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FORMULATION AND NUTRITIONAL EVALUATION OF TOM BROWN PRODUCED FROM SELECTED LOCALLY AVAILABLE RAW MATERIALS

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Abstract: Tom Brown is highly nutritious, locally produced West African, hot cereal or porridge made from roasted blend of maize, millet, guinea corn, soybeans and groundnuts often enriched with ingredients like fish powder, dates, and spices. It is underly used as a weaning food for babies (6 months plus) and a nutrient-dense breakfast for all ages, known for preventing malnutrition and aiding weight gain. Standard food processing techniques were employed, and proximate composition, energy value, and sensory attributes of the formulated samples were determined using established analytical methods. Proximate analysis showed that moisture content ranged from 9.10 to 10.20 percent, indicating good shelf stability. Crude protein increased significantly with fortification, ranging from 8.45 percent in the control sample to 17.50 percent in the most fortified sample. Fat content ranged from 3.10 to 6.80 percent, while crude fibre increased from 1.50 to 4.50 percent. Ash content ranged from 1.20 to 3.45 percent, reflecting improved mineral density. Carbohydrate content decreased progressively from 75.55 to 58.65 percent due to increased protein and fat inclusion. Energy values ranged from 363.90 to 365.80 kcal per 100 g, meeting recommended levels for complementary foods. Mineral composition improved across formulations, with calcium increasing from 165.40 to 240.50 mg per 100 g, magnesium from 140.25 to 195.75 mg per 100 g, iron from 2.50 to 5.60 mg per 100 g, and sodium from 70.20 to 94.10 mg per 100 g. Vitamin analysis revealed progressive increases in Vitamin B1 from 0.18 to 0.42 mg per 100 g, Vitamin B2 from 0.09 to 0.35 mg per 100 g, Vitamin B3 from 0.30 to 0.74 mg per 100 g, and Pro vitamin A from 5.10 to 15.80 mg per 100 g. Sensory evaluation using a 9 point hedonic scale indicated general acceptability scores ranging from 6.35 to 7.10, demonstrating moderate to high consumer acceptance despite nutrient enhancement. The findings demonstrate that fortified Tom Brown produced from locally available raw materials offers improved nutritional adequacy and acceptable sensory qualities. The study concludes that such formulations can serve as affordable and sustainable alternatives to commercial complementary foods, with strong potential to contribute to improved child nutrition and food security.

Keywords: malnutrition, Tom Brown, weaning food, babies' breakfast, proximate composition, energy value, sensory attributes viscosity

1.0 Introduction

Tom Brown has been defined as a food supplement produced from blends of nutritious locally available ingredients and typically prepared as a porridge for infants and children between 6-59 months old (Catholic Relief Services, 2021). It has been used as a weaning food in most parts of West Africa and has attracted multiple researches all in a bid to improve its nutrient composition to meet the nutritional

requirements of infants and children (Nagai et al., 2009). Its use is not only limited to household use, but also has been expanded to a humanitarian context to mitigate the challenge of Moderate Acute Malnutrition (MAM) in North-East Nigeria (Catholic Relief Services, 2021).

“Tom Brown” weaning food was observed to be of high protein status, and supported the growth of rats. Compared to standard protein reference diet, “Tom Brown” was observed to be of higher total nitrogen and protein contents, with comparable nitrogen and protein intakes, carcass and faecal nitrogen, PER, NPR and

TD in rat model. The product also had a significant positive effect on weight changes, NPU and BV in rats, comparable to the reference diet. The results of this study indicate that “Tom Brown”, made from the combination of maize, groundnut, soybean and guinea corn, has adequate caloric and protein value and quality required for weaning foods, (Banigo et al., 1974); Akingbala et al., 1981).

In conclusion, since the protein status of “Tom Brown”, and its nutritional impact on rats are comparable to that of standard protein reference diet; and the materials for its preparation are readily available and affordable, “Tom Brown” is hereby recommended for use as weaning food. Moreso, patients with nutritional problems, mostly children with kwashiorkor, marasmus and nutritional anaemia may also depend on “Tom Brown” for their recovery (Essien et al., 2010).

Nutrition is the science that deals with the study of food constituents and their effects in the body. In humans and other mammals, nutrition starts at birth with breastfeeding. Breastfeeding is the nursing of an infant on the mother’s breast (Frazer and Cooper, 2003). Breastfeeding is the best start in life because the breast milk contains all the nutrients needed in appropriate proportion for the growing infant. Exclusive breastfeeding, according to WHO (1990) is highly recommended. This is an act of breastfeeding an infant from birth without giving water or solid foods until the child is six months old. Thereafter, breastfeeding continues with the addition of water and semi solid foods till the child is two years old. This act helps to promote good health, growth and development before the child is weaned (World Health Organization, 2025).

Weaning is an introduction of soft, easily swallowed and digested foods to supplement the infant’s feeding early in life (Onofiok and Nnanyelugo, 1992). It is also the time an infant’s breastfeeding is gradually changed to semi solid foods to replace the nutrients which are present in breast milk (Frazer and Cooper, 2003). This should be carefully planned so that the diets contain all classes of nutrients in their correct proportion suitable for the child’s growth and development. According to Bender and Bender (1995), weaning foods are especially formulated for infants aged between three and nine months for the transition between breastfeeding or bottle feeding and normal intake of semi solid foods. Weaning period is a crucial period in an infant’s life. At the age of five to six months, most infants begin to eat supplementary semi solid foods. At this stage, homogenized infant’s foods play a major role in their nutrition (Martinez et al., 2004).

In most developing countries of the tropics, during weaning period, protein shortage in the diets is common and is usually found in association with deficiency in calories. The low-income group constitutes the bulk of the population that are particularly at risk in such situation. They usually have no alternative than to depend on the local products from cereals and legumes which are cheaper than the animal products and commercial baby formulas (Okoh, 1998). In the Medical Centre, University of Calabar, Calabar – Nigeria, there are many locally prepared foods from legumes and cereals. One of these foods, commonly used as weaning formula, is called “Tom Brown”. It is made up of maize, groundnut, soybean and guinea corn. These foodstuffs are locally grown, usually roasted or fried and blended together to give a nourishing brownish diet, which is served as pap. “Tom Brown” is recommended and used as weaning food for children. However, there is paucity of information on the

nutritional value of the product, “Tom Brown”. The present study is designed to evaluate the nutritional quality of “Tom Brown” weaning formula (Doctors Without Borders, 2024).

Malnutrition remains a significant public health challenge in many developing countries, including Ghana, taking various forms such as protein- energy malnutrition and deficiencies in essential vitamins and minerals (Adu- Afarwuah et al. 2023). These nutritional gaps adversely affect children's cognitive development, growth, and overall health (Bommer et al. 2020).

Traditional weaning foods such as Tom Brown, a porridge made from roasted maize, millet, legumes, and other grains, are common in Ghanaian diets. Tom Brown is valued for its availability and popularity across communities. It has been effectively used as a supplementary therapeutic diet for treating moderate acute malnutrition, demonstrating good recovery and low mortality rates (Sewor and Jayalakshmi 2024). Research indicates that adding hydrothermally treated soybeans or biofortified maize to Tom Brown improves its nutritional value and acceptance (Kalumbi et al. 2019; Siwela et al. 2020).

Despite its benefits, Tom Brown does not contain all the key nutrients that are essential for optimal child growth. Many Ghanaian children, especially in rural areas, do not receive the necessary nutrients, leading to widespread stunting and under nutrition (Aryeetey et al. 2022). A study on complementary food mixes in Ghana linked unfortified plant- based foods to prevalent infant malnutrition (Sewor and Jayalakshmi 2024). Also, a study on how dietary diversity is related to the hematological status of preschool children in Ghana revealed that anemia prevalence (Hb < 11 g/dL) among children aged 6–59 months was 66.8% (Saaka and Galaa 2017).

In a similar study to determine anemia prevalence and its predictors among children under five years in Ghana using a multilevel analysis of the Cross- sectional 2019 Ghana Malaria Indicator Survey and cited in (Aheto et al. 2023) indicated that 54% of children under 5 years were anemic. Additionally, poor complementary feeding practices exacerbate the issue, with 14% of infants introduced to these foods before three months of age (Wiafe et al. 2023).

Though popular, conventional cereal and legume mixes do not meet recommended nutrient levels for certain nutrients, especially the micronutrients and fats (Temba et al. 2016).

Enhancing the diet with grain legumes can improve protein and micronutrient adequacy (De Jager et al. 2019). Consequently, with its proven efficacy in treating mild acute malnutrition, Tom Brown can be a vital nutritional source for children. Roasting grains improves digestibility and reduces antinutritional factors such as phytates and tannins, further aiding nutrient absorption (Mahanta et al. 2020).

On the other hand, eggs are a rich source of high- quality protein, essential vitamins, and minerals, making them crucial for human nutrition (Rafed et al. 2024). Nutrients such as riboflavin, selenium, choline, and vitamins A, D, B12, and B9 are abundant in eggs. Egg powder retains these nutritional benefits while at the same time offering a longer shelf life and straightforward incorporation into various dishes (Wulandari and Arief 2022). Besides, iron from egg powder is more bioavailable than legume sources. Egg powder fortification can significantly enhance the nutritional profile of Tom Brown, addressing its deficiencies and boosting its overall health benefits. This is particularly valuable in resource- limited settings where eggs are readily available due largely to some extent domestic rearing of fowls and the relative affordability (Javed et al. 2018).

Wa Municipality in Ghana's Upper West Region faces severe food insecurity, poverty, and child undernourishment. Despite progress through social security programs, institutional barriers hinder effective implementation (Burchi 2021).

Nutritional deficiencies persist, particularly among children in rural areas within the Municipality (Ecker and van Asselt 2017). Concerns about the nutritional value of meals provided through the “school- feeding programme” highlight the need for ongoing efforts to combat poverty, food insecurity, and nutritional deficiencies (Bigson et al. 2019).

Improving the nutritional value of food through fortification strategies such as adding egg powder to Tom Brown is crucial. However, consumer acceptance of the fortified product is also essential for success. Children are more likely to consume and benefit from a nutritionally enhanced food if it is palatable and culturally acceptable (Chakona and Shackleton 2019). Sensory evaluation, which includes taste, texture, aroma, and overall acceptability, is vital for the success of any fortification intervention (Hummel et al. 2018). Studies have shown that cultural preferences and sensory qualities significantly impact the acceptability of fortified foods (Boateng et al. 2019; Huey et al. 2022).

In spite of these, prior research on food fortification for child nutrition often focused on isolated nutrient enrichment such as iron and vitamin A or single- ingredient interventions, neglecting the synergistic potential of combining locally available staples with underutilized protein sources such as egg powder. Thus, the wider concept of this study is to address critical gaps in multidimensional fortification, as there is limited data of evidence on composite products that simultaneously enhance macronutrients (protein, carbohydrates), critical micronutrients (iron, zinc, folate), and address energy density in a single formulation. The focus is to bridge the gap on the practical feasibility of this intervention, in the midst of scarce data on the functional properties (viscosity, solubility) and shelf life stability of egg powder- fortified staples which are essential for scalability in low- resource settings, as well as providing more insights into the acceptability– sustainability trade- offs regarding the insufficient understanding of how nutrient fortification ratios such as egg powder: corn flour affect sensory preferences and compliance in study populations, especially children. The narrow objective of this study is therefore to evaluate the nutritional composition, sensory acceptability, and potential health benefits of egg powder- fortified Tom Brown in school- aged children, 5–12 years. The study's findings will provide valuable insights into the feasibility of this fortification strategy and its potential impact on improving child nutrition in the Wa Municipality (Nyefene et al., 2025).

Pumpkin (*Curcubita*) pulp is a nutrient-rich food containing antioxidants and carotene, which promotes immunity against diseases in the human body (Perez, 2016).

Despite being a vegetable, it is under-utilized and lacks commercial recognition and market potentials, which underline its cultivation on a small-scale level (Agbugba et al., 2011). Studies have shown the potentials of pumpkin pulp as a food supplement and a food source in the mitigation of Vitamin A deficiency due to its mineral and carotene content; therefore, its utilization limited to its consumption as a vegetable and as thickeners for soups and purees at the household level is expanding to cover more beneficial grounds (Nakazibweet al., 2020).

Soybeans are nutrient rich legumes characterized by their high-quality protein content which is not only a double of the protein content of other legumes and twelve times that of milk, but also, have a relatively high amount of essential amino acids that significantly levels up to the protein requirements of humans (Adelakun et al., 2013; Chatterjee et al., 2018).

Pearl millet (*Pennisetum glaucum*) is listed as one of the most important cereals serving as a staple food for millions of people in several African and Asian countries (Dias-Martins et al., 2018). In Nigeria, millions of tons of pearl millet is cultivated and utilized as an alternative income source to poor farmers and as a staple in many homes largely in Northern Nigeria (Izge & Song, 2013). According to Bello et al. (2018), a thick binding paste known as “tuwo” can be produced from it. It is also used in the production of a popular beverage in northern Nigeria and southern Niger (“fura” in Hausa language) by

rolling the ground flour into balls, parboiling them and reconstituting it using fermented milk (*nono*). Although millet flour does not contain gluten, it contains a significant amount of protein and minerals therefore, can be an excellent alternative for gluten containing cereals for people with celiac disease (Adéoti et al., 2017; Kulkarni et al., 2021).

Rice is one of the highly consumed staples in Nigeria and has the potential to provide the minimum calorie requirement of an average Nigerian per day (FAO, 2001). African rice (*Oryza glaberrima*) is native to Africa. Although its cultivation is declining due to its low yield, it is still highly sought after due to its unique taste and hardness, which is highly desirable to its consumers (Sié et al., 2012).

Tom brown is one of the nutritious foods among Nigerians that is consumed by adults and children either as breakfast or in between meals. According to Catholic Relief Services (2021), Tom Brown is produced from roasting six parts cereals (sorghum, maize and millets), three parts soybean and one-part groundnuts. In this study, the addition of pumpkin pulp will serve as a good source of vitamin A (Nakazibwe et al., 2020).

Energy, protein and micronutrients are essential for adequate development and growth in infants and for adequate body functioning in adults (UNICEF, 2019). Vitamin A deficiency is common amongst children and infants in the world and causes adverse effects in their growth and development and can even lead to death if not attended to (Tenagashaw et al., 2017). According to FAO (2001) reports, malnutrition is one of the leading global health challenges and has been reported as the leading root cause of some ailments suffered in adulthood.

Malnutrition and poor dietary intake remain major public health concerns in many developing countries, especially among infants, children, and low-income households. There is therefore a growing need to develop nutrient-dense, affordable, and culturally acceptable complementary foods from locally available raw materials. Tom Brown, a traditional weaning and breakfast porridge, is widely consumed across Nigeria and other parts of Africa because of its energy-giving properties. However, the conventional preparation, often based on a single cereal, is limited in protein, vitamins, and minerals, thereby making it nutritionally inadequate for optimal growth and health. This study is justified by the need to improve the nutritional quality of Tom Brown through the inclusion of locally available crops such as soybean, pearl millet, pumpkin pulp, and local rice. Soybean is rich in protein and essential amino acids, millet provides dietary fiber and micronutrients, pumpkin pulp is high in beta-carotene, vitamins, and minerals, while local rice serves as an affordable energy source. Combining these ingredients has the potential to enhance the proximate, mineral, and vitamin composition of Tom Brown, while maintaining its sensory acceptability.

Furthermore, utilizing indigenous raw materials supports food security, reduces reliance on imported food products, and encourages agricultural sustainability. It also provides an opportunity for value addition to local crops, thereby boosting farmers' income and promoting rural economic development. Therefore, this study is necessary not only for improving household nutrition but also for contributing to national efforts in tackling hidden hunger, reducing child malnutrition, and achieving food-based solutions for better health outcomes.

The aim of this study was to formulate Tom Brown from selected locally available raw materials, evaluate its nutritional composition, and suitability as a nutrition complementary food.

2.0 Methodology

2.1 Material

2.1.1 Sampling

The ingredients used for the formulations are roasted corn flour produced from locally available corn obtained by market survey. Among these ingredients are maize, millet, sorghum, groundnut, rice, crayfish, date, and yellow maize

2.1.2 Apparatus/Equipment

Among the equipment used are: tray, weighing balance, drying equipment, roasting pan (pot), grinding machine, gas cooker, and sieving basket

2.1.3 Chemical Reagent

The chemical reagents used: Sulfuric acid (H_2SO_4); Sodium hydroxide (NaOH); Boric acid (H_3BO_3); Hydrochloric acid (HCl); Petroleum ether; Ethanol; Magnesium oxide (MgO); Copper sulfate (CuSO_4); Sodium sulfate (Na_2SO_4); Phenolphthalein indicator; Mixed indicator (methyl red and bromocresol green); and Distilled water.

2.1.4 Sample Treatment

2.1.4.1 Roasted Corn Flour

The *Tom Brown* used in this study was made from locally produced corn. Yellow corn was purchased from the Oje Market, the bad ones carefully removed, and the remaining was roasted using dry heat in a gas-operated oven at about 150°C – 200°C . During the roasting, the corn was turned or stirred up to ensure even roasting and avoid burning. The roasting process was deemed complete when the corn turned brown in color. The roasted corn was then allowed to cool down and milled into flour (Ubbor et al. 2022).

2.1.4.2 Egg Powder

Egg powders find application in various food industry sectors as a flavoring and texturizing additive. They are created from whole eggs and carefully dried using various methods to increase their shelf life and produce a high-quality final product.

The egg powder utilized in this study is made commercially using the spray drying method and with chicken eggs from Emmpekk Farms, Nigeria, and Delta state. The spray drying process usually involves the use of hot gas to convert liquid eggs into dry egg powder.

2.1.4.3 The Spray Drying Process

In order to retain the composition and consistency the liquid feed (liquid egg) was prepared by passing through pre-processing steps such as pasteurization to ensure safety. The liquid feed was atomized into droplets to increase the surface area for efficient drying. The Nozzle Atomizers approach was used, where high-pressure nozzles were employed to create a fine spray. In the drying chamber, hot gas (air) was introduced, where the temperature and flow rate of the hot gas were carefully controlled, and the droplets were made to come into contact with the hot gas, causing rapid evaporation of the moisture. Losing moisture from the droplets resulted in solid particles formation with shapes and sizes that are influenced by factors such as feed properties, atomization, and drying conditions. The dried particles were then separated from the drying air using a cyclone separator, and the particles were collected at the bottom. The dried egg powder was then collected and milled to obtain a uniform particle size.

Airtight zip lock- like bags were used to store the powder to prevent moisture absorption and contamination (Pirkwieser et al. 2022).

2.1.5 Sample Preparation

2.1.5.1 Production of Toasted Local Rice Flour

Toasted local rice flour was produced using the method described by Joy and Ledogo (2016) with slight modification. The rice grains were sorted, steeped in clean water (16 h), drained (with a stainless screen), oven dried with Galle kemp, 300 Plus, England(60°C for 12 h), toasted with stainless pot on a gas flame for 10 min and milled into fine flour with an attrition mill (model SK30-SS).

2.1.5.2 Production of Toasted Millet Flour

Toasted millet flour was produced according to the method described by Mridula et al. (2008). Millet grains were sorted, washed in clean tap water, tempered (2 h), drained (using plastic sieve), oven dried with Gallenkemp, 300 Plus, England(60°C for 4 h), toasted with stainless pot on a gas flame for 10 min and milled into fine flour with an attrition mill (model SK-30-SS).

2.1.5.3 Production of Toasted Pumpkin Pulp Flour

The method described by Shamaail and Saher (2020) was used to produce toasted pumpkin pulp flour. The Pumpkin fruits were sorted, washed, cut open, deseeded. The pulps were extracted, drained using perforated plastic screen, oven dried with Gallenkemp, 300 Plus, England (60°C for 72 h), toasted with stainless pot on a gas flame for 5 min and milled into fine flour using an attrition mill (Yoshita model GX 390, 13.0 HP, made in China).

2.1.5.4 Production of Toasted Soybean Flour

The method described by Agume et al. (2017) was employed in the production of toasted soybean flour. The soybeans were sorted, soaked in water (12 h), drained using plastic sieve, dehulled manually by robbing the seeds in between hands, washed off the seed coats, drained again, oven dried (60°C for 60 h), toasted with stainless pot on a gas flame for 20 min and milled into fine flour with an attrition mill (model SK-30-SS).

Table 1: Tom Brown Formulations (%).

2.1 Methodology

The following composition was investigated: Protein Determination; Nitrogen- Free Extract (NFE); Moisture Content and Total Solids; Ash Content; Fat Content (Soxhlet Extraction); Crude Fiber; Chemical Analyses; and Sensory Evaluation

3.0 Results and Discussion

3.1 Results

3.1.1 Proximate Composition

The proximate composition results showed that fortification of maize-based Tom Brown with millet, soybean, groundnut, and crayfish significantly improved its nutritional quality. Moisture content ranged between 9–10%, which is below the recommended maximum of 12% for dry food products, indicating good shelf stability and reduced risk of microbial spoilage. Crude protein increased progressively with

higher inclusion of soybean and crayfish. This improvement is nutritionally important because maize is deficient in essential amino acids such as lysine and tryptophan, while soybean and crayfish provide high-quality protein. The cereal-legume-animal protein combination therefore improved both protein quantity and quality. Fat content increased due to groundnut and soybean inclusion, thereby enhancing energy density. Ash content also increased, reflecting improved mineral composition. Crude fibre increased moderately, supporting digestive health. Although carbohydrate content decreased slightly as protein and fat increased, it remained the major nutrient component and primary energy source. Energy values ranged between 360–366 kcal/100g, which falls within recommended levels for complementary foods.

Table 1: Proximate Composition (%) and Energy Value (kcal/100g)

Sample	Moisture	Protein	Fat	Ash	Fibre	Carbohydrate	Energy (kcal/100g)
TB1	10.20	8.45	3.10	1.20	1.50	75.55	363.90
TB2	9.85	12.60	4.85	2.10	2.80	67.80	364.05
TB3	9.60	14.25	5.40	2.75	3.40	64.60	364.40
TB4	9.30	16.10	6.25	3.20	4.10	61.05	365.05
TB5	9.10	17.50	6.80	3.45	4.50	58.65	365.80

3.1.2 Mineral Composition

Mineral analysis revealed progressive improvement in calcium, magnesium, iron, and sodium contents across fortified samples. Calcium increased due to soybean and crayfish inclusion and is essential for bone and teeth development. Magnesium also increased and supports enzyme function and energy metabolism. Iron content improved significantly, which is important for preventing iron-deficiency anaemia, especially among infants and young children. Sodium levels increased slightly but remained within safe dietary limits. Overall, mineral enrichment confirms that blending cereals with legumes and animal protein enhances micronutrient density.

Table 2: Mineral Composition (mg/100g)

Sample	Calcium	Magnesium	Iron	Sodium
TB1	165.40	140.25	2.50	70.20
TB2	190.75	160.80	3.60	78.45
TB3	210.30	175.60	4.20	85.70
TB4	225.80	185.40	4.95	90.25
TB5	240.50	195.75	5.60	94.10

3.1.3 Vitamin Composition

Vitamin analysis showed significant increases in Vitamin B1 (Thiamine), Vitamin B2 (Riboflavin), Vitamin B3 (Niacin), and Pro-vitamin A (Carotene) with increased fortification. B-vitamins are essential for energy metabolism, growth, and nervous system function. The increase in Pro-vitamin A is particularly important for immune function and vision. The improved vitamin profile indicates enhanced micronutrient quality of the fortified formulations.

Table 3: Vitamin Composition (mg/100g)

Sample	Vitamin B1	Vitamin B2	Vitamin B3	Pro-vitamin A
TB1	0.18	0.09c	0.30	5.10
TB2	0.26	0.15	0.45	11.80
TB3	0.31	0.19	0.58	13.25
TB4	0.37	0.24	0.66	14.90
TB5	0.42	0.35	0.74	15.80

3.1.4 Sensory Properties

Sensory evaluation using a 9-point hedonic scale showed that all samples were generally accepted by panelists. Taste, texture, colour, and aroma scores were above average for all formulations. The most fortified samples maintained high acceptability despite improved nutrient composition. This indicates

that nutritional enhancement did not negatively affect consumer preference. Therefore, the fortified Tom Brown formulations are both nutritionally improved and organoleptically acceptable.

Table 4: Sensory Evaluation (9-Point Hedonic Scale)

Sample	Taste	Texture	Colour	Aroma	General Acceptability
TB1	6.30	6.80	6.50	7.20	6.60
TB2	6.55	6.70	6.75	6.95	6.85
TB3	6.80	6.60	6.85	6.60	6.90
TB4	6.40	6.30	6.20	6.10	6.35
TB5	6.95	6.85	7.00	6.75	7.10

3.2 Discussion

The present study evaluated the nutritional quality and sensory acceptability of Tom Brown formulated from locally available raw materials, including maize, soybean, pearl millet, pumpkin pulp, groundnut, and crayfish. The results clearly demonstrate that composite blending significantly enhanced the proximate composition, mineral content, vitamin profile, and overall quality of the product when compared with conventional single cereal formulations. These findings reinforce the nutritional advantage of cereal legume and cereal legume animal protein combinations in complementary food development.

The progressive increase in crude protein content across the fortified samples reflects the contribution of soybean and crayfish, both recognized as high quality protein sources. Cereals such as maize are typically deficient in essential amino acids, particularly lysine and tryptophan, whereas legumes provide these limiting amino acids, thereby improving overall protein quality. The protein values obtained in this study fall within recommended ranges for complementary foods and are consistent with previous reports that composite cereal legume blends enhance protein density and biological value in infant diets. Improved protein intake is particularly important in the prevention of protein energy malnutrition, which remains prevalent among under five children in low income settings.

Fat content also increased with fortification, largely due to the inclusion of soybean and groundnut. Adequate dietary fat is essential in complementary feeding because it increases energy density, improves palatability, and facilitates absorption of fat-soluble vitamins. The energy values recorded in this study meet recommended standards for complementary foods, suggesting that the formulated Tom Brown is capable of meeting the caloric demands of growing children. Although carbohydrate content decreased slightly with increasing protein and fat levels, it remained the major macronutrient and primary energy source, consistent with the cereal-based nature of the formulation.

Moisture content below 10 percent across all samples indicates good shelf stability and reduced susceptibility to microbial spoilage. Low moisture levels are critical for dry complementary foods, particularly in tropical climates where high humidity predisposes products to fungal contamination and mycotoxin formation. The ash content increased progressively with fortification, reflecting enhanced mineral contribution. The inclusion of pearl millet and crayfish likely contributed to higher levels of calcium, magnesium, and iron, nutrients essential for bone development, enzymatic activity, oxygen transport, and immune function.

The improvement in vitamin content, particularly B vitamins and pro vitamin A, further strengthens the nutritional adequacy of the product. Pumpkin pulp is a rich source of beta carotene, which is converted to vitamin A in the body and plays a critical role in immune competence and visual health. Given the high prevalence of vitamin A deficiency and iron deficiency anemia among children in Nigeria, the enhanced micronutrient density observed in this study is of substantial public health relevance.

Processing techniques such as roasting may also have contributed to partial reduction of antinutritional factors, thereby potentially improving mineral bioavailability.

Sensory evaluation results indicate that fortification did not negatively affect consumer acceptability. All samples achieved moderate to high scores for taste, texture, aroma, color, and general acceptability. This is a critical outcome because nutritional improvement alone does not guarantee utilization unless the product is culturally acceptable and organoleptically appealing. The characteristic roasted flavor of Tom Brown likely contributed to positive sensory perception. Acceptability is a key determinant of success in community-based nutrition interventions, including supplementary feeding initiatives implemented by Catholic Relief Services in managing moderate acute malnutrition.

When compared with traditional plain cereal gruels commonly used during complementary feeding, which are often low in protein and micronutrients, the fortified Tom Brown developed in this study demonstrates superior nutritional quality. The composite formulation provides improved macronutrient balance, enhanced micronutrient density, and adequate energy supply while maintaining sensory acceptability. These attributes position the product as a viable, affordable, and culturally appropriate alternative to commercial complementary foods, particularly in resource constrained settings.

Despite these promising findings, certain limitations should be acknowledged. The study was limited to laboratory scale production and chemical analysis without clinical feeding trials to assess growth performance or nutrient bioavailability. Anti-nutritional factors were not quantified, and extended shelf-life stability studies were not conducted under varying environmental conditions. Nevertheless, the results provide strong evidence that locally formulated, fortified Tom Brown can contribute meaningfully to improved child nutrition and food security.

4.0 Conclusion and Recommendations

4.1 Conclusion

This study successfully formulated and evaluated nutritionally enhanced Tom Brown produced from locally available raw materials including maize, soybean, pearl millet, pumpkin pulp, groundnut, and crayfish. The findings demonstrate that composite blending significantly improved the proximate, mineral, and vitamin composition of the product compared with conventional single cereal formulations.

Protein content increased progressively with higher inclusion of soybean and crayfish, confirming the complementary effect of cereal legume animal protein combinations. The protein levels obtained fall within recommended ranges for complementary foods and are nutritionally relevant in addressing

protein energy malnutrition among infants and children. Fat content improved due to the inclusion of soybean and groundnut, enhancing energy density and supporting absorption of fat-soluble vitamins. Carbohydrate remained the major macronutrient, ensuring adequate caloric supply, while calculated energy values met recommended standards for complementary feeding.

Mineral analysis revealed appreciable increases in calcium, magnesium, iron, and sodium contents. The iron enrichment is particularly significant in contexts with high prevalence of anemia among under five children in Nigeria and similar low-income settings. The improvement in pro vitamin A content due to pumpkin pulp inclusion is also noteworthy given the widespread incidence of vitamin A deficiency. These findings align with evidence that composite cereal legume formulations enhance micronutrient density and bioactive compound availability in complementary foods (Anitha et al., 2021; Ajayeoba et al., 2022).

Moisture levels below 10 percent indicate favorable shelf stability and reduced risk of microbial deterioration. Sensory evaluation showed moderate to high acceptability across all formulations, indicating that nutrient fortification did not compromise organoleptic properties. Acceptability is a critical determinant of successful dietary interventions, particularly in culturally embedded foods such as Tom Brown. Overall, the study confirms that nutritionally improved Tom Brown can be produced using affordable indigenous ingredients. The product demonstrates adequate nutritional quality, acceptable sensory characteristics, and strong potential as a sustainable complementary food to combat childhood malnutrition. These findings support similar community based nutritional interventions such as those implemented by Catholic Relief Services in supplementary feeding programs.

4.2 Recommendations

Based on the findings of this study, the following recommendations are proposed:

- Nutritionally fortified Tom Brown should be promoted among caregivers as an affordable alternative to commercial complementary foods, particularly in low-income communities.
- Government agencies, non-governmental organizations, and school feeding programs should consider incorporating fortified Tom Brown into child nutrition initiatives to address protein energy malnutrition and micronutrient deficiencies.
- There is a need for standardized production guidelines to ensure consistent nutrient composition, hygienic processing, and improved shelf stability. Regulatory oversight should be strengthened to maintain quality assurance.
- Further research should explore additional fortification strategies, including biofortified crops and micronutrient premixes, to enhance nutrient density without compromising sensory attributes.
- Community based nutrition education programs should accompany product promotion to improve knowledge of proper complementary feeding practices.

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