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REVIEW PAPER

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Systematic review evaluating locally sourced food resources alternatives to standard milk-based ready-to-use therapeutic food

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ABSTRACT

Severe acute malnutrition (SAM) remains a leading cause of illness and death among children aged 6–59 months in developing countries. Although community-based management of acute malnutrition has expanded treatment through ready-to-use therapeutic foods (RUTF), standard milk-based formulations rely heavily on imported ingredients, raising concerns about cost, sustainability, and supply-chain insecurity. This systematic review evaluated locally sourced alternatives to standard milk-based RUTF, focusing on low-milk and milk-free products for uncomplicated SAM. Following PRISMA guidance, the review searched Scopus, Web of Science and PubMed for peer-reviewed studies published between 1999 and 2025. Search terms were structured using a PECO framework covering children with SAM, alternative RUTF formulations, standard RUTF comparators, nutritional composition and treatment performance. Forty-eight studies met the inclusion criteria. Data were extracted on study setting, ingredients, protein, lipid, vitamin A, mineral composition, weight gain velocity, and recovery rate. Most RUTF initiatives were reported in Sub-Saharan Africa, South and Southeast Asia, and the Middle East. Three product categories were identified: standard RUTF, low-milk RUTF, and fully milk-free RUTF. As milk content decreased, legumes and other non-dairy protein sources became more prominent. However, many alternative formulations showed nutritional gaps, particularly in iron, zinc, calcium, and potassium. Weight gain velocity ranged from -0.2 to 5.7 g/kg/day, and no alternative formulation consistently met the minimum target of 5 g/kg/day. Nevertheless, 66.7% achieved recovery rates above 75%. Locally sourced alternatives are promising, but require further optimization to improve nutrient adequacy, growth outcomes and resilience to dependence on imported milk supplies globally.

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INTRODUCTION

In developing countries, severe acute malnutrition (SAM) remains a critical public health challenge affecting approximately 13.7 million children under five years of age worldwide (Al Amad *et al.,* 2025). SAM is responsible for one in five deaths among children under five years of age (Al Amad *et al.,* 2025). The management of SAM has experienced a profound shift, transitioning from costly hospital-based care to Community-based Management of Acute Malnutrition (CMAM) approach (Irena *et al.,* 2015; Bahwere *et al3.,* 2016). CMAM is a public health approach to treat children with uncomplicated SAM as outpatients at home using ready-to-use therapeutic foods (RUTF) while children with medical complications are referred to inpatient facilities for stabilization (Akande *et al.,* 2023; Al Amad *et al.,* 2025).

RUTF is defined as a high-energy, nutrient dense and ready-to-eat food designed to provide complete nutritional rehabilitation for children from six months of age onward, requiring neither reconstitution with water nor refrigeration (Sarfraz *et al.,* 2023). The standard formulation comprises peanut paste, skimmed milk powder, sugar, vegetable oil, and micronutrient premixes, delivering approximately 520-550 kcal per 100 grams with protein comprising 10-12% of energy and fat 45-60%. (James *et al.,* 2023). Although CMAM has significantly improved treatment of acute malnutrition, the resilience of developing countries health systems remains compromised by a heavy dependence on imported milk-based formulations. Recent global crises (COVID 19, conflict, and energy crisis) have suggested to give priority to short food supply chain. Interest in developing RUTF using locally sourced food resources keeps growing.

Macronutrients (protein, lipid), vitamins (vitamin A) and minerals (iron, zinc, calcium and potassium) play integrated role in restoring physiological functions, repairing tissue and enabling rapid catch-up growth in children with severe acute malnutrition. RUTF should provide high-quality protein to ensure a complete amino acid profile. Essential amino acids play a crucial role in restoring normal body functions and driving rapid catch-up growth (Bahwere *et al.,* 2016; Moustiés *et al.,* 2022; Akande *et al.,* 2023). Lipids are the primary driver of RUTF's high energy density (Moustiés *et al.,* 2022). Lipid also acts as transport vehicle for fat-soluble vitamin (A, D, E and K) (Moustiés *et al.,* 2022; Muhammad *et al.,* 2025). Specially, long chain polyunsaturated fatty acids are of interest for brain development and retina functions (Jones *et al.,* 2015; Moustiés *et al.,* 2022). Vitamin A ensures the adequate functioning of the immune system (Akande *et al.,* 2023). It is crucial for correcting diminished mucosa caused by severe acute malnutrition. Moreover, it supports both visual functions and healthy growth (Kangas *et al.* 2020; Akande *et al.,* 2023). A deficiency in potassium can lead to growth failure and metabolic disturbances during the rehabilitation process (Kangas *et al.,* 2024). Calcium provides essential support for bone health and haematological functions (Muhammad *et al.,* 2025). However, excessive calcium can inhibit the absorption of others mineral (e.g. iron) (Bahwere *et al.,* 2016). Iron plays a crucial role in correcting anaemia and restoring body iron stores (Bahwere *et al.,* 2016). Zinc is vital for immune system support. It helps reducing the incidence and severity of infection like diarrhoea and pneumonia (Isanaka *et al.,* 2010; Van Der Kam *et al.,* 2016).

In malnutrition management, weight gain velocity and recovery rate are the primary indicators of program performance. Weight gain velocity measures rate at which children gain weight during treatment. It allows comparison across individuals and program (Oakley *et al.,* 2010; Bahwere *et al.,* 2024). World Health Organization defines a weight gain velocity range of 5-10 g/kg/day to consider a malnutrition management programme effective (World Health Organization, 2023).

Recovery rate is the percentage of children recovered or cured out of the total number of children (Bahwere *et al.,* 2017). A minimum recovery rate of 75% is defined according to SPHERE standard to consider a management malnutrition program as effective

(Bahwere *et al.,* 2016; Al Amad *et al.,* 2025). This systematic review synthesizes the evidence regarding locally sourced RUTF alternatives to standard milk-based formulations to treat SAM in children aged 6–59 months. Specifically, it examines whether low-milk and milk-free formulations implementation can imply minimum weight gain velocity of 5 g/kg/day and a recovery rate higher than 75%.

SEARCH STRATEGY

Systematic review was conducted according to the guideline for reporting systematic reviews (Page *et al.,* 2021). Three electronic databases (i.e. Scopus, Web of science and PubMed) were used to identify peer-reviewed articles published between 1999 and 2025. The search strategy was elaborated according to the Population, Exposure, Comparison, and Outcome (PECO) approach. The Population (P) was the children aged 6–59 months with SAM. The Exposure (E) was the alternative RUTF. The Comparison (C) was standard RUTF. The Outcomes included macronutrient contents (protein, lipid and energy), micronutrient contents (iron, zinc, calcium, potassium, vitamin A or carotenoids) and protein digestibility as well as recovery indicators (e.g. weight-gain velocity and haemoglobin improvement).

The following Boolean search queries were used in Scopus, Web of science and Pubmed on 27 April 2026.

Scopus

TITLE-ABS-KEY (children OR "6–59 months" OR "young children" OR "infants" OR "toddlers") AND ("severe acute malnutrition" OR "SAM" OR "malnutrition" OR "undernutrition") AND ("ready-to-use therapeutic food" OR RUTF*) AND ((protein AND lipid AND energy) OR "protein digestibility" OR iron OR zinc OR calcium OR potassium OR "Vitamin A" OR carotenoid OR "weight gain velocity" OR haemoglobin)).

Web of science

(Children OR "6–59 months" OR "young children" OR "infants" OR "toddlers") AND ("severe acute malnutrition" OR "SAM" OR "malnutrition" OR "undernutrition") AND ("ready-to-use therapeutic food" OR RUTF*) AND ((protein AND lipid AND energy) OR "protein digestibility" OR iron OR zinc OR calcium OR potassium OR "Vitamin A" OR carotenoid OR "weight gain velocity" OR haemoglobin).

PubMed

(Children OR "6–59 months" OR "young children" OR "infants" OR "toddlers") AND ("severe acute malnutrition" OR "SAM" OR "malnutrition" OR "undernutrition") AND ("ready-to-use therapeutic food" OR RUTF*) AND ((protein AND lipid AND energy) OR "protein digestibility" OR iron OR zinc OR calcium OR potassium OR "Vitamin A" OR carotenoid OR "weight gain velocity" OR haemoglobin).

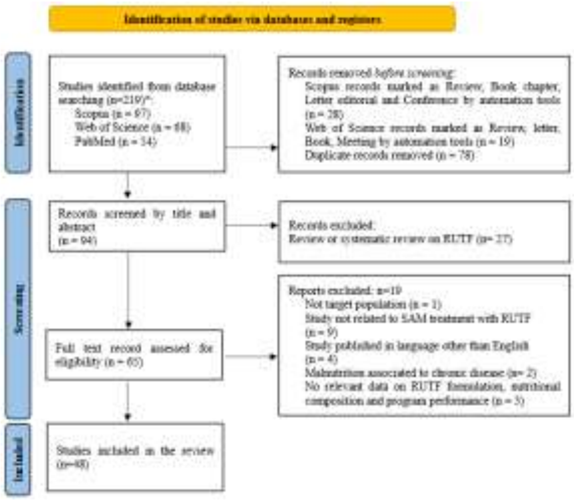


Fig. 1. Flow chart of studies selection

The flow chart used for study selection was presented in the Fig. 1. On the 48 studies included in this review, data on (1) country of RUTF initiative implementation, (2) RUTF ingredients, (3) protein, lipid, vitamin A, minerals (iron, zinc, calcium, potassium), rehabilitation initiative performance (weight gain velocity and recovery rate) were extracted and compiled in Excel. The mean value of the ingredients proportion and the mean value of nutritional composition (protein, lipid and minerals content) were computed according to the categories of RUTF.

RESULTS AND DISCUSSION

Fig. 2 presents the main geographical areas where ready-to-use therapeutic foods (RUTF) have been implemented in the world. RUTF implementation has been concentrated in three main areas in the world i.e. (1) Sub-Saharan Africa, (2) South and Southeast Asia and (3) Middle East.

Number of identified initiatives related to RUTF per country

Fig. 2. Spatial distribution of the RUTF initiatives identified around the world

In East Africa, RUTF initiatives are prominent in Malawi. Furthermore, Malawi is home to a major UNICEF-certified factory that has supplied the Ministry of Health with RUTF (Bahwere *et al.,* 2016; Bahwere *et al.,* 2017). Other significant efforts could also be found in Kenya, Uganda, Ethiopia, and South Sudan (Jilcott *et al.,* 2010; Yazew, 2022; Muzeyi *et al.,* 2024; Heymsfield *et al.,* 2025).

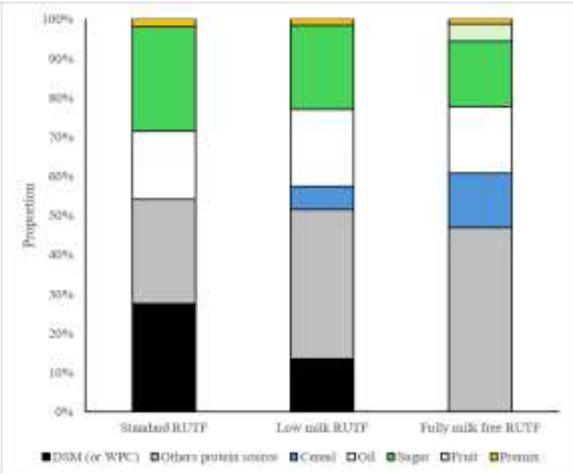
In Central and Southern Africa, the Democratic Republic of Congo (DRC) and Zambia have been the primary focal points of RUTF initiatives including clinical research. The focus in those countries were the adaptation and development of local formulations to substitute ingredients like dry skimmed milk (SDM) or whey protein concentrate (WPC) (Irena *et al.,* 2015; Bahwere *et al.,* 2016).

In West Africa, RUTF initiatives have been found in Nigeria, Niger, Burkina Faso and Mali. Clinical research, assessment of alternative dosage protocols and development of local formulations to address acute malnutrition were explored in those countries (Isanaka *et al.,* 2010; Kangas *et al.,* 2019; Kangas *et al.,* 2020; Muhammad *et al.,* 2025).

In Middle East, RUTF implementation in Yemen has been done in CMAM during humanitarian crises (Al Amad *et al.,* 2025).

In South and Southeast Asia, India, Pakistan, Cambodia, and Indonesia have concentrated clinical trials and the valorisation of local resources in RUTF formulation (Batool *et al.,* 2023; Sigh *et al.,* 2023; Bahwere *et al.,* 2024).

Fig. 3 presents most common groups of ingredients used to formulate RUTF and the mean value of their proportion according to RUTF. DSM (or WPC), others source of protein (e.g. legume, fish and insect), cereal (maize, sorghum, millet), oil, sugar, fruit and premix (i.e. supplement of vitamins and minerals) were mixed in different proportion to produce RUTF.



DSM: Dry skimmed milk; WPC: Whey protein concentrate

Fig. 3. RUTF classification and their formulations

Three groups i.e. standard RUTF, low milk RUTF and fully milk-free RUTF can be distinguished. From standard to fully milk-free RUTF, proportion of dry skimmed milk decreased while the content of others protein increased. On the contrary the proportion of oil remained similar (17-19%) across the three groups. In addition, the use of fruit in RUTF is only reported in fully milk-free RUTF.

Standard RUTF is the WHO-recommended formulation. It is typically containing 25–30% DSM or WPC as the primary protein source. It is complemented by peanut paste (20–30%), vegetable oil (15–20%), sugar (10–15%), and a micronutrient premix (Hossain *et al.,* 2020).

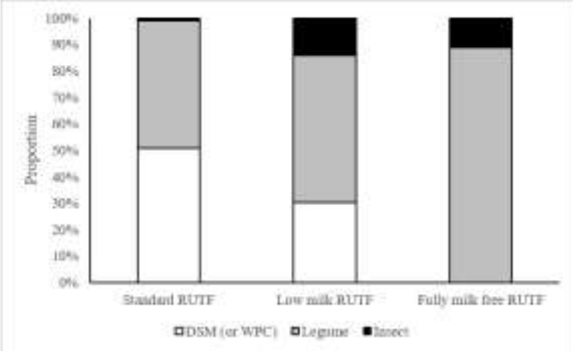
The nutritional contribution of milk is to provide complete protein with all essential amino acids and micronutrients such as calcium and vitamin B12. Moreover, milk contains lactose, which serves as an energy source and facilitates mineral absorption (Bahwere *et al.,* 2016). In addition, milk has also a techno-functional property by improving palatability (Bahwere *et al.,* 2016; Hossain *et al.,* 2020).

Low-milk RUTF increases protein supplementation from ingredients other than milk (or WPC) (Oakley *et al.,* 2010; Akomo *et al.,* 2019). Although DSM (or WPC) content is lower than 25% its role remains for providing limiting amino acids (particularly methionine) to complement plant protein (Bahwere *et al.,* 2017; Muhammad *et al.,* 2025).

Fully milk-free RUTF rely on legume (soybean, bambara, groundnut, sesame, chickpea, mungbean), cereals (maize, sorghum, millet), fish, insect and novel ingredients (rice bran, moringa) as ingredients (Owino *et al.,* 2014; Irena *et al.,* 2015; Akomo *et al.,* 2019; Moustiés *et al.,* 2022; Akande *et al.,* 2023; Sigh *et al.,* 2023). This formulation can reduce ingredient costs by 30–50% compared to standard RUTF (Muhammad *et al.,* 2025).

Fig. 4 presents the mean value of protein distribution according to RUTF groups. Milk contributed approximately to half of total protein sources. Legume contributes to 49% meanwhile insects count for 1% to the mean value of protein distribution of standard RUTF.

Although the mean value of insect proportion remained similar (11-14%) in low milk RUTF and fully milk-free RUTF, their mean proportion in milk and legume differs. Indeed, when mean proportion of DSM (or WPC) is around 30% in low-milk RUTF, its use is completely substituted by legume in fully milk-free RUTF.



DSM: Dry skimmed milk; WPC: Whey protein concentrate

Fig. 4. Protein distribution according to RUTF groups

Fig. 5 presents the protein, lipid and vitamin A content of RUTF according to the WHO recommendation. The protein content of RUTF should range between 13 and 16.5 g/100g according to WHO recommendation. Most protein value of Standard RUTF were in that range except 4 out 13 identified formulations. On 12 identified low milk RUTF formulations, only 4 formulations have protein content ranging between 13 and 16.5 g/100g. Only 5 out of 13 milk-free formulations were conformed to WHO recommendations. In general, 56% of the low milk and milk-free RUTF have a protein content higher than 16.5 g/100g.

The recommended lipid content of RUTF ranged between 26 and 36.7 g/100g. No formulations had a lipid content higher than 36.7 g/100g. Most of the Standard and Low milk RUTF have a lipid content conform to the recommended values. On the other hand, 4 out of the 13 milk-free formulations have a lipid content lower than 26 g/100 g.

The recommended vitamin A content of RUTF range from 0.8 to 1.1 mg/100g. A percentage of 25% (3 out of 12) of standard RUTF had vitamin A content lower than 0.8 mg/100g. The proportion of RUTF with deficient vitamin A content was 44% (4 out of 9) and 17% (1 out of 6) for low-milk and milk-free RUTF, respectively.

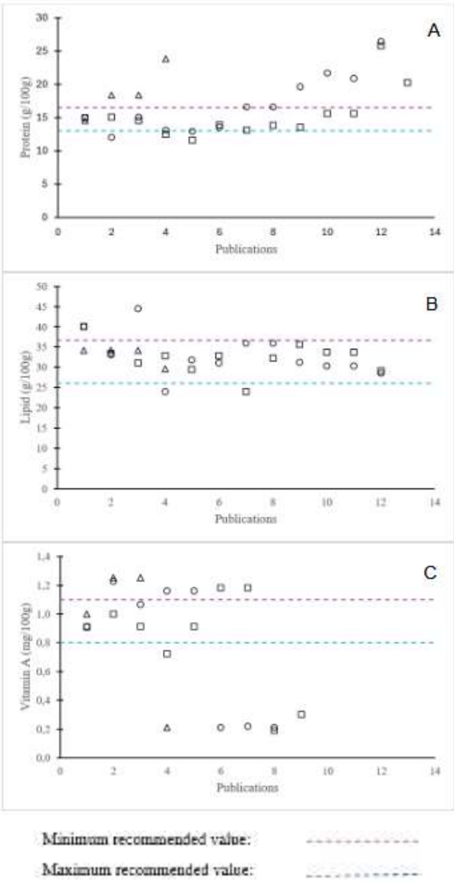


Fig. 5. Protein (A), lipid (B) and vitamin A (C) content of standard (□), low milk (O) and milk-free (Δ) RUTF

Fig. 6 presents the iron, zinc, calcium, potassium content of RUTF according to the WHO recommendation. The recommended iron content of RUTF is 10-14 mg/100g. A percentage of 27% (4 out of 15) of standard RUTF had an iron content lower than 10 mg/100g. The proportion of RUTF with deficient iron content increased with low-milk and milk-free RUTF.

Indeed, a percentage of 55% (6 out of 11) and 36% (4 out of 11) of RUTF deficient iron content were recorded for low milk and milk-free RUTF, respectively.

The recommended zinc content of RUTF is 11-14 mg/100g. A percentage of 33% (5 out of 15) standard RUTF had a zinc content lower than 11 mg/100g. The proportion of RUTF with deficient zinc content was 55% (6 out of 11) and 36% (4 out of 11) for low-milk and milk-free RUTF, respectively.

The recommended calcium content of RUTF is 300-600 mg/100g. A percentage of 40% (6 out of 15) of standard RUTF had a calcium content lower than 300 mg/100g. The proportion of RUTF with deficient calcium content was 64% (7 out of 11) and 50% (5 out of 10) for low-milk and milk-free RUTF, respectively.

The recommended potassium value of RUTF is 1100-1400 mg/100g. A percentage of 43% (6 out of 14) of standard RUTF had a potassium lower than 1100 mg/100g. The proportion of RUTF with deficient potassium content was 70% (7 out of 10) and 75% (6 out of 8) for low-milk and milk-free RUTF, respectively.

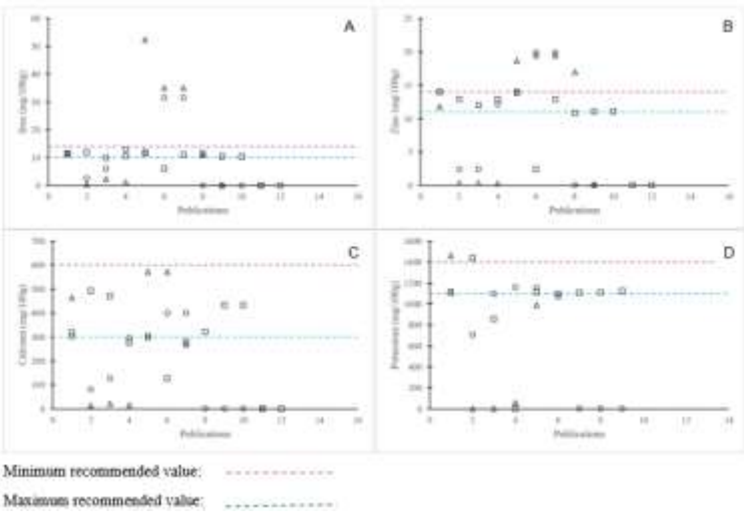


Fig. 6. Iron (A), zinc (B), calcium (C) and potassium (D) content of standard (□), low milk (O) and milk-free (Δ) RUTF

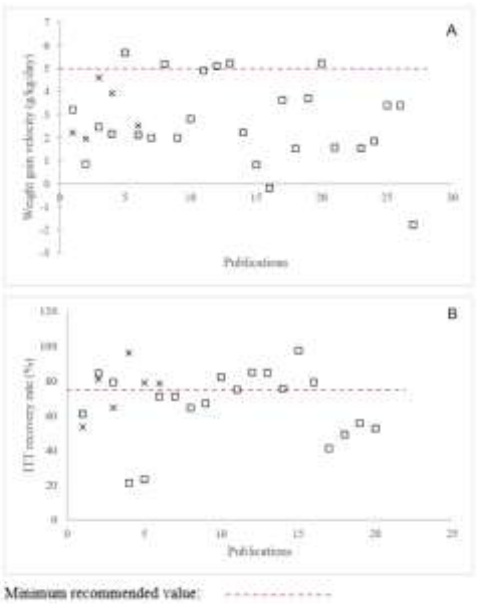


Fig. 7. Weight gain velocity and recovery rate of standard (□) and alternatives (X) (low milk and milk-free) RUTF

Fig. 7 presents the weight gain velocity and recovery rate of standard and alternative (low milk and milk free) RUTF. Weight gain velocity recorded from identified publications ranged from -0.2 and 5.7 g/kg/day. Only 19% (5 out of 26) standard RUTF implied a weight gain velocity higher than 5. On the contrary, none of the alternative (low milk and milk free) RUTF implied a minimum weight gain velocity of 5. The implementation of standard RUTF leaded to effective response (5-10 g/kg/day) and poor response (< 5 g/kg/day) in 19% and 81% of case, respectively. Meanwhile, the low milk and milk free RUTF leaded to poor response. Although weight gain velocity is useful monitoring indicator, recovery rate provides additional information to evaluate the efficiency of malnutrition program management.

Recovery rate recorded from identified publications ranged from 21% to 97.5%. Only 40% (8 out of 20) of identified standard RUTF had a recovery rate >75%. Meanwhile, 66.7% (4 out of 6) of the identified alternative (low milk and milk free) RUTF had a recovery rate >75%.

Futures perspectives in alternatives RUTF

Although RUTF are widely used to treat SAM by improving anthropometric outcomes, emerging priorities such as (a) enhancing gut microbiome to ensure higher recovery and (b) balanced n-6 and n-3 polyunsaturated fatty acid ratio for children neurodevelopment are raising issues to sustain clinical recovery (James *et al.,* 2023; Sigh *et al.,* 2023; Barbazza *et al.,* 2026).

Microbiota diversity and maturity are related to children ponderal growth (Kamng'ona *et al.,* 2019). Children with SAM often show persistent gut microbiota immaturity. This immaturity leads to poor intestinal nutrient absorption, impaired immunity, and reduced recovery rate even after therapeutic food interventions (Blanton *et al.,* 2016; Zoghi *et al.,* 2024). Beyond what can be achieve with RUTF, strategy should explore the shift from RUTF to microbiota-directed complementary foods (MDCF) in CMAM. Unlike RUTF designed for caloric density and macronutrient intake, MDCF use a combination of plant-based protein (chickpeas, soybean and peanuts), source of prebiotics (rice bran, green banana or sweet potato flour), soybean oil, sugar and micronutrients mix (Mostafa *et al.,* 2024; Barbazza *et al.,* 2026).

Polyunsaturated fatty acids (PUFA) (i.e. n-3 and n-6 PUFA) are essential for brain bran functions (James *et al.,* 2023). Unfortunately, standard RUTF contains suboptimal amount of n-3 PUFA and unbalanced n-6 and n-3 ratio (James *et al.,* 2023). Unbalanced ratio of PUFAs affect mental and psychomotor development of young children. Low milk and milk-free RUTF use more diverse ingredients to achieve a more favourable fatty acid balance (Bahwere *et al.,* 2017). Most single seed oil does not have the correct balance of PUFA. Different oil composites of vegetable oils could be formulated from tropical oils and seed oils including palm oil, soybean oil sesame oil and cotton seed oil (Mohamed *et al.,* 2021).

CONCLUSION

Locally sourced low-milk and milk-free RUTF represent promising alternatives to standard milk-based formulations for the treatment of severe acute malnutrition in children aged 6–59 months.

Although these formulations may improve local supply resilience and reduce ingredient costs, the evidence synthesized in this review shows persistent challenges in meeting WHO-recommended nutrient composition, especially for iron, zinc, calcium, and potassium. Moreover, none of the identified alternative formulations in this review achieved the minimum recommended weight gain velocity, despite acceptable recovery rates in several studies. Extended duration of treatment allows to recover children with low weight gain velocity. These findings highlight the need for further optimization and clinical validation of alternative RUTF, with particular attention to micronutrient adequacy, functional recovery, gut microbiota support, and fatty acid quality.

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