VITAMIN COMPOSITION OF LOCALLY SOURCED BREAKFAST MEAL FOR SCHOOL-AGED CHILDREN

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Abstract

This research evaluated the vitamin composition of locally sourced and formulated breakfast meals for school-aged children, contributing to sustainable nutrition. An experimental design was adopted to produce flours from various locally available foodstuffs, including corn, date, sweet potato, oat, and bonga fish. Six samples of breakfast meals were formulated at different ratios using these flours. Standard laboratory analytical method of Association of Official Analytical Chemists (AOAC) laboratory analytical methods were employed to determine the vitamin composition of the samples. The results revealed that the samples contained significant amounts of vitamins B1 (0.74-0.93 mg/100g), B2 (1.24-1.66 mg/100g), B3 (1.75-2.83 mg/100g), carotene (26.72-38.41 ug/g), E (1.83-2.57 mg/100g), K (3.31-6.91 ug/g), B6 (1.45-2.73 mg/100g), B9 (4.74-6.81 ug/g), and D (0.35-0.82 ug/g). These findings support the use of local ingredients in child nutrition, may better support the nutritional needs of school-aged children, particularly for cognitive development, energy metabolism, and immune function. Further studies are recommended to examine these breakfast formulations' shelf-life.

Keywords: Breakfast, Composition, Locally sourced, Meal, School-aged children, Vitamin

Introduction

Breakfast is often regarded as the most crucial meal of the day, requiring a balance of nutrition and wholesomeness. The word breakfast is the first meal of the day and its origin was derived from the late Middle English verbs break and fast. The word literally means to break the fasting period from the day before. Apart from providing energy, breakfast foods are good sources of important nutrients such as calcium, iron and B vitamins, protein and fibre, (Revathymol & Vineetha, 2021). The United States Department of Agriculture (USDA) Food & Nutrition Service (2023) stated that breakfast should deliver adequate protein, fiber, minerals, vitamins, and other micronutrients with minimal sugar and fat, especially from processed food groups. Vitamins are organic compounds that are essential for normal physiological functions, including metabolism, immune function, and cell repair. The role of vitamins in maintaining overall health and preventing deficiencies cannot be overemphasized (Gibson, 2020). An adequate breakfast meal includes a mix of carbohydrates, proteins, and fats and essential vitamins and minerals (Carlson, 2020). Balvin and Treviño (2019) noted that breakfast contributes significantly to daily micronutrient intake, such as iron, B vitamins (folate, thiamine, riboflavin, niacin, vitamin B6, and vitamin B12), and vitamin D. Rekha et al. (2020) also pointed out that a healthy breakfast should include three major food groups: grains, milk, and fruits. The nutrient contents on the various food groups ensures proper health and eradicates malnutrition.

Globally, malnutrition remains a pressing issue, with an estimated 140 million children under five years being stunted and 47 million suffering from wasting (UNICEF, 2020). In sub-Saharan Africa, these issues are compounded by socioeconomic challenges and limited access to diverse, nutrient-rich foods. Research has shown that in many developing countries, including Nigeria, traditional diets are often carbohydrate-centric and lack adequate protein, vitamins, and minerals. This dietary imbalance contributes to various forms of malnutrition, including protein-energy malnutrition (PEM) and micronutrient deficiencies. Studies have shown that common breakfast options like maize-based porridge often fall short in providing essential nutrients such as iron, zinc, and vitamin A (Adeoso et al., 2022). One of the key contributors to malnutrition is the inadequacy of balanced complementary meal, especially those given to young children transitioning from breastfeeding to family diets. Research has revealed that most traditional complementary meal in many African countries, such as maize-based porridges, are often low in essential nutrients like proteins, vitamins, and minerals. These foods primarily provide carbohydrates, leading to dietary imbalances that do not meet the full nutritional needs of growing children. Furthermore, even though there are some commercial breakfast meal products, the constant fluctuations in the economy of the nation affects its availability and affordability. This factor poses a challenge to school aged children getting the adequate required nutrition for proper growth and cognitive functioning. In addition, despite the critical need for nutrient-dense complementary foods, many households in rural, semi-urban, and urban-poor areas cannot afford animal-source foods (ASFs) like meat, fish, and dairy products, which are rich in high-quality proteins and bioavailable micronutrients. This economic barrier necessitates the exploration of alternative, affordable, and locally available food sources to enhance the nutritional quality of school aged children's diets. One of the primary challenges in child nutrition is ensuring that children accept and enjoy their meals. Many traditional and nutritious food formulations may be rejected by young children due to unfavorable sensory attributes. This rejection can lead to inadequate nutrient intake, contributing to deficiencies that affect overall health and development. In order to address these issues. It is needful to incorporate diverse food groups in formulation of meals for school- aged children.

School-aged children are children between the ages of 5 and 18 who are attending school. This stage is characterized by developmental phases such as early school age (5-8 years), middle school age (9-12 years), late school age (13-15 years), (Jose & Andrew, 2023). The nutrition of children during this period is critical for supporting proper growth and development. Breakfast plays a crucial role in meeting these nutritional needs by providing the necessary energy and nutrients to start the day. The breakfast in this study combined several food groups, each contributing unique nutritional benefits. This research work determined the vitamin composition of breakfast meal formulated from corn, oat, bonga fish, sweet potato, and date. These various food sources are easily obtained in our local environment and normally consumed in isolation or snacked on but this study is set to combine them all to formulate an adequate meal. Each ingredient contributes uniquely to the meal's nutritional profile. Corn (*Zea mays* L.), also known as maize, is one of the cereal grains domesticated in Mesoamerica and subsequently cultivated throughout the American continent. As one of the major cereal grains, corn is a staple food for large groups of people in Latin America, Asia, and Africa (Sule, *et al* 2019). Corn is proverbially utilized directly for human food all over the world. In the United States, corn is widely processed into various types of products, such as cornmeal, grits, starch, flour, snacks, tortillas, and breakfast cereals, and is also generally used for animal feed. It can be utilized as a raw ingredient to create a variety of foods, including flour, starch, breakfast cereals, snacks, and cornmeal (Shah, *et al* 2019). Corn is rich in carbohydrates and dietary fiber but typically low in protein and certain micronutrients (Babarinde *et al*., 2024). Bonga fish *(Ethmalosa fimbriata*) is a nutrient-dense species, rich in protein, essential amino acids, omega-3 fatty acids, and other nutrients such as calcium, phosphorus, iron, and zinc (Ighalo et al 2021).

Bonga fish plays a vital role in the nutritional and economic landscape of West Africa. Bonga fish flour, primarily valued for its protein content, is also rich in vitamins such as: Vitamin D which is essential for calcium absorption and bone health. Bonga fish flour serves as a natural source of fat-soluble vitamin (Udeh *et al*., 2023), Vitamin A which contributes to maintaining vision and immune health (Onyeike & Anyakora, 2021), Vitamin E, an antioxidant found in fish flour helps protect cells from oxidative damage (Ali *et al.*, 2020). The inclusion of fish flour in composite flours has been encouraged due to its high nutrient density (Adepoju & Olayemi, 2021). Bonga fish supplies high-quality protein, omega-3 fatty acids, calcium, and vitamin D, essential for growth and development. Sweet potato (*Ipomoea batatas*) is a dicotyledonous plant that belongs to the family *Convolvulaceae*. The young leaves and shoots are sometimes eaten as greens. The skin is usually brown, beige, red, or purple, with white, red, pink, yellow, orange, or purple flesh. Sweet potato is not only a source of energy; it also supplies important nutrients, mainly vitamin A (beta carotene), Vitamin B6, Vitamin C and Vitamin E, as well as dietary fiber and they are low in fat and cholesterol, (Mitra 2019). Oat (*Avena sativa L.*) is unique among all cereal crops because it possesses many nutrients that bear value for human food, animal feed, health care, and cosmetics (Varma *et al* 2019). Oat is an important source of carbohydrates, dietary soluble fiber, balanced protein, lipids, different phenolic compounds, vitamins, and minerals (Joyce *et al*, 2019). Oat as an ancient grain is recently being incorporated into the breakfast cereals, beverages, bread and infant foods across major products from food-based companies, (Boukid *et al*, 2019). Oat offers a high content of dietary fiber, B-vitamins, iron, and magnesium, supporting digestive health and energy metabolism. Date fruits (*Phoenix dactylifera*) are rich sources of dietary fibre, vitamins and minerals. Date fruits also contain phytochemicals such as anthocynins, phenolics, sterols, carotenoids, procyanidins and flavonoids and these compounds are known to possess multiple beneficial effects, (Al-Farsi & Lee, 2018). Date fruits equally possess free radical scavenging antioxidants, gastroprotective, hepatoprotective, nephroprotective, anti-cancer and immune stimulant. Dates are high in natural sugars, providing quick energy, and are rich in dietary fiber, potassium, and magnesium, supporting overall health and electrolyte balance. The combination of these ingredients aims to create a balanced breakfast meal that addresses both macronutrient and micronutrient needs. By developing a nutrient-dense, affordable breakfast option, this research aims to contribute to the reduction of malnutrition, boost immune system, reduce micro nutrients deficiencies, and address a crucial gap in child nutrition research thereby ensuring that the developed meals are nutritious in order to improve the overall health and development of school aged children in Nigeria and similar countries.

Purpose of the Study.

The general purpose of the study was to determine the vitamin composition of the locally sourced breakfast meal for school-aged children. Specifically, the study:

1. produced flours from the corn, date, sweet potato, oat and bonga fish;
2. formulated breakfast meal using the flours from corn, date, sweet potato, oat and bonga fish at different ratios;
3. determined the vitamin composition of the formulated breakfast meal.

Materials and Methods

The study adopted an experimental research design. This allows for comparison among the different ratios of the formulated breakfast samples.

Source of raw materials: The raw materials for the study are Corn, Dates, Sweet potato, Oat and Bonga fish. These were locally purchased from Eke, Awka market in Awka town, Anambra State.

Sample preparation:

Corn was prepared by measuring out 3000g (3kg). It was sorted to remove stones, dirt, dust, and chaff. It was washed, strained and allowed to dry. It was toasted for 30 minutes, aired and milled into flour. The resulting flour was sieved using a 0.4mm mesh size, and then stored in air tight container and kept at room temperature for later use.

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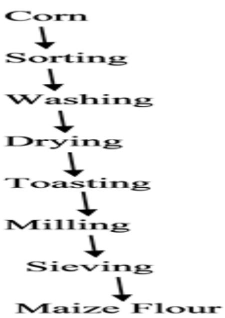

Figure 1: Flow Chart of Preparing Maize Flour

Preparation for date flour

Dates was sorted, washed, soaked, the seeds removed, dehydrated and milled into flour. 3000g of Date flour was used.

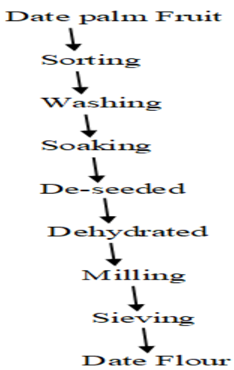

Figure 2: Flow Chart for Preparing Date Flour

Preparation of Sweet potato flour

Sweet potato was sorted to get good and firm ones, washed in clean water, peeled, cut into tiny bits, washed and dehydrated. It was milled into flour. The resulting flour was sieved using a

0.4mm mesh size, and then stored in air tight container and kept at room temperature for later use.

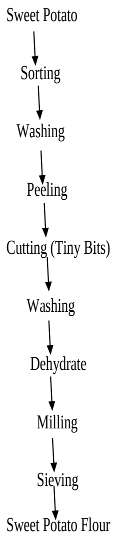

Figure 3: Flow Chart for Preparing Sweet potato

Preparation of Oat flour

3000g of Oat was measured and toasted, after which it was then milled into flour and sieved.

Figure 4: Flow Chart for Preparing Oat Flour

Preparation for bonga fish powder

Bonga fish was deboned, washed in a salty solution and oven dried and milled into flour. 300g of bonga fish powder was used.

Figure 5: Flow Chart for Preparing Bonga Fish Flour

Formulation of breakfast samples

Six samples were produced of various proportions from the food sources used in formulating the breakfast meal

Sample A comprised of 25.6% corn, 22% sweet potato, 22% dates, 0.4% bonga fish and 30% oat.

Sample B comprised of 30% corn, 40% sweet potato, 0% dates, 0.4% bonga fish and 29.6% oat.

Sample C comprised of 29.8% corn, 30% sweet potato, 10% dates, 0.4% bonga fish and 29.8% oat.

Sample D comprised of 30% corn, 10% sweet potato, 30% dates, 0% bonga fish and 30% oat.

Sample E comprised of 40% corn, 10% sweet potato, 20% dates, 0.4% bonga fish and 27.6% oat.

Sample F comprised of 29.6% corn, 0% sweet potato, 40% dates, 0.4% bonga fish and 30% oat.

Laboratory/Vitamins Analysis

Determination of vitamin B1 (Thiamin)

5g of the sample was homogenized with 50ml of ethanoic sodium hydroxide. It was filtered into a 100ml conical flask, 10ml of the filtrate was pipette and the colour was develop by addition of 10ml of 1%potassium dichromate and read the absorbance at 360nm. A blank solution is also prepared (Onwuka 2018).

Determination of Vitamin B2 (Riboflavin)

5g of the sample was extracted with 100ml of 50% ethanol and shaken for one hour. This was filtered into 100ml flask 10ml of the extract was pipette into 50ml volumetric flask. 10ml of 5% potassium permanganate and 10ml of 30% H_2O was added and allowed to stand over a hot water bath for 30min. 2ml of 40% sodium sulphate was added. This was made up to 50ml mark and the absorbance was measured at 510nm using a spectrophotometer (AOAC 2023).

Determination of Vitamin B3 (Niacin)

5g of the sample was treated with 50ml 1N H_2SO_4 and shaken for 30min. 3drops of ammonia solution were added to the sample and filtered. The filtrate was pipette into a 50ml volumetric flask and 5ml of potassium cyanide was added. This was acidified with 5ml of 0.02N H_2SO_4 and absorbance was measured using a spectrophotometer at 470nm (Eitenmillar & DeSouza 2020)).

Determination of vitamin A (carotene)A weighed quantity of sample containing not more than 1g of fat and at least 240 unit of vitamin A was mixed with 30ml absolutes alcohol and 3ml of 5% potassium hydroxide and boiled gently under reflex for 30min in a stream of oxygen free nitrogen. It was allowed to cool rapidly. 30 ml of water was added and transferred to the separator, then washed in with 3x50ml either and the vitamin A was extracted by shaking for 1min. The lower layer was discarded after complete separation and the extracted was washed with 4x50ml water the mixing was done cautiously; during the first two washes to avoid emulsion formation.

Determination of vitamin K

The procedure for color development, as adapted from Menotti's procedure, is as follows. The solution in which the concentration of vitamin K is being determined is placed in a flask and the sodium pentacy anoamine ferroate reagent is added. The solution is stirred and then allowed to stand for fifteen minutes to allow maximum color development. When the blue color has developed, the absorption of the solution is measured by means of a spectrophotometer at 650nm. Standard vitamin K solution. The standard vitamin K solution was prepared by dissolving 5 milligrams of crystalline vitamin K in water and diluting it to 100 milliliters. This solution is stable for 4 to 6 hours. The absorption of the solution was read on a spectrophotometer at 650nm, against a reagent blank (AOAC 2023).

Determination of Vitamin B6 (pyridoxine hydrochloride)

Vitamin B6 Twenty milligram of solid (BEV 1307-1308) or 60 ml of liquid samples (SOF 1301-
1302, HER 13041305 and ENE 1309-1312) was added into a 125 ml Erlenmeyer flask, filtered and degassed by sonication for five minutes. A 10 ml aliquot of the degassed sample was placed in each of five 100 ml volumetric flasks which were then made up using 0.1 N HCl after which absorbance was measured at 290 nm (Gusam *et al* 2011).

Determination of Vitamin B9 (folic acid)

The standard or sample solution of folic acid 1.0 ml was mixed with 1.0 ml of 4 mol l-
hydrochloric acid, 1.0 ml of 1% (w/v) sodium nitrite, 1.0 ml of 1% (w/v) sulfuric acid and 1.0ml
of 1% (w/v) 3-aminophenol which was resulting in an orange-yellow complex. The absorption of completion was measured at 460 nm using UV-Visible spectrophotometer. For the analysis of folic acid (AOAC 2023).

Determination of vitamin D

Vitamin D content was determined by mixing the carr-price reagent (20% m/v of antimony trichloride in chloroform with 40% pure acetylchloride) freshly prepared and must be free from alcohol. 9ml of the carr-price will be added to 1ml sample extracted with chloroform and the extinction is measure at 500nm against the reagent blank. And the concentration is extrapolated from a standard curve graph using the vitamin D standard (AOAC 2023).

Determination of vitamin K

The procedure for color development, as adapted from Menotti's procedure, is as follows. The solution in which the concentration of vitamin K is being determined is placed in a flask and the sodium pentacy anoamine ferroate reagent is added. The solution is stirred and then allowed to stand for fifteen minutes to allow maximum color development. When the blue color has developed, the absorption of the solution is measured by means of a spectrophotometer at 650nm. Standard vitamin K solution. The standard vitamin K solution was prepared by dissolving 5 milligrams of crystalline vitamin K in water and diluting it to 100 milliliters. This solution is stable for 4 to 6 hours. The absorption of the solution was read on a spectrophotometer at 650nm, against a reagent blank (AOAC 2023).

Method of Data Analysis

The results were expressed as mean ± standard deviation and the test for statistical significance was carried out using one-way analysis of variance (ANOVA). The Statistical Package for Social Sciences (SPSS, Version 20) software was used to determine significant differences. Significant means was separated using Duncan's New Multiple Range Test (DNMRT) and differences was considered significant at ($p<0.05$)

Results

Table 1: Vitamin content of the locally sourced breakfast meal

S/N	B1 (mg/100g)	B2 (mg/100g)	B3 (mg/100g)	Carotene	E (mg/100g)	K (ug/g)	B6	B9	D
A	0.77c±0.01	1.36c±0.02	1.89e±0.00	34.88c±0.02	2.31d±0.01	5.61d±0.01	2.61b±0.01	5.47c±0.01	0.72b±0.00
B	0.74c±0.01	1.24d±0.01	2.41c±0.01	38.41a±0.01	2.48c±0.00	3.31f±0.01	1.84d±0.01	4.87d±0.03	0.35e±0.01
C	0.81b±0.02	1.55b±0.01	1.95c±0.01	36.48b±0.04	2.57b±0.01	6.76b±0.02	1.45e±0.00	4.74e±0.02	0.63c±0.00
D	0.93a±0.01	1.66b±0.02	2.83a±0.01	32.75e±0.01	1.83f±0.01	6.19c±0.01	2.61b±0.01	5.76b±0.02	0.46d±0.02
E	0.85^{b}±0.01	1.36c±0.00	1.75f±0.01	33.81^{d}±0.01	2.61a±0.01	5.47e±0.01	2.35c±0.01	5.47c±0.01	0.75b±0.01
F	0.90a±0.02	1.63a±0.02	2.58b±0.02	26.72f±0.02	1.91e±0.02	6.91a±0.01	2.73^{a}±0.01	6.81a±0.01	0.82a±0.01

Values of mean ± standard deviation of duplicate sample a-c Mean with similar super script in each row are not significantly different ($P>0.05$) Sample A: complementary food from 25.6% corn, 22% sweet potato, 22% dates, 0.4% bonga fish and 30% oat. Sample B: 30% corn, 40% sweet potato, 0% dates, 0.4% bonga fish and 29.6% oat. Sample C: 29.8% corn, 30% sweet potato, 10% dates, 0.4% bonga fish and 29.8% oat. Sample D: 30% corn, 10% sweet potato, 30% dates, 0% bonga fish and 30% oat. Sample E: 40% corn, 10% sweet potato, 20% dates, 0.4% bonga fish and 29.6% oat. Sample F: 29.6% corn, 0% sweet potato, 40% dates, 0.4% bonga fish and 30% oat. Sample G: control which is Moppet food, a commercial breakfast meal.

Results

Table 1 presents the results of the vitamin composition of the formulated breakfast samples. The results showed that Thiamine (B1) values ranged from 0.74 ± 0.01 mg/100 g (Formulation B) to 0.93 ± 0.01 mg/100 g (Formulation D). Formulations D and F had the highest B1 content, significantly higher than B ($p < 0.05$). Thiamine is critical for energy metabolism and cognitive function, particularly in children, where it supports brain development and academic performance (Adolphus et al., 2016). Riboflavin (B2) concentrations varied from 1.24 ± 0.01 mg/100 g (Formulation B) to 1.66 ± 0.02 mg/100 g (Formulation D). Formulations D and F were statistically superior ($p < 0.05$) to others, indicating their potential to meet riboflavin needs, which are essential for growth and energy production in school-aged children (Gibson, 2003). Niacin (B3) levels ranged from 1.75 ± 0.01 mg/100 g (Formulation E) to 2.83 ± 0.01 mg/100 g (Formulation D). Formulation D had the highest niacin content, significantly greater than all others ($p < 0.05$). Niacin supports neurological function and energy metabolism, key for sustaining attention and learning in children (Adolphus et al., 2013). β-Carotene (Provitamin A) concentrations ranged from 26.72 ± 0.02 µg/100 g (Formulation F) to 38.41 ± 0.01 µg/100 g (Formulation B). Formulation B exhibited the highest β-carotene content ($p < 0.05$), suggesting a stronger contribution to vitamin A status, which is vital for vision and immune function in children (Aaron et al., 2011).

Tocopherol (Vitamin E) values ranged from 1.83 ± 0.01 mg/100 g (Formulation D) to 2.61 ± 0.01 mg/100 g (Formulation E). Formulation E had the highest vitamin E content ($p < 0.05$), which is important for antioxidant protection and immune health in growing children (Bhattacharya et al., 2006). Phylloquinone (Vitamin K) levels ranged from 3.31 ± 0.01 µg/g (Formulation B) to 6.91 ± 0.01 µg/g (Formulation F). Formulation F was significantly richer in vitamin K ($p < 0.05$), supporting blood clotting and bone health, which are critical during childhood growth (Weber, 2001). Pyridoxine (B6) concentrations ranged from 1.45 ± 0.00 mg/100 g (Formulation C) to 2.73 ± 0.01 mg/100 g (Formulation F). Formulation F had the highest B6 content ($p < 0.05$), contributing to neurotransmitter synthesis and cognitive development (Yao et al., 2019). Folate (B9) values ranged from 4.74 ± 0.02 μg/100 g (Formulation C) to 6.81 ± 0.01 μg/100 g (Formulation F). Formulation F was significantly higher ($p < 0.05$), supporting DNA synthesis and cognitive performance in children (Arora, 2022). Cholecalciferol (Vitamin D) levels ranged from 0.35 ± 0.01 μg/100 g (Formulation B) to 0.82 ± 0.01 μg/100 g (Formulation F). Formulation F had the highest vitamin D content ($p < 0.05$), crucial for bone health and immune function, particularly in populations with limited sun exposure (Gibson, 2020).

Discussion of the findings

The results indicate significant variability in the vitamin profiles of the locally formulated breakfast meals, with formulations D and F consistently showing higher concentrations for most vitamins (B1, B2, B3, B6, B9, K, and D). These formulations may better support the nutritional needs of school-aged children, particularly for cognitive development, energy metabolism, and immune function. For instance, higher B-vitamin content (B1, B2, B3, B6, B9) in formulations D and F aligns with findings from recent studies showing that B-vitamins enhance cognitive performance, attention, and memory in children (Adolphus et al., 2016; Arora, 2022). The elevated β-carotene in Formulation B is noteworthy, as vitamin A precursors are essential for vision and immune health, particularly in undernourished populations (Aaron et al., 2011). However, the lower vitamin D content across all formulations, particularly in formulation B (0.35 ± 0.01 μg/100 g), suggests a potential gap in meeting the recommended dietary allowances (RDA) for children, which is approximately 15 μg/day (Institute of Medicine, 2011). This is consistent with studies indicating that breakfast meals often fall short of providing adequate vitamin D, necessitating fortification or supplementation (Gibson, 2003). Similarly, the vitamin E content, while highest in formulation E, remains modest compared to the RDA (7–11 mg/day for children aged 4–13 years), suggesting room for improvement in antioxidant provision. Recent empirical studies underscore the importance of breakfast composition for school-aged children.

Adolphus et al. (2016) conducted a systematic review demonstrating that breakfast consumption, particularly meals rich in B-vitamins and micronutrients, enhances cognitive performance in domains like memory and attention, with stronger effects in undernourished children. Similarly, Arora (2023) highlighted those breakfasts providing adequate B-vitamins (B1, B6, B9) improve cognitive function and academic performance in children, particularly when consumed regularly. Another study by Yao (2019) found that breakfast frequency and quality, including micronutrient content, significantly impact cognitive development, with fortified meals showing greater benefits in disadvantaged populations. These findings support the need for optimizing the vitamin composition of breakfast meals, as seen in formulations D and F, to maximize cognitive and health outcomes.

Conclusion

This study investigated the vitamin composition of locally sourced breakfast meals for school-aged children. The vitamin content of six different samples was checked. The results revealed significant variations in the composition and properties of the samples. Formulations D and F exhibit superior vitamin profiles, particularly for B-vitamins, vitamin K, and vitamin A, making them ideal for supporting the nutritional needs of school-aged children. However, low values of vitamin D and E across all formulations highlight the need for targeted fortification to meet RDAs. These findings align with recent research emphasizing the role of micronutrient-rich breakfasts in enhancing cognitive and academic performance in children. Further studies should investigate the long-term impact of these formulations on health and academic outcomes, incorporating bioavailability and glycemic response analyses.

Recommendations

1. Since the breakfast meal samples from the blends of corn, date, sweet potato, oat and bonga fish contained reasonable amounts of vitamins such as vitamin B1, B2, B3, carotene, K, B6, B9, it is suggested that the breakfast meal be taken as its consumption poses no danger to human health, rather promotes healthy living.
2. The availability and affordability of the local food items used for this research work will help in reducing economic constraints in getting nutrient rich meal for children.
3. This study is beneficial in the reduction of micronutrient deficiency related diseases for the vulnerable group especially the children.
4. More research should be conducted on the shelf life of the formulated breakfast meal to determine its commercial viability.

References

Aaron, G. J., Kariger, P., Aliyu, R., Flach, M., Iya, D., Obadiah, M., and Baker, S. K. (2011). A multi-micronutrient beverage enhances the vitamin A and zinc status of Nigerian primary schoolchildren. *The Journal of Nutrition*, 141(8), 1565–1572. (https://www.cambridge.org/core/journals/nutrition-research-reviews

Adeoso, A. O., Oresanya, T. O., Oyebamiji, O. O. and Ogunmuyiwa, Y. A. (2022). Nutritional analysis and sensory evaluation of crab shell fortified bread. *Proceedings of the Nutrition Society*, 81(OCE5).

Adepoju, F. and Olayemi, A. (2021). Nutritional benefits of bonga fish flour. *African Journal of Nutritional Sciences,* 23(1), 56-63.

Adolphus, K., Lawton, C. L., Champ, C. L., and Dye, L. (2016). The effects of breakfast and breakfast composition on cognition in children and adolescents: A systematic review. *Advances in Nutrition,* 7(3), 590S–612S.(https://pmc.ncbi.nlm.nih.gov/articles/PMC4863264/)

Al-Farsi, M. A. and Lee, C. Y. (2018). Nutritional and functional properties of dates: A review. *Critical Reviews in Food Science and Nutrition*, 48, 877-887

Ali, S., Hassan, T. and Mahdi, N. (2022). Nutritional benefits of date palm-derived flour in functional foods. *International Journal of Nutrition*, 12(4), 455-468.

Arora, S. K. (2022). Effects of breakfast on cognitive function of children. Acta Scientific Nutritional Health, Effects of Breakfast on Cognitive Function of Children. 6(4), 75-79. (https://www.researchgate.net/publication/359663654

Association of Official Analytical Collaboration (2023) AOAC Official Method 923.03. Ash of Flour: Direct Method. In: Latimer Jr., G.W., Ed., Official Methods of Analysis of AOAC international, 22nd Edition, Oxford University Press, C32-2. https://doi.org/10.1093/9780197610145.003.2929

Babarinde, G. O. and Ebun, A. A. (2024). Hepatotoxicity and biochemical evaluation of a novel breakfast food produced from the blend of fonio (*Digitaria iburua Stapf*) and pigeon pea (*Cajanus cajan* (L.) Mill spaugh) in albino rats. *Bulletin of the National Research Centre*

Balvin F. L., Treviño, R. P., Echon, R. M., Garcia-Dominic, O. and DiMarco, N. (2013). Association between Frequency of Ready-to-Eat Cereal Consumption, Nutrient Intakes, and Body Mass Index in Fourth- to Sixth-Grade Low-Income Minority Children. *Journal of the Academy of Nutrition and Dietetics*, 113(4), 511-519. https://doi.org/10.1016/j.jand.2013.01.006

Bhattacharya, J., Currie, J., and Haider, S. J. (2006). Breakfast of champions? The School Breakfast Program and the nutrition of children and families. *The Journal of Human Resources*, 41(3), 445–466. (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6883765/)

Carlson, R. M., Campbell, J., Goodman, A., Moller, M. and Moller, T. (2020). Food sources for the future: A review of alternative proteins and food systems. *Sustainable Food Systems*, 3(2), 122-135.

Eitenmillar R.R., & Desouza, S.C. (2020) Effects of processing and storage on the folate content of spinach and broccoli. *Journal of Food Sciences.* 51(3), 626-628.

Gibson, R. S. (2020). Principles of Nutritional Assessment. Oxford University Press.

Gusam, N., Fudalej, F., Kallel, H. and Nic and., J. M. (2011). A Molecular Approach to Optimize HIFN Alpha 2b Expression and Secretion in *Yarrowia Lipolytica*. *Application of Microbiological Biotechnology*. 2011; 89:109-119.

Ighalo, J. O. and Ogunniyi, J. M. (2021). Protein content and functional properties of fish-based composite flours. *Journal of Nutritional Biochemistry*, 53(2), 157-167.

Institute of Medicine. (2011). Dietary Reference Intakes for Calcium and Vitamin D. National Academies Press.

Joyce, S. A., Kamil, A., Fleige, L. and Gahan, C. G. M. (2019). The Cholesterol-Lowering Effect of Oats and Oat Beta Glucan: Modes of Action and Potential Role of Bile Acids and the Microbiome. *Front. Nutrition*, 6, 171.

Mitra, S. (2019). Nutritional status of orange fleshed sweet potatoes in alleviating vitamin A malnutrition through a food-based approach. *Journal of Nutrition and Food Science.* 2(8):6–9.

Onwuka, G. I. (2018). *Food Analysis and Instrumentation (Theory and Practice).* Naphtali Printers, Lagos Nigeria. ISBN 978047686.

Rekha, P., Sumathi, K., Samyuktha, S., Saranya, A., Tharunya, G. and Prabha, R. (2020). Sensor-based waste water monitoring for agriculture using IoT. In 2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS) (pp. 436–439). IEEE. https://doi.org/10.1109/ICACCS48705.2020.9074292.

Revathymol, P. R. and Antony, V. (2021). Formulation and awareness of handy breakfast recipes for college-going girls. *International Journal of Home Science*, 7(1), 140–143.

Shah, T. R., Prasad, K., Kumar, P. and Yildiz, F. (2019). Maize- a potential source of human nutrition and health: a review. Cogent Food and Agriculture. 5 (2) 234-237.

Sule, E. I., Umoh, V. J., Whomg, C. M. Z., Abdullahi, L. O. and Alabi, O. (2019). Chemical and nutritional value of maize and maize products obtained from selected markets in Kaduna State, Nigeria. *African Journal of Food Science and Technology*, 5(4), 100- 104.

Udeh, G., Okwu, G. and Onyeike, E. (2023). The contribution of bonga fish flour to vitamin D intake. *Journal of Marine Nutritional Studies*, 25(2), 187-194.

UNICEF. (2020). Global annual results report 2020: Goal area 2. https://www.unicef.org/reports/global-annual-results-report-2020

U.S. Department of Agriculture, Economic Research Service. (2023). Household food security in the United States in 2022. https://www.ers.usda.gov/publications/pub-details/?pubid=103579

Varma, P. Bhankharia, H. and Bhatia, S. (2019). Oats. A Multi-Functional Grain. *J. Clin. Prev. Cardiol*, 5, 9–17.

Weber, P. (2001). Vitamin K and bone health. *Nutrition*, 17(10), 880–887.

Yao, J., (2019). Effect of eating breakfast on cognitive development of elementary and middle school students: An empirical study using large-scale provincial data. *Frontiers in Public Health*, 7, 344. (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6883765/)