

**COMPARATIVE ANALYSIS OF NUTRITIONAL COMPOSITION OF READY TO
USE THERAPEUTIC FOOD (RUTF) AND TOMBROWN.**

BY

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CERTIFICATION

This is to certify that the research project reported here was conducted by JEROME HOPE SIZAH (2010304052) and has been approved as meeting the requirements for the award of Bachelor of Science (B.Sc.) degree in Biochemistry of the Usmanu Danfodio University Sokoto.

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DEDICATION

I dedicate this work to God almighty the giver of life and strength and also to my parents Mr and Mrs Jerome Sizah Audu and My siblings Saviour Jerome, Rachael Jerome and Zion Jerome for their unwavering love and support throughout this BSc. program and also to every child out there suffering from Severe Acute Malnutrition.

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ABSTRACT

Severe Acute Malnutrition (SAM) is a condition affecting children, especially in northern Nigeria. Studies have shown that SAM can be mitigated using Ready-to-Use Therapeutic Food (RUTF), but its unavailability and cost of purchase have undermined its effectiveness in the treatment of SAM. This study aims to comparatively evaluate the nutritional composition of RUTF and tombrown and also check if tombrown can serve as an alternative to RUTF, as it is locally made, which makes it readily available and cheaper. The proximate parameters such as moisture, lipid, ash, protein were determined using AOAC (2022) method, phytochemical parameters such as flavonoid, saponin, tannin, carotenoids, alkaloid, phenols and cardiac glycosides were quantitatively determined using AOAC (2022) method and mineral element such as Iron, selenium, calcium, zinc, magnesium, copper and potassium were analysed using Atomic Absorption Spectrophotometer. The results obtained revealed that RUTF contained higher nutritional composition as compared to Tombrown, although tombrown can be modified during production to meet the demands of children suffering from Severe Acute Malnutrition (SAM).

Keywords: Severe Acute Malnutrition (SAM), Ready-To-Use Therapeutic Foods (RUTF), Tombrown, Proximate parameters, Phytochemical parameters and Mineral Element.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Nutrition plays a pivotal role in sustaining life, promoting growth, and maintaining physiological functions in humans. An adequate diet provides the essential macronutrients and micronutrients needed for metabolic processes and resistance against disease (WHO, 2021). Inadequate intake of these nutrients, particularly among infants and children, often leads to malnutrition, which remains a leading cause of morbidity and mortality globally, especially in low- and middle-income countries (Black *et al.*, 2020). It encompasses both undernutrition (wasting, stunting, underweight, and micronutrient deficiencies) and overnutrition (overweight and obesity), reflecting a double burden increasingly seen in transitioning economies. Undernutrition persists as a major cause of morbidity and mortality among children under five, weakening immune function, impairing growth, and reducing cognitive development (UNICEF, WHO & World Bank, 2023). Malnutrition, particularly protein–energy malnutrition, remains a public health challenge in sub-Saharan Africa, accounting for a significant proportion of under-five mortality (UNICEF, 2023). Globally, an estimated 45 million children suffer from wasting, while 148 million are stunted due to chronic nutrient deprivation, repeated infections, and inadequate caregiving practices (WHO, 2022). The causes of malnutrition can be poverty, food insecurity, poor dietary diversity, suboptimal infant feeding, and limited access to clean water, sanitation, and healthcare. At the biochemical level, inadequate intake of essential macronutrients and micronutrients disrupts metabolic processes, immune responses, and physiological development (Black *et al.*, 2020; Bhutta *et al.*, 2017). Despite the availability of international interventions such as RUTF, their high production and importation costs limit accessibility for many low-income

households and communities (Sadler *et al.*, 2021). Locally available weaning foods such as Tombrown offer an affordable alternative; however, their nutrient density, safety, and biochemical composition relative to standard therapeutic foods have not been adequately characterized (Afolabi *et al.*, 2020).

In recent decades, nutritional interventions have been developed to combat malnutrition through both community-based and clinical strategies (Fabiansen *et al.*, 2017).

Tombrown is a traditional complementary food commonly produced and consumed in many West African households, particularly in Nigeria and Ghana (Adewole *et al.*, 2024). It is typically a dry cereal blend prepared from roasted maize, soybean, groundnut, and sometimes millet or sorghum, milled into fine flour and reconstituted with water into a porridge (Attou *et al.*, 2020). The composition of Tombrown varies depending on locally available ingredients and household preferences. As a staple weaning food, it serves as a major source of energy, protein, and essential minerals for growing children, although its nutritional adequacy compared with standard therapeutic foods remains a concern (Adewole *et al.*, 2024).

Ready-to-Use Therapeutic Food (RUTF), on the other hand, is a scientifically formulated, energy-dense paste designed for the nutritional rehabilitation of children suffering from severe acute malnutrition (Schoonees *et al.*, 2019). RUTF is typically composed of peanuts, milk powder, sugar, vegetable oil, and a vitamin-mineral premix, providing a balanced and bioavailable source of nutrients (Akuu and Amagnya, 2023). Its long shelf life, ease of use, and therapeutic efficacy have made it a cornerstone of community-based management of malnutrition (CMAM) programs across Africa and Asia (Fabiansen *et al.*, 2017).

Given that both Tombrown and RUTF serve as dietary interventions for young children, comparing their nutritional composition provides valuable insight into their relative adequacy and potential for nutritional rehabilitation. While RUTF is commercially produced under standardized conditions, Tombrown remains a household-level formulation whose nutrient

composition can vary widely (Nyefene *et al.*, 2025). Therefore, a comparative evaluation of their proximate, phytochemical, and mineral content is essential to determine whether Tombrown could serve as a cost-effective, locally sustainable alternative to imported RUTF formulations (Lartey *et al.*, 2025).

1.2 Statement of the Problem

Previous studies revealed, that locally prepared complementary foods does not frequently meet the recommended daily requirements for energy and micronutrients essential for child growth. Moreover, variations in ingredient ratios, roasting time, and processing techniques can significantly affect the nutritional quality of Tombrown. Without comprehensive biochemical evaluation, it is difficult to establish the suitability of Tombrown as a therapeutic or supplementary food comparable to RUTF. This research, therefore, seeks to fill that gap by evaluating and comparing the proximate, phytochemical of Tombrown and RUTF under standardized laboratory conditions.

1.3 Justification of the study

Malnutrition remains a critical public health concern in Northern Nigeria, particularly in Sokoto State, where high rates of wasting, stunting, and micronutrient deficiencies persist among children under five. According to recent national surveys, Sokoto consistently records some of the highest levels of childhood undernutrition in the country, driven by food insecurity, low dietary diversity, and recurrent infections (National Bureau of Statistics & UNICEF, 2021). Addressing this burden requires evidence-based nutritional interventions tailored to the dietary patterns and available food resources within the region.

Ready-to-Use Therapeutic Food (RUTF) has been globally recognized as the standard treatment for severe acute malnutrition (SAM) due to its high energy density, balanced

macronutrient profile, and fortified micronutrient content (WHO, 2013; UNICEF, 2019). However, the widespread use of RUTF in Northern Nigeria is challenged by cost, supply chain disruptions, and reliance on imported formulations, which limit sustainable access for many vulnerable households (Akuu and Amagnya, 2023).

Tombrown, a traditional cereal-legume blend commonly consumed in Northern Nigeria is affordable, culturally acceptable, and made from locally available ingredients such as maize, millet, sorghum, groundnuts, and soybeans. Despite its frequent use as a complementary food, there is limited scientific data comparing its nutritional composition with that of RUTF, particularly within the context of Sokoto where traditional foods play an important role in child feeding practices (Ijarotimi and Olufunke, 2012).

A comparative analysis of RUTF and Tombrown is therefore carried out to determine whether locally formulated foods can provide adequate nutrients required for growth and rehabilitation of malnourished children. This research will help identify strengths, limitations, and possible nutrient gaps in Tombrown relative to RUTF, informing nutrition-sensitive interventions, improved complementary feeding strategies, and the potential development of fortified or optimized local alternatives. Such evidence is vital for policymakers, nutrition programs, and community-level initiatives aiming to reduce malnutrition in Sokoto State and Northern Nigeria as a whole.

1.4 Aim of the Study

This study aims to evaluate the nutritional composition of Tombrown and Ready-to-Use Therapeutic Food (RUTF) through laboratory-based analyses of their proximate, phytochemicals and mineral components.

1.5 Specific Objectives

The specific objectives of this study are to:

1. Determine the proximate composition (moisture, ash, crude protein, crude fat, crude fiber, and carbohydrate content) of Tombrown and RUTF.
2. Quantitatively determine the phytochemical constituents (such as tannins, saponins, flavonoids, alkaloids, and phenolic compounds) present in Tombrown and RUTF.
3. Compare the nutritional quality of Tombrown and RUTF and observe their potential implications for nutritional rehabilitation and food security.
4. To offer recommendations on the use of Tombrown as an alternative to combat severe acute malnutrition (SAM).

1.6 RESEARCH QUESTIONS

1. What are the proximate compositions of RUTF and Tom Brown?
2. What are the phytochemical compositions of RUTF and Tom Brown?
3. Are there significant differences in their nutrient contents and energy values?
4. To what extent does Tom Brown meet the nutritional requirements for managing malnutrition?
5. Can Tom Brown be considered a suitable alternative to RUTF for nutritional rehabilitation programs?
6. What factors influence the observed differences in nutrient composition between RUTF and Tom Brown.

CHAPTER TWO

2.0 Literature Review

2.1 Global Perspective on Malnutrition

Despite significant global progress, the 2023 Global Nutrition Report indicates that over 148 million children under five remain stunted, while 45 million are wasted (Global Nutrition Report, 2023). The COVID-19 pandemic and recent economic shocks have exacerbated food insecurity, particularly in West Africa, where household diets rely heavily on cereals with limited protein quality (FAO, 2022). Strategies promoting locally produced therapeutic foods are therefore essential not only for nutrition security but also for strengthening regional food systems and resilience (Lartey *et al.*, 2025).

Malnutrition represents both a clinical and biochemical disorder rooted in nutrient imbalance. Nutritional rehabilitation, whether through RUTF or improved local formulations such as Tombrown targets the biochemical restoration of growth and metabolic homeostasis (Nel and Lombard, 2025).

2.2 Nutritional Rehabilitation

Nutritional rehabilitation refers to the systematic restoration of nutritional status in malnourished individuals through adequate dietary, therapeutic, and behavioral interventions (WHO, 2021). The process typically involves two complementary strategies: clinical rehabilitation, focusing on the treatment of severe acute malnutrition using therapeutic foods such as RUTF, and community-based rehabilitation, emphasizing locally available nutrient-dense foods (Nel and Lombard, 2021).

Biochemically, rehabilitation aims to reverse catabolism and re-establish positive nitrogen balance, replenish glycogen and fat stores, and correct electrolyte and micronutrient

imbalances (Akuu and Amagnya, 2023). The composition of therapeutic foods is therefore designed to deliver a high energy-to-weight ratio (≥ 520 kcal/100 g), adequate protein (10–12 %), essential fatty acids, and balanced mineral–vitamin content (Schoonees *et al.*, 2019).

2.3 The Use of Tombrown in African Households

In West Africa, traditional complementary foods such as Tombrown are widely used for infant feeding due to their affordability, cultural acceptance, and local ingredient availability (Essien *et al.*, 2010). However, such foods are often limited by low nutrient density and the presence of antinutritional factors, including phytates and tannins, which reduce mineral bioavailability (Attou *et al.*, 2020). Conversely, Ready-to-Use Therapeutic Food (RUTF) is a standardized, fortified formulation scientifically developed to meet international specifications for nutritional rehabilitation (Fabiansen *et al.*, 2017).

Comparing these two food systems provides biochemical insight into how indigenous diets can be improved or reformulated to match therapeutic standards (Lopes *et al.*, 2024). Locally optimized versions of Tombrown enriched with legumes or micronutrient premixes could potentially bridge nutrient gaps and contribute to sustainable, community-based rehabilitation programs (Ubbor *et al.*, 2022).

2.4 Composition and Nutritional Importance of Tombrown

Tombrown is a traditional cereal-legume complementary food widely consumed in West Africa, particularly Ghana and Nigeria, as a weaning porridge for infants and a breakfast meal for adults (Essien *et al.*, 2010). It is produced by blending and milling roasted grains and legumes, most commonly maize (*Zea mays*), soybeans (*Glycine max*), and groundnuts (*Arachis hypogaea*) sometimes supplemented with millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*), or crayfish to enhance flavour and nutrient content (Attou *et al.*, 2020).

The roasting step reduces moisture content, enhances shelf stability, and develops characteristic flavour through Maillard reactions (Lartey *et al.*, 2025).

2.4.1 Proximate Composition of Tombrown

The proximate composition of Tombrown depends largely on the ratios of cereals to legumes and the degree of roasting. Studies have reported moisture contents between 3 % and 7 %, indicating good storage stability (Adewole *et al.*, 2024). Crude protein levels generally range from 12 % to 22 %, largely contributed by soybeans and groundnuts, which complement the lysine-deficient maize proteins (Ubbor *et al.*, 2021). The lipid content averages 10 %–15 %, supplying essential fatty acids and energy. Carbohydrates constitute the largest fraction (55 %–65 %), primarily in the form of starch, which provides readily available energy (Nel and Lombard, 2021). Crude fibre levels (3 %–5 %) aid gastrointestinal motility, while ash content (2 %–4 %) reflects the mineral density of the blend (Essien *et al.*, 2010er).

Biochemically, the combination of cereals and legumes enhances the amino-acid profile, yielding a more balanced source of essential amino acids such as lysine, methionine, and tryptophan (Adewole *et al.*, 2024). This synergy follows the principle of protein complementarity, improving the biological value of the food and supporting tissue growth during early childhood (Morris & Mohiuddin, 2023).

2.4.2 Phytochemical Composition of Tombrown

Tombrown also contains several secondary metabolites derived from its plant ingredients, including flavonoids, phenolic acids, tannins, alkaloids, saponins, and Cardiac glycosides (Ubbor *et al.*, 2021). These compounds exert dual effects: while moderate levels act as antioxidants that scavenge reactive oxygen species, excessive concentrations may reduce nutrient bioavailability through chelation or protein precipitation (Hossain *et al.*, 2025).

Roasting has been shown to significantly reduce antinutritional factors such as trypsin inhibitors and phytates, thereby improving protein digestibility and mineral absorption (Attou *et al.*, 2020). The antioxidant capacity of Tombrown, attributed mainly to flavonoids and phenolics, may contribute to oxidative stress reduction and improved immune function in children (Nyefene *et al.*, 2025).

2.5 Nutritional and Public-Health Importance of Tombrown

From a nutritional-biochemistry perspective, Tombrown provides a balanced matrix of macronutrients and micronutrients required for growth, energy metabolism, and immune competence. Its high caloric density and digestibility make it suitable for infants transitioning from exclusive breastfeeding (Nyefene *et al.*, 2025). Economically, Tombrown is a low-cost, locally sourced alternative to imported weaning foods, supporting household food security and promoting self-reliance (Lartey *et al.*, 2025).

Beyond its direct nutritive role, Tombrown also carries sociocultural significance. It aligns with traditional feeding customs, thereby increasing caregiver compliance and acceptance in community-based nutrition programs (Akinwotu *et al.*, 2025). When properly formulated and fortified, Tombrown has potential to serve as an effective, culturally appropriate tool for mitigating moderate acute malnutrition in children (Akomo *et al.*, 2021).

2.6 Ready-to-Use Therapeutic Food (RUTF): Composition and Usage

Ready-to-Use Therapeutic Food (RUTF) is a scientifically formulated, high-energy, lipid-based paste specifically designed for the dietary management of severe acute malnutrition (SAM) in children aged 6–59 months (Schoonees *et al.*, 2019). It was developed as a core component of the Community-Based Management of Acute Malnutrition (CMAM) strategy introduced by the World Health Organization (WHO), the United Nations Children’s Fund

(UNICEF), and related agencies to reduce global child mortality (WHO, 2021). RUTF allows for home-based treatment of malnutrition without the need for hospitalization or complex preparation, making it a breakthrough in nutrition interventions (Akuu and Amagnya, 2021).

2.6.1 Composition and Formulation Principles of RUTF

Standard RUTF formulations are based on a peanut (groundnut) matrix blended with milk powder, sugar, vegetable oil, and a vitamin–mineral premix (Fabiansen *et al.*, 2017). The typical composition provides approximately 520–550 kcal per 100 g, with 10–12% protein, 45–60% fat, and the remainder as carbohydrates (UNICEF, 2023). The product is fortified with essential vitamins (A, D, E, K, B-complex, and C) and minerals (iron, zinc, calcium, magnesium, copper, iodine, selenium, and potassium) at levels sufficient to meet daily requirements for children during the rehabilitation phase (Akomo *et al.*, 2021).

The high lipid content serves not only as a concentrated energy source but also as a protective matrix that minimizes water activity, preventing microbial growth and ensuring long shelf life (Schoonees *et al.*, 2019). Milk powder contributes bioavailable proteins (casein, whey) and lactose, which improve nitrogen retention and palatability (Akuu and Amagnya, 2023). The inclusion of sugar enhances energy density and sensory acceptance among children, while emulsifiers ensure homogeneity of the paste (Adu-Afarwuah *et al.*, 2016).

From a biochemical standpoint, RUTF is formulated to promote rapid reversal of the catabolic state observed in severe malnutrition. The energy-to-protein ratio and lipid fraction stimulate insulin secretion, facilitating anabolic processes such as muscle and tissue regeneration (Schoonees *et al.*, 2019). The formulation also maintains an appropriate balance between omega-6 and omega-3 fatty acids, supporting membrane integrity and anti-inflammatory responses (Akomo *et al.*, 2021).

2.6.2 Processing and Quality Control of RUTF

Production of RUTF follows strict hygienic and nutritional standards, typically under Hazard Analysis and Critical Control Point (HACCP) protocols to ensure safety and consistency (UNICEF, 2023). Ingredients are roasted, milled, and mixed under controlled temperature and humidity conditions to maintain nutrient stability. The low moisture content (<2.5%) eliminates the need for refrigeration and permits storage for up to 24 months in sealed foil pouches (Akuu and Amagnya, 2023).

Recent innovations include milk-free or plant-based RUTF formulations, designed to reduce production costs and improve sustainability in low-income countries (Fabiansen *et al.*, 2017). Studies in Malawi and Niger have demonstrated comparable efficacy of soy-based RUTF in promoting weight gain and recovery rates in malnourished children (Potani *et al.*, 2021). Such innovations expand the potential for local production using regionally available ingredients such as soy, millet, and groundnut, thereby fostering self-sufficiency and reducing dependency on imported therapeutic foods (Lartey *et al.*, 2025).

2.6.3 Biochemical and Therapeutic Role of RUTF

Biochemically, RUTF facilitates recovery through restoration of energy metabolism, nitrogen balance, and micronutrient homeostasis. The combination of readily digestible macronutrients accelerates ATP generation, while high-quality proteins enhance tissue synthesis and immune competence (Semba & Bloem, 2021). The inclusion of zinc and vitamin A promotes epithelial repair and immune function, whereas iron and copper support hemoglobin synthesis (Bailey *et al.*, 2015). Additionally, antioxidant vitamins (E and C) mitigate oxidative stress, which is often elevated in malnourished individuals (Morris & Mohiuddin, 2023).

The biochemical design of RUTF ensures that the metabolic stress of refeeding is minimized. Its isotonic composition prevents osmotic diarrhea, a common complication of liquid-based feeding regimens, and allows for safe, gradual repletion of glycogen and lipid stores (Schoonees *et al.*, 2019). This makes RUTF particularly suitable for outpatient rehabilitation, where consistency and tolerance are critical.

2.6.4 Use of RUTF in Nutritional Rehabilitation Programs

RUTF is typically administered under CMAM protocols at 200 kcal/kg/day, divided into 2–3 portions, over a rehabilitation period of 6–8 weeks depending on the degree of malnutrition (UNICEF, 2023). Clinical evaluations have shown that recovery rates exceed 85% when properly implemented (Adu-Afarwuah *et al.*, 2020). Moreover, RUTF use has significantly reduced the case-fatality rate of severe acute malnutrition from over 20% in hospital-based programs to below 5% in community-based interventions (WHO, 2021).

Despite its success, several challenges persist. The reliance on imported milk powder and vitamin premixes increases production costs, and peanut-based formulations raise concerns about allergies (Potani *et al.*, 2021). These constraints have led to growing interest in localized RUTF production, incorporating indigenous ingredients such as sorghum, soybeans, or cowpea flour, many of which overlap with Tombrown components (Lartey *et al.*, 2025). Such innovations not only reduce cost but also align with the broader goal of achieving sustainable nutrition solutions in Africa.

2.6.5 Comparative Relevance of RUTF to Tombrown

Both Tombrown and RUTF share a similar nutrient delivery framework, cereal-legume-based formulations with emphasis on protein complementarity and energy density. However, while Tombrown is a traditional complementary food formulated informally, RUTF represents a

standardized therapeutic product with controlled nutrient specifications and quality assurance (Nyefene *et al.*, 2025).

2.7 Nutritional Components of RUTF and Tombrown

The nutritional value of any food is determined by the chemical composition and the bioavailability of its constituent nutrients. In nutritional biochemistry, proximate, phytochemical, and mineral analyses provide fundamental insights into the food's potential contribution to human metabolic needs and overall health (Morris & Mohiuddin, 2023). For both Tombrown and RUTF, understanding these components is crucial to evaluating their adequacy in preventing or managing malnutrition.

2.7.1 Proximate Composition

Proximate composition refers to the estimation of major nutrient classes in food, typically including moisture, ash, crude protein, crude fat, crude fibre, and carbohydrates (Akomo *et al.*, 2021). Each parameter provides biochemical and physiological insights into the food's energy density, nutrient balance, and shelf stability.

Moisture content determines the perishability of foods. High-moisture foods are prone to microbial spoilage and nutrient degradation, while low-moisture foods like Tombrown and RUTF (<7%) exhibit enhanced storage stability (Adewole *et al.*, 2024).

Ash content represents the total inorganic mineral matter in food, providing an index of mineral richness (Lopes *et al.*, 2024). Foods with high ash content tend to supply essential electrolytes and trace elements critical for biochemical reactions.

Crude protein estimation, typically through the Kjeldahl method, reflects the total nitrogenous compounds in the food (Bender, 2009). Proteins are fundamental for enzymatic reactions, tissue repair, and immune competence. In Tombrown, protein content is largely

derived from soybeans and groundnuts, whereas RUTF's protein originates from milk powder and legumes (Fabiansen *et al.*, 2017). Protein quality in both foods is enhanced by the presence of essential amino acids such as lysine, methionine, and tryptophan, which contribute to higher biological value and improved nitrogen retention (Morris & Mohiuddin, 2023).

Crude fat content determines the energy density of the diet. Lipids contribute approximately 9 kcal/g and are essential for fat-soluble vitamin absorption (Adu-Afarwuah *et al.*, 2020). RUTF's lipid profile, enriched with vegetable oils, provides essential fatty acids linoleic and α -linolenic acids vital for membrane integrity and cognitive development (Schoones *et al.*, 2019). Tombrown, though lower in total fat, can be enriched with groundnut or palm oil to improve its caloric and nutritional value (Lopes *et al.*, 2024).

Crude fibre promotes gut motility and contributes to satiety. Moderate fibre levels (3–5%) are ideal in complementary foods, as excessive fibre may reduce nutrient absorption (Attou *et al.*, 2020).

Carbohydrate content constitutes the primary energy source, typically determined by difference. The major carbohydrates in cereal-based foods are starch and simple sugars, which undergo enzymatic hydrolysis to glucose for ATP synthesis (Hsia, 2023). Carbohydrate concentration in Tombrown and RUTF contributes significantly to their energy yield, a vital parameter for rehabilitating energy-depleted children.

Overall, proximate analysis provides the baseline nutritional portrait necessary for assessing dietary adequacy, guiding both product formulation and policy development in nutrition rehabilitation programs.

2.7.2 Phytochemical Components

Phytochemicals are non-nutritive bioactive compounds produced by plants that influence human health through antioxidant, antimicrobial, and metabolic-modulatory mechanisms (Semba & Bloem, 2021). Common classes include tannins, flavonoids, alkaloids, phenolics, saponins, and phytates (Akinwotu *et al.*, 2025). While RUTF, being a highly processed and standardized product, contains minimal phytochemicals, Tombrown, derived from whole grains and legumes contains appreciable levels of these compounds, depending on ingredient type and processing conditions (Attou *et al.*, 2020).

Flavonoids and phenolic acids act as potent antioxidants, scavenging free radicals and reducing oxidative stress, thereby supporting immune function and tissue repair (Lopes *et al.*, 2024). Moderate flavonoid levels in Tombrown may provide additional health benefits beyond basic nutrition, such as improved cardiovascular function and reduced inflammation (Hossain *et al.*, 2025).

Tannins, though beneficial in small amounts due to their antimicrobial properties, can bind proteins and digestive enzymes, reducing digestibility when present in excess (Afolabi *et al.*, 2020).

Phytates chelate divalent minerals such as Fe^{2+} , Zn^{2+} , and Ca^{2+} , thereby lowering bioavailability (Adewole *et al.*, 2024). However, roasting, an essential step in Tombrown preparation has been shown to significantly degrade phytates, tannins, and trypsin inhibitors (Attou *et al.*, 2020).

Saponins contribute to cholesterol-lowering effects through bile acid binding but may cause bitterness in high concentrations (Akinwotu *et al.*, 2025).

Alkaloids, though less abundant, exhibit antimicrobial and stimulant properties. Their low levels in cereals and legumes pose minimal toxicity risk but may modulate gastrointestinal physiology favorably (Appiah *et al.*, 2022).

From a nutritional-biochemical perspective, phytochemicals in Tombrown represent both a challenge and an opportunity: while antinutritional effects must be minimized through processing, the residual antioxidant and health-promoting properties enhance its functional-food potential.

2.7.3 Mineral Elements and Their Physiological Roles

Minerals are inorganic elements essential for various biochemical and physiological processes. They are classified as macrominerals (required in large quantities, e.g., calcium, phosphorus, sodium, potassium, and magnesium) and microminerals or trace elements (required in minute quantities, e.g., iron, zinc, copper, selenium, and iodine) (Bailey *et al.*, 2015).

In Tombrown, major minerals such as calcium, magnesium, and phosphorus contribute to bone mineralization, neuromuscular activity, and energy metabolism through ATP synthesis (Morris & Mohiuddin, 2023). Iron and zinc are critical trace elements: iron is a key component of hemoglobin and cytochromes, while zinc plays catalytic and structural roles in over 300 enzymes (Semba & Bloem, 2021). The presence of legumes such as soybeans enhances mineral density, although bioavailability can be compromised by phytate interactions (Halilu and Addis, 2016).

RUTF, in contrast, contains added minerals in bioavailable forms, including ferrous sulfate (FeSO_4), zinc gluconate (Zn^{2+}), and calcium carbonate (CaCO_3), fortified to meet therapeutic targets (UNICEF, 2023). These supplements ensure efficient absorption and metabolic utilization, compensating for deficiencies in severely malnourished children (Schoonees *et al.*, 2019). The balance between sodium and potassium in RUTF is carefully maintained to restore electrolyte equilibrium and prevent edema during refeeding (Akuu and Amagnya, 2023).

Micronutrient fortification in therapeutic foods directly addresses deficiencies common in undernourished populations, including anemia, immune dysfunction, and growth retardation (Bailey *et al.*, 2015). By contrast, the mineral content of Tombrown can vary widely depending on the type and source of grains and legumes used, underscoring the need for biochemical standardization if it is to be positioned as a therapeutic alternative (Halilu and Addis, 2016).

2.8 Comparative Evaluation of RUTF and Tombrown

Comparative evaluation of traditional complementary foods such as Tombrown and standardized therapeutic products like Ready-to-Use Therapeutic Food (RUTF) requires analysis across multiple dimensions: nutrient density and composition, nutrient bioavailability, production consistency and quality control, cost and supply-chain considerations, cultural acceptability, and programmatic effectiveness in nutritional rehabilitation (UNICEF, 2023).

Nutrient density is a primary differentiator: RUTF formulations are engineered to deliver a high energy density ($\approx 520\text{--}550$ kcal/100 g) and specific proportions of protein and lipids to meet therapeutic targets for treating severe acute malnutrition, with micronutrients added in bioavailable forms to correct common deficiencies rapidly (Schoonees *et al.*, 2019; UNICEF, 2023). By contrast, Tombrown, a cereal–legume blend produced from ingredients such as maize, millet, sorghum, soybean and groundnut typically has lower and more variable energy and micronutrient density depending on ingredient ratios and household processing methods (FAO, 2024).

Bioavailability of minerals and the presence of antinutritional factors further separate the two products. RUTF uses fortified mineral salts and carefully selected ingredient matrices that maximize uptake and minimize inhibitors, thereby improving the likelihood of correcting

deficiencies (Fabiansen *et al.*, 2017; UNICEF, 2023). Traditional Tombrown contains phytates, tannins and other plant secondary metabolites that can chelate divalent cations and reduce absorption unless processing steps (roasting, fermentation, germination) are applied to lower antinutrients (Attou *et al.*, 2020; FAO, 2024).

Production consistency and quality assurance are areas in which RUTF has an advantage. Industrially manufactured RUTF follows defined nutritional specifications and quality-control protocols (HACCP, packaging for low moisture), ensuring product homogeneity, microbiological safety, and predictable nutrient content (UNICEF, 2023). Tombrown, being largely produced at household or small-scale commercial levels, exhibits substantial batch-to-batch variation in proximate and micronutrient composition unless standardized recipes and fortification are adopted (ICRC, 2023).

Cost, local sourcing and supply resilience complicate the trade-off. Imported or milk-heavy RUTF increases program costs and creates supply vulnerabilities in resource-limited settings, prompting research and programmatic interest in locally produced RUTF variants made from soy, sorghum, or other indigenous ingredients (Fetriyuna *et al.*, 2023; Bell *et al.*, 2024). Similarly, Tombrown is inexpensive and uses locally available raw materials, offering potential economic and logistical advantages if reformulated, fortified, and quality-controlled to meet therapeutic requirements (FAO, 2024; MSF, 2024).

Acceptability and cultural fit favor traditional foods in many contexts: caregivers often prefer local preparations such as Tombrown for reasons of taste, familiarity, and feeding practices, which can improve adherence in community programs (MSF, 2024). However, clinical trials and reviews indicate that when locally produced, properly formulated alternative RUTF/RUSF products are manufactured to meet compositional guidance, they can achieve recovery outcomes comparable to standard RUTF in many settings (systematic reviews 2023–2024), though results vary by formulation and context.

Safety and programmatic monitoring are non-negotiable in therapeutic use. RUTF's low water activity and sealed packaging confer long shelf life and reduced microbial risk, supporting outpatient treatment models (UNICEF, 2023). For Tombrown to serve in a therapeutic capacity, production must incorporate moisture control, hygienic processing, and fortification with micronutrient premixes—measures that require investment in training, equipment, and regulatory oversight (Fetriyuna *et al.*, 2023).

Taken together, the comparative evidence suggests a pragmatic pathway: optimize traditional formulations like Tombrown by standardizing recipes, applying processing methods to reduce antinutrients, and incorporating fortification or enrichment steps; concurrently, pursue local RUTF production innovations that use indigenous raw materials to lower costs and increase supply resilience (Bell *et al.*, 2024; Fetriyuna *et al.*, 2023). Such hybrid strategies aim to retain cultural acceptability and affordability while delivering the compositional reliability and bioavailability required for effective nutritional rehabilitation (UNICEF, 2023; FAO, 2024).

CHAPTER THREE

3.0 Materials and Methods

3.1 Study Area and Sample Collection

This study was conducted in Sokoto State, Nigeria, located in the Northwestern geopolitical zone of the country. Sokoto lies between latitudes 13°02'N and 5°14'E and experiences a semi-arid tropical climate characterized by a long dry season and a short wet season (Nigerian Meteorological Agency (NiMET), 2023). The region's dietary patterns predominantly include cereal-based staples such as maize, millet, and sorghum, which form the foundation of many traditional foods including Tombrown. The choice of Sokoto as the study area was informed by the wide availability of both locally produced Tombrown and commercially imported Ready-to-Use Therapeutic Food (RUTF), enabling effective comparative sampling within a single geographical zone.

Five different food products were inspected for expiry dates and packaging integrity and purchased from reputable supermarkets within Sokoto metropolis, ensuring that samples were obtained in their original, sealed packaging to maintain product integrity. The products were categorized as follows:

- **Sample A:** Plumpy Nut
- **Sample B:** Rebound
- **Sample C:** Yashfik Tombrown
- **Sample D:** Tombrown (K&G Foods)
- **Sample E:** Naawu Tombrown

3.2 Reagents, and Equipment

3.2.1 List of Reagents Used

Table 1: List of Reagents

S/N	REAGENTS	GRADE	MANUFACTURER
1	Diethyl ether	Reagent	May and baker,UK.
2	Petroleum ether	Reagent	May and baker, UK.
3	Glacial acetic acid	Reagent	May and baker, UK.
4	Chloroform	Reagent	May and baker, UK.
5	n-hexane	Reagent	May and baker, UK.
6	Sulfuric acid (H ₂ SO ₄)	GPR	BDH chemical company poole, England.
7	Ferric chloride (FeCl ₃)	GPR	BDH chemical company poole, England.
8	Hydrochloric acid (HCl)	GPR	BDH chemical company poole, England.
9	Sodium hydroxide	Analar	BDH chemical company poole, England.
10	Boric Acid	AR grade	BDH.
11	Distilled water		BCH Laboratory.

3.2.2 List of Equipment and Glassware Used

Table 2: List of equipment

S/N	EQUIPMENTS	MODEL	MANUFACTURER
1	Weighing balance	Mettler P 163	Gallen kamp, UK.
2	Heating mantle	Ex 10/23	Quick fit, UK.
3	Drying cabinet	RSS 306A	Armour tech.
4	Retort stand		Gallen kamp, UK.
5	Measuring cylinder	Glass	Pyrex glass, UK.
6	Burette		Pyrex, England.
7	Pipette		Pyrex, England.
8	Water bath	SB-1100	EYELA Co. LTD., Shanghai.
9	Spectrophotometer	AE350	ERMA INC, Japan.
10	Filter paper	Whatman	Finland.
11	Oven	DZF-6021	
12	Conical flask	Glass	Pyrex, England.
13	Funnel		Pyrex, England.
14	Khedjahl digestion unit		Gerhardt Analytical Systems, Germany.
15	Muffle furnace		Carbolite Gero UK.

3.3 METHODS

3.3.1 PROXIMATE ANALYSIS

A proximate analysis comprises the mass percentage of moisture, ash, lipid, and protein. It was recommended by the Association of Official Analytical Chemists (AOAC) in 1990.

DETERMINATION OF ASH CONTENT

A dry platinum dish was weighed as W0 and 2g of the sample was added into the crucible and weighed as W1, the crucible containing the sample was then put into the muffle furnace and heated 550°C until fully ashed. The crucible was then allowed to cool and weighed as W2.

CALCULATION

$$\% \text{Ash} = \frac{W2 - W0}{W1 - W0} \times 100$$

Where:

W0 = weight of crucible + sample before ashing

W1 = weight of crucible + sample after drying

W2 = weight of crucible+ sample after ashing

DETERMINATION OF MOISTURE CONTENT

The moisture can was weighed empty as W0. 2g of the samples each was introduced into the empty crucible and weighed as W1, it was then transferred into the hot air drying oven to dry at 105°C for two hours and was allowed to cool and weighed as W2, with minimum exposure to air. The loss of weight due to the drying is calculated as follows:

$$\% \text{Moisture} = \frac{W1 - W2}{W1 - W0} \times 100$$

Where;

W0 = weight of empty crucible

W1 = weight of crucible + sample before drying

W2 = weight of crucible+ sample after drying

PROTIEN DETERMINATION BY KJELDAHL

The basic principle behind this method is that, nitrogen in the milk protein is converted to ammonia by boiling with conc. H_2SO_4 which converts it into ammonium sulphate. It is then further distilled with boric acid solution. By titration with standard acid oxidation, the percentage crude protein is calculated. The digestion is aided by the addition of khedjahl catalyst. This method involves 3 stages as follows;

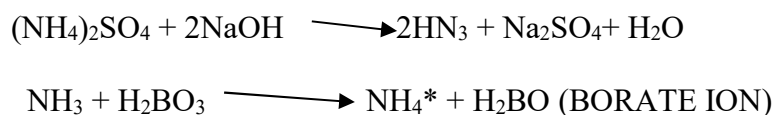
Digestion

Digestion converts organic nitrogen (N) to ammonia (NH_3) and other organic matter to carbon dioxide and water. 2g of samples were weighed and then placed into 100ml kjeldahl flask. $\frac{1}{2}$ kjeldahl tablets were added to each sample followed by 20ml conc. H_2SO_4 , the flask was then place in a heater mantle and heated until the black color disappeared.

N (in sample) _____ $(\text{NH}_4)_2\text{SO}_4$

Distillation

After digestion, the diagram flask was then connected to a receiving flask by a tube. With the addition of 40% NaOH makes the digest $(\text{NH}_4)_2\text{SO}_4$ strongly alkaline and converted to ammonia gas as in the equation below:



Titration

The solution collected was then titrated with 0.01N HCL to an end point where the color was observed to change from blue to pink, which indicated the end point.

The crude protein was based on the nitrogen content of the samples and was calculated using the formula below:

$$\begin{aligned}\% \text{Nitrogen} &= \text{TV} \times 0.01 \times 0.014 \times 50 \times 100 \\ &\quad \frac{2 \times 10}{} \\ \% \text{Protein} &= \% \text{N} \times 6.25\end{aligned}$$

TV = Titer Value

Nitrogen factor = 0.014

Conversion factor = 6.25

Normality of HCL = 0.1

DETERMINATION OF LIPID CONTENT

An empty crucible was weighed as W1, 2g of each sample was weighed into the crucible and weighed as W2, 200ml of petroleum ether was added into the crucibles, The crucibles were then placed into the oven at 1500c-1100c for about 5-6hrs. The crucibles were then removed carefully and allowed to cool and it was weighed as W2 after which the amount of lipid

extracted is obtained by the difference between the weight of the flask before and after extraction.

$$\% \text{Lipid} = \frac{W1 - W3}{W2} \times 100$$

Where:

W1 = Initial weight of the empty thimble

W2 = Weight of the thimble plus sample before extraction

W3 = Weight of the thimble plus sample after extraction

Carbohydrate by Difference

Carbohydrate by difference = 100- (moisture+ash+lipid+protein)

3.3.2 Phytochemical Analysis

Phytochemicals are non-nutritive bioactive compounds produced by plants that influence human health through antioxidant, antimicrobial, and metabolic-modulatory mechanisms (Semba & Bloem, 2021).

Determination of Flavonoids

1.0g of each sample was placed in a 250ml beaker, 20ml of 2% HCl was added and boiled for 35 minutes and filtered using whatman filter paper while hot to recover the extract. The filtrate was treated with ethyl acetate dropwise twice. The precipitated flavonoid was filtered, weighed and %flavonoid was calculated.

$$\% \text{Flavonoid} = \frac{W3 - W1}{W2} \times 100$$

Where; W1= weight of empty filter paper

W2= weight of sample

W3= weight of filter + flavonoids

Determination of Saponins

1.0g of each sample was weighed into a 250ml conical flask, 20ml of 50% of alcohol was added and boiled under reflux for 30 minutes and was filtered using whatman No. 1 filter paper. The filtrate was cooled, equal volume of acetone was added to complete the precipitation of saponin. The filtrate was filtered, weighed and %Saponin was calculated.

$$\% \text{Saponins} = \frac{W3 - W1}{W2} \times 100$$

Where; W1= weight of empty filter paper

W2= weight of sample

W3= weight of filter + saponins

Determination of Alkaloids

1.0g of each sample was weighed into a 250ml beaker and 20ml of ethanol was added and filtered using whatman No. 1 filter paper, 4ml of 0.0025M of H₂SO₄ was added and partitioned with ether to remove unwanted materials, NH₃ was also added for precipitation and filtered. The filter paper was allowed to dry, then it was weighed.

$$\% \text{Alkaloids} = \frac{W3 - W1}{W2} \times 100$$

Where; W1= weight of empty filter paper

W2= weight of sample

W3= weight of filter + Alkaloids

Determination of Glycosides

1.0g of each sample was weighed into a 250ml beaker, 10ml of 70% ethanol was added and the mixture was filtered. 1ml of the filtrate, 1ml of 12.5% lead acetate and 8ml of distilled water were all added into a test tube, and shaken vigorously. 5ml of the filtrate was pipetted into another test tube and 1ml of 4.7% Na₂PO₄ (disodium hydrogen phosphate) was added to

precipitate excess lead, 4ml of distilled water was added to make up the volume. The mixture was filtered twice with a whatman No. 1 filter paper, 10ml of Baljet's reagent was added to the purified filtrate. 10ml of Baljet's reagent and 10ml of distilled water was added into another test tube which served as blank. The two solutions were allowed to stand for one hour for maximum colour development and a UV-Vis spectrophotometer was used to measure absorbance at 495nm.

$$\% \text{Glycoside} = \frac{Ax100}{17}$$

Determination of Polyphenols

0.01g of each sample was weighed into a 250ml beaker, 10ml of methanol was added and the mixture was filtered using Whatman No. 1 filter paper. 100µl of the filtrate was transferred into a test tube, 100µl of standard gallic acid was weighed into another test tube, 200µl of folic ciocalteau was added into each of the test tubes, 800µl of Na₂CO₃ was also added into each test tube, 100µl of 95% methanol to serve as standard. The mixture was allowed to stand for two hours at room temperature and absorbance was measured at 765nm using UV-Vis Spectrophotometer.

$$\% \text{Phenolic} = \frac{\text{Absorbance of sample} \times \text{Concentration of standard}}{\text{Absorbance of standard}}$$

Determination of Tannins

0.1g of each sample was added into a 100ml conical flask, 50ml of distilled water was added, the mixture was boiled for 30minutes and it was filtered. 10ml of the filtrate was added into a test tube, 10ml of standard tannic acid was added into another separate test tube, 10ml of distilled water was also added into another separate test tube to which served as standard. 10ml of 17% tannic acid was added into each of the test tube and 2.5ml of Folin Dennis

reagent was also added into each of the test tube and allowed to stand for 20minutes and absorbance was taken at 760nm.

$$\% \text{ Tannin} = \frac{\text{Absorbance of sample} \times \text{concentration of standard}}{\text{Absorbance of standard}}$$

3.4.3 Determination of Mineral Composition

The mineral composition of the food samples, including iron (Fe), zinc (Zn), selenium (Se), calcium (Ca), copper (Cu), magnesium (Mg), and potassium (K) was determined using Atomic Absorption Spectrophotometry (AAS) in accordance with the AOAC (2022) official methods and established analytical protocols for food mineral quantification (Pearson, 2021; Skoog *et al.*, 2022).

Sample Digestion

Each sample was subjected to wet digestion to convert the organic blend into a clear aqueous solution suitable for AAS analysis. 2.0 g of the sample was weighed into a clean crucible and ashed in a muffle furnace at 105⁰C. The ashed sample was transferred into a conical flask and 5ml of HCl was added and it was shaken vigorously, then distilled water was added to make the the volume 50ml and it was filtered with a whatman No.1 filter paper and stored in a sample bottle for further analysis.

Instrumental Analysis by AAS

Mineral concentrations were determined using a PerkinElmer AAnalyst 400 Atomic Absorption Spectrophotometer equipped with hollow cathode lamps for each element. The instrument was calibrated using freshly prepared standard solutions of known concentrations for Fe, Zn, Se, Ca, Cu, Mg, and K. The mineral analysis follows standard Association of Official Analytical Chemists (AOAC) procedures (AOAC, 2016):

1. **Sample Preparation:** Each sample is homogenized. A known quantity (5 ml for milk, 5 g for formula) is digested using nitric acid and perchloric acid until a clear solution is obtained. The digested solution is diluted with deionized water and transferred into volumetric flasks.

2. **Mineral Determination:**

- Calcium, magnesium, sodium, potassium, iron, zinc, copper, and selenium are determined using Atomic Absorption Spectrophotometry (AAS).
- Phosphorus is determined colorimetrically using a spectrophotometer (AOAC, 2016).

Quality Control: Blank samples and standard solutions are analyzed alongside test samples to ensure accuracy and reproducibility (Konieczka, 2018)

3.5 Data Analysis

The results obtained from the proximate, phytochemical, and mineral analyses of the Tombrown and Ready-to-Use Therapeutic Food (RUTF) samples were expressed as mean $\pm$ standard deviation (SD).

CHAPTER FOUR

4.0 RESULT

4.1 Interpretation of Results.

The figures below gives a graphical representation of the analysis carried out with figure 1.0 for the proximate analysis, figure 2.0 for the phytochemical analysis and figure 3.0 for the mineral element analysis.

Figure 1.0 shows that, Sample A and has the same amount of ash content, sample c has the highest moisture content, sample A has the highest lipid content, Sample C has the highest protein content and finally Sample A has the highest carbohydrate content.

Figure 2.0 shows that, Sample A has the highest content of flavonoid, saponnin and alkaloids, Sample E highest content of polyphenol, Sample D highest content of tannin and cardiac glycoside is in minute quantity for all samples.

Figure 3.0 shows that, Sample C has the highest content of Iron, Sample A has the highest content of Zinc, Sample E has the highest content of selenium and calcium, Sample A has the highest content of copper, Sample B has the highest content of magnesium and potassium.

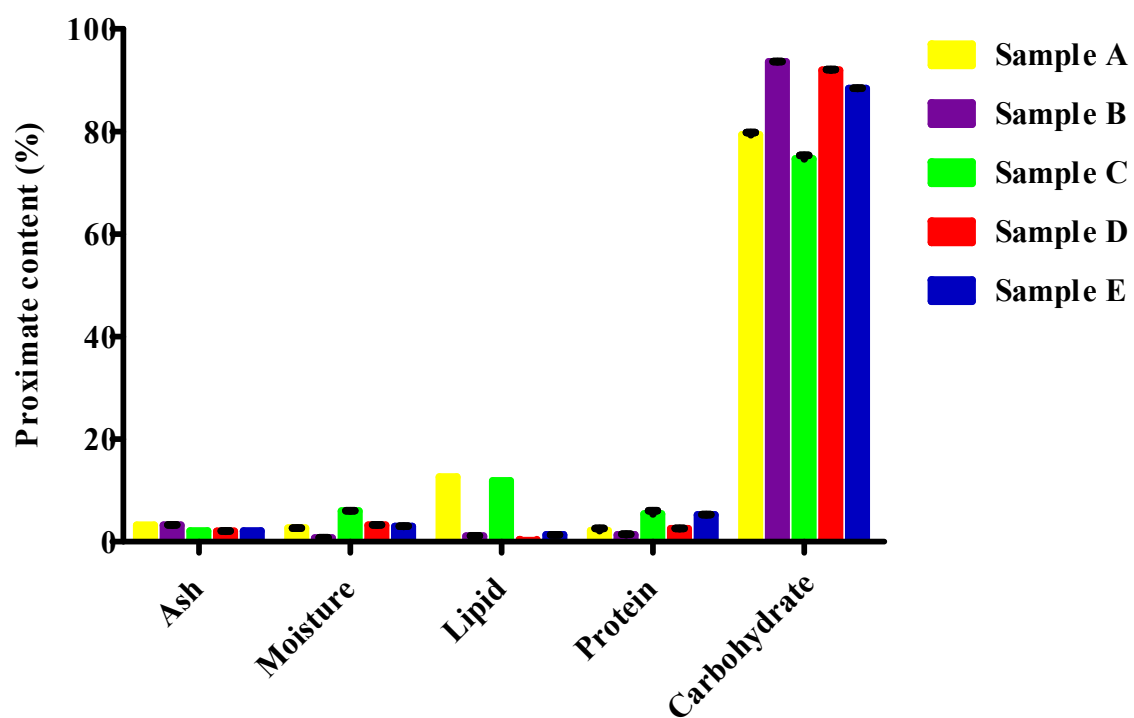


Figure 1.0: Proximate Composition of RUTF and Tombrown.

Are means signif. different? ($P < 0.05$) No

Is there significant matching? ($P < 0.05$) Yes

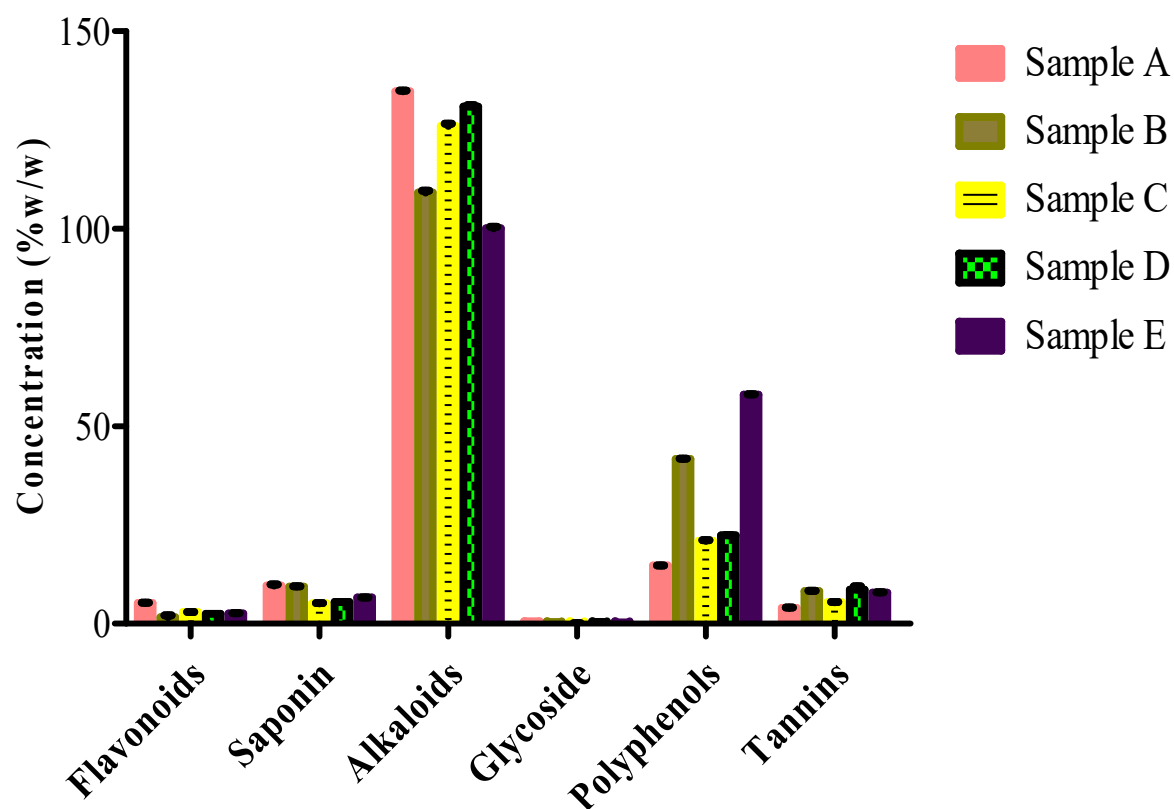


Figure 2.0: Phytochemical Composition of RUTF and Tombrown.

Are means signif. different? (P < 0.05) No

Is there significant matching? (P < 0.05) Yes

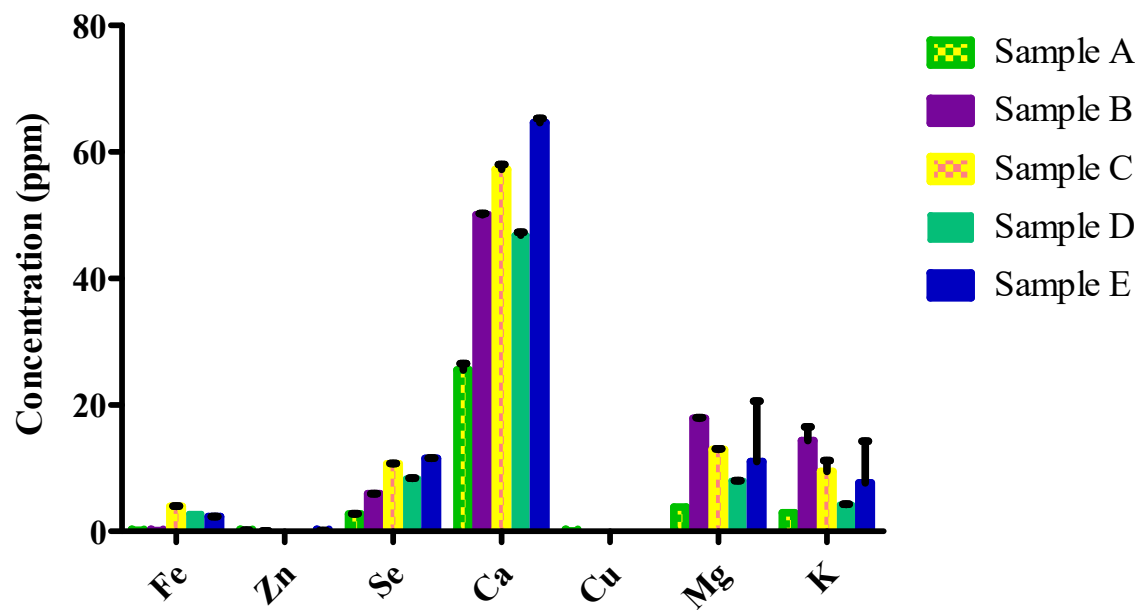


Figure 3.0: Mineral Element Composition of RUTF and Tombrown.

Are means signif.different? ($P < 0.05$) Yes

Is there significant matching? ($P < 0.05$) Yes

CHAPTER FIVE

5.0 DISCUSSION, CONCLUSION AND RECOMMENDATION

5.1 DISCUSSION

The comparative analysis of the nutritional composition of Ready-to-Use Therapeutic Food (RUTF) and Tombrown highlights important differences in their proximate, mineral, and phytochemical composition, reflecting their respective formulation methods and intended nutritional purposes.

5.1.1 Proximate composition of Tombrown and Ready-to-Use Therapeutic Food (RUTF)

The proximate results demonstrate significant variation in the macronutrient composition of both food categories.

Moisture Content

Moisture content influences the shelf life, microbial stability, and physical texture of food products. Among the samples, Sample B recorded the lowest moisture content ($0.75 \pm 0.03\%$), while Sample C showed the highest ($5.97 \pm 0.09\%$). The relatively low moisture levels across all samples ($<7\%$) indicate satisfactory storage stability, as moisture contents below 10% inhibit microbial proliferation and enzymatic degradation (Fellows, 2009).

The observed variation reflects the nature of the products: RUTFs are semi-solid pastes with minimal free water due to their high-fat composition, while Tombrown flours may absorb more atmospheric moisture during handling (sengev *et al.*, 2016). The slightly elevated moisture in Yashfik Tombrown may also be attributed to differences in roasting and milling conditions, which affect residual water retention (Adeyeye and Akingbala, 2015; Siddiq *et al.*, 2013).

Ash Content

Ash content represents the total mineral residue after complete combustion of organic material. The ash content ranged from $2.06 \pm 0.02\%$ to $3.24 \pm 0.06\%$, with RUTFs generally exhibiting higher mineral content than Tombrown samples. This difference can be attributed to mineral contents in RUTF formulations, which are designed to meet specific therapeutic standards (Schoones *et al.*, 2019).

The ash values of the Tombrown samples (2.06–2.11%) are consistent with previous findings for locally processed cereal–legume blends. These results suggest that while Tombrown provides appreciable minerals, the lack of enrichment may limit its ability to meet the micronutrient requirements of malnourished children when compared with standardized therapeutic foods.

Crude Lipid Content

Lipid content varied markedly among samples, with Plumpy Nut ($12.61 \pm 0.01\%$) and Yashfik Tombrown ($11.87 \pm 0.01\%$) exhibiting significantly higher fat levels than the others ($p < 0.05$) while, K&G Tombrown ($0.20 \pm 0.01\%$) and Rebound ($1.09 \pm 0.07\%$) recorded very low lipid content.

The high fat content in Plumpy Nut aligns with the purpose of its formulation to supply high energy density required for rapid weight recovery in malnourished children (UNICEF, 2021). Similarly, the elevated lipid content in Yashfik Tombrown suggests that its producers have incorporated oilseed ingredients (likely groundnut or soybean), enhancing its caloric value (Sachdev and Anura, 2024). Lipids not only provide 9 kcal/g but also aid the absorption of fat-soluble vitamins (A, D, E, and K), reinforcing their importance in both formulations (Alzaid *et al.*, 2015).

Crude Protein Content

Protein values ranged from $1.38 \pm 0.11\%$ to $5.40 \pm 0.67\%$, indicating a significant variation between formulations ($p < 0.05$). The relatively low protein content of the RUTF samples in this study may result from product brand variation and batch differences, as commercially available RUTFs typically contain between 10–12% protein (Sigh *et al.*, 2018).

The moderate protein levels in the Tombrown samples (2.52–5.40%) correspond with their cereal–legume composition, as legumes such as soybeans and groundnuts are primary protein sources (Semba *et al.*, 2021). These values suggest that certain Tombrown formulations particularly Yashfik and Naawu could contribute meaningfully to dietary protein intake, though their amino acid profiles and digestibility require further evaluation.

Carbohydrate Content

Carbohydrate levels were highest in Sample B ($93.55 \pm 0.12\%$) and Sample D ($91.98 \pm 0.10\%$), while the lowest value was recorded for Sample C ($74.66 \pm 0.71\%$). The high carbohydrate content in some Tombrown samples reflects their cereal-based composition, primarily maize and sorghum, which are rich in starch and serve as major energy sources (Borrelli *et al.*, 2025).

The moderate carbohydrate content in Plumpy Nut and Yashfik Tombrown indicates a more balanced nutrient profile, with sufficient lipid and protein fractions to meet the caloric and anabolic demands of rehabilitation feeding (Pontani *et al.*, 2021). High carbohydrate content in traditional cereal blends can reduce nutrient density, necessitating protein and micronutrient enrichment. (Suri *et al.*, 2014)

5.1.2 Phytochemical Composition of Tombrown and Ready-to-Use Therapeutic Food (RUTF)

Phytochemical composition of cereal legume foods provides information on bioactive compounds that may affect antioxidant, antimicrobial, or antinutritional effects. (Rawat *et al.*, 2023).

Flavonoids

Flavonoid concentrations calculated in the dataset ranged from 1.66 to 5.19 (mean values), with Sample A with the highest value (5.19 ± 0.12) and Sample B with the lowest value (1.66 ± 0.50). Flavonoids are plant-derived polyphenolics with antioxidant and anti-inflammatory functions relevant to cellular protection during nutritional stress (Safe *et al.*, 2021). The flavonoid levels in both Tombrown and RUTF samples is consistent with the plant-based ingredients in these products and with prior reports that cereal–legumes retain flavonoid compounds following roasting and processing (Kour *et al.*, 2022).

Saponins

Saponin values were relatively high in Samples A and B (9.63 ± 0.34 and 9.42 ± 0.02 , respectively) compared with the Tombrown samples (5.14–6.63). Saponins, are largely derived from leguminous constituents, can lower cholesterol level and also perform immunomodulatory function. However, it affects palatability and intestinal absorption at high concentrations (Silva *et al.*, 2024). The measured saponin range calculated in this research work falls within levels commonly observed in legume-containing foods and thus suggests functional bioactivity without indication of toxicity (Timilsena *et al.*, 2023).

Alkaloids

Alkaloid concentrations were notably large numerically in the dataset (range ≈ 100 –135), with Sample A (134.79 ± 0.17) and sample D (130.95 ± 0.39) among the highest. Alkaloids are a type of natural compound which possess different pharmacological activities. Natural

products, including alkaloids, which originate from plants, have emerged as potential protective agents against neurodegenerative disorders (NDDs) and chronic inflammations (Aryal *et al.*, 2022). High alkaloid levels in RUTF and Tombrown may confer antimicrobial and immunomodulatory benefits, reflecting the presence of plant-based ingredients; however, excessive concentrations could negatively affect palatability and nutrient absorption (Dey *et al.*, 2020).

Glycosides

Glycoside levels were low across all samples (0.10–0.623), with Sample A showing the highest value. Glycosides in cereal-legume based foods are typically present as glycosylated phenolics or minor cardiac precursors and, at these low concentrations, they are more likely to contribute to antioxidant potential than to present toxicity (Lin *et al.*, 2016).

Polyphenols

Polyphenolic measurements showed marked differences across samples: Sample E and Sample B recorded the highest range of polyphenol (57.96 ± 0.14 and 41.65 ± 0.16 respectively), while Sample A and Sample C were lower (14.72 ± 0.07 and 20.99 ± 0.11 , respectively). Polyphenols are powerful antioxidants that can contribute to cellular protection and anti-inflammatory effects (Rana *et al.*, 2022). The wide range observed suggests substantial formulation and processing differences between brands; the high polyphenol values in some samples may reflect ingredient choice (e.g., inclusion of ingredients rich in phenolic compounds) or concentration effects from processing (Zhang *et al.*, 2022).

Tannins

Tannin levels varied from 4.04 ± 0.07 (sample A) to 8.58 ± 0.90 (sample D), with Tombrown brands showing higher tannin level than Plumpy Nut (sample A). Tannins can act as antioxidants but also bind proteins and reduce digestibility when present in large amounts (Cosme *et al.*, 2025). The tannin concentrations calculated are comparable with values found

in cereal–legume blends and indicate that modest antinutritional effects could occur if not controlled during processing (e.g., roasting, fermentation) (Mashau *et al.*, 2025).

5.1.3 Mineral Element Composition of Tombrown and Ready-to-Use Therapeutic Food (RUTF)

The mineral analysis revealed marked differences between Tombrown and RUTF formulations.

Iron (Fe)

The calculated mean for iron ranged from 0.136 Sample B(Rebound) and 0.171 sample A (Plumpy Nut) up to 3.937 sample C (Yashfik Tombrown) and 2.808 sample D (K&G Tombrown) and 2.318 sample E (Naawu). The observed differences in iron concentration could be as a result of raw-material differences (type and proportion of legumes/cereals), processing effects, or analytic scale/unit choice (Kavitha and Maravali, 2014). Iron is biochemically essential for oxygen transport and redox enzymes (Gozzelino and Arosio 2016).

Zinc (Zn)

The mean calculated in the samples are Sample A = 0.1497, B = 0.0457, C = 0.0330, D = 0.0430, E = 0.0993. Plumpy Nut (A) shows the highest calculated mean, while for Tombrown samples it was lower, except for Naawu (E). Zinc is crucial for growth and immune function; the differences can be nutritionally meaningful, depending on the measurement unit and Required dietary allowance (Maares and Haase, 2016). Phytate-mediated inhibition is a key determinant of zinc bioavailability in cereal–legume foods (Joy *et al.*, 2014).

Selenium (Se)

The mean calculated for selenium in the samples includes: Sample A = 2.747, B = 5.943, C = 10.688, D = 8.367, E = 11.526. Tombrown samples (especially C and E) present higher Se means than RUTFs here. Selenium is an essential trace element for antioxidant enzyme function (glutathione peroxidase), but its content in plant-based foods is sensitive to soil selenium and processing (Malagoli *et al.*, 2015).

Calcium (Ca)

The mean calculated for calcium are relatively increased from 25.529 (Plumpy Nut) and 50.060 (Rebound) to 57.223 (Yashfik), 46.862 (K&G), and 64.647 (Naawu). Notably, Tombrown samples (C and E) shows higher Calcium content than Plumpy Nut. Calcium is central for bone health and cellular signaling; plant blend can contain substantial calcium bound to phytates and oxalates, which alter bioavailability (Wallace *et al.*, 2021).

Copper (Cu)

The mean calculated for the samples ranges from 0.0907 (A), 0.0257 (B), 0.0223 (C), 0.0213 (D), 0.0350 (E). Plumpy Nut (A) shows a larger Cu mean compared with the others. Copper is required for iron metabolism and redox enzymes; these trace differences are notable but must be interpreted in relation to dietary requirements (Gulec and Collins, 2014).

Magnesium (Mg)

The mean for Magnesium ranges from 3.851 (A), 17.892 (B), 12.971 (C), 7.997 (D), 16.578 (E). Rebound (B) and Naawu (E) show relatively high Mg means. Magnesium is important for ATP-dependent reactions and is commonly abundant in legumes and nuts however, processing and ingredient composition can cause variations in nutrient composition (De Baaij *et al.*, 2015).

Potassium (K)

The mean calculated for potassium in the samples are 2.943 (A), 14.354 (B), 9.503 (C), 4.232 (D), 11.473 (E). Potassium is the most abundant intracellular cation and is important for fluid/electrolyte balance (Adebo *et al.*, 2022).

RUTFs such as Plumpy Nut are clinically approved for the management of SAM, their cost, dependency on importation, and limited availability restrict widespread use in low-resource settings (Schoonees *et al.*, 2019) while, Tombrown is locally sourced, culturally accepted, and economically accessible, aligning with sustainable nutrition goals and community-based management of malnutrition (Appiah *et al.*, 2022). However, purposeful selection of ingredients during production of Tombrown can improve its nutritional composition.

5.2 CONCLUSION

This research work comparatively evaluated the nutritional composition of Tombrown and Ready-to-Use Therapeutic Food (RUTF) through comprehensive proximate, phytochemical, and mineral analyses, the research showed that RUTF still remains the best treatment for severe acute malnutrition so far as it contains high amounts of protein, lipid content, and mineral elements but Tombrown on the otherhand, contains moderate levels of carbohydrates, dietary fiber, and plant-derived phytochemicals such as phenols and flavonoids, which contribute to antioxidant benefits however, it can be modified (modifications may include fortification with milk powder, vegetable oils, and micronutrient premixes, as well as processing techniques like malting, roasting, or fermentation) during production process to enhance nutrient density, digestibility and nutritional content generally and also serve as an alternative for treatment of severe acute malnutrition.

5.3 RECOMMENDATIONS

- i. Sensitization programs on the dangers, signs, symptoms and precaution of severe acute malnutrition should be done adequately and frequently especially in the Northern part of the country due to its prevalence.
- ii. Tombrown producers should select ingredients to enhance nutrient density of Tombrown during production.
- iii. Further research should assess the bioavailability and sensory attributes of enhanced Tombrown.

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