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NUTRIENT AND ANTINUTRIENT PROFILES OF THREE MICRONUTRIENT-RICH POWDERS FROM LOCAL VEGETABLES AND BEEF LIVER: FORMULATION, COMPOSITION AND SENSORY ACCEPTABILITY

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ABSTRACT

Hidden hunger, together with foetal growth restriction, stunting, wasting, and poor breastfeeding, accounts for over 3.1 million child deaths annually. Young children are especially vulnerable due to high nutrient demands and limited dietary diversity. Food fortification is a cost-effective strategy to reduce deficiencies. Micronutrient-rich powders (MRPs) were formulated from green bean, carrots, beetroot, spinach, and cow liver. Nutrient and antinutrient compositions were analyzed using standard laboratory methods. Sensory evaluation was conducted on a 9-point hedonic scale. The MRPs (MRP-001, MRP-002, MRP-003) contained 14.84–16.50 g/100 g protein, 4.84–4.85 g/100 g fat, 7.05–7.87 g/100 g ash, and 48.99–53.24 g/100 g carbohydrate, with no significant differences ($p < 0.05$) in macronutrient content. Vitamin A (0.85–2.05 mg/g) and vitamin C (0.04–0.07 mg/g) were present in appreciable amounts, along with vitamins D, B9, and B12, which varied significantly across formulations. Minerals including iron (0.006–0.008 mg/g), potassium (16.85–20.02 mg/g), sodium (0.27–0.29 mg/g), calcium, and magnesium were also detected in good quantities. Antinutrient levels were within safe limit for oxalate (0.024-0.029mg/g), phytate (0.015-0.020mg/g) and tannins (0.27-0.49g/g). Sensory evaluation showed that MRP-003 was the most acceptable in taste (6.40), texture (7.20), flavour (6.00), colour (7.00), aroma (6.80) and overall acceptability (6.20). The study demonstrates the potential of locally sourced ingredients in producing nutrient-dense powders that may help prevent and manage childhood micronutrient deficiencies. These formulations could provide an affordable dietary supplement, particularly in low- and middle-income countries. Further research is required to assess long-term efficacy and safety.

Keywords: Micronutrient Rich Powder, Hidden Hunger, Vegetables, Food Fortification, Malnutrition, Nutrient Composition

INTRODUCTION

Malnutrition remains a major global health challenge, particularly in low- and middle-income countries (LMICs), where inadequate intake of energy, protein, and essential micronutrients persists (Clark et al., 2020; Bhupathiraju et al., 2025). Micronutrient deficiencies affect more than 2 billion people worldwide (Yilmaz and Yilmaz, 2025) and contribute together with foetal growth restriction, stunting, wasting, and poor breastfeeding practices, to nearly 3.1 million child deaths annually (Black et al., 2013). In LMICs, limited dietary diversity, high reliance on nutrient-poor staple foods, infection-related malabsorption, and increased nutrient demands during growth, pregnancy, and lactation further exacerbate these deficiencies (Bailey et al., 2015; Chen and Michalak, 2018; French et al., 2019).

Sub-Saharan Africa bears the most significant burden, accounting for more than half of global micronutrient deficiency cases with an estimated 80% of women of reproductive age and 62% of children under-5 being deficient in ≥1 micronutrient (Ohanenye et al., 2021). Global food systems are also failing to provide adequate micronutrient density, a situation worsened by rising anthropogenic CO_2 levels that reduce iron and zinc concentrations in crops (Ritchie, 2024; Smith and Myers, 2018). Other factors contributing to these deficiencies include poor maternal and child dietary patterns, limited access to nutritious food, increased micronutrients demand by body during pregnancy, lactation period as well as childhood stage below five years of age (Ojiewo et al., 2015; von Grebmer et al., 2014).

To address this growing burden, efficient and sustainable approaches are required. Large-scale food fortification (LSFF) have been highlighted by the World Health Assembly resolution in 2023 as an important and highly recommended intervention for addressing poor micronutrient intakes (WHO, 2023). Home fortification using multiple micronutrient powders (MNPs) for children 6–23 months is another proven strategy, shown in randomized trials to significantly reduce anaemia and iron deficiency (De-Regil et al., 2013; Salam et al., 2013), though real-world impacts have been more modest (Locks et al., 2017). Concerns also exist regarding iron supplementation among iron-replete children due to potential infection risks (De-Regil et al., 2013; Deepak et al., 2020 Soofi et al., 2013 Salam et al., 2013).

Developing nutrient-dense powders from locally available foods, such as green beans, spinach, beetroot, carrots, and liver, offers a culturally appropriate and sustainable approach to improving children's micronutrient intake. Utilizing local ingredients reduces dependence on imported supplements while providing rich sources of vitamins, minerals, and antioxidants critical for child growth and development (Deepak et al., 2020). Therefore, the aim of this study is to develop a micronutrient rich powder from selected vegetables and cow liver for prevention and management of malnutrition among children.

MATERIALS AND METHODS

Sample collection

Green beans, carrots, spinach and beetroot sourced from Farin Gida Jos, Plateau state while cow liver was bought from Garki market, FCT-Abuja. Plant materials were taken to the department of Plant Science and Biotechnology, Bayero University Kano for identification (*Spinacia Olercea L.* (BUKHAN 0020), *Daucus carota L.* (BUKHAN 0563), *Phaseolus vulgaris L.* (BUKHAN 0629), *Beta vulgaris L.* (BUKHAN 0514)).

Processing of Ingredients

Fresh carrots, spinach, and green beans were washed under running water, blanched, oven-dried at 40 – 45ºC for 24 hours, adopted from Costa *et al.* (2021) with modification; beetroot was washed under running water, peeled, grated, and oven-dried at 65ºC for 10 hours (Ulya and Rina, 2022); while Cow liver was washed under running water, cut into small sizes, boiled until cooked, drained, oven-dried at 70ºC for 20 hours (Anand et al., 2024). All the dried ingredients were then milled using an electric blender made by Yongkang Jinweilei electrical appliance Co., Ltd (model JJ -668, rating: AC220-240V, 50/60Hz, 300W) into fine powdered and store in an airtight containers. Preparation of each food constituents followed procedures necessary for enhancing the safety, acceptability and nutrition quality of the final product.

Formulation of the Micronutrient-Rich Powder

The five ingredients processed into powders were mixed in different ratio (Table 1) to formulate three (3) samples of the micronutrients-rich powder after pilot trials using same ingredients. Electric blender was used to mix the ingredients to achieve homogeneity.

Table 1: Ingredients Ratio for the Formulation of the Micronutrients-Rich Powder

Ingredients	MRP-001 (%)	MRP-002 (%)	MRP-003 (%)
Green Beans	20	20	20
Carrot	20	40	20
Spinach	20	20	20
Beetroot	20	20	25
Cow Liver	20	00	15
Total	100	100	100

Chemical Compositional Analysis of the Ingredients and the Formulated Micronutrient Rich Powders (MRPs)

The moisture, crude protein, crude fat, fiber and ash contents of the ingredients and that of the MRP samples were determined using the standard methods (AOAC, 2010), total carbohydrate was calculated by difference (FAO, 2003) while energy was calculated using the Atwater Conversion factors in Kcal. Vitamins was analyzed using Spectrophotometry (UV-Vis) as modified by Koche (2011) and the elemental profile of the samples were determined from mineral ash by an Atomic Absorption Spectrometry (AAS) using a Hitachi-Z8200 model spectrometer coupled to a Hitachi graphite furnace. The samples were prepared and analyzed according to method 925.10 (AOAC, 2010). The antinutrients composition such as oxalate, phytate and tannins was determined using the method described by (Inuwa et al., 2011).

Sensory Evaluation of the Formulated Micronutrients-Rich Powder

Thirty (30) caregivers were selected from Federal University Teaching Hospital, Lafia to examine the sensory attributes of the formulated samples. The choice of caregivers was made based on the fact that they are familiar with children feeding preference and cues and they also have knowledge of what to look out for when examining the sensory attributes of their children's foods. The consumer acceptability of the three formulations was assessed following the method described by Sosanya et al. (2018) with modification, using a 9-Point Hedonic scale questionnaire with 9 as likely extremely, 8 as like very much, 7 as like moderately, 6 as like slightly, 5 as neither like nor dislike, 4 as dislike slightly, 3 as dislike moderately, 2 as dislike very much and 1 as dislike extremely. One gram (1g) of each of the sample was added to about four tablespoons of local pap (ogi) made from sorghum and millet, presented with different codes along with a questionnaire to the panelists for assessment. The panelists were asked to assess the samples in terms of appearance, colour, texture/consistency, taste, flavour and overall acceptability. Clean drinking water was served to the panelists to rinse their pallets before and after evaluating each sample.

Statistical Analysis

All the investigations were carried out in triplicate, and results were expressed as mean ± SD (standard deviation). Statistical analysis was performed using one way ANOVA (Analysis of Variance) in the SPSS program (SPSS 21.0). Duncan test was used to determine statistical differences at $p < 0.05$

RESULTS AND DISCUSSION

Food fortification is an efficient strategy in combating public health burden of hidden hunger (Jha et al., 2024), in developing countries especially Nigeria with high prevalence among children and women of reproductive age. In this study, three formulations were developed from a mixture of available vegetables (green beans, carrots, spinach and beetroot) and a cow liver in different proportions. Combination of vegetables and meat powder is suitable as a carrier for micronutrients rich formulations and attention in this study also focus particular on microbiological purity of these products.

The proximate composition of foods includes moisture, ash, lipid, protein and carbohydrate contents. These food components may be of interest in the food industry for product development, quality control (QC) or regulatory purposes (Thangaraj, 2016). Proximate composition of the formulated micronutrients-rich powder is presented in Table 2. The protein content of the formulated micronutrients-rich powder were 14.8, 14.84 and 16.50 g/100g, with MRP-001 having the highest protein. The higher protein content may be because of higher proportion of cow liver (20%) in the formula compared to other samples (table 1). The protein contents observed is lower than that reported by Yusuf et al. (2025) who reported the 23.23, 22.97 and 22.77 g/100g, respectively from three Multi-Micronutrient Powder Formulations in Kebbi state, Nigeria. Findings on fat content revealed that MRP-001 had 4.85 g/100g of fat, MRP-002 and MRP-003 had 4.84 g/100g each, respectively, of fat, lower than that reported by Yususf et al., 2025. The moisture content of the products were 8.78 g/100g, 9.21 g/100g and 8.13 g/100g, respectively in MRP-001, MRP-002 and MRP-003. Almost similar to 8.00, 7.87 and 7.77 g/100g reported by Yusuf et al., 2025 in F1, F2 F3 of their formulation. However, the moisture contents observed is higher than the UNICEF's 2021 requirements of not more than 5% moisture (loss-on-drying) on the Multiple Micronutrient Powder (MNP). Lowering moisture contents will allow the products to be safely stored at ambient tropical conditions for a longer period. Lower moisture may limit microbial activity in a wide range of environments including salt water, food, wood, biofilms, and soils (Bumba, 2023). MRP-002 had the highest (7.87 g/100g) ash content, MRP-001 had 7.18 g/100g of ash, while MRP-003 had the least

(7.05 g/100g). This may probably be as a result of higher vegetable proportions in MRP-001 and MRP-003 than MRP-002. This suggests that the formulations are good to be use in home fortification for prevention and management of micronutrient deficiencies in children who are the target beneficiaries of the innovated formulations. Base on the result of proximate composition (table 2), MRP-001 has better nutrition profile.

The first year of life is important for the growth of gut microflora, and low dietary fiber can inhibit their growth; and low fiber diet also has implications for child constipation (O'Keefe, 2019). The human gastrointestinal tract harbors one of the most complex ecosystems on the planet; a vast community of microbial residents exists here in an intricate relationship that has co-evolved over time. Dietary fibre has long been established as a nutritionally important, health-promoting food ingredient (Cronin *et al*., 2021), and improving sensory attributes of food (Yangilar, 2013). Table 2 shows that MRP-001 had the highest (12.70 g/100g) fiber content, that is because of higher proportion of vegetables as compared to MRP-002 (11.50 g/100g), and MRP-003 (11.90 g/100g). The study showed there were no statistical significant differences ($p < 0.05$) in protein, fiber, fat, moisture and ash contents of the formulated products. The study showed significant difference ($P < 0.05$) in carbohydrate content of the products with MRP-001 had 49.99 g/100g, MRP-002 had 51.88 g/100g, while MRP-003 had 53.24 g/100g of carbohydrate. Higher carbohydrate content observed in MRP-003 suggest that the other formulations (MRP-001 and MRP—2) has higher compositions of protein, fat and total ash. Information on proximate composition of the formulations is presented to give the nutritional profile of the products beyond micronutrients compositions. All the formulations are found to be macronutrients-dense, suggesting that beyond the important of the products in prevention and management of hidden hunger, the products can also play crucial role in prevention and management of other forms of acute undernutrition in target groups.

Table 2: Proximate Composition of Formulated Micronutrient-Rich Powder

Sample (g/100g)	Crude Protein	Crude Fibre	Fat Content	Moisture	Total Ash	Carbohydrate
MRP-001	16.50 ± 0.22^{a}	12.70 ± 0.01^{a}	4.85 ± 0.01^{a}	8.78 ± 0.18^{b}	7.18 ± 0.40^{b}	49.99 ± 0.78^{c}
MRP-002	14.84 ± 0.70^{b}	11.50 ± 0.06^{c}	4.84 ± 0.00^{a}	9.21 ± 0.01^{a}	7.87 ± 0.02^{a}	51.88 ± 0.07^{b}
MRP-003	15.30 ± 0.03^{b}	11.90 ± 0.10^{b}	4.84 ± 0.01^{a}	8.13 ± 0.03^{c}	7.05 ± 0.01^{b}	53.24 ± 0.65^{a}

Values are presented in mean ± standard deviation of n = 3. Means with same alphabets in the same column are not significantly different at $P < 0.05$. Key: MRP – Micronutrients Rich Powder.

Micronutrients plays significant roles in rapid growth especially in children, prevention of frequent infectious diseases, and during high metabolic demands. However, poor dietary diversity put children at increased risk of vitamins and mineral deficiencies, which in turn impede recovery, impair immune function, and adversely affect cognitive and physical development in children. Effective prevention and management of undernutrition therefore must include targeted micronutrient interventions.

Vitamin A is crucial for maintaining healthy vision, immune function, and cellular differentiation. All the formulated micronutrient rich powder showed substantial amounts of vitamin A with MRP-003 showed to contain highest (2.05 mg/g), followed by MRP-001 (1.17 mg/g) and MRP-002 (0.85 mg/g). The vitamin A contents in the formulations exceeded the minimal 350 µg/g requirement in the formulation of MNP (UNICEF, 2021); and also higher than that reported by Yusuf et al. (2025) in F1 (139.6 µg/g), F2 (132.7 µg/g) and F3 (126.4 µg/g). In addition, the values per gram reported in this study also appears to be higher than that reported by James and Matemu, (2018) which ranged from 2.40 to 4.34 mg/100g in their formulations. The higher levels observed in these products can related to potential enhancement in vitamin A content due to the contribution of other vitamin-rich ingredients such as liver and β-carotene sources like carrot, beetroot, green beans and spinach, which may improve the prevention of vitamin A deficiency-related disorders, such as night blindness and impaired immune function. Folate is known for its various bodily functions including production of Red Blood Cells (RBCs), DNA synthesis and it is especially important in preventing neural tube defects in the developing fetus. It was observed that the three formulated products had some amount of vitamin B9 were 0.03 mg/g, 0.02 mg/g and 0.04 mg/g in MRP-003, MRP-002 and MRP-001, respectively; higher than minimal 160 µg/g recommended by UNICEF for the formulation of MNP. This shows that aside children, it can also contribute to 400 µg Recommended Dietary Allowance (RDA) for women of reproductive age, with even higher needs during pregnancy (National Institutes of Health, 2021), if consume.

Vitamin C is an essential water-soluble antioxidant that aids in collagen synthesis, enhances iron absorption, and supports immune function. Vitamin C content was observed to be significantly higher in MRP-002 than other formulations (table 3) to contribute to 15-75 mg RDA for Vitamin C for children (Institute of Medicine (IOM)).

Vitamin B12 is a water-soluble vitamin that is naturally present in some foods, added to others, and available as a dietary supplement and a prescription medication. Because vitamin B12 contains the mineral cobalt, compounds with vitamin B12 activity are collectively called cobalamins. Vitamin B12 is required for the development, myelination, and function of the central nervous system; healthy red blood cell formation; and DNA synthesis (Stabler, 2020). The findings also shows that MRP-001, MRP-002 and MRP-003 had 0.79, 0.56 and 0.70 µg/g of vitamin B12, respectively. The higher vitamin B12 content observed in MRP-001 and MRP-003 compared to MRP-002 can be associated with higher proportion of cow liver in the earlier formulations. Vitamin D, a fat soluble vitamin which plays an important roles in maintaining bone health and immune functions is observed to be lower in all the three formulated products because of the poor sources used in the formulation (table 3). The result shows that its lowest (0.0027 nmol/g) in MRP-002, while MRP-001 and MRP-003 had 0.0035 and 0.0036 nmol/g. That can be explained by the lack of animal source in the product. Data on Table 3 shows significant difference ($P < 0.05$) between the vitamin A, C, D, B_9 and B_{12}.

Calcium (Ca) is essential for numerous physiological processes, including bone health, muscle contraction, nerve signaling, and blood clotting. Approximately 99% of the body's Ca is stored in bones and teeth, providing structural support and serving as a reservoir to maintain extracellular Ca levels. Adequate Ca intake prevents osteoporosis and maintains bone density (Beto et al., 2015), particularly in stages of growth, such as infancy and childhood (Shertukde et al., 2021). Calcium content was observed to be significantly higher in MRP-002 (0.10 mg/g followed by MRP-003 (0.09 mg/g) and MRP-001 (0.09 mg/g), far below the 369.4 mg/g (F3), 362.9 mg/g (F2) and 354.3 mg/g (F1) reported by Yusuf et al. (2025).

Early childhood is characterised by high physiological iron demand to support processes including blood volume expansion, brain development, tissue growth and generation of effective immune responses (Armitage and Moretti, 2019). Adequate iron status is therefore a prerequisite for optimal child development, yet nutritional iron deficiency and inflammation-related iron restriction are widespread amongst young children in low- and middle-income countries (LMICs) (Armitage and Moretti, 2019). Iron content was observed to be significantly higher in MRP-001 (0.008 mg/g) followed by MRP-003 (0.007 mg/g) and MRP-002 (0.006 mg/g). That can be attributed to the higher cow liver in MPR-001 than MRP-003 and the absent in MRP-002. This suggest that addition of animal source to the formulation increases it iron content. This shows that the formulated products can be a good source of iron when incorporated in the diet of children and other population groups. Consuming food with these formulations may increase haemoglobin level as observed by Nawiri et al. (2013), who reported a significant increase of haemoglobin by 4.6% among preschool children after eating dried vegetables, indicating that dried vegetable provides iron when incorporated in the diet. Moreover, anemia prevalence in 4–9-year-old children was reduced from 37.3% to 33.3% after consuming dried leafy vegetables powder in their diet formulations in Ghana (Egbi et al., 2018).

Potassium (K) plays a vital role in maintaining electrolyte balance, nerve function, and cardiovascular health, helping to regulate blood pressure and reduce the risk of hypertension (Beto *et al.,* 2015). Table 4 revealed the potassium contents for the various formulated micronutrients-rich powder not to be significantly different, with MRP-002 had the highest composition (20.02 mg/g) followed by MRP-003 (18.99 mg/g) and MRP-001 (16.85 mg/g). The high potassium content in these formulated products can supports electrolyte balance and overall cardiovascular health (Palmer, 2015).

Magnesium (Mg) an essential mineral, critical for enzymatic reactions, muscle and nerve function, and bone health, and is important preventing muscle cramps and cardiovascular disorders (Volpe, 2013). As illustrated in table 4, magnesium content of these formulations were 0.0061 mg/g, 0.0062 mg/g and 0.0061 mg/g, respectively in MRP-001, MRP-002 and MRP-003, lower than what was reported by Yusuf et al. (2025). Magnesium deficiency in adult women has been linked to pre-eclampsia, muscle cramps, and fatigue (Rosanoff *et al.,* 2012).

Sodium plays a vital role in maintaining bodily functions, including regulating fluid balance, controlling blood pressure, ensuring proper nerve and muscle function, and transporting essential nutrients like glucose and amino acids into cells. Dietary sodium is required in very small amounts to support circulating blood volume and blood pressure (BP) (Gowrishankar et al., 2020). Table 4 shows that sodium content of the formulated micronutrients-rich powder were 0.27 mg/g, 0.29 mg/g, and 0.28 mg/g, respectively in MRP-001, MRP-002 and MRP-003. The lower sodium content per gram shows that the use of this formulations in home fortification will not pose the risk of consuming sodium beyond the adequate intake (AI) for children and youth aged 1 to 18 years, extrapolated from the adult AI of 1,500 mg/day, using average estimated energy requirements for different groups (Government of Canada, 2018).

These results highlight the elemental composition consistency across the samples, with Potassium showing the widest variation and Magnesium and Iron being the most stable (table 4).

Table 3: Vitamins Composition of Formulated Micronutrient-rich Powder

Sample	Vitamin A (mg/g)	Vitamin B_9 (mg/g)	Vitamin B_{12} (µg/g)	Vitamin C (mg/g)	Vitamin D (nmol/g)
MRP-001	1.17 ± 0.01^b	0.04 ± 0.00003^a	0.79 ± 0.001^a	0.06 ± 0.0001^b	0.0035 ± 0.00004^a
MRP-002	0.85 ± 0.02^c	0.02 ± 0.0001^c	0.56 ± 0.001^c	0.07 ± 0.0004^a	0.0027 ± 0.00001^b
MRP-003	2.05 ± 0.05^a	0.03 ± 0.00003^b	0.70 ± 0.003^b	0.04 ± 0.00004^c	0.0036 ± 0.00019^a

Vitamin B_{12} is given in (µg/g); Vitamin D is given in nmol/g. Values are presented in mean ± standard deviation of n = 3. Means with same alphabets in the same column are not significantly different at $P < 0.05$.

Table 4: Minerals Composition of Formulated Micronutrient-rich Powder

Sample	Calcium (Ca) (mg/g)	Iron (Fe) (mg/g)	Potassium (K) (mg/g)	Magnesium (Mg) (mg/g)	Sodium (Na) (mg/g)
MRP-001	0.09 ± 0.0008^c	0.008 ± 0.00005^a	16.85 ± 0.651^c	0.0061 ± 0.00003^b	0.27 ± 0.0005^c
MRP-002	0.10 ± 0.0007^a	0.006 ± 0.00006^c	20.02 ± 1.398^a	0.0062 ± 0.00003^a	0.29 ± 0.0037^a
MRP-003	0.09 ± 0.0034^b	0.007 ± 0.00004^b	18.99 ± 0.593^b	0.0061 ± 0.00003^c	0.28 ± 0.0011^b

Values are presented in mean ± standard deviation of n = 3. Means with same alphabets in the same column are not significantly different at $P < 0.05$.

The presence of antinutritional factors such as phytates, oxalates and tannins in foods has been reported to affect the effective utilization of its nutrients in human nutrition (Ijarotimi and Keshinro, 2012). Table 5 report phytates content of the MRP-001, MRP-002 and MRP-003 to be 0.029, 0.016 and 0.015 mg/g, respectively, higher than the phytate content recorded between 1.86 ± 0.10 and 1.91 ± 0.10 mg/kg by Yusuf et al. (2015). Phytates may inhibit absorption of some nutrients like minerals in the small intestines (Gupta and Gangoliya 2015), and thus are required to be kept within recommended levels for foods to be utilized by the body efficiently (Schlemmer *et al*, 2019). Data presented on table 5 shows that oxalates concentrations to be 0.029, 0.024 and 0.029 mg/g, respectively in MRP-001, MRP-002 and MRP-003; which is lower than the amount that can cause toxicity. However, these values exceeded oxalate concentrations reported by Yusuf et al. (2025). Tannins, a class of polyphenolic compounds and major secondary metabolites in plants, are essential in defining the sensory characteristics and nutritional quality of beverages, fruits, vegetables, and other plant-based foods (Cosme et al., 2025). These compounds are abundant in plant derived foods, particularly in cereals, nuts, chocolate, legume seeds, fruits, and vegetables, as well as in beverages such as wine, cider, tea, and cocoa (Sun *et al*., 2022). Data presented in table 5 ranged from 0.27 to 0.49 g/g, shows the levels to be below the ingestion dose of 45mg/100g of body weight per day that was reported by Samantha *et al., (*2004) to cause toxicity.

Table 5: Anti-Nutrients Content of Formulated Micronutrient-rich Powder

Sample	Oxalates (mg/g)	Phytates (mg/g)	Tannins (g/g)
MRP-001	0.029 ± 0.0004^{a}	0.020 ± 0.0020^{a}	0.27 ± 0.0070^{c}
MRP-002	0.024 ± 0.0000^{c}	0.016 ± 0.0010^{b}	0.49 ± 0.0037^{a}
MRP-003	0.026 ± 0.0004^{b}	0.015 ± 0.0010^{c}	0.35 ± 0.0070^{b}

Tannins is given in (g/g). Values are presented in mean ± standard deviation of n = 3. Means with same alphabets in the same column are not significantly different at $P < 0.05$.

Sensory evaluation is an important tool for consumers in choosing their food. The results from the mean sensory attributes (including texture, taste, flavor, colour, aroma and overall acceptance) scores of the formulated micronutrient rich powder were presented in Table 6. Texture is characterized by the way the complementary food feels in the mouth of the judges (Sa'eedu et al., 2025). The result obtained for the sensory attributes revealed that MRP-003 was rated highest in all the attributes, suggesting better acceptance among the consumers as evidenced by their rating of acceptability attributes. Although MRP-001 and MRP-002 were also accepted by the consumer with above average scores across the attributes. This better acceptability and higher scores can be attributed to preparations methods employed during the formulation of the products. This is supported by the report of Muhimbula *et al*. (2011); Bintu *et al*. (2019), who observed that food processing techniques help in enhancing the palatability of foods.

Table 6: Sensory Evaluation of the Formulated Micronutrient-Rich Powder and Control MNP

Sample	MRP-001	MRP-002	MRP-003
Taste	5.60 ± 1.52^{ab}	4.40 ± 1.67^{b}	6.40 ± 2.07^{a}
Texture	5.80 ± 2,28^{b}	5.20 ± 2.59^{b}	7.20 ± 1.92^{a}
Flavor	4.20 ± 0.44^{b}	4.00 ± 1.00^{b}	6.00 ± 1.87^{a}
Colour	4.80 ± 1.10^{b}	6.20 ± 1.79^{a}	7.00 ± 0.71^{a}
Aroma	4.60 ± 1.81^{b}	5.20 ±1.30^{b}	6.80 ± 1.92^{a}
Overall Acceptability	4.80 ± 1.30^{b}	4.80 ± 1.79^{b}	6.20 ± 1.92^{a}

Data presented as mean ± standard deviation (n = 30). Means having different alphabets in the same row are significantly different at $P<0.05$.

CONCLUSION

Findings revealed that micronutrient-rich powder from selected vegetables (green beans, carrots, beetroot, and spinach) and cow liver for the prevention and management of childhood malnutrition was successfully formulated and evaluated. The formulated products demonstrated a promising nutritional profile, with substantial amounts of essential vitamins and minerals. The proximate composition analysis revealed that the products are macronutrient-dense, with significant protein, fiber, and carbohydrate content. The vitamin and mineral analysis showed that the formulations has potential to contribute to their RDAs. The sensory evaluation indicated that the formulated products were acceptable to consumers, with MRP-003 showing better acceptance across all attributes and exhibiting a favorable nutritional profile. The antinutrient content was within safe limits, suggesting that the products can be effectively utilized by the body without affecting the bioavailability. Overall, this study highlights the potential of using locally available ingredients to develop nutrient-dense powders that can help address micronutrient deficiencies in children.

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