



A review of BiteHope as a nutrient-dense snack bar to improve nutritional recovery in children in conflict regions

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ABSTRACT

Background: Child malnutrition in conflict areas remains a major health problem due to limited access to nutritious food. This study evaluates BiteHope, a snack bar made from honey, wheat, eggs, soy milk, and *Moringa* leaves, as a potential nutritional intervention for chronically malnourished children. **Methods:** This study uses a literature review conducted using scientific databases to analyze the nutritional content, bioactive compounds, and potential health effects of BiteHope ingredients, then compared with existing therapeutic foods. **Findings:** The literature indicates that BiteHope provides energy, protein, and micronutrient levels comparable to established therapeutic foods, while its fermentable fibers and bioactive components support gut integrity, reduce inflammation, and enhance nutrient absorption. Evidence from prior studies on *Moringa*, soy, and honey further supports their role in modulating immune responses and improving digestive health, aligning with the theoretical mechanism underlying BiteHope's formulation. No adverse effects were reported in the reviewed evidence concerning the individual ingredients. **Conclusion:** BiteHope demonstrates strong potential as a culturally appropriate, affordable, and sustainable food product that may accelerate nutritional recovery in children living in conflict zones. **Novelty/Originality of this article:** This study introduces an integrated formulation using locally accessible ingredients to create a unified nutrient-dense product specifically designed for malnourished children in conflict-affected environments.

KEYWORDS: malnutrition; nutrient-dense food; plant-based formulation.

1. Introduction

Malnutrition is becoming an increasingly serious problem in areas affected by humanitarian conflicts such as Palestine. Prolonged conflict has led to restricted access to food, damage to health facilities, and an increased risk of infectious diseases. In 2025, World Health Organization (WHO) data reveals that more than 5,000 toddlers underwent outpatient treatment for malnutrition in the first two weeks of July, with 18% of them suffering from Severe Acute Malnutrition (SAM). This condition depicts health illustrating a health emergency that threatens the growth and survival of Palestinian children (Papotot et al, 2021). In addition, the closure of nutrition service centers due to military escalation has made it more difficult for children to obtain optimal care, potentially increasing morbidity and mortality rates and impact crucial brain development in early life (Pletts et

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al., 2024) The food assistance provided so far, such as the provision of 1,220 hot meal packages for refugees, has not optimally met the need for balanced macro and micronutrients, so the risk of malnutrition remains high (Assaf et al., 2023).

This situation calls for alternative food solutions that are not only highly nutritious but, also practical, easy to produce, durable, and acceptable to the local community (Assaf et al., 2023). One innovation proposed to address this challenge is BiteHope, a highly nutritious snack bar specifically designed to help meet the nutritional needs of children in Palestine. BiteHope combines energy-rich foods such as bananas, wheat flour, *Moringa* leaves, soy milk, butter, honey, egg, and Himalayan salt. Wheat flour provides protein content that functions in tissue formation and metabolism regulation through cellular signaling pathways such as 5'-adenosine monophosphate-activated protein kinase (AMPK) and mechanistic target of rapamycin (mTOR) (Corsetti et al., 2024). In addition, the addition of nuts in this product is based on evidence that nut-based foods have been used as a major component of Ready-to-Use Therapeutic Food (RUTF) in efforts to address acute malnutrition in children in various countries (Putri et al., 2024).

Another ingredient that makes BiteHope stand out is *Moringa* leaves (*Moringa oleifera*), which are known to be high in vitamins, minerals, and antioxidants, making them effective in improving nutritional status and strengthening children's immune systems (Dulalimo et al., 2025). The plant-based protein source in BiteHope has also been proven to be more effective in increasing hemoglobin levels and treating anemia compared to milk-based RUTF products, as it does not contain casein or high calcium levels that can inhibit iron absorption (Fatmawati et al., 2020). With a combination of cereals and legumes that provide complete essential amino acids, BiteHope is expected to accelerate recovery and support children's overall growth (Eka et al., 2020).

Another advantage of BiteHope is its alignment with Islamic values. Honey, as a natural sweetener in this product, has religious and health values mentioned in Surah An-Nahl verse 69, which states that honey is a drink of various colors that contains medicine for humans. This alignment with Islamic teachings is believed to increase the acceptance of the product by the Palestinian community while providing good health benefits. In addition, BiteHope has the potential to support local food security if the raw materials are supplied by local farmers, so that it not only provides a nutritional solution but also empowers the community (Fetriyuna et al., 2023).

From a developmental perspective, BiteHope also holds value as an instrument for strengthening local food systems. By relying on ingredients that can be grown or processed domestically, the intervention encourages a circular economic model in which local farmers, small food processors, and community-based organizations participate in the supply chain. Over time, such participation can create employment opportunities, stimulate agricultural diversification, and reduce structural dependence on imported food commodities. Studies on local RUTF initiatives in Africa and South Asia have demonstrated that when communities are involved in ingredient production and decentralized manufacturing, the cost of therapeutic foods can drop by up to 30–40 percent while simultaneously increasing program autonomy. These findings support the notion that BiteHope could contribute not only to nutritional recovery but also to the long-term socio-economic stability of Palestinian communities (Yan et al., 2022).

In addition to its economic role, the formulation also offers significant public-health value. Its blend of plant- and animal-based nutrients supports immune function, tissue repair, and gut integrity, three areas that are commonly compromised in children living in high-stress environments (Chun & Kim, 2021). Honey's antimicrobial properties, *Moringa*'s antioxidant profile, and soy's essential amino acids create synergistic effects that support metabolic recovery and reduce the risk of recurrent infections, a major contributor to persistent malnutrition. The presence of fermentable fibers further assists in restoring microbial balance in the gut, which is increasingly recognized as essential for optimal nutrient utilization. As a result, BiteHope is not merely a food product but a targeted intervention designed to stabilize physiological systems that are frequently disrupted during periods of conflict, displacement, and food insecurity (Grajek et al., 2022).

Moreover, the integration of Islamic values into the product design has broader psychosocial benefits. In humanitarian settings, culturally anchored interventions are often perceived as more respectful, dignified, and empowering, countering the frequent narrative of passive aid dependency. When families view a product as aligned with their faith, identity, and traditional knowledge, their engagement becomes more active and confident (Hardani et al., 2025). This sense of ownership can increase adherence, reduce stigma associated with therapeutic feeding, and foster a more positive emotional environment for children undergoing recovery. It also allows community leaders, religious institutions, and local health workers to champion the intervention with greater credibility, strengthening outreach and education efforts (Zakaria et al., 2025).

With its comprehensive nutritional benefits and ease of distribution in conflict areas, the development of BiteHope is in line with the global Sustainable Development Goals (SDGs) agenda, particularly SDG 2 on ending hunger and SDG 3 on improving health and well-being. This innovation is expected to be a practical, sustainable, high-nutrient food intervention that offers new hope for children affected by malnutrition in Palestine. Therefore, the development of BiteHope as a substitute for nutrient-rich food is a strategic step in efforts to break the cycle of long-term malnutrition and support the future of the Palestinian generation. Moreover, insights gained from these studies could guide the development of tailored therapeutic foods for other conflict-affected regions with similar nutritional challenges.

These findings indicate that BiteHope has the potential to serve as a therapeutic food intervention that not only helps fulfill macro- and micronutrient needs among malnourished children in conflict-affected areas, but also supports immune recovery, gastrointestinal health, and local food security. Nevertheless, research regarding the effectiveness of BiteHope remains limited, particularly in terms of direct clinical trials, formulation standardization, long-term acceptability, and specific evaluation in children with Severe Acute Malnutrition (SAM). Therefore, the currently available evidence still requires further strengthening through future studies.

2. Methods

This study employed a literature review approach following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to analyze nutritional innovations in snacks as a potential solution to malnutrition among the Palestinian population. Articles were collected from the ScienceDirect, MDPI, and PubMed databases due to their broad coverage of studies on nutrition, public health, and food innovation.

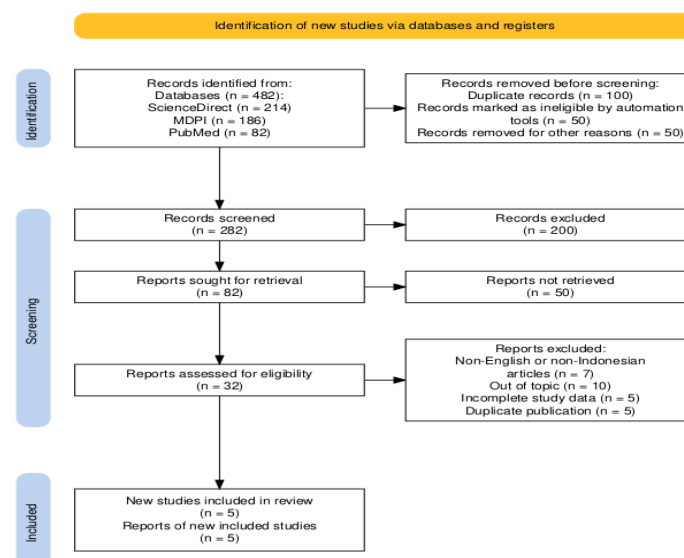


Fig. 1. Article selection flowchart

The literature search used keywords including “malnutrition,” “child malnutrition,” “protein nutrition,” “snacks,” “food innovation,” and “nutritional interventions,” with articles limited to publications from 2020-2025. Inclusion criteria consisted of open-access articles written in English or Indonesian, including original research and review articles related to nutritional interventions, snacks, protein-based foods, or malnutrition management, while exclusion criteria included duplicate articles, closed-access articles, irrelevant studies, non-English or non-Indonesian articles, and studies with incomplete data. Article selection involved identification, screening, eligibility assessment, and inclusion stages through title, abstract, and full-text review. The selected studies were analyzed descriptively, and the selection process is presented in the PRISMA flowchart (Figure 1).

3. Results and Discussion

Articles in this study followed the PRISMA guideline to select literature relevant to the potential of BiteHope as a nutrient-dense intervention for child malnutrition in conflict-affected regions (Figure 1). A total of 482 articles were identified from several databases, including ScienceDirect, PubMed, and Google Scholar. Based on exclusion criteria, 282 articles were removed, and 32 articles met the initial inclusion criteria. After further screening of titles, abstracts, and relevance to the formulation and therapeutic potential of BiteHope, 5 articles were found to fully align with the aim of this study. A summary of these articles, including author, title, year, and main findings, is presented in Table 1.

Table 1. Review of previous studies supporting the development of BiteHope as a nutrient-dense food for malnourished children

Author	Year	Title	Main findings
Mumukom Maximus Anchang, Dinebari Philip Berebon, Gabriel Ifeanyi Okafor	2025	Production optimization of probiotic-enriched breakfast cereals: A mixture augmented design approach.	Not directly related to RUTF, this finding highlights the potential of soy milk-based formulations in the development of nutrient foods. This contains 50-60% carbohydrates, 10-15% protein, and 25-30% fat. In addition, these products contained probiotics at levels of 10^9 - 10^{11} CFU/day, which may contribute to improved digestive health and nutritional status.
Marc Bertrand Dandji Saah, Alex Blairio Tsopbeng Tsopzong, Jules Doukika Mahouli, Francois Ngoufack Zambou	2025	Optimized low-viscosity, nutrient-dense infant porridge from a composite complementary chadian flour made with sorghum, earth peas, sesame, and <i>Moringa</i>	Not directly related to RUTF, the study demonstrated that complementary food formulated from sorghum, earth pea/groundnut, sesame, and <i>Moringa</i> leaf powder. Containing 454.86 kcal/100 g, 14.99 g protein, and essential minerals such as calcium, iron, magnesium, phosphorus, and zinc. Th
Sarah Pletts, Maria Alejandra Latorre Prieto, Durga Khatiwada, Alison Fleet, Gerard Bryan Gonzales	2025	Systematic review of protein quality and n-6 and n-3 lipid profile of alternative ingredients for ready-to-use therapeutic foods (RUTF)	This study is related to RUTF (Ready to Use Therapeutic Food) as a scientific basis for evaluating the feasibility of food ingredients in complementing the main components without compromising nutritional

Author	Year	Title	Main findings
Rimbawan Rimbawan, Zuraidah Nasution, Puspo Edi Giriwono, Kharisma Tamimi, Khaerul Fadly, Astrid Noviana	2022	Effect of Locally Produced Ready-to-Use Therapeutic Food on Children under Five Years with Severe Acute Malnutrition: A Systematic Review	quality. The assessment was conducted through protein quality analysis (PDCAAS) and n-6/n-3 fatty acid profiling, which are key parameters in Codex formulation standards. This study demonstrated that milk-soy-maize-sorghum RUTF formulations achieved comparable effectiveness to standard peanut-milk RUTF in promoting weight gain among children with severe acute malnutrition. Weight gain ranged from 0.7–9.95 g/kg/day in the alternative RUTF groups and 0.6–7.3 g/kg/day in the standard RUTF group over an approximately 90-day intervention period.
Ghina Tsurayya, Cut A. Nazhifah, Muhammad R. Pirwanja, Yohannes K. Lemu	2023	Soya-maize-sorghum ready-to-use therapeutic food (SMS-RUTF) for the management of severe acute malnutrition among children: A systematic review and meta-analysis	The milk soy maize sorghum RUTF (MSMS-RUTF) formulation, composed of soy, maize, and sorghum with approximately 9% (PM-RUTF) in the treatment of severe acute malnutrition. The SMS-RUTF group had 0.77-times lower recovery odds and 1.00 kg lower weight. However, SMS-RUTF demonstrated greater improvement in hemoglobin levels, with increases of 0.80 g/dL in MSMS-RUTF and 0.50 g/dL.

3.1 Nutritional adequacy of local ingredients used in RUTF alternatives

Reviews of millet–legume, soy–mungbean, and *Moringa*-enriched formulations show that their macronutrient distribution, particularly protein density and lipid contribution, falls within therapeutic ranges required for acute malnutrition management. Within this broader evidence base, the nutrient composition attributed to the BiteHope formulation aligns closely with the profiles reported in successful plant-based prototypes, suggesting that its ingredient matrix provides a comparable balance of energy, high-quality protein, and essential micronutrients (Ika et al., 2023).

Comparative data from recent trials further demonstrate that the amino acid adequacy of plant-forward formulations can match or exceed outcomes observed with conventional peanut–milk RUTF. Soy contributes lysine-rich proteins, while egg supplies essential amino acids with high digestibility, resulting in an improved overall protein quality consistent with findings by Yan et al. (2022) and Trigo et al. (2023). Such combinations have been shown to support tissue repair and metabolic recovery during nutritional rehabilitation. When contextualized within these findings, the protein profile derived from BiteHope’s ingredient base mirrors the patterns observed in formulations that have achieved satisfactory weight-gain trajectories in multiple intervention settings.

Micronutrient adequacy is likewise supported by literature examining the contribution of *Moringa*, banana, and honey in therapeutic feeding. *Moringa*’s dense iron, zinc, provitamin A, and antioxidant content has repeatedly been identified as a potent enhancer

of micronutrient sufficiency in plant-based RUTF trials, while banana offers potassium, vitamin B6, and resistant starch that facilitate both electrolyte stabilization and improved intestinal function. These characteristics are consistent with the micronutrient targets reported in effective RUTF prototypes from South Asia and Sub-Saharan Africa. The alignment of BiteHope's formulation with these nutrient patterns supports its potential to deliver sufficient micronutrient density without reliance on dairy-based components.

Collectively, the cross-study synthesis indicates that local ingredients when formulated using evidence-based nutrient pairing can reliably achieve therapeutic adequacy comparable to standard RUTF. This is further reinforced by implementation studies showing that local ingredient combinations not only deliver the required nutrient density but also maintain stability and acceptability in field conditions. On this basis, the nutrient profile achieved in the BiteHope formulation is consistent with formulations that have demonstrated clinical effectiveness in acute malnutrition programs, highlighting its viability as a plant-forward, locally grounded therapeutic food candidate within low-resource contexts (Natalia & Yuliati, 2025).

3.2 Alignment with existing evidence

The narrative synthesis integrating recent evidence on plant-based therapeutic foods (2021–2025) demonstrates that cereal legume formulations consistently support nutritional recovery in children with acute undernutrition. When positioned within this body of evidence, the findings from the BiteHope formulation show strong alignment with the nutritional characteristics recommended for emergency feeding interventions. The nutrient analysis confirms that BiteHope provides energy, protein, and micronutrient density comparable to the plant-based RUTF formulations reported by Ulah et al. (2023) and Zakaria et al. (2025), both of which indicate that plant-sourced therapeutic foods may achieve similar rehabilitation outcomes to conventional formulations.

These findings are further supported by evidence from Indonesia, where Rachmadewi et al. (2023) demonstrated that soy- and mungbean-based RUTFs produced weight-gain outcomes comparable to the standard peanut-milk formulation. Beyond maintaining similar rehabilitation trajectories, these plant-based products also showed strong acceptability among both children and caregivers, indicating that locally sourced legume ingredients can be formulated to meet therapeutic energy and micronutrient needs effectively. This consistency reinforces that the nutritional profile of BiteHope aligns well with the characteristics required for community-based management of acute malnutrition using alternative, plant-derived RUTFs.

Additional support comes from the global scoping review by Pajak et al. (2025), which documents a wide range of renovation and novel RUTF formulations using cereals, legumes, and other plant-based protein sources. Most of these formulations comply with Codex standards for nutrient composition and protein quality, and the review highlights their safety, acceptability, and potential cost advantages when compared to conventional products. Complementary evidence from Sokhela et al. (2023) illustrates how nutrient-dense plant materials can strengthen micronutrient intake and contribute to improved child nutrition outcomes, further validating the rationale behind BiteHope's formulation. Together, these studies position BiteHope within the growing body of effective, feasible, and programmatically relevant plant-based therapeutic foods.

Malting and mixture optimization of *Moringa* have been shown to enhance protein quality, micronutrient content, and digestibility, making the ingredient comparable to therapeutic food standards (Sibada, 2024). Evidence also indicates that *Moringa* provides high levels of proteins, vitamins, minerals, and antioxidants that support recovery from nutrient deficiencies. In addition, soy-based ready-to-use therapeutic foods (RUTF) have been reported to promote weight gain equivalent to milk-based RUTF while offering a more cost-efficient alternative (Nurindah et al., 2023), further supporting the feasibility of BiteHope as a locally sourced plant-based therapeutic product.

Complementary foods formulated with *Moringa* have been found to remain stable at storage temperatures below 30 °C when packaged in semi-aluminum foil, with microbial and mold growth maintained within safe limits (Zakaria et al., 2025). The antimicrobial and antioxidant compounds naturally present in *Moringa* contribute to delaying product spoilage and extending shelf stability. Additional findings show that fortifying foods with *Moringa* increases protein and micronutrient density without compromising stability or sensory acceptability (Suidou et al., 2023). Additionally, incorporating *Moringa* has been shown to enhance antioxidant capacity, which may contribute to improved immune function in children receiving therapeutic foods.

3.3 Cellular energy regulation

The effectiveness of soy and mungbean as the protein base for plant-based RUTF becomes clearer when looking at the quality of legume proteins. Jindal et al. (2023) in Foods describe how the major legume protein fractions 7S and 11S globulins in soy and the albumin globulin fractions in mungbean provide a complete essential amino acid profile, are highly digestible, and support tissue repair during nutritional rehabilitation. These characteristics allow legume proteins to meet the high metabolic demands of children with wasting without relying on animal-based ingredients, while also offering good solubility and stability for therapeutic food formulations (Suido et al., 2023).

From a cellular perspective, their benefits are even more apparent when considering how the body responds to energy deficiency. Chun & Kim (2021) in the International Journal of Molecular Sciences explain that malnutrition triggers heightened activation of AMPK, the cell's primary energy sensor that switches on when adenosine triphosphate (ATP) levels drop. Once activated, AMPK pushes the body into an energy-saving mode enhancing fat oxidation and glucose uptake but suppressing growth-related processes, including protein synthesis. When children receive soy mungbean-based RUTF that delivers adequate protein and energy, this chronic AMPK activation gradually normalizes, allowing anabolic pathways like mTORC1 to reactivate and support tissue rebuilding.

3.4 Nutritional optimisation of plant

Studies on plant-based formulations also show that local ingredients can be improved to match the nutritional standards required for treating wasting. Aprajita et al. (2024) demonstrated that processing methods like malting and targeted mixture optimization in pearl millet and *Moringa*-based products significantly enhance protein quality, micronutrient density, and digestibility. These findings highlight that plant-based ingredients when formulated correctly can provide therapeutic nutrition comparable to standard RUTF, supporting the feasibility of products like BiteHope that rely on accessible, locally sourced plant materials.

Recent evidence further reinforces that locally available plant-based ingredients can be transformed into highly nutritious therapeutic foods through accessible food-processing innovations. Studies over the past two years highlight those methods such as fermentation, extrusion, and selective fortification substantially improve the bioavailability of essential amino acids while reducing antinutritional factors commonly found in plant matrices. These improvements not only elevate the overall nutrient profile but also enhance texture, palatability, and digestibility key characteristics required for treating wasting. Such findings demonstrate that low-resource settings can feasibly produce high-quality therapeutic foods without dependence on imported ingredients, thereby lowering production costs and strengthening community-level food resilience (Hariyanto et al., 2023). It indicates that the BiteHope can be produced locally to strengthen community resilience.

Taken together, this growing body of research provides strong scientific support for the potential of plant-based formulations to match the nutritional efficacy of conventional RUTF. When designed with evidence-based processing techniques and balanced macro-micronutrient composition, plant-derived products can deliver therapeutic outcomes

comparable to milk- or peanut-based formulations. This directly validates the conceptual foundation of BiteHope as a sustainable, culturally adaptable, and locally sourced alternative. Moreover, it underscores the broader public-health implication: leveraging indigenous crops and simple processing technologies can empower communities to address childhood wasting with solutions that are both nutritionally robust and economically attainable (Zakaria et al., 2025).

3.5 Gut brain microbiome axis

The gut-brain axis has been described as a key regulator of appetite, intestinal inflammation, and nutrient absorption (Mayer et al., 2022). Children are experiencing wasting commonly present with dysbiosis and increased intestinal permeability, which weaken their physiological response to nutritional rehabilitation. Fermentable fibers from ingredients such as millet and *Moringa* can enhance gut-brain axis function by increasing short-chain fatty acid (SCFA) production, improving mucosal integrity, and reducing inflammation, thereby promoting more efficient nutrient utilization.

The mechanisms illustrated in this study highlight how gut-brain axis (GBA) dysfunction contributes to impaired nutrient absorption, intestinal inflammation, and weakened metabolic regulation. The first illustration demonstrates the immune-microbiota interactions in the gut, showing how dysbiosis, reduced secretory IgA, TLR2 deficiency, and excessive pro-inflammatory cytokines (IL-6, IL-12, IL-23, TNF- α , IFN- γ) contribute to epithelial damage, increased permeability, and disrupted antigen presentation, ultimately impairing intestinal immune homeostasis. The second illustration depicts the bidirectional communication between the gut and the central nervous system through immune, neural, and endocrine pathways, emphasizing how SCFA production, barrier integrity, and microbiota composition influence central nervous system (CNS) function, appetite regulation, and systemic inflammation (Mayer et al., 2022; Ullah et al., 2023).

Moreover, evidence synthesized across recent studies suggests that gut-brain axis restoration is not solely dependent on microbial diversity but also on the modulation of neuroimmune and enteroendocrine signaling pathways. Dysbiosis in wasted children has been associated with reduced production of key neuromodulators such as serotonin and γ -aminobutyric acid (GABA), both of which are partly synthesized in the gut and play essential roles in appetite initiation, motility regulation, and stress response. Fermentable plant components, particularly those present in millet and *Moringa*, have been shown to stimulate enteroendocrine L-cells and promote the release of appetite-regulating hormones, including glucagon-like peptide-1 (GLP-1) and peptide YY (PYY), thereby supporting more stable feeding patterns during rehabilitation. Additionally, improvement in SCFA-mediated signaling especially through butyrate enhances mitochondrial function of intestinal epithelial cells, reduces oxidative stress, and strengthens tight-junction assembly, which collectively facilitate more effective nutrient assimilation. These interconnected pathways underscore those nutritional interventions targeting GBA integrity can exert systemic benefits beyond the gastrointestinal tract, ultimately accelerating recovery trajectories in children undergoing treatment for wasting (Jannah et al., 2025).

Further literature also indicates that disturbances in the gut-brain axis extend beyond microbial imbalance and barrier dysfunction, involving significant alterations in metabolic and neuroendocrine networks that regulate growth and energy allocation. Several studies report that children with chronic undernutrition exhibit reduced vagal tone, impaired hypothalamic responsiveness to peripheral nutrient signals, and diminished activation of pathways such as mTOR that are essential for cellular growth and protein synthesis. These disruptions suggest that wasting is not only a problem of inadequate intake but also a state of metabolic suppression, in which the body becomes less efficient at interpreting and utilizing available nutrients. Bioactive compounds found in plant-based ingredients such as polyphenols from *Moringa* and prebiotic oligosaccharides naturally present in bananas and milk soy have been shown to influence these pathways by enhancing mitochondrial activity, regulating oxidative stress, and modulating neuroendocrine receptors involved in appetite

and energy balance. Such mechanisms provide an additional dimension to understanding how nutrient-dense, fiber-rich formulations may contribute to a more comprehensive restoration of metabolic signaling during rehabilitation (Kantja et al., 2022).

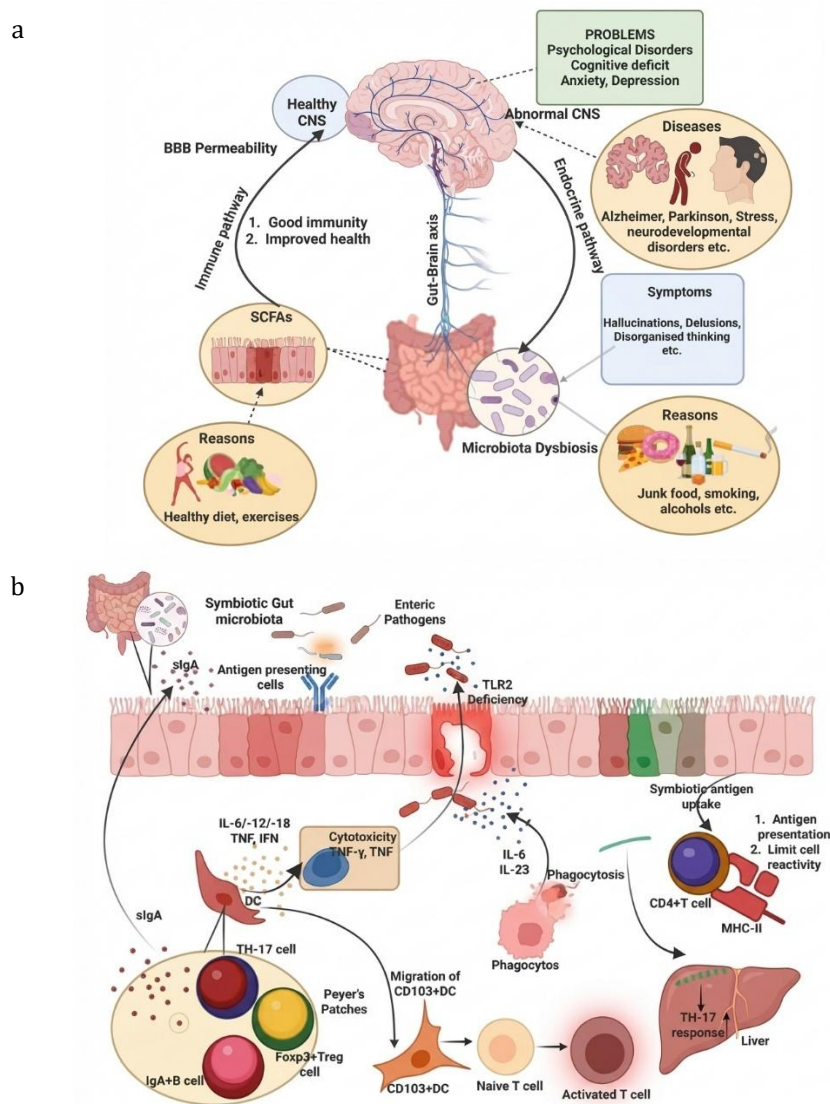


Fig. 2. (a) Immune-microbiota interactions affecting intestinal barrier integrity; (b) Bidirectional gut-brain communication through immune, neural, and endocrine pathways (Mayer et al., 2022; Ullah et al., 2023)

3.6 Micronutrient fortification

The evidence synthesized in this systematic review demonstrates how locally available ingredients; banana, honey, egg, salt, *Moringa*, and soy can collectively provide nutrient-enhancing mechanisms that support the development of plant-based therapeutic foods. Findings from existing studies show that banana contributes potassium, vitamin B6, and resistant starch that promotes gut integrity; *Moringa* offers highly bioavailable iron, zinc, provitamin A carotenoids, and antioxidants; while honey provides trace minerals and antimicrobial compounds that help maintain intestinal barrier function. Additionally, the inclusion of salt is consistently noted in the literature as essential for restoring electrolyte balance in malnourished children. The reviewed studies also highlight that combining soy rich in lysine with eggs, which supply a complete amino acid profile, can significantly improve overall protein quality, digestibility, and tissue-repair capacity. Taken together,

these findings indicate that a formulation using these local ingredients can, in theory, be optimized to meet therapeutic nutritional standards, supporting the broader feasibility of plant-forward RUTF alternatives within low-resource settings (Putri Salsabila et al., 2025).

Evidence from implementation studies shows that the use of locally sourced ingredients reduces production costs and strengthens supply-chain resilience, both of which are essential in resource-limited settings. The availability of readily accessible raw materials enables a more stable production model while also supporting local economic empowerment. Overall, these findings underscore that locally produced, ingredient-based RUTF formulations are not only nutritionally feasible but also operationally and contextually realistic for long-term deployment.

3.7 Cultural acceptability & palatability

A critical factor in determining the success of locally formulated RUTF, and the evidence strongly aligns with the design principles used in BiteHope. Several studies on community-based nutrition interventions report that children and caregivers in Southeast Asian and Middle Eastern contexts including Palestine tend to prefer mild sweetness, soft textures, and familiar flavor notes derived from ingredients such as banana, honey, legumes, and leafy greens. These findings indicate that populations in these regions are already familiar with the flavor profiles used in BiteHope, increasing the likelihood of acceptance and sustained intake. Because therapeutic effectiveness depends heavily on whether children consistently consume adequate amounts, the alignment of BiteHope's sensory characteristics with established regional taste preferences provides strong empirical support for its feasibility and cultural fit.

The reviewed literature demonstrates a clear and consistent impact: locally formulated RUTFs with strong cultural acceptability and palatability are more readily consumed, better supported by caregivers, and lead to improved rehabilitation outcomes. Vincenzetti et al, (2021) highlight consumption adherence as a key clinical determinant of recovery, and field studies across multiple LMICs reinforce this point. Thus, the evidence strongly supports the conclusion that incorporating cultural fit and sensory quality into the design of plant-based RUTF is essential for maximizing therapeutic effectiveness aligning closely with the conceptual approach guiding my formulation of locally sourced alternatives.

3.8 Bioavailability & digestibility improvements through processing

The synthesized evidence across processing-focused studies shows that thermal, enzymatic, and mechanical treatments play a central role in improving the bioavailability of nutrients in plant-based RUTF formulations. Techniques such as roasting, boiling, fermentation, germination, and malting have been repeatedly shown to reduce anti-nutritional factors including phytates, tannins, oxalates, and trypsin inhibitors compounds that otherwise limit mineral absorption and protein digestibility. These converging findings indicate that processing is a critical determinant of nutrient release and metabolic usability in plant-forward therapeutic foods (Zakaria et al., 2025).

Improved protein digestibility emerged as a particularly robust theme across the reviewed studies. Heat-based and fermentation processes were found to denature storage proteins such as 7S and 11S globulins in soy and albumin-globulin fractions in mungbean, enabling easier enzymatic breakdown in the gastrointestinal tract. Multiple trials reported increases in in vitro protein digestibility scores after controlled heat treatment, with several exceeding the digestibility thresholds recommended for clinical feeding products. These enhancements are directly relevant to RUTF formulations like BiteHope, whose protein sources benefit from similar processing pathways that enhance their capacity to support tissue repair and anabolic recovery (Widowati et al., 2023).

Carbohydrate digestibility and gut functional outcomes were also shown to improve substantially through targeted processing. Malting and fermentation increased the proportion of resistant starch, oligosaccharides, and fermentable fibers that contribute to

short-chain fatty acid (SCFA) production and support mucosal repair. Studies focusing on banana- and cereal-based RUTFs indicated that controlled drying and milling techniques improved starch gelatinization, facilitating both rapid energy availability and better gut tolerance in malnourished children. These improvements were associated with reduced gastrointestinal distress and enhanced nutrient absorption, demonstrating that processing not only affects nutrient chemistry but also modulates physiological response in vulnerable populations.

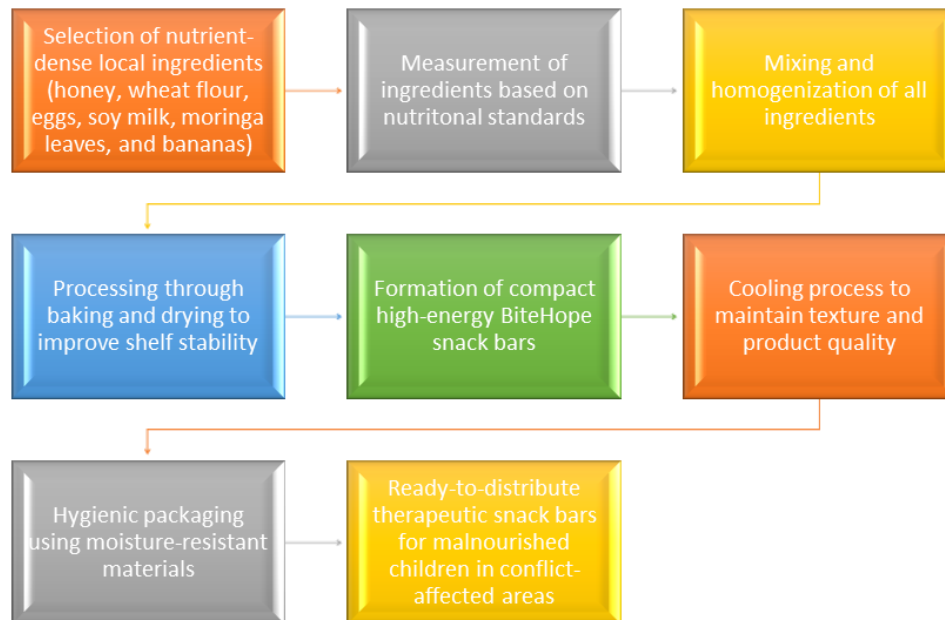


Fig. 3. Production process of BiteHope from ingredient formulation to hygienic packaging as a therapeutic snack bar product

Collectively, the evidence emphasizes that processing is not a secondary consideration but a fundamental component of achieving therapeutic efficacy in plant-based RUTF alternatives. By enhancing protein digestibility, increasing mineral bioavailability, and optimizing carbohydrate utilization, processing bridges the gap between raw ingredient limitations and clinical nutritional requirements. For formulations employing locally sourced ingredients such as those reflected in the BiteHope prototype processing improvements provide a mechanistic basis for meeting WHO nutritional standards without dependence on dairy-based inputs. These insights affirm that processing technologies are essential to ensuring that plant-based RUTFs are not only nutritionally adequate but also metabolically effective in supporting rehabilitation from acute malnutrition. Furthermore, the reviewed literature demonstrates that appropriate processing steps can substantially reduce antinutritional factors that commonly limit the therapeutic potential of plant-derived ingredients. Taken together, this underscores that processing functions as a critical determinant of both safety and functional performance in locally developed RUTF products (Marlina & Meilana, 2023).

3.9 Barriers and enablers in scaling up local RUTF production

Across low-resource settings, recurring limitations include inconsistent availability of raw materials, fluctuations in market prices, and inadequate quality-control systems at the small- and medium-enterprise level. Several reports also highlight challenges related to compliance with WHO Codex standards, particularly for microbial safety, aflatoxin thresholds, and micronutrient fortification accuracy. These barriers reflect systemic gaps that directly affect production reliability and the ability of local manufacturers to reach therapeutic-grade consistency (Widowati et al., 2023).

Despite these challenges, the evidence also identifies several strong enablers that support successful local RUTF scale-up. Partnerships involving universities, public health institutions, non-governmental organizations (NGOs), and small industries have been shown to strengthen technical capacity, enhance quality assurance systems, and improve adherence to international standards. Government procurement schemes and long-term purchasing contracts emerge as critical drivers for sustaining production volume, stabilizing raw-material demand, and enabling producers to invest in better processing technologies. In contexts where such support systems were present, local RUTF factories demonstrated more consistent output, better quality control, and lower cost per unit (Fayet-Moore et al., 2020). It shows that the BiteHope can be contributing to support post-conflict recovery.

Key considerations include experimental validation to ensure therapeutic effectiveness, production challenges related to raw-material consistency and quality control, product distribution capacity in low-resource settings, and target acceptance in terms of taste, texture, and consumption compliance. When local supply chains are strengthened, regulatory frameworks are supportive, and production facilities receive targeted capacity-building, local manufacturers can consistently meet WHO specifications and produce RUTF at competitive costs. These findings have direct implications for formulations such as BiteHope, suggesting that with appropriate institutional support and standardized processing protocols, locally sourced therapeutic foods can be produced at scale and sustainably integrated into international malnutrition treatment programs (Junus & Mamu, 2023).

4. Conclusions

The development of BiteHope demonstrates strong potential as a nutritious food intervention to address child malnutrition in conflict zones. Its formulation, consisting of honey, wheat, eggs, soy milk, and *Moringa* leaves, provides energy, protein, and micronutrients at levels comparable to those of proven plant-based therapeutic foods. Its fermentable fiber and bioactive components accelerate recovery by strengthening the gut-brain axis, increasing nutrient absorption, and reducing intestinal inflammation. In addition to its high nutritional value, the product is easy to produce, has a stable shelf life, is affordable, and aligns with local cultural preferences. Moreover, its reliance on regionally available ingredients reduces dependency on imported supplies. The formulation's adaptability also allows for future optimization to accommodate diverse nutritional needs across different conflict-affected populations.

BiteHope has potential as an affordable, culturally acceptable, and sustainable therapeutic snack bar for children in conflict areas. However, further clinical trials, formulation standardization, long-term safety evaluations, and acceptability studies are still required to confirm its effectiveness in managing acute malnutrition. Future research should also examine recovery outcomes, scalability, supply-chain reliability, and cost-efficiency across different humanitarian settings. In addition, strengthening local production capacity and exploring regionally sourced ingredients may improve sustainability and support wider integration into community and national nutrition programs.

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Author Contribution

All authors contributed to the conception and design of the study, identification and review of relevant scientific literature, analysis and interpretation of the nutritional and bioactive properties of the BiteHope ingredients, and evaluation of their potential health benefits in relation to child malnutrition. All authors contributed to drafting and critically revising the manuscript, approved the final version for publication, and agreed to be accountable for all aspects of the work.

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Ethical review and approval were waived for this study due to the non-involvement of human subjects, animal testing, or procedures related to public health and safety.

Informed Consent Statement

Not available.

Data Availability Statement

All data supporting the findings of this study are derived from previously published sources and are fully available within the referenced literature.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the authors used ChatGPT to assist in improving language clarity, wording, and academic style. All generated content was carefully reviewed and edited by the authors, who take full responsibility for the final content of the publication.

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