metabolites [10]. Cowpeas (Vigna unguiculata L. Walp.) represent an important source of protein for the local population [11]. It is also rich in micronutrients, particularly beta-carotene and vitamin E [12].

Furthermore, it is worth noting that during this nutritional deficiency, disturbances in carbohydrate and lipid status have been observed in school-aged children [13]. Indeed, triglycerides play a role as lipid reserves and thus serve as an energy source for the body. Excessive levels of triglycerides lead to cardiovascular diseases [14]. Triglyceride deficiency depletes the body's energy reserves, leading to excessive fatigue and muscle weakness [15]. As for total cholesterol, it is the most abundant membrane lipid and maintains membrane fluidity. Its deficiency leads to increased fragility of red blood cells, while its high level is a risk factor in the development of atherosclerosis and cardiovascular diseases [16]. The same is true for cholesterol components (LDL-c and HDL-c). They are associated with an increased risk of cardiovascular diseases, particularly strokes. Indeed, a high LDL-c level promotes cholesterol accumulation in arterial walls, accelerating the formation of atherosclerotic plaques [17]. However, an LDL-c deficiency presents a low cardiovascular risk or is dependent on low total cholesterol levels due to underlying malnutrition [18]. Moreover, an HDL-c deficiency is associated with an increased cardiovascular risk [19].

Furthermore, a drop in blood glucose is a consequence of insufficient intake and depletion of energy stores [20]. Elevated blood glucose (hyperglycemia) can be chronic and lead to the development of insulin resistance due to poor absorption of blood glucose. This could maintain hyperglycemia and, eventually, progress to type 2 diabetes. Moreover, this increase constitutes a potential risk factor for cardiovascular disease [21].

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 and an emergency to diversify children diets.

2. Materials and Methods

The article should be written in English. An article should be between 6 and 25 pages, and exceed 2000 words. For original research articles, it should include the headings Introduction, Materials and Methods, Results, Discussion and Conclusions. Other types of articles can be written with a more flexible structure.

2.1. Meterial

2.1.1. Study Population

This study takes into account school-aged children in 12 public schools across 12 villages in the Nawa region in southwestern Côte d'Ivoire.

2.1.2. Ethical Approval

Before beginning this work (data collection), ethical approval was obtained from the National Research Ethics Committee (Ref: 009/MSHP/CNER-kp). The authorities of each village and the school principals were contacted and informed before the study began in their respective localities.

2.1.3. Study Framework

This is a longitudinal study conducted over one school year (nine months). The study took place in 12 localities from four departments in Côte d'Ivoire, specifically in the NAWA region (Buyo, Gueyo, Meagui, Soubre).

2.2. Methodology

2.2.1. Determining the Sample Size

The sample size was calculated using the Leslie Fisher formula, taking into account 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 is 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 children's general health status was assessed by a healthcare professional to ensure that only those in good health prior to the study were included. Therefore, students with chronic illnesses or a family history of such illnesses were excluded.

2.2.4. Consent

Informed, written, and signed consent was obtained from each parent or legal guardian of participating students after discussion of the purpose and benefits of the study, and from each official at each participating school. Participants were informed that their participation was voluntary and of their right to withdraw from the interview at any time. A standardized questionnaire, including information on dietary and hygiene habits and medical history, was administered to each child. The confidentiality of participants' information was also ensured by a security code. Only anonymized data were submitted for statistical analysis.

2.2.5. 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 cowpea

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 received rice with tomato sauce and fish (a staple dish usually served in school canteens)
2) Group 2: Received sweet potato stew enriched with green soybeans
3) Group 3: Received sweet potato stew enriched with white cowpea
4) Group 4: Received sweet potato stew enriched with green soybeans and white cowpeas.

2.2.6. Sampling

Blood collection required a fasting period of 8 to 12 hours during the active phase. A total of three samples were collected at different times. Before the study, a sample was taken from the children (Phase 0). After three (3) months of consuming the various foods, another sample was taken (Phase 1). And six (6) months after consuming the foods, a final sample was taken (Phase 2). Whole blood was then collected in separate tubes (gray and red) and sent to the laboratory. After centrifugation at 3000 rpm for five (5) minutes, the plasma was used immediately for glycemic tests and the aliquoted serum for lipid tests.

2.2.7. Lipid and Carbohydrate Parameters Measurement

Total cholesterol and its HDL-c and LDL-c fractions, triglycerides, and blood glucose were measured using the cobas C311 analyzer and compared to serum reference values for each studied parameter (Table 1) [22].

Table 1. *Serum reference values for lipid parameters [22].*

Parameters studied	Reference values
Total cholesterol	1.06 - 2.50 g/L
HDL-c	0.40 - 0.80 g/L
LDL-c	1.01 - 1.60 g/L

Parameters studied	Reference values
Triglycerides	0.30 - 1.34 g/L
Blood glucose	0.75 - 1.10 g/L

2.2.8. Statistical Analyses

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

3. Results and Discussion

3.1. Carbohydrate Profile of the Study Population

In this study, normal blood glucose values were observed in all children groups regardless of the sampling period. In groups 2, 3, and 4, there was a decrease (from 0.75 to 0.71 g/L; from 0.83 to 0.75 g/L; and from 0.82 to 0.72 g/L, respectively) from baseline (P0) to phase 1, followed by an increase (from 0.71 to 0.79 g/L; from 0.75 to 0.85 g/L; and from 0.78 to 0.83 g/L) from phase 1 to phase 2, with a significant difference ($P < 0.05$) (Figure 1).

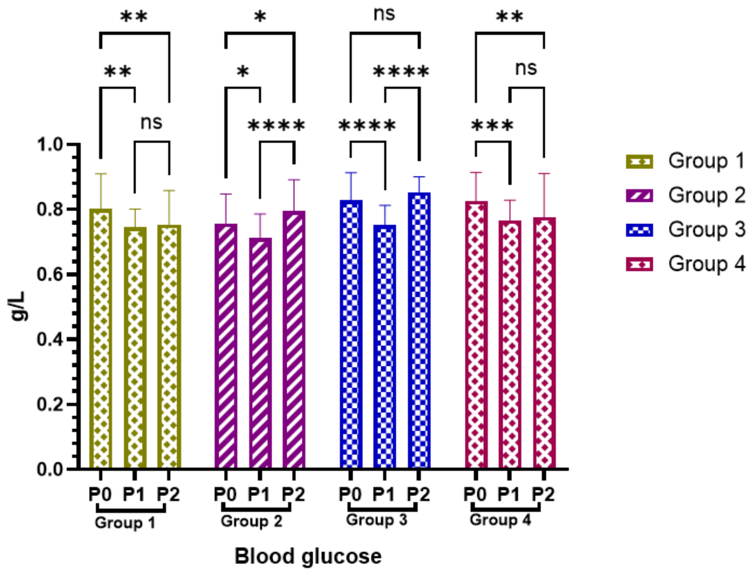

Figure 1. Variation in carbohydrate levels across different groups of children.

P-value a: Group 1 vs. Group 2; P-value b: Group 1 vs. Group 3; P-value c: Group 1 vs. Group 4.
The difference is significant at $P < 0.05$ (Student's t-test). ns: Not significant difference;
*: Statistically significant diference; **: Highly significant difference;
: Highly significant difference; *: Very highly significant difference.

3.2. Lipid Profile of the Studied Population

Mean total cholesterol values in this study remained with in normal limits (1.17-1.36 g/L) in all children across all groups,

except for the first sampling phase (before food consumption) in group 4 (P0), where this value was below the reference value (0.99 g/L). However, a significant increase in the mean value during the second and final sampling phase (from 1.17 to 2.78 g/L) was observed, compared to the control group. For children in groups 2 and 3, a non-significant increase ($P > 0.05$) in the mean total cholesterol value was observed during the three- and six-month post-consumption periods, compared to the control group, in which a decrease from 1.29 to 1.26 g/L was observed (Table 2).

Regarding mean HDL-c and LDL-c levels, a decrease in HDL-c and LDL-c was observed in all children, regardless of the food consumed or the sampling period, with the exception of the last sampling phase (P2) for Group 4, where an increase in HDL-c (from 0.29 to 0.61 g/L) and LDL-c (from 0.63 to 1.47 g/L) levels was observed. However, this increase was significant ($P < 0.05$) at the three (3) and six (6) month periods following consumption of the sweet potato and soybeans enriched with cowpea (Group 4) (Table 2).

Regarding triglycerides, mean values remained normal in all children, regardless of the group or the sampling period. With the exception of groups 2 and 4, which showed a non-significant increase in their mean value compared to the control group, group 3 experienced a decrease (from 1.08 ± 0.06 to 0.98 ± 0.05 g/L) in the mean triglyceride value at the last sampling period (six months after consumption of sweet potato enriched with cowpeas). This decrease was significant (P

< 0.05) (Table 2).

Table 2. *Mean serum lipid profile values in the study population.*

Lipid parameters (Reference value)	Phases	Group 1 (n = 60)	Group 2 (n = 60)	Group 3 (n = 60)	Group 4 (n = 60)
T-chl (1.06 - 2.50 g/L)	P0	1.29 ±0.29 ^{ns}	1.17 ±0.21 ^{ns}	1.19 ±0.25 ^{ns}	0.99 ±0.32^{ns}
	P1	1.24 ±0.31 ^{ns}	1.19 ±0.24 ^{ns}	1.17 ±0.31 ^{ns}	1.17 ±0.29*
	P2	1.26 ±0.25 ^{ns}	1.20 ±0.27 ^{ns}	1.20 ±0.26 ^{ns}	2.48 ±12.11**
HDL-c (0.40 - 0.60 g/L)	P0	0.32 ±0.07 ^{ns}	0.29 ±0.05 ^{ns}	0.30 ±0.06 ^{ns}	0.25 ±0.08^{ns}
	P1	0.31 ±0.08 ^{ns}	0.30 ±0.06 ^{ns}	0.29 ±0.08 ^{ns}	0.29 ±0.07*
	P2	0.31 ±0.06 ^{ns}	0.30 ±0.07 ^{ns}	0.30 ±0.06 ^{ns}	0.61 ±2.38*
LDL-c (1.06 - 1.50 g/L)	P0	0.74 ±0.20 ^{ns}	0.67 ±0.16 ^{ns}	0.68 ±0.21 ^{ns}	0.55 ±0.24^{ns}
	P1	0.70 ±0.27 ^{ns}	0.67 ±0.24 ^{ns}	0.66 ±0.34 ^{ns}	0.63 ±0.25*
	P2	0.71 ±0.18 ^{ns}	0.69 ±0.21 ^{ns}	0.71 ±0.20 ^{ns}	1.47 ±9.10*
TG (0.30 - 1.34 g/L)	P0	1.15 ±0.06 ^{ns}	1.02 ±0.05 ^{ns}	1.08 ±0.06 ^{ns}	1.05 ±0.07 ^{ns}
	P1	1.12 ±0.07 ^{ns}	1.11 ±0.10 ^{ns}	1.09 ±0.15 ^{ns}	1.21 ±0.09 ^{ns}
	P2	1.16 ±0.05 ^{ns}	1.03 ±0.06 ^{ns}	0.98 ±0.05 *	1.07 ±0.06 ^{ns}

Group 1 (Control) = Rice + sauce; Group 2 = Sweet potato + soybeans; Group 3 = Sweet potato + cowpea;
Group 4 = Sweet potato + soybeans + cowpea. The difference is significant for P < 0.05 (Student's t-test).
ns: not significant; *: significant difference; **: highly significant

4. Discussion

The results of this study showed that the children's lipid and carbohydrate levels remained normal compared to the reference ranges throughout the study. Indeed, dietary diversification plays an important role in human health and well-being. It is essential and, above all, allows a living organism to receive appropriate amounts of energy and nutrients, as is the case in children. This indicates that the foods consumed by these children did not affect the biochemical parameters studied (blood glucose, total cholesterol, HDL cholesterol, LDL cholesterol, and triglycerides).

It should be noted that rice dish with sauce consumed by the children in the control group is a staple food for many populations. The quality and quantity of carbohydrates in this type of diet could affect the body's glycemic response [23]. Indeed, consuming food, an important source of carbohydrates for the body, allows for the production of insulin, thus facilitating the absorption of blood glucose [24]. This leads to a slight decrease in blood glucose levels. These results corroborate those of Thomas et al. [25], who revealed that excessive insulin secretion leads to a drop in blood glucose (hypoglycemia). Furthermore, these children were subjected to a non-diversified diet. This kept the average blood glucose level relatively constant until the end of the study.

Furthermore, children fed meals based on sweet potato and soy, sweet potato and cowpea, and sweet potato, soy, and cowpea respectively experienced a decrease in blood glucose levels. This decrease could be explained by the presence of protein in sweet potato (tuber), which allows for slow glucose absorption. These results also confirm the work of Patel et al. [26], who showed that the presence of an inhibitory protein (α-amylase) in sweet potato allows for slow glucose absorption, leading to a decrease in blood glucose levels. However, an increase in blood glucose was observed in these children. This level, however, did not exceed normal reference values. This increase could be due to dietary diversification, particularly the combination of tubers and legumes (soybeans and cowpeas), which provides a diet rich in fiber and protein to children.

According to Larasati et al. [27], dietary diversification is an indicator of diet quality that allows for optimal blood glucose management. Indeed, glucose optimization is necessary to provide energy to every cell in the body. Excess glucose leads to an overproduction of pro-inflammatory cytokines, which could result in impaired function and various pathologies [28]. Thus, a diverse diet in children is essential for maintaining good health.

Regarding triglycerides, one of the main groups of lipids, hypertriglyceridemia is increasingly diagnosed in children due to the rising prevalence of childhood obesity [29]. It can result from increased triglyceride production or reduced triglyceride elimination. In this study, average triglyceride levels were observed in all children, with no significant differences. Our results confirm the work of Lartey et al. [30] who reported that school-aged children in Ghana had a lipid profile (Triglycerides, LDL-c, HDL-c) without significant variation. Furthermore, the lipid profile can be influenced by factors including diet and physical activity [31]. This dish, composed of sweet potato, soy, and white cowpea, reduces the risk of dyslipidemia and therefore does not lead to the development of cardiovascular diseases.

Total cholesterol is synthesized by the liver but it can also be obtained through diet. In this study, children showed no significant average variations for total cholesterol. This suggests that they were following a diet that did not have negative consequences on their health. The same observation was made in Greece, where studies revealed average total cholesterol values without significant variations in children [32]. However, in Brazil, studies have shown that high levels of total cholesterol in children are associated with a lifestyle characterized by higher consumption of sugary drinks and shorter sleep duration [33]. Similarly, in Brazil, the work of Rinaldi et al. [34] showed that overweight or obese children, due to dairy consumption, had high total cholesterol levels. This, in turn, increases the risk of cardiovascular disease and stroke. Therefore, consuming a dish composed of sweet potatoes combined with legumes (soybeans and cowpea) could help reduce hypercholesterolemia.

Furthermore, it should be noted that lipoproteins (LDL-c) are proteins that transport total cholesterol, synthesized by the liver or obtained from food. In this study, all children had low LDL-c levels, except for those fed sweet potatoes, soybeans, and cowpea, in whom a significant increase was observed six months after consumption. However, this increase remained with in normal reference values. This could lead to a normal influx of this lipoprotein into blood vessel cells [35]. However, the low LDL-c levels obtained in this study are similar to those found by Jennifer et al. [36]. These low levels would lead to a reduction in fatty (cholesterol) plaque deposited in the artery, thus reducing cardiovascular risks.

As for HDL-c lipoproteins, they transport cholesterol from cells to the liver to be metabolized and then excreted in bile and feces. The study results showed non-significant low HDL-c levels in all children, except for those fed sweet potato, soybeans, and cowpea, for whom a significant increase was observed six months after consumption. This increase falls within the normal reference range. Thus, the results of this study are consistent with those of Delisle et al. [37] who also found low HDL-c levels. These low levels could constitute a cardiovascular risk factor. However, the increase observed in the sixth month of consumption of sweet potato, soybeans, and cowpea -based foods is beneficial to the body. It helps to bind excess total cholesterol to facilitate its elimination. Indeed, an increase in HDL-c levels is protective against cardiovascular disease [38] and is associated with a reduced risk of osteoarthritis [39]. So, children consuming this food may be protected against cardiovascular disease and osteoarthritis.

5. Conclusion

In light of the study results, it should be noted that carbohydrate and lipid parameters remained within normal reference ranges, with the exception of average HDL-c and LDL-c levels, which decreased in children during the study. However, starting at six months of age after consuming sweet potato, soybeans, and cowpea-based meals, the children experienced an increase in their lipoproteins (LDL-c and HDL-c). Thus, the sweet potato, soybeans, and cowpea-enriched meal helped protect the children against metabolic diseases. This dish could be a good choice for introductions variety into school canteens to improve children's lipid and carbohydrate status.

Abbreviations

HDL-c	High-Density Lipoprotein Cholesterol
LDL-c	Low-Density Lipoprotein
COBAS c311	Comprehensive Biochemical Analysis Clinical 311
TG	Triglycerides
Chl-T	Cholesterol Total

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Author Contributions

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Jean Simon Yao: Formal Analysis, Writing - review & editing.

Yapi Guillaume Yaye: Data curation, Software

Christophe Kouame: Resources, Supervision

Allico Joseph Djaman: Project administration, Validation

Conflicts of Interest

The authors declare no conflicts of interest.

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