

Evaluation of the Mineral, Physical and Chemical Properties of Enteral Tube Feeds Powder Administered in Jos University Teaching Hospital, Jos Plateau State, Nigeria

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Abstract

Background

Adequate nutritional support is fundamental to preventing and managing malnutrition, particularly among hospitalized patients who are unable to meet their nutritional requirements through oral feeding. However, selecting an appropriate enteral feeding formulation remains a challenge in many teaching hospitals. With the increasing emphasis on individualized enteral nutrition and patient-specific nutritional requirements, characterization of locally prepared feeding formulations is essential to ensure their nutritional adequacy and suitability for clinical use.

Objective

This study evaluated the mineral composition and selected physical and chemical properties of enteral tube-feeding powders administered at Jos University Teaching Hospital (JUTH), Jos, Plateau State, Nigeria.

Methods

Ready-to-use, sealed enteral feeding powders were obtained from the Department of Nutrition and Dietetics, JUTH. Three formulations were evaluated based on their constituent ingredients and preparation ratios. DIETREND consisted of maize, soybean, and groundnut in a 6:3:1 ratio; JOT-M-MIX contained millet, soybean, and groundnut in a 6:3:1 ratio; while BRAN MIX was prepared from Dietrend chaff and acha (fonio) in a 5:2 ratio. The mineral composition, osmolality, and viscosity of the formulations were determined using standard analytical procedures.

Results

Considerable variation was observed in the mineral composition, osmolality, and viscosity of the three enteral formulations. Approximately 30 mineral elements were identified across the samples. Magnesium, phosphorus, sulphur, calcium, iron, and zinc were detected at appreciable concentrations and were significantly higher ($p < 0.05$) in JOT-M-MIX and BRAN MIX than in DIETREND. Other mineral elements were present at relatively low concentrations. Significant differences were also observed in viscosity among the formulations. At 100°C, DIETREND had significantly greater viscosity (1644.00 ± 3.46 cP) than JOT-M-MIX and BRAN MIX ($p < 0.05$). Similarly, viscosity at 37°C was significantly higher in DIETREND (3661.33 ± 31.83 cP) than in the other two formulations ($p < 0.05$). Osmolality measured immediately after preparation and following four days of storage was significantly higher in JOT-M-MIX and BRAN MIX than in DIETREND ($p < 0.05$).

Conclusion

The mineral composition of the evaluated blenderized enteral formulations was, to some extent, comparable with FAO/WHO/UNU reference standards. However, the observed differences in mineral composition and physicochemical characteristics indicate the need for appropriate formulation and quality control. Strategic reformulation and, where necessary, fortification of these locally prepared diets could improve their nutritional adequacy and potential suitability as cost-effective rehabilitation feeds for patients requiring enteral nutritional support.

INTRODUCTION

Feeding is a fundamental biological function necessary for sustaining life and supporting the biochemical and physiological activities of the human body (Mahsa et al., 2017). However, illness can interfere with both the ability and willingness of individuals to eat. Difficulties associated with chewing and swallowing are frequently observed among patients with neurological disorders, gastrointestinal conditions, cancer, and brain injuries. Consequently, a considerable proportion of hospitalized patients experience varying degrees of malnutrition, with estimates ranging from approximately 30% to 60% (Mahsa et al., 2017). The problem is particularly pronounced among critically ill patients who are unable to consume sufficient food to meet their nutritional requirements. In such circumstances, increased catabolic activity may occur, resulting in muscle wasting, impaired respiratory and gastrointestinal functions, and compromised immune responses (Bjuresater, 2012; Mula et al., 2014).

Critical illness can substantially alter normal feeding patterns and may impair oral intake because of swallowing difficulties, physical obstruction, reduced consciousness, or other limitations. These circumstances necessitate the use of alternative methods of delivering nutrients. Nutritional support may involve dietary supplementation, enteral nutrition using either commercially manufactured or hospital-prepared formulations, or partial or complete parenteral nutrition (Mahsa et al., 2017). Enteral nutrition (EN) is widely regarded as an important component of nutritional care for patients who cannot adequately meet their energy and protein requirements through oral feeding. Its use aims to minimize the adverse consequences associated with inadequate nutritional intake during hospitalization (Brown et al., 2015). Compared with parenteral nutrition, enteral feeding offers several advantages, including improved nutritional support, shorter hospitalization, lower healthcare costs, reduced mortality, and fewer complications (Mula et al., 2014).

A wide range of enteral formulations is available to meet the diverse nutritional and clinical requirements of patients. These include polymeric, semi-elemental, modular, disease-specific, immunonutrition, pulmonary, renal, hepatic, diabetes-specific, and blenderized formulations (Brown et al., 2015). Commercial enteral formulas are specifically formulated to provide adequate quantities of macronutrients and micronutrients and to minimize the risk of nutritional deficiencies. Typically, these products contain whole proteins as sources of nitrogen, carbohydrates derived from ingredients such as starch,

maltodextrins, or oligosaccharides, and lipids primarily obtained from vegetable oils. They may also contain vitamins, minerals, and trace elements in predetermined concentrations (Brown et al., 2015).

Before the widespread development of commercial enteral products, hospital-prepared foods were commonly blended and diluted to achieve a consistency suitable for administration through feeding tubes. However, these preparations were associated with concerns regarding microbial contamination, feeding-tube obstruction, and inadequate nutrient delivery, particularly among critically ill patients. Despite the increasing availability and relatively high cost of commercial formulas, blenderized tube feeding remains an option for some patients and caregivers. Such feeds are prepared from conventional foods, including milk, eggs, meat, fruits, vegetables, and oils. Their continued use may be influenced by affordability, limited access to commercial products, cultural preferences, and the greater flexibility they provide in selecting and combining food ingredients (Brown et al., 2014).

The use of blenderized tube feeding has increased alongside the growing number of patients requiring long-term enteral nutritional support. Some patients and caregivers have reported improved tolerance of whole-food-based preparations, including fewer gastrointestinal symptoms such as gagging, retching, vomiting, diarrhoea, and constipation, as well as improved maintenance of body weight (Bennett et al., 2020). Although blenderized tube feeding is not generally recommended as the primary option for all patients requiring enteral nutrition, it may be considered in selected circumstances. Families may opt for this approach because of gastrointestinal intolerance to polymeric formulas, food allergies or intolerances, or other individual feeding challenges (Sforza et al., 2023).

One potential advantage of blenderized enteral nutrition is the incorporation of a wider variety of fresh and minimally processed foods. Such foods may provide bioactive compounds, including phytochemicals, while also potentially influencing the composition and diversity of the gut microbiota (Bennett et al., 2020). In appropriately selected patients, whole-food-based formulas may therefore provide an opportunity for greater individualization of enteral nutritional care according to specific nutritional and clinical needs (Carter et al., 2018). Although many developed countries have increasingly shifted from hospital-prepared feeds toward commercially manufactured formulas (Bowling, 2004), hospital-prepared enteral feeding remains relatively common in developing countries, including Nigeria (Nyati et al., 2016).

Despite its widespread use, there remains limited information regarding the nutritional and physicochemical characteristics of blenderized enteral feeds prepared and administered in Nigerian healthcare facilities. This knowledge gap is important because the nutritional composition of such feeds can vary according to the ingredients selected, proportions used, processing techniques, and preparation procedures. Inadequate micronutrient provision is also a significant nutritional concern, making assessment of the mineral composition of foods used in enteral preparations particularly relevant. In addition, physicochemical characteristics such as osmolality and viscosity require careful consideration because they may influence the suitability, tolerance, and administration of tube feeds.

Nutritional support is an important determinant of clinical outcomes among critically ill patients. Nevertheless, approaches to nutritional management differ considerably between healthcare settings, potentially because of differences in professional knowledge, available information sources, clinical practices, and the degree of standardization of nutritional care. Inadequate knowledge among dietitians has also been identified as a potential barrier to maintaining appropriate consistency in nutritional management of critically ill patients (Mula et al., 2014). Furthermore, selecting an appropriate enteral formula remains a challenge in many hospitals, particularly where locally prepared feeds constitute a substantial component of nutritional support. Unlike commercial formulas, which generally have standardized nutrient compositions and physicochemical characteristics, blenderized feeds may differ considerably depending on their ingredients and preparation methods.

Evidence regarding the adequacy and suitability of blenderized enteral feeds remains inconsistent. Some investigations have indicated that blended foods and milk-based preparations may fail to provide adequate quantities of essential nutrients and may be unsuitable for certain patients, particularly those with impaired digestive function (Adom, 2020). Conversely, other evidence suggests that blenderized preparations may offer adequate nutritional support at a lower cost than commercially produced formulas (Epp, 2018). These conflicting findings highlight the importance of evaluating locally prepared enteral feeds rather than assuming that their nutritional adequacy is either sufficient or inadequate.

Adequate micronutrient intake is particularly important because deficiencies of essential minerals can have serious consequences for health. Dietary surveys in Nigeria have identified inadequate consumption of several important minerals, including calcium, magnesium, iron, and iodine, among different population groups. Reported inadequacies include low calcium, magnesium, and iron intake among female adolescents and women, as well as insufficient iron intake among girls aged 10–14 years (Lindsay, 2021). For patients dependent on enteral nutrition, inadequate provision of these nutrients may be especially concerning because their dietary intake is largely determined by the composition of the prescribed feeding formula.

Previous studies have similarly produced divergent findings regarding the nutritional quality of blenderized enteral feeds. Sullivan et al. (2004) reported that such preparations could contain insufficient quantities of essential nutrients, potentially limiting their usefulness in critically ill patients. In contrast, Hron et al. (2019) found that blenderized feeds could provide required nutrients and were associated with favorable patient outcomes. Ojo et al. (2020) further reported differences between blenderized and commercial formulas, particularly with respect to macronutrient and micronutrient content, viscosity, and osmolality. Felicio (2012) also observed considerable variability and inconsistency in the macro- and micronutrient composition of blenderized enteral feeds. Collectively, these findings raise concerns about whether locally prepared formulations consistently satisfy the nutritional requirements of patients who depend on enteral feeding.

Given the continued use of hospital-prepared blenderized enteral feeds in Nigeria, the limited availability of data on their composition, and the variability reported in previous studies, there is a need for systematic evaluation of these preparations. Assessing their mineral composition together with relevant physical and chemical characteristics can provide evidence regarding their nutritional adequacy and suitability for tube feeding. Therefore, this study evaluates the mineral, physical, and chemical properties of enteral tube feeds administered at the University of Jos Teaching Hospital, Nigeria.

METHODS

Study setting

The study was conducted using ready-to-use enteral feed powders obtained from the Department of Nutrition and Dietetics, Jos University Teaching Hospital (JUTH), Jos, Plateau State, Nigeria. JUTH is a tertiary healthcare institution providing specialist healthcare services, clinical training and research activities. Laboratory analyses of the enteral feed samples were conducted at the Institute for Global Food Security (IGFS), Queen's University Belfast, Northern Ireland, United Kingdom, and the Institute of Experimental Medicine, Queen's University Belfast.

Sample collection and preparation

Three ready-to-use, sealed enteral feed powder formulations were obtained from the Department of Nutrition and Dietetics, JUTH. The samples were individually placed in sealed Ziploc bags and transported at room temperature to the laboratories at the Institute for Global Food Security, Queen's University Belfast, Northern Ireland, United Kingdom.

The formulations and their constituent grain ratios were as follows:

- Dietrend: maize, soybean and groundnut in a ratio of 6:3:1.
- JOT-M-MIX: millet, soybean and groundnut in a ratio of 6:3:1.
- Bran Mix: bran from Dietrend and acha (fonio) in a ratio of 5:2.

Processing of grain ingredients

The grain ingredients used in the enteral feed formulations underwent a series of processing procedures before formulation. These included winnowing, sorting, soaking, sprouting and fermentation, washing, drying, roasting, milling, cooling, weighing, packaging and sealing.

During winnowing, the grains were separated from dust, light husks and other unwanted materials. Sorting was subsequently performed manually to remove stones, damaged grains and other foreign materials. The grains were then soaked in water for a predetermined period to soften the seed coats and facilitate sprouting and fermentation. Sprouting and fermentation were undertaken to improve the nutritional quality and potential nutrient bioavailability of the grain ingredients.

Following soaking, the grains were washed and dried. Acha (fonio), in particular, was washed using a calabash to facilitate the removal of sand particles. The grains were subsequently dried indoors. Soybeans and groundnuts were roasted to improve flavour and reduce undesirable components. The groundnuts were additionally peeled following roasting to remove the seed coats.

The processed grains were milled according to the specified formulation ratios and allowed to cool before packaging to minimize moisture absorption. The products were weighed into appropriately labelled packages and subsequently sealed until analysis.

Figure 1 summarizes the sequence of sample collection, grain processing, formulation and laboratory analyses.

Equipment and reagents

The equipment used for sample preparation and laboratory analyses included an Osmomat 030 cryoscopic osmometer (Gonotec, Germany), Gonotec calibration standards, Rainin calibrated digital pipettes (LO-941534K; SL 20–200 µL), sterile sample bottles, Retsch ball mill (PM 100), Ohaus Precision electronic balance (AX822; 0.01–820 g), Thermo Scientific iCAP TQ inductively coupled plasma mass spectrometer (ICP-MS), gloves, safety glasses, nose mask, permanent marker.

The reagents used included nitric acid (HNO₃), 30% hydrogen peroxide (H₂O₂), rhodium internal standard (15 µg/mL; 5 ppb), and distilled water.

Viscometric determination

For viscometric analysis, 25 g of each enteral feed powder was dispersed in 100 mL of water at room temperature (approximately 25°C) and stirred using a bamboo stirrer until adequately dispersed and free of visible lumps. Subsequently, 150 mL of boiling water (approximately 100°C) was added to obtain a total volume of 250 mL. The mixture was stirred for 2 min and transferred to an AGB 1000 electric hotplate and stirrer, where it was continuously stirred while heated for 5 min.

Immediately after preparation, the hot mixture (approximately 100°C) was transferred into the sample cup of a Brookfield DV-1 + viscometer (Model LVDV-1+) and viscosity was measured. The prepared samples were subsequently allowed to cool to approximately 37°C, after which viscosity was measured again. Viscosity measurements were therefore obtained at approximately 100°C and 37°C.

Osmolality determination

Aliquots of the prepared enteral feed samples were collected aseptically in sterile 20-mL bottles prior to viscometric measurements. The aliquots were transported to the Institute of Experimental Medicine, Queen's University Belfast, for osmolality analysis.

A Gonotec Osmomat 030 cryoscopic osmometer was used to determine sample osmolality. The instrument was allowed to initialize according to the manufacturer's operating procedure and was calibrated using Gonotec calibration standards of 300 mOsmol/kg (Ref. 30.9.0020; Lot 14194044) and 500 mOsmol/kg (Ref. 30.9.0500; Lot 7343C42).

Following calibration, the instrument was zeroed using 50 µL of distilled water pipetted into a 0.5-mL Eppendorf tube using a Rainin calibrated digital pipette (20–200 µL). Subsequently, 50 µL of each sample was transferred into a 0.5-mL Eppendorf tube and introduced into the osmometer for measurement. The probe surface was cleaned with dampened tissue paper after each measurement.

Osmolality was determined immediately after sample preparation following cooling to room temperature and again after four days of storage in an aseptically sealed 20-mL tube.

Mineral analysis by ICP-MS

Mineral concentrations in the enteral feed samples were determined using inductively coupled plasma mass spectrometry (ICP-MS). An empty 50-mL centrifuge tube was first weighed, after which approximately 1000 ± 50 µg of each sample was accurately weighed into the tube.

Two millilitres of nitric acid (HNO₃) were added to each sample in a fume cupboard, and the samples were allowed to undergo acid digestion overnight (approximately 18 h). Following nitric acid digestion, 2 mL of 30% hydrogen peroxide (H₂O₂) were added to each digest. The contents were mixed for approximately 10 s and allowed to stand for 1 h before microwave digestion.

Microwave digestion was performed using a programmed workflow consisting of heating to 55°C within 5 min followed by a 10-min hold, heating to 75°C within 5 min followed by a 10-min hold, and heating to 95°C within 5 min followed by a 30-min hold. The samples were subsequently allowed to cool for approximately 30–60 min.

Following digestion, the tubes were centrifuged, where necessary, for 10 min at 4500 rpm to collect material adhering to the tube walls. Rhodium internal standard (15 µg/mL; 5 ppb) was added to the samples, standards and controls, followed by vortex mixing for approximately 2 s. The stabilized digests were subsequently introduced into a Thermo Scientific iCAP TQ ICP-MS for mineral analysis according to the instrument's analytical workflow.

Statistical analysis

Data were summarized as mean ± standard deviation (SD). Pairwise comparisons between measurements were performed using the student's *t*-test. Statistical significance was set at *p* < 0.05. All statistical analyses were performed using SPSS version 25.

RESULTS

Table 1, 2 and 3 presents the mineral composition of enteral feed powder made from maize, soya beans and groundnut (DIETREND), millet, soya beans and groundnut (JOT-M-MIX) and Dietrend and acha (fonio) (BRAN MIX) is presented in tables 1. The results of the study showed that twenty-nine mineral elements were present in the samples. From the results, lithium and beryllium concentrations were found to be the same (0.01 ± 0.00 mg/100g) in all the three samples and was not significant (*p* > 0.05) different from each other. However, boron was significantly significant (*p* < 0.05) higher (0.08± 0.00 mg/100g) in bran mix sample when compared with other samples. Also, magnesium was significantly (*p* < 0.05) higher (15.56 ± 0.41 mg/100g) in bran mix sample when compared with other samples. In addition, silicon and phosphorus concentrations in JOT-M-MIX sample were significantly (*p* < 0.05) higher compared to samples DIETREND and BRAN MIX. Again, from the results, sulphur and calcium concentrations were significantly (*p* < 0.05) higher in BRAN MIX sample when compared with other samples. Tritium, Vanadium and cobalt concentrations were found to be the same (0.00 ± 0.00mg/100g) in all the three samples and was not significant (*p* > 0.05) different from each other. Manganese concentration in JOT-M-MIX sample was significantly (*p* < 0.05) higher (0.17± 0.00 mg/100g) compared to samples DIETREND and BRAN MIX, while iron concentration in DIETREND sample was significantly (*p* < 0.05) higher (0.60± 0.03mg/100g) compared to samples DIETREND and JOT-M-MIX.

From the results, copper and zinc concentrations were found to be significantly (*p* < 0.05) higher in JOT-M-MIX sample when compared with other samples. Germanium, arsenic, selenium, cadmium, indium, Bismuth and uranium concentrations were found to be the same (0.00 ± 0.00 mg/100g) in all the three samples and were not significant (*p* > 0.05) different from each other. Also, radium concentration was significantly (*p* < 0.05) higher (0.10± 0.00 mg/100g) in DIETREND sample.

Table 1: Mineral composition of enteral feed powder (mg/100g)

Sample	Lithium	Beryllium	Boron	Magnesium	Silicon	Phosphorus	Sulphur	calcium	Tritium	Vanadium	mang
DIETREND	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.01± 0.00 ^a	9.94 ± 1.74 ^a	0.51± 0.05 ^a	22.24 ± 0.74 ^a	9.09 ±0.34 ^a	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.13 ± 0.00 ^a
JOT-M-MIX	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.07± 0.00 ^b	15.48 ± 0.15 ^b	0.76 ±0.00 ^b	26.45 ± 0.05 ^b	15.59 ± 0.08 ^b	3.43 ±0.05 ^b	0.00 ± 0.00 ^b	0.00 ± 0.00 ^b	0.17± 0.00 ^b
BRAN MIX	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.08± 0.00 ^c	15.56 ± 0.41 ^b	0.29 ±0.01 ^c	25.97 ± 0.72 ^b	16.25± 0.42 ^b	3.65 ±0.05 ^b	0.00 ± 0.00 ^b	0.00 ± 0.00 ^b	0.15 ± 0.40 ^c

Values are expressed as mean ± SEM, n = 3; columns with different superscript are significantly different at p < 0.05

Table 2: Mineral composition of enteral feed powder (mg/100g)

Sample	cobalt	copper	Zinc	germanium	arsenic	Selenium	radium	Strontium	Zirconium	Molybdenum	Cadmium	Indi
DIETREND	0.00± 0.00 ^a	0.02 ± 0.00 ^a	0.14± 0.00 ^a	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.07 ± 0.00 ^a	0.01 ± 0.00 ^a	0.13 ± 0.05 ^a	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.00± 0.00 ^a
JOT-M-MIX	0.00± 0.00 ^a	0.06 ± 0.00 ^b	0.28± 0.00 ^b	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.08± 0.00 ^b	0.06 ±0.00 ^b	0.02 ± 0.00 ^b	0.01 ± 0.00 ^b	0.00 ± 0.00 ^a	0.00± 0.00 ^a
BRAN MIX	0.00± 0.00 ^a	0.05 ± 0.00 ^c	0.22± 0.00 ^c	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a	0.10± 0.00 ^c	0.06 ±0.00 ^c	0.03 ± 0.11 ^c	0.01 ± 0.00 ^b	0.00 ± 0.00 ^a	0.00± 0.00 ^a

Values are expressed as mean ± SEM, n = 3; columns with different superscript are significantly different at p < 0.05

Table 3: Mineral composition of enteral feed powder (mg/100g)

Sample	Iodine	Barium	Tantalum	Lead	Bismuth	Uranium
DIETREND	0.05 ± 0.18 ^a	0.01 ± 0.00 ^a	0.02 ± 0.01 ^a	0.00± 0.00 ^a	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a
JOT-M-MIX	0.02 ± 0.00 ^b	0.09 ± 0.00 ^b	0.00 ± 0.00 ^b	0.02± 0.00 ^b	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a
BRAN MIX	0.03 ± 0.00 ^c	0.11 ± 0.00 ^c	0.00 ± 0.00 ^b	0.00 ±0.10 ^a	0.00 ± 0.00 ^a	0.00 ± 0.00 ^a

Values are expressed as mean ± SEM, n = 3; columns with different superscript are significantly different at p < 0.05

Table 4 shows the physicochemical property. The viscosity and osmometry of enteral tube feeds powder administered in Jos University teaching hospital, Jos is presented in table 4. From the results, viscosity varied among the samples. Viscosity (cp) at 100°C in DIETREND sample was significantly (p< 0.05) higher (1644.00±3.46) compared to JOT-M-MIX and BRAN MIX samples, also, Viscosity (cp) at 37°C in DIETREND sample was significantly (p< 0.05) higher (3661.33±31.83) compared to samples BRAN MIX and JOT-M-MIX. In addition, Osmometry immediately after preparation and after four days storage in JOT-M-MIX and BRAN MIX samples were significantly (p< 0.05) higher compared to DIETREND sample.

Table 4: Physicochemical property of enteral tube feeds powder administered in Jos University teaching hospital, Jos.

Parameter	Viscosity (cp) at 100°C	Viscosity (cp) at 37°C	Osmometry immediately after Prep.	Osmometry after four days storage
DIETREND	1644.00±	3661.33±	0.02±	0.10±
	3.46 ^a	31.83 ^a	0.00 ^a	0.00 ^c
JOT-M-MIX	289.14±	1804.00±	0.04±	0.06±
	1.77 ^b	2.00 ^b	0.00 ^b	0.00 ^b
BRAN MIX	180.70±	936.00±	0.04±	0.06±
	1.27 ^c	3.46 ^c	0.00 ^b	0.00 ^b

Values are expressed as mean ± SEM, n = 3; columns with different superscript are significantly different at $p < 0.05$

DISCUSSION

The present study demonstrated substantial heterogeneity in the mineral composition and physicochemical characteristics of the blenderized enteral nutrition (EN) powders administered at Jos University Teaching Hospital. The differences observed among Dietrend, Jot-M-Mix, and Bran Mix indicate that the nutritional characteristics of hospital-prepared enteral feeds cannot be assumed to be equivalent, even when the formulations are intended to provide nutritional support to similar patient populations. Jot-M-Mix and Bran Mix generally exhibited higher concentrations of several minerals than Dietrend, suggesting that the choice and relative contribution of individual food ingredients may be important determinants of the micronutrient profile of blenderized EN. This finding supports previous concerns that blenderized formulations may provide inconsistent nutrient concentrations compared with commercially manufactured EN products, which are generally designed to deliver nutrients within specified ranges (Ojo et al., 2020).

The observed variability is clinically relevant because patients receiving enteral nutrition may depend substantially, and in some cases almost entirely, on the feeding formulation to meet their nutritional requirements. Although whole-food-based formulations have potential advantages, nutritional adequacy cannot be inferred solely from the use of diverse food ingredients. The present findings suggest that some of the blenderized formulations may not consistently provide adequate amounts of selected micronutrients relative to recommended requirements. This is particularly important where enteral feeding is prolonged, because relatively small deficits in individual nutrients may become nutritionally significant over time. However, the findings should be interpreted in the context of the patient's total nutritional prescription, including feeding volume, frequency, additional supplements, and other sources of nutrient intake. Therefore, the present results indicate a potential risk of inadequacy rather than demonstrating that patients receiving these formulations necessarily developed micronutrient deficiencies.

Differences in the mineral composition of the three formulations may partly reflect the nutritional characteristics of their constituent ingredients. The inclusion of millet and acha (fonio) in Jot-M-Mix and Bran Mix, respectively, may have contributed to their relatively greater mineral concentrations. Nevertheless, ingredient composition alone is unlikely to explain the entire variation. Nutrient retention in prepared feeds is influenced by cooking conditions, processing methods, food maturity, harvesting and storage practices, ingredient proportions, and preparation errors (Mokhalalati et al., 2004). Thus, differences between formulations may reflect not only the intrinsic nutrient composition of the raw materials but also the processes through which those materials were transformed into enteral feeds.

An important structural issue underlying these findings is the lack of standardized recipes and preparation protocols for blenderized EN. Unlike commercial formulas, which are manufactured under controlled conditions with defined nutrient specifications, hospital-prepared feeds can vary according to the ingredients available, the quantities used, preparation techniques, and the personnel involved. This inherent variability may compromise reproducibility and makes it difficult to ensure that patients receive a consistent nutrient supply. The findings of Madden et al. (2019) provide further support for this concern, as nutrient delivery was reduced following the loss of residues during preparation and straining, with the resulting feeds providing less than estimated requirements for several nutrients. These observations suggest that nutritional assessment of blenderized EN should consider not only the theoretical composition of the ingredients but also the nutrients that remain in the final product actually administered to the patient.

The physicochemical findings provide an additional dimension to the nutritional concerns. Dietrend demonstrated significantly higher viscosity and osmolality than Jot-M-Mix and Bran Mix ($p < 0.05$), indicating that the formulations differed considerably in their suitability for tube administration. High viscosity is particularly important in enteral feeding because excessively thick preparations may flow poorly through narrow-bore feeding tubes and increase the likelihood of tube obstruction (Sullivan et al., 2004). Consequently, a formulation with an apparently acceptable nutrient composition may still present practical limitations if its physical characteristics interfere with the delivery of the prescribed volume.

The elevated osmolality observed in Dietrend also warrants consideration. The chemical composition, solubility, molecular characteristics, and macronutrient constituents of an enteral preparation can influence its osmolality and, consequently, nutrient handling and gastrointestinal tolerance (Savino, 2018). However, osmolality should not be interpreted in isolation as evidence of poor clinical suitability. Patient tolerance is influenced by several interacting factors, including feeding rate, gastrointestinal function, disease status, fluid requirements, and the composition of the overall feeding regimen. Nevertheless, the simultaneous presence of relatively high viscosity and osmolality in Dietrend suggests that this formulation may require particular attention during preparation and administration.

These physicochemical differences are especially relevant in settings where blenderized feeds are administered through small-diameter tubes. Poor flow characteristics may result in interruptions to feeding and may also interfere with the administration of water or medications through the same tube. Such

interruptions could reduce the amount of nutrition actually delivered relative to the amount prescribed. Thus, assessment of enteral feed quality should extend beyond proximate or mineral composition to include properties that determine whether the feed can be reliably delivered through the intended feeding route.

Despite these limitations, the continued use of blenderized EN should not be interpreted solely as evidence of inadequate nutritional practice. Whole-food-based feeding may provide important practical and psychosocial benefits. Hurt et al. (2015) reported that some patients receiving blenderized EN did not experience substantial concerns associated with its use, while Martin and Gardner (2017) suggested that food-based formulas may restore a sense of normalcy and provide patients and caregivers with greater control over food selection. Blenderized feeding may also facilitate the incorporation of dietary fibre, phytochemicals, and prebiotic components that are not necessarily prominent in some conventional formulas (Martin and Gardner, 2017). These potential benefits provide a rationale for its continued consideration in selected patients, provided that nutritional adequacy, food safety, and tube compatibility can be adequately addressed.

The apparent disagreement between studies regarding the adequacy of blenderized EN further emphasizes the importance of context. Sullivan et al. (2004) reported inadequate nutrient provision from some blenderized preparations, whereas Hron et al. (2019) found that appropriately prepared blenderized feeds could provide required nutrients and were associated with favorable outcomes. Similarly, Ojo et al. (2020) reported lower macro- and micronutrient concentrations and greater viscosity and osmolality in blenderized feeds compared with commercial products. These apparently divergent findings may be attributable to differences in recipes, ingredient selection, preparation procedures, patient populations, analytical methods, and feeding protocols. Therefore, the nutritional adequacy of blenderized EN should not be generalized across formulations or healthcare settings. Instead, each formulation should be evaluated according to its actual composition and intended clinical use.

The public health relevance of these findings is particularly important in Nigeria, where hospital-prepared enteral feeds remain an important component of nutritional support. In a population already affected by inadequate intake of several essential micronutrients, including calcium, magnesium, iron, and iodine (Lindsay, 2021), reliance on nutritionally inconsistent enteral formulations may further complicate the provision of adequate nutrition to vulnerable patients. This does not imply that blenderized feeding is inherently inferior to commercial EN; rather, it underscores the need for evidence-based formulation and monitoring. In resource-constrained environments, affordability and accessibility may make hospital-prepared feeds a practical necessity, making optimization and standardization potentially more realistic strategies than simply replacing them with commercial products.

From a clinical perspective, the findings support the need for dietitians and other healthcare professionals to move beyond prescribing blenderized EN on the basis of ingredient availability alone. Nutritional prescriptions should consider the patient's individual requirements, underlying disease, nutritional status, expected duration of enteral feeding, and the nutrient density of the selected formulation. Where feasible, recipes should be standardized, ingredient quantities carefully measured, preparation losses minimized, and the final product periodically subjected to nutritional and physicochemical assessment. This approach may improve consistency in nutrient delivery while reducing avoidable problems associated with tube administration.

Importantly, the present study evaluated the composition and physical and chemical properties of the feeds rather than directly measuring patient outcomes. Therefore, associations between the identified nutritional deficiencies or physicochemical characteristics and outcomes such as changes in body composition, morbidity, mortality, hospital readmission, or healthcare expenditure should be interpreted as potential clinical implications rather than established effects. Longitudinal clinical studies are required to determine whether differences in the composition and administration characteristics of blenderized EN translate into measurable differences in nutritional status, tolerance, treatment interruptions, and patient outcomes.

Conclusion

This study demonstrates marked variability in the mineral composition and physicochemical properties of blenderized enteral nutrition feeds administered at Jos University Teaching Hospital. Some formulations did not achieve the expected levels of selected minerals, while significant differences in viscosity and osmolality were also observed. These findings raise concerns about the consistency and nutritional adequacy of hospital-prepared enteral feeds, particularly when they are used as the principal source of nutrition for patients requiring prolonged enteral support. However, the findings do not establish that blenderized EN is inherently nutritionally inferior to commercial formulas. Rather, they highlight the consequences of formulation and preparation variability and the importance of standardization, nutritional assessment, and appropriate clinical monitoring. Given the continued reliance on hospital-prepared feeds in resource-constrained settings, efforts should focus on developing validated recipes, standardizing preparation procedures, and ensuring that formulations meet patients' nutritional requirements while remaining physically suitable for tube administration. Further clinical and intervention studies are needed to establish whether optimizing blenderized EN composition and physicochemical characteristics improves nutrient delivery, feeding tolerance, and clinically relevant patient outcomes.

Declarations

Author Contributions

C.V.E: Conception, methodology, data analysis, investigation, data curation, writing original draft, manuscript preparation and revision.

E.E.O: Conception, methodology, data analysis, investigation, data curation, writing original draft and resources

E.M.O: Investigation, validation, resources.

M.M.O: Investigation, resources.

U.B.I: Investigation, resources, supervision

All authors reviewed the manuscript.

Declaration of Generative AI and AI-Assisted Technologies in Scientific Writing

AI was used to comprise and correct grammatical. CHATGPT and quillbot was used.

Availability of data and materials

The data and materials supporting the findings of this study are available from the corresponding author upon reasonable request.

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Ethical declarations

Ethics approval and consent to participate: Not applicable.

Clinical trial number: Not applicable.

References

1. Bennett K, Hjelmgren B, Piazza J. Blenderized tube feeding: health outcomes and review of homemade and commercial prepared products. *Nutr Clin Pr.* 2020;35:417–31. [CrossRef].
2. Bjuresäter K, Larsson M, Athlin E. Struggling in an inescapable life situation: being a close relative of a person dependent on home enteral tube feeding. *J Clin Nurs.* 2012;21(7–8):1051–9. 10.1111/j.1365-2702.2010.03596.x.
3. Brown B, Roehl K, Betz M. Enteral nutrition formula selection current evidence and implications for practice. *Nutr Clin Pract.* 2014. doi:0884533614561791.
4. Brown B, Roehl K, Betz M. Enteral nutrition formula selection: current evidence and implications for practice. *Nutr Clin Pract.* 2015;30:72–85.
5. Carter H, Johnson K, Johnson TW, Spurlock A. Review - systematic blended tube feeding prevalence, efficacy and safety: what does the literature say? *J Am Association Nurse Practitioners.* 2018;30(3).
6. Epp L. Blenderized feeding options the sky's the limit. *Practical Gastroenterol.* 2018;42(6):30–9.
7. Adom R. Nutrient profiles of enteral feeds in selected hospitals in Accra, Ghana [Master's thesis]. Accra, Ghana: University of Ghana; 2020. 116 p.
8. Felicio BA. Food and nutritional safety of hospitalized patients under treatment with enteral nutrition therapy in the Jequitinhonha Valley, Brazil. *Nutr Hosp.* 2012;27(6):2122–9.
9. Bowling TE. Enteral nutrition. *Hosp Med.* 2004;65(12):712–6. 10.12968/hosp.2004.65.12.712.
10. Hron B, Fishman E, Lurie M, Clarke T, Chin Z, Hester L, Rosen R. Health outcomes and quality of life indices of children receiving blenderized feeds via enteral tube. *J Pediatr.* 2019;211:139–46.
11. Hurt RT, Edakkanambeth Varayil J, Epp LM, Pattinson AK, Lammert LM, Lintz JE, Mundi MS. Blenderized tube feeding use in adult home enteral nutrition patients: a cross-sectional study. *Nutr Clin Pract.* 2015;30:824–9. [CrossRef].
12. Madden AM, Baines S, Bothwell S, Chen E, Goh S, Jerome L, Sommariva-Nagle C, Szychta M. A laboratory-based evaluation of tube blocking and microbial risks associated with one blended enteral feed recipe. *J Hum Nutr Diet.* 2019;32:667675. [CrossRef] [PubMed].
13. Martin K, Gardner G. Home enteral nutrition: updates, trends, and challenges. *Nutr Clin Pract.* 2017;32:712–21. [CrossRef].
14. Mahsa M, Ali T, Abdolrasoul S. School of Nutrition, Tabriz University of Medical Sciences, Tabriz, I. R. Iran; 2School. Bacterial contamination and nutritional adequacy of enteral tube feedings in Iran. *Progress in Nutrition.* 2017;Vol. 19, N. 3:283–290. 10.23751/pn.v19i3.5139
15. Lindsay KL, Gibney ER, McAuliffe FM. Maternal nutrition among women from Sub-Saharan Africa, with a focus on Nigeria, and potential implications for pregnancy outcomes among immigrant populations in developed countries. *J Hum Nutr Diet.* 2012;25(6):534–46. 10.1111/j.1365-277X.2012.01253.x.
16. Mokhalalati JK, Druyan ME, Shott SB. Comer OGM. Microbial, nutritional and physical quality of commercial and hospital prepared tube feedings in Saudi Arabia. *Saudi Med J.* 2004;25(3):331–41.
17. Mula C, Ncama BP, Maluwa A. Nurses' competency and challenges in enteral feeding in the Intensive Care Unit (ICU) and High Dependency Units (HDU) of a referral hospital, Malawi. *Malawi Med J.* 2014;26(3):55–9. September 2014.
18. Nyati M, Ogada I, Nyirenda C. Adequacy of Energy, Zinc and Selenium Intakes among Adult Inpatients Receiving Total Naso-gastric Tube Feeding Admitted to a Copperbelt Province Referral Hospital, in Ndola District, Zambia. *BMC Nutr.* 2016;2(64):1–9. <https://doi.org/10.1186/s40795-016-0103-5>.
19. Ojo O, Rodrigues A, Adegboye A, Ojo OO, Wang X, Brooke J. An evaluation of the nutritional value and physical properties of blenderised enteral nutrition formula: a systematic review and meta-analysis. *Nutrients.* 2020;12(1840).
20. Sforza E, Limongelli D, Giorgio V, Margiotta G, Proli F, Kuczyńska EM, Leoni C, Rigante D, Contaldo I, Veredice C. The impact of blenderized tube feeding on gastrointestinal symptoms, a scoping review. *Appl Sci.* 2023;13:2173. <https://doi.org/10.3390/app13042173>.

21. Sullivan MM, Sorreda-esguerra P, Platon MB, Castro CG, Chou NR, Shott S, Alarcon P. Nutritional analysis of blenderized enteral diets in the Philippines. Asia Pac J Clin Nutr. 2004;13(4):385–90.

Figures

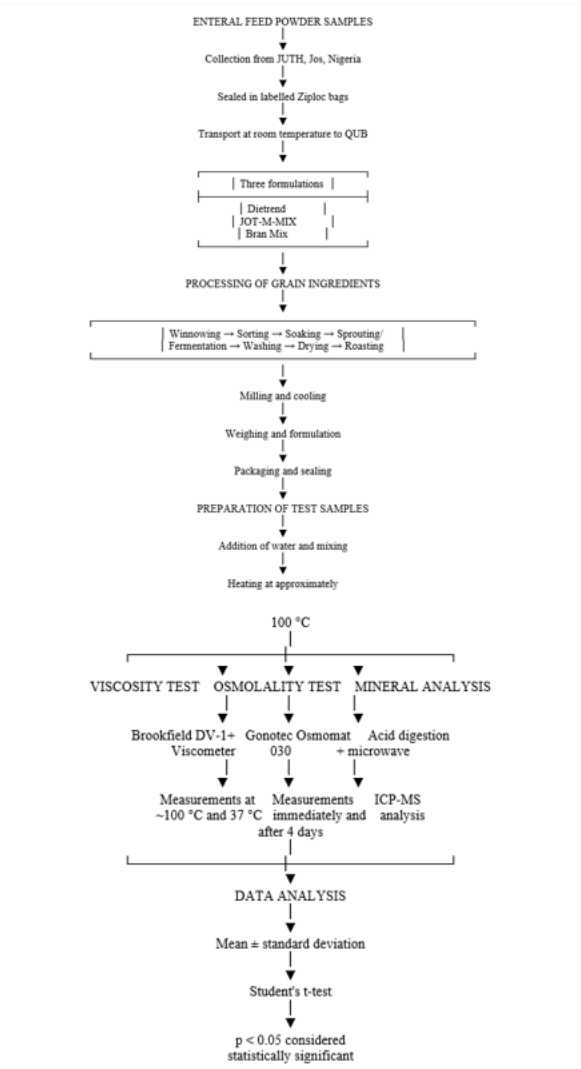


Figure 1
Flow chart of sample collection, processing and laboratory analysis