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Traditional and Innovative Functional Foods Developed from *Moringa oleifera* and Malted Finger Millet (*Eleusine coracana*): Nutritional Quality, Processing Technologies, Health Benefits, and Future Perspectives

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Abstract : Lately the global burden of malnutrition, those small nutrient gaps, and diet related non-communicable diseases has gotten more intense, so the push for sustainable functional foods made from nutrient-dense plant sources is also growing, like really. In this area, *Moringa oleifera* and malted finger millet *(Eleusine coracana)* feel like pretty solid candidates, because they match up well in terms of nutrient make-up, they bring a lot of bioactive compounds, and they show wide-ranging health benefits. In order to identify present research gaps and future opportunities, this review critically assesses and integrates recent evidence on the nutritional quality, functional properties, processing technologies, and traditional as well as innovative food products developed from Moringa oleifera and malted finger millet *(Eleusine coracana)*.
Using Scopus, Web of Science, PubMed, ScienceDirect, and Google Scholar, the review was carried out in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) standards, with a focus on papers published between 2020 and 2026. While malted finger millet offers complex carbohydrates, dietary fiber, calcium, iron, resistant starch, and improved mineral bioavailability after germination, *Moringa oleifera* is a rich source of high-quality protein, essential amino acids, vitamins, minerals, carotenoids, flavonoids, glucosinolates, and phenolic compounds. They greatly enhance nutritional quality, antioxidant capacity, and functional performance when incorporated into both conventional and novel food products, such as baked goods, gluten-free formulations, supplemental meals, functional drinks, extruded snacks, and ready-to-eat items. The impact of processing techniques on nutrient retention, bioavailability, and product quality is also included in the study. These techniques include malting, fermentation, drying, extrusion, encapsulation, and composite flour technology. Standardization of raw materials, sensory acceptance, clinical validation, marketing, and regulatory harmonization continue to be obstacles despite promising advancements. To aid in the creation of functional foods that are economically feasible, future research should concentrate on sophisticated processing technologies, nutrigenomics, AI-assisted product optimization, carefully planned clinical investigations, and sustainable production techniques. Overall, Moringa oleifera and malted finger millet's complimentary nutritional and functional qualities demonstrate their significant potential to support enhanced public health, sustainable food systems, and food and nutrition security.

Keywords - *Eleusine coracana*, *Moringa oleifera*, malted finger millet, bioactive substances, functional foods, food product development, processing technologies, sustainable nutrition, and health advantages.

I. Introduction

Global attempts to find sustainable, nutrient-rich, and functional food supplies that may simultaneously address nutritional security and enhance human health have increased due to the rising burden of obesity, malnutrition, micronutrient deficiencies, and diet-related non-communicable illnesses. In recent years, functional foods have become a major strategy for improving public health and lowering the risk of chronic diseases. Functional foods are essentially those that provide physiological advantages beyond their ordinary nutritional value (Fekete et al., 2025). Because of that, researchers are now looking more closely at crops that are still underused, plus medicinal plants with high nutritional density, bioactive compounds, and a kind of climate adaptability. In other words they are getting more scientific attention (Divya et al., 2024; Jaglan et al., 2025).
Between these resources, *Moringa oleifera Lam*., sometimes called the drumstick tree or miracle tree, has been more and more noticed as one of the most nutritious plants around the world. M. oleifera, which first came from the Indian subcontinent and is now cultivated in tropical, and also subtropical zones, is valued for a pretty striking nutritional blend. Its foliage contains high quality proteins, essential amino acids, dietary fiber, plus vitamins (A, C, E, and B-complex) and minerals such as calcium, iron, potassium, magnesium, and zinc (Sahu, 2020). It also carries a broad set of phytochemicals, including phenolic acids, flavonoids, carotenoids, glucosinolates and isothiocyanates. These bioactive components also back up its increasing use in functional food development and nutraceutical markets, because they help with a bunch of biological activities, like antioxidant, anti-inflammatory antimicrobial, and even antidiabetic, antihyperlipidemic, hepatoprotective, cardioprotective, plus immunomodulatory actions. (Alegbeleye, 2018; Divya et al., 2024; Jaglan et al., 2025).

Finger millet *(Eleusine coracana)* , sort of like what people say "ragi" for, has changed in how it is seen used to be treated as a traditional staple crop , now it is more often recognized as a climate-resilient "nutri-cereal" due to its unusually strong nutritional profile and its environmental adaptability (Ashoka et al., 2023). Also, beyond holding meaningful amounts of polyphenols and various antioxidant chemicals, finger millet works as a solid source of complex carbs, dietary fiber, calcium, iron, phosphorus, potassium, plus the sulfur-containing amino acids such as methionine. Finger millet has a higher calcium presence and a lower glycaemic index than a lot of the popular cereals, and that makes it kind of especially useful for folks managing metabolic syndrome, diabetes, osteoporosis, and cardiovascular conditions. On top of that it has this ability to thrive on marginal soils and drought circumstances, so it ends up giving a real lift to sustainable farming and food security in poorer countries, (Kaur et al., 2024).

Malting has become, one of the most successful bioprocessing methods for improving the nutritional and functional character of finger millet in a more or less direct way. During soaking, germination and the carefully controlled drying, endogenous enzymes such as α-amylase, proteases, and phytases get switched on and they stay active (Malleshi et al., 2026). As a result proteins and starch get broken down, antinutrients like phytates and tannins drop, mineral bioavailability gets better, protein digestibility improves, and the level of bioactive compounds goes up. Since the malted ragi offers this improved nutritional value plus easier digestion it has gained real importance as an ingredient in things like supplemental foods, newborn formulas, therapeutic diets, sports nutrition products, and ready to use functional foods (Jagati et al., 2021).

The production of nutrient-dense functional foods is somehow made possible by the complimentary nutritional qualities of malted ragi and M. oleifera, which just fit together. Moringa brings in high-quality protein, vital vitamins, antioxidants, and phytochemicals, while malted ragi is a great source of slowly digesting carbs, dietary fiber, minerals, and those bioactive phenolic compounds (CHANDRA, 2022). Together, these parts can work in concert, helping to boost the overall functional qualities, micronutrient density, antioxidant capacity, and nutritional quality of food compositions. Recent studies also show that Moringa and finger millet have been successfully included into baked goods, biscuits, cookies noodles, pasta, extruded snacks, morning cereals, supplemental meals, instant mixes, dairy substitutes, drinks, and gluten-free items as well. However, increasing amounts of moringa frequently contribute a distinctive green color and a mild bitterness, making it necessary to optimize ingredient proportions and processing processes in order to retain consumer acceptance (Jaglan et al., 2025).

While moringa leaves and pods have been used in soups, curries, chutneys, herbal teas, and vegetable dishes throughout Asia and Africa, finger millet has long been used in traditional food systems to make porridges, malt beverages, fermented foods, flatbreads, dumplings, and infant foods. Recent developments in food processing technologies, including as encapsulation, spray drying, freeze drying, fermentation, extrusion, and high-pressure processing, have made it easier to create novel value-added products that blend conventional ingredients with cutting-edge food technology. These developments meet customer demand for clean-label, plant-based, and sustainable food items while also enhancing nutritional quality and shelf stability. (Divya et al., 2024; Jaglan et al., 2025).

Even though there is an increasing amount of research on M. oleifera and finger millet separately, the studies that are now available mostly concentrate on their pharmacological characteristics, nutritional makeup, or discrete food uses. There are currently few thorough reviews that incorporate the nutritional quality, functional qualities, processing technologies, sensory attributes, commercialization potential, and future research directions of the traditional and novel food products created especially from the combination of moringa and malted ragi (Divya et al., 2024; Jaglan et al., 2025).

Thus, the goal of this review is to critically assess both conventional and novel food products made from *Moringa oleifera* and malted ragi *(Eleusine coracana)*, with a focus on their nutritional makeup, functional qualities, processing methods, product development approaches, sensory attributes, potential for health promotion, commercialization opportunities, present research gaps, and future prospects. This review kind of aims to give researchers , food technologists, nutritionists and policymakers a pretty thorough understanding about how these ingredients, work in creating sustainable, nutrient rich functional foods for boosting global nutritional security. It does this by pulling together current scientific evidence, sort of in a synthesizing way.

This review feels kind of innovative, because it uses an integrated approach for bringing malted finger millet and *Moringa oleifera* together, almost like they work as complimentary functional food ingredients. The current review looks in depth at their nutritional synergy, the bioactive composition, and also processing technologies, plus it covers conventional and novel food products. Then there are the commercialization opportunities and future research directions too, all in one continuous framework. That is different from earlier reviews that often handled these resources independently, or just linked them in a more separate way. Overall, the study provides an updated scientific base for creating sustainable, nutrient dense and health promoting functional foods, by stitching together more recent evidence, especially findings published between 2020 and 2026.

2. METHODOLOGY

2.1 Review Design

When conducting this review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines were followed, just to keep things methodical, transparent, and kind of repeatable, for locating, choosing, evaluating and then synthesizing the existing literature on both usual and brand-new food products made from *Moringa oleifera* and malted ragi *(Eleusine coracana)*. The PRISMA 2020 framework was applied to strengthen methodological rigor, lessen selection bias, and make sure that the literature search, plus the study selection steps, are reported in a thorough way even if the present work is more of a narrative review (Page et al., 2021).

2.2 Review Objectives

The present review was undertaken with the following objectives:

1. To assess critically the nutritional worth, functional properties, and processing approaches for malted ragi *(Eleusine coracana)* along with *Moringa oleifera*, used in both conventional and, in some new food items where it is applied.
2. To pull together the available data on how food products are created, their ability, to encourage wellbeing, where the studies still feel thin and uncertain, and what might happen next for the use of malted ragi as well as *Moringa oleifera* in sustainable, functional meals.

2.3 Research Questions

The review was guided by the following research questions:

RQ1. What scientific information is now available, about the nutritional makeup, the functional traits, and the processing methods of malted ragi and *Moringa oleifera* in both every day and newer food products?
RQ2. What research trends, gaps and coming chances exist for crafting more sustainable functional meals using malted ragi along with *Moringa oleifera*, in a kind of blend that seems useful day to day.

2.4 Literature Search Strategy

Five electronic databases, Scopus, Web of Science Core Collection, PubMed, ScienceDirect and Google Scholar, were used for a fairly thorough literature search. The databases were picked since they give broad coverage of peer-reviewed work across agriculture, nutrition, food science, and the health sciences, so it kind of covers the right ground.
To catch the most current advances in functional food innovation, food processing technologies and also value-added product development, the search was set to include research published from January 2010 to June 2026. The emphasis however is on the more recent period, meaning 2020–2026, because that's where most of the newest findings show up.
For this Medical Subject Headings (MeSH), a set of database specific indexing terms, and also plain text keywords all mixed together, you know linked using Boolean operators like "AND" and sometimes "OR". It was basically done in combination, though the connections were not always super clean. Among the main search phrases were:

- Moringa oleifera
- Drumstick tree
- Finger millet
- Eleusine coracana
- Malted ragi
- Germinated finger millet
- Traditional food products
- Functional foods
- Innovative food products
- Food fortification
- Nutritional quality
- Processing technologies
- Value-added food products

A representative search strategy was:
("Moringa oleifera" OR "drumstick tree") AND ("finger millet" OR *"Eleusine coracana*" OR "malted ragi") AND ("traditional food" OR "innovative food products" OR "functional foods" OR "food product development") The reference lists of pertinent review articles and original research papers were carefully searched to find more relevant works in order to guarantee completeness.

2.5 Eligibility Criteria

Studies were selected according to predefined inclusion and exclusion criteria.

Inclusion Criteria

Studies were included if they:

- Appeared in journals with peer review
- Were composed in English
- They looked at the production of food products using Moringa oleifera, finger millet (Eleusine coracana), or malted ragi
- Provided information on nutritional makeup, functional characteristics, processing methods, sensory assessment, shelf life, health advantages, or commercialization
- Were released between 2010 and 2026.

Exclusion Criteria

- The following were excluded:
- Letters, book chapters, dissertations, patents, conference abstracts, and editorials; duplication of publications
- Articles whose complete text is not accessible
- Research that has no bearing on food applications and only focuses on agronomic, pharmacological, or animal feeding factors
- Publications that are not in English.

2.6 Study Selection

Duplicate articles were found and eliminated once all collected records were put into reference management software. The titles and abstracts of the remaining articles were examined to determine their applicability to the review's goals. After meeting the eligibility requirements, full-text articles were evaluated for inclusion. To ensure openness throughout the review process, justifications for excluding studies throughout the full-text screening step were recorded.

The study selection followed the four stages recommended by the PRISMA 2020 framework:

1. Identification of records.
2. Screening of titles and abstracts.
3. Eligibility assessment through full-text review.
4. Final inclusion of studies for qualitative synthesis (Page et al., 2021).

A total of 1,284 records were found by the database search, which included manual searches of reference lists as well as studies obtained from Scopus, Web of Science, PubMed, ScienceDirect, and Google Scholar. 1,070 records were screened using titles and abstracts after 214 duplicate records were eliminated. Because they didn't fit the predetermined qualifying requirements, 872 of these records were eliminated. After 198 publications' entire texts were evaluated for eligibility, 118 studies were eliminated for a variety of reasons, such as duplication of previously published data, absence of methodological details, non-English language, or lack of relevance to food product development. Ultimately, the qualitative synthesis contained 80 studies. Figure 1 illustrates the research selection procedure in accordance with PRISMA 2020 standards.

2.7 Data Extraction

Relevant information from each eligible study was extracted using a standardized data extraction form. The extracted variables that are included:

- Author(s) and year of publication;
- Country of study;
- Type of food product;
- Raw materials used;
- Processing technology employed;
- Nutritional composition;
- Functional and bioactive properties;
- Sensory characteristics;
- Shelf-life outcomes;
- Reported health benefits; and
- Major findings and conclusions.

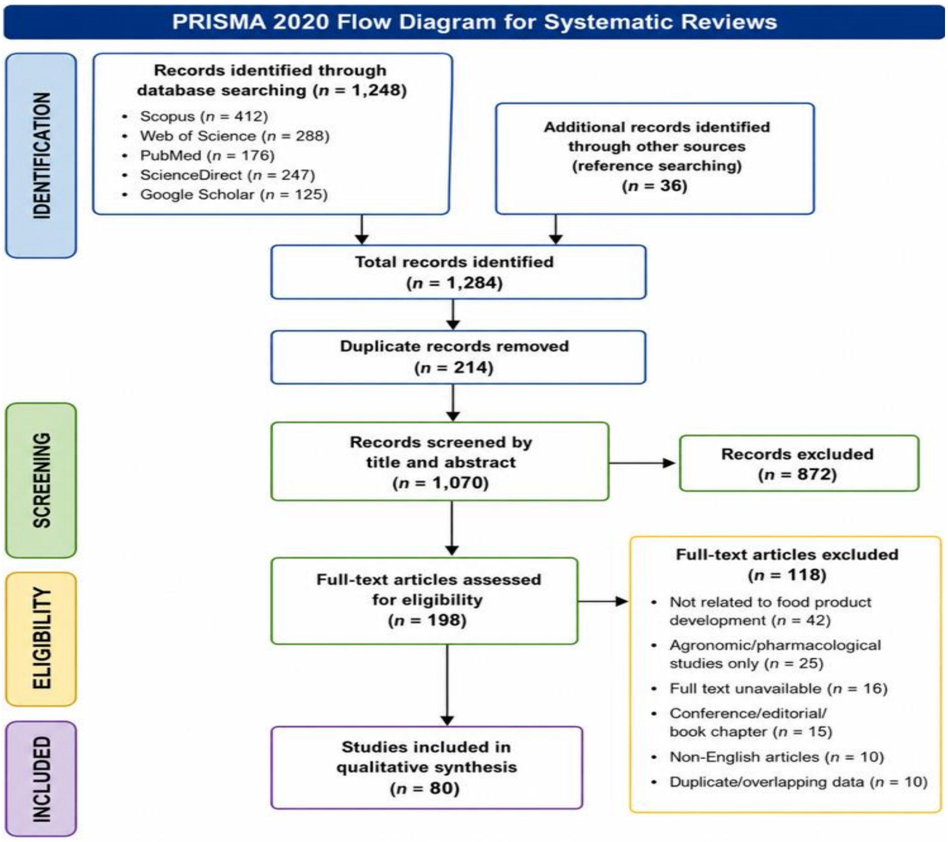

Figure 1: The PRISMA 2020 flow diagram shows, how the studies that were used in this review got found, then screened, then assessed for eligibility, and finally included. For the literature search, we used Scopus, Web of Science, PubMed, ScienceDirect, Google Scholar, plus a manual check of reference lists. After we removed duplicates, the papers that still met the pre-set inclusion criteria were put into the qualitative synthesis, once eligibility had been evaluated properly.

2.8 Quality Assessment

Peer reviewed papers that were, indexed in reputable scientific databases only, were taken into account in order to boost the whole review's scientific trustworthiness. If we look at it in terms of research design, the analytical ways used, how samples were processed, the nutritional assessment itself, and the way results were reported, then the methodological quality plus usefulness of the included studies were examined in a critical manner. Studies that used confirmed laboratory techniques, along with appropriate statistical analysis, were weighted more strongly, for lack of a better term.

2.9 Data Synthesis

A quantitative meta-analysis wasn't possible because of the variety in study design, food formulas, and the different ways processing is done. Also the reported results varied a lot, so it just didn't line up cleanly. As a result, a qualitative narrative synthesis was carried out.

The included studies were organized into the following thematic categories:

- Nutritional quality of Moringa oleifera and malted ragi
- Functional and bioactive properties
- Traditional food products
- Innovative food product development
- Processing technologies
- Sensory evaluation and shelf-life
- Health-promoting properties
- Research gaps and future perspectives.

The creation of sustainable functional foods based on *Moringa oleifera* and malted ragi was made possible by this topic synthesis, which also made it easier to identify new trends, technical developments, and future research goals.

3. NUTRITIONAL QUALITY OF *Moringa oleifera* AND MALTED RAGI (*Eleusine coracana*)

Moringa oleifera and finger millet (*Eleusine coracana*), especially in its malted form, have received a lot of attention due to the growing demand for nutrient-dense and functional dietary ingredients (Chellappan & Peramaiyan, 2024). Because of their complementing nutritional profiles, these ingredients are excellent choices for creating functional meals with additional value. Malted ragi gives us sort of complex carbohydrates, plus dietary fiber, very accessible minerals, and better digestibility once it's been germinated, while M. oleifera is also recognized for its surprisingly strong protein quality, a rich vitamin load, mineral wealth, and a wide set of phytochemicals. One likely pathway for tackling protein energy malnutrition, micronutrient shortages, and diet linked chronic ailments could be to put both into everyday food items together (Alegbeleye, 2018; Divya et al., 2024; Kaur et al., 2024).

3.1 Nutritional Composition of *Moringa oleifera*

Moringa oleifera because it has remarkable nutritional and therapeutic qualities, gets called the "Miracle Tree", and it is generally accepted as one of the most nutrient-rich food plants. Since it contains high amounts of proteins, plus essential amino acids, vitamins, minerals, dietary fiber and also bioactive phytochemicals, the leaves are considered by many as the most important of its edible portions, (Leone et al., 2015; Divya et al., 2024).

On a dry-weight basis, fresh moringa leaves kinda have about 20–30% protein, and in that mix there are all the key amino acids needed for human nutrition. These leaves are a good plant-based protein source, because they're especially rich in lysine, leucine, valine, isoleucine, methionine, threonine, phenylalanine, plus tryptophan, which is nice for dietary completeness. Also, moringa leaves tend to show notably higher concentrations of calcium, iron, potassium, magnesium, phosphorus, and zinc than many other leafy vegetables, and this helps with bone health, hemoglobin synthesis, electrolyte balance, and immunological function (Gopalakrishnan et al., 2016; Divya et al., 2024).

M. oleifera is a pretty good source of vitamins A, C, E, and a range of B-complex vitamins along with macronutrients and mineral things. Vitamin C supports antioxidant defense, and also helps with iron absorption, while vitamin A is mostly present as β-carotene, which is important for immune system work, eyesight, and epithelial integrity. Then vitamin E, by guarding the cellular membranes from oxidative injury, also boosts its own antioxidant role (Falowo et al., 2018).

Besides the more "nutrition" part, moringa leaves contain a bunch of bioactive phytochemicals like flavonoids (kaempferol and quercetin), phenolic acids (caffeic and chlorogenic acids), glucosinolates, isothiocyanates, carotenoids, tannins, and saponins. The usefulness of moringa as an ingredient for nutraceuticals and functional food use has been emphasized because these compounds show antioxidant, anti-inflammatory, antimicrobial, antihyperglycemic, antihypertensive and cardioprotective effects in both experimental work and clinical investigations (Mbikay, 2012; Divya et al., 2024).

Even when moringa shows this remarkable nutritional profile, it also has some naturally occurring anti nutrient substances like phytates, oxalates, tannins, and saponins, that if swallowed in excess could reduce the mineral uptake. Still, it's been shown that using processing methods, like blanching, drying, fermenting, and boiling can significantly cut down these compounds, while keeping most of the nutritional value intact (Leone et al., 2015).

3.2 Nutritional Composition of Malted Ragi *(Eleusine coracana)*

Finger millet, it has this exceptional mineral content, plus dietary fiber and resistant starch, and even phenolic compounds too, so it ends up being one of those most nutritious minor cereals, you know. It is especially good for people dealing with diabetes or metabolic issues, because compared to many processed cereals, it still has meaningful amounts of carbs that digest slowly. And the calcium part is honestly pretty striking: with roughly 300–350 mg of calcium per 100 g, it's way higher than wheat rice, or maize, so it becomes one of the richer natural cereal calcium sources (Shobana et al., 2013; Kaur et al., 2024).

About 7–10% of finger millet grains are made up of protein, and it's kind of notable for having comparatively high levels of sulphur containing amino acids such as methionine, which other cereals often miss. Also, finger millet brings dietary fiber, iron, phosphorus, potassium, magnesium, along with trace minerals that help with bone mineralization, better metabolic control, and cardiovascular wellbeing (Devi et al., 2014)

Polyphenols, flavonoids, tannins, and other antioxidant substances are pretty abundant in finger millet. These phytochemicals help, with reducing oxidative stress, scavenging free radicals, and also slowing down starch digestion in a more or less steady way. They even seem to take part in the regulation of glucose metabolism. Because of that, when you compare finger millet-based diets with refined grain products, they've been associated with better metabolic health and lower glycaemic responses (Shobana et al., 2013; Kaur et al., 2024).

3.3 Effect of Malting on Nutritional Quality

One of the best ways to improve the nutritional along with functional quality of finger millet is malting, it includes carefully regulated soaking, germination, and finally drying, though people sometimes skip details. During germination, endogenous enzymes like α-amylase, β-amylase, proteases, and phytases get activated, and this triggers biochemical changes that boost nutrient availability, as well as digestibility. (Taylor & Emmambux, 2008).

When you significantly reduce antinutritional bits such as phytates, tannins, and enzyme inhibitors, the malting process sort of boosts how well minerals like calcium, iron, and zinc get absorbed. Malted ragi is particularly good for infant complementary foods, therapeutic diets, and geriatric nutrition, because the germination step ramps up free amino acids and soluble proteins, plus it raises B-complex vitamins and γ-aminobutyric acid (GABA) it also supports antioxidant activity. At the same time, it tends to lower starch viscosity (Shobana et al., 2013; Kaur et al., 2024).

Also, malting creates carbs that get digested bit by bit, and that helps with glycaemic management, keeps you full for a longer while. This seems to happen because protein digestion improves and the starch structure is changed a bit. Because of those nutritional improvements, people have started using malted ragi more in quick drink mixes, weaning meals, bakery items, extruded snacks, fermented foods, and even sports nutrition formulations (Devi et al., 2014).

3.4 Complementary Nutritional Potential of Moringa and Malted Ragi

Malted ragi and Moringa oleifera together give kind of a complementary set of nutritional advantages, which helps folks come up with functional meals that feel more nutrient rich overall. Moringa brings high-quality protein, key vitamins, iron, and potent antioxidant phytochemicals, and malted ragi is basically a rich source of complex carbohydrates, calcium, dietary fiber, plus slowly digesting starch. Put simply, these bits really help when it comes to tackling hidden hunger, and also support maternal, child and geriatric nutrition, because using them side by side can improve protein quality, boost micronutrient density, raise antioxidant capacity, and even help mineral bioavailability (Alegbeleye, 2018; Divya et al., 2024 ; Kaur et al., 2024).

According to recent research, when the right levels of inclusion are maintained, fortifying bakery items, complementary foods, beverages, and snack pieces with moringa leaf powder alongside malted ragi really boosts protein amount, mineral concentration, antioxidant activity , and overall nutritional quality, without messing up the product functionality (Falowo et al., 2018; Jaglan et al., 2025). In other words, these findings point to a strong promise for bringing together those nutrient-dense ingredients for making reasonably priced, sustainable, and more health-promoting food products.

4. FUNCTIONAL PROPERTIES OF *Moringa oleifera* AND MALTED RAGI (*Eleusine coracana*)

4.1 Overview of Functional Properties

Lately the demand for functional foods boosted with bioactive substances has gone up, mainly because chronic illnesses are becoming more common and also because consumers are getting more aware about how diet and health are connected. Functional foods are basically those foods that help improve physiological processes and reduce the chances of chronic illnesses, so you'll often see them described that way (Granato et al., 2020). *Moringa oleifera*, along with malted ragi, has turned into an attractive pair of functional food ingredients since they're rich in proteins, dietary fiber, vitamins, minerals, phenolic compounds, flavonoids, and a bunch of other phytochemicals. And beyond just raising the nutritional value, adding them into everyday food preparations can bring antioxidant, anti-inflammatory, antidiabetic, antibacterial, cardioprotective, immunomodulatory, plus gut health-supporting effects too (Divya et al., 2024; Kaur et al., 2024).

These two ingredients, when they're complementing each other's nutritional profiles, give a real opportunity to make functional meals that can, at the same time, support long term health and wellness and help ease several kinds of nutritional gaps.

4.2 Antioxidant Properties

Ageing, and also many long lasting chronic illnesses, like as cancer, diabetes mellitus, cardiovascular disease, and neurological diseases, are said to be strongly influenced by oxidative stress, or somehow it is. Reactive oxygen species (ROS) get neutralized by dietary antioxidants, so they help shield biological components from oxidative damage.

Antioxidant phytochemicals such as quercetin, kaempferol, chlorogenic acid, caffeic acid, ferulic acid, β-carotene, ascorbic acid, tocopherols, and other polyphenols are abundant in Moringa oleifera. These substances kinda show a potent ability to scavenge free radicals, stop lipid peroxidation, and also boost the activity of endogenous antioxidant enzymes such as glutathione peroxidase, catalase and superoxide dismutase (Leone et al., 2015; Divya et al., 2024).

Similarly, finger millet contains plenty of anthocyanins, flavonoids, tannins, and phenolic acids, mainly in the seed coat. When you bump up the concentration and the bioavailability of those free phenolic components, germination plus malting seems to further improve the antioxidant potential. Several studies have pointed out that malted finger millet has much higher antioxidant activity than unmalted grains, which makes it more useful for food formulations (Devi et al., 2014; Kaur et al., 2024).

4.3 Antidiabetic Properties

Foods that have low glycaemic indices and also help regulate glucose are getting noticed more and more, because diabetes mellitus still is, kind of a big worldwide health problem. For example finger millet contains dietary fiber, resistant starch, and also a slowly digested starch. This whole mix works to delay how glucose is absorbed, and it also slows down carbohydrate digestion a bit. On top of that, it has polyphenolic substances that can drop post meal blood glucose levels by slowing digestive enzymes like α-amylase and α-glucosidase (Shobana et al., 2013).

Then there is Moringa oleifera, which adds more antidiabetic activity. This is tied to bioactive compounds such as chlorogenic acid, quercetin, and isothiocyanates. These compounds can support insulin sensitivity, reduce hepatic glucose production, and also protect pancreatic β-cells from oxidative stress, (Mbikay, 2012; Divya et al., 2024).

So, overall, combining moringa with malted ragi looks promising for dietary management of diabetes as well as metabolic syndrome, especially when they are shaped into functional food products.

4.4 Anti-inflammatory Properties

Obesity, heart disease, arthritis, cancer, and several metabolic conditions have been tied to chronic low grade inflammation. And yeah, both finger millet and moringa carry bioactive compounds that supposedly help with anti-inflammatory effects, mainly by tuning the inflammatory signaling routes and by reducing pro inflammatory cytokines.

Moringa is especially rich in isothiocyanates, flavonoids, and phenolic acids, and it can suppress cyclooxygenase-2 (COX-2), nuclear factor-kappa B (NF-κB), plus other inflammatory mediators like interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α) (Leone et al., 2015).

In a similar way, finger millet has polyphenols that have been reported to cut down oxidative stress and lower inflammatory markers, so there might be a role for them in preventing long term inflammatory disorders (Devi et al., 2014).

4.5 Cardioprotective Properties

Globally, cardiovascular diseases keep being the main reason people die. Eating meals that are rich in dietary fiber, antioxidants and phytochemicals, consistently seems to help cardiovascular well-being.

When finger millet is used regularly, the soluble fiber along with its polyphenols can reduce the uptake of cholesterol in the intestine, while also supporting lipid metabolism. So, blood cholesterol levels may drop. On top of that, the low glycaemic index, supports improved metabolic health too, (Shobana et al., 2021).

When total cholesterol goes down, along with low-density lipoprotein (LDL) and triglycerides, and when high-density lipoprotein (HDL) goes up, moringa has been described as giving antihyperlipidemic plus antihypertensive support. Also, potassium, flavonoids, and antioxidant compounds appear to back endothelial function, and help blood pressure management a bit more (Mbikay, 2012; Divya et al., 2024).

4.6 Antimicrobial and Immunomodulatory Properties

With the increase in antibiotic resistance, people have been looking harder for natural antimicrobial agents. A bunch of Gram-positive and Gram-negative bacteria, plus fungi and foodborne pathogens are inhibited by the antimicrobial compounds in moringa, for example benzyl isothiocyanates, niazimicin, flavonoids, and phenolic acids (Falowo et al., 2018).

Also, moringa seems to help in a different way. By boosting antioxidant defense mechanisms and tuning immune cell activity vitamins A, C, E, zinc, selenium, and various bioactive phytochemicals help support a more steady immunological function (Divya et al., 2024).

And then there's finger millet which, because of its antioxidant compounds, minerals, and dietary fiber, also supports gut linked immune functioning and overall physiological resilience (Kaur et al., 2024).

4.7 Gastrointestinal Health and Prebiotic Potential

Because it helps keep regular bowels moving, supports a more balanced gut flora, and boosts the making of short chain fatty acids, dietary fiber is vital for keeping gastrointestinal health going.

Both soluble and insoluble dietary fiber, which boosts intestinal health and stretches satiety, are present in finger millet in a good amount. During germination, nutrient absorption gets better because digestibility rises and antinutritional chemicals are reduced (Devi et al., 2014).

Dietary fiber along with bioactive substances in moringa leaves can also help expand the range of gut microbes, at the same time reducing gut inflammation. So, mixing these components into functional meals might support better metabolic performance, and improve intestinal wellbeing (Divya et al., 2024).

4.8 Functional Synergy of Moringa and Malted Ragi

When you bring together the complimentary nutrients and phytochemicals, Moringa oleifera with malted ragi kind of create this synergistic functional profile. Moringa brings quality proteins, key vitamins, minerals and also a range of bioactive substances, and malted ragi gives slowly digesting carbohydrates, calcium, dietary fibre, and phenolic antioxidants. Together, beyond just backing multiple physiological processes like antioxidant defense, glycaemic control, cardiovascular health, immune modulation and gastrointestinal wellbeing, this interaction seems to raise both the nutritional density and the practical functional effect of the final food products (Alegbeleye, 2018; Divya et al., 2024; Kaur et al., 2024).

Table 1. Nutritional Composition and Functional Properties of *Moringa oleifera* and Malted Finger Millet

Parameter	***Moringa oleifera***	**Malted Finger Millet (*Eleusine coracana*)**	**Health/Functional Significance**	**Key References**
Major macronutrients	High-quality protein, dietary fibre	Complex carbohydrates, dietary fibre, moderate protein	Supports growth, satiety, and metabolic health	Divya et al. (2024); Kaur et al. (2024)
Major minerals	Calcium, iron, potassium, magnesium, zinc	Calcium, iron, phosphorus, magnesium	Bone health, haemoglobin synthesis, enzyme function	Divya et al. (2024); Kaur et al. (2024)
Major vitamins	Vitamins A, C, E, B-complex	B-complex (enhanced after malting)	Immunity, antioxidant defence	Divya et al. (2024)
Principal phytochemicals	Flavonoids, glucosinolates, phenolic acids, carotenoids	Polyphenols, tannins, flavonoids	Antioxidant and anti-inflammatory activities	Jaglan et al. (2025); Kaur et al. (2024)
Antioxidant activity	Very high	High	Reduces oxidative stress	Divya et al. (2024)
Antidiabetic potential	Improves insulin sensitivity	Low glycaemic index, resistant starch	Better glycaemic control	Kaur et al. (2024)
Cardioprotective effects	Improves lipid profile	Supports cardiovascular health	Reduces cardiovascular disease risk	Divya et al. (2024)
Effect of processing	Drying affects vitamin retention	Malting improves digestibility and mineral bioavailability	Enhances nutritional quality	Kaur et al. (2024)
Major applications	Functional foods, beverages, supplements	Bakery, complementary foods, gluten-free products	Functional food development	Gull et al. (2025); Siroha & Bangar (2024)

Table 1 summarizes the major nutritional components, bioactive compounds, and functional properties of *Moringa oleifera* and malted finger millet, highlighting their complementary roles in functional food development.

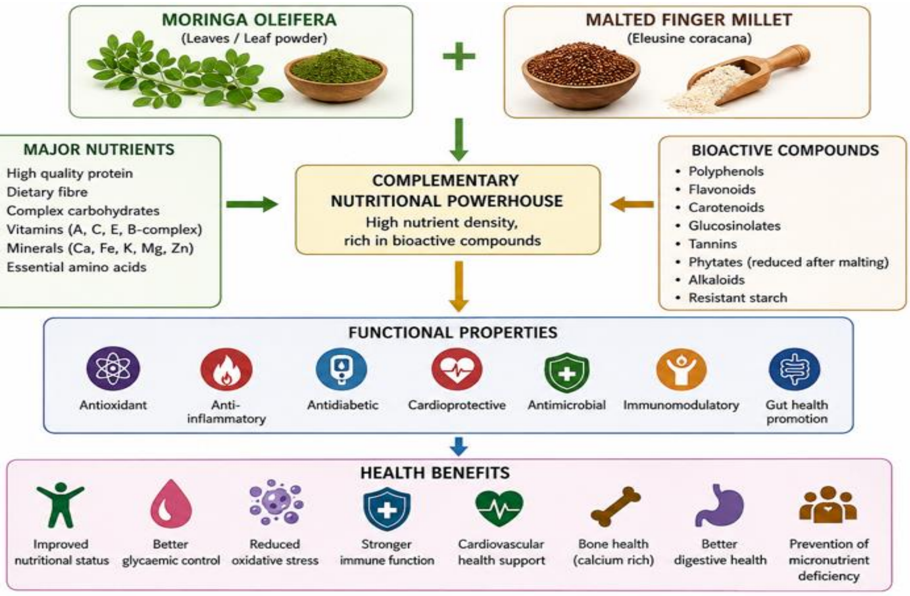

Figure 2. Mechanistic Framework of the Nutritional and Functional Potential of *Moringa oleifera* and Malted Finger Millet

The complimentary nutritional and physiological potential of malted finger millet and Moringa oleifera is shown in Figure 2. Their abundance of proteins, dietary fiber, vitamins, minerals, and bioactive phytochemicals supports the production of nutrient-dense functional foods by providing antioxidant, anti-inflammatory, antidiabetic, cardioprotective, immunomodulatory, and gut health-promoting qualities.

Therefore, creating food products that are enriched with both malted ragi and moringa is a viable approach to alleviating hidden hunger, enhancing the quality of diets, and advancing sustainable functional nutrition.

5. TRADITIONAL FOOD PRODUCTS DEVELOPED FROM *Moringa oleifera* AND MALTED RAGI (*Eleusine coracana*)

For a long time, traditional food systems have used locally available cereals and leafy greens to put together nutrient dense meals that are somehow tuned to local diet habits and cultural tastes. Since their nutritional content is high, they're usually affordable, and they can really work across a range of agroclimatic settings, Moringa oleifera and finger millet (Eleusine coracana) have been quite central in the everyday diets of many Asian and African countries. Even so, these plant sources have often been consumed on their own, but now people are paying more attention to using them together in standard food formulations, mainly because there's this newer interest in sustainable nutrition, and functional foods. Beyond meeting modern nutritional requirements, their complementary nutritional patterns give room to improve dietary variety, reduce hidden hunger, and help preserve traditional food know how (Kaur et al., 2024; Siroha & Bangar, 2024).

For ages, people in India, Nepal, Sri Lanka, Ethiopia, Uganda, and quite a few other African countries have been eating traditional dishes that are made from finger millet, like just the usual kind. There's not much processing, they rely on ingredients that are locally sourced and the cooking methods tend to boost nutritional bioavailability via soaking, fermentation, germination, and heating. In a similar kind of way, because of the nutritional + therapeutic qualities, leaves, pods, and blossoms from Moringa oleifera have been used for a long time in soups, curries, chutneys, sauces, herbal drinks, and even supplementary dishes. These old-school eating habits are now getting more and more recognized by modern food research as a pretty good beginning for making functional foods, with more nutritional value and health promoting traits (Divya et al., 2024; Jaglan et al., 2025).

5.1 Traditional Food Products Prepared from Finger Millet

Because finger millet has that really good nutritional profile, it is also naturally gluten-free, lasts longer in storage, and is easy to adapt with different processing methods, so it has ended up being used quite a lot in many traditional kitchen recipes. We can usually find finger millet as a familiar ingredient in porridges, flatbreads, fermented goods, dumplings, and even drinks across South Asia, and especially in southern India. Through conventional ways like soaking, fermentation, and malting, the phytates and other antinutritional factors get reduced, while protein digestibility improves, minerals become more bioavailable, and antioxidant activity also rises, not to mention it often boosts the sensory quality a bit (Kaur et al., 2024; Anal et al., 2024).

5.1.1 Ragi malt

One of the oldest and more popular traditional drinks made from germinated finger millet is ragi malt, lots of people really rely on it. To create malt flour, the grains are soaked, then left to germinate with regulated conditions, after that dried, roasted, and finally ground down. Depending on local tastes, the flour is boiled with milk or water, and then sweetened using sugar or jaggery. Ragi malt seems especially beneficial for infants, children, pregnant women, the elderly, and people recovering from illness because during malting the process boosts free amino acids and B-complex vitamins, at the same time it reduces phytate content and also improves calcium bioavailability (Kaur et al., 2024).

5.1.2 Ragi mudde

Finger millet balls, also called ragi mudde, are a traditional staple meal that people usually eat in Tamil Nadu, Andhra Pradesh and Karnataka. The finger millet flour is stirred in boiling water to make a sort of cohesive dough, then it gets shaped into little round balls. Folks like it because ragi mudde has a pretty high dietary fiber content and the carbs are digested more slowly, so you get energy for a while longer. Most times it is served along with vegetable curries, meat-based gravies, or even lentil based soups, so the whole dish ends up with more protein, like overall protein support (Kaur et al., 2024).

5.1.3 Ragi porridge (Ragi Ambli)

One of the first complimentary meals, eaten in East Africa and India, is ragi porridge. It can be made with fermented batter, malted flour, or whole grain flour, depending on local customs maybe. Since fermentation lowers viscosity and ups the taste, along with digestibility and mineral absorption, this food is particularly good for clinical nutrition and newborn feeding. Ragi porridge is still a major piece of maternal and child nutrition programs, mostly because it has lots of calcium and iron, (Sadh et al., 2024; Kaur et al., 2024).

5.1.4 Fermented finger millet foods

One of the earliest ways people process finger millet at home is via fermentation, really. Dosa, idli, ambli, and those native drinks that come from natural lactic acid fermentation are examples of traditional fermented goods. In general, fermentation makes the protein digestibility better, keeps more B-group vitamins available, improves mineral bioavailability, and the taste is also more favorable, so yeah. At the same time the antinutritional aspects are decreased, not fully maybe but still. And according to some newer work, fermentation turns out to be a successful method for boosting the functional qualities as well as the nutritional value of meals made from millet (Roopashri et al., 2023).

5.2 Traditional Food Products Prepared from *Moringa oleifera*

Moringa is usually eaten more like a leafy vegetable, than like a grain, as opposed to finger millet. The plant edible parts, like the leaves, immature pods, blossoms, and seeds, have been part of everyday home meals for a long while in Southeast Asia, India, and many African countries. Even when people keep the same traditional cooking style, those dishes still deliver notable amounts of vitamins, minerals, antioxidants and phytochemicals (Divya et al., 2024).

5.2.1 Moringa leaf curry

To make nutrient rich vegetable curries, you often cook fresh moringa leaves together with onions, lentils, coconut, and various spices. In these kinds of formulations, Iron and calcium, plus provitamin A carotenoids, vitamin C, and dietary antioxidants are present in notable amounts. Regular eating is usually related to a stronger intake of micronutrients, in particular for women and children living in places where resources are limited (Divya et al., 2024).

5.2.2 Moringa soup

Fresh leafy parts are simmered together with vegetables herbs and a mix of spices, so you get a traditional moringa soup. People often say it helps especially when someone is recuperating from an illness, mostly because its nutrients are rather easy to digest, and it has a strong antioxidant-rich composition. The proteins minerals vitamins and other bioactive substances that end up in the bowl can support the immune system, and also nudge the overall nutritional condition in a better direction, (Jaglan et al., 2025).

5.2.3 Moringa chutney

Chutney, which is a pretty familiar side dish in southern Indian home cooking, is usually made by blending moringa leaves together with coconut, some roasted legumes, garlic, tamarind, and a mix of spices. In a way, this type of preparation works as a practical route to nudge the everyday intake of antioxidants and micronutrients, without having to compromise on the general taste, smell, and texture people still expect (Divya et al., 2024).

5.2.4 Moringa herbal tea

Herbal tea, which is being eaten, for its supposed health perks, is usually made by letting dried moringa leaves steep in hot water. As a caffeine-free functional drink it has become pretty popular among health conscious consumers, because of its natural richness in polyphenols, flavonoids, and antioxidant compounds (Jaglan et al., 2025).

5.3 Traditional Complementary Foods Incorporating Moringa and Finger Millet

To boost the nutritional value of meals for newborns and very young kids, many Asian and African cultures have been leaning more and more on older complementary feeding ways, using a mix of finger millet flour together with moringa leaf powder. Moringa brings along high-quality protein, iron, vitamin A precursors, vitamin C, and assorted bioactive phytochemicals, while finger millet supplies energy, calcium, and those complex carbohydrates. When the fortification levels are put in place correctly, studies have shown these pairings can lift protein quality, increase micronutrient density, and also improve antioxidant capacity, all while still keeping an acceptable taste and texture, more or less. For communities that are struggling economically, these familiar recipe types seem to be a steady pathway for tackling micronutrient deficiencies as well as protein-energy malnutrition (Divya et al., 2024; Kaur et al., 2024).

5.4 Significance of Traditional Food Products

More than just cultural heritage, traditional meals made with finger millet and Moringa oleifera, stand for sustainable eating habits that are also supported by today's nutritional research. You don't really need any complex technology either, because normal processing steps like soaking, germination, fermentation, roasting,and plain home cooking can help nutrients become more usable in the body. At the same time, these routines can reduce antinutritional factors and make the taste more appealing, so people actually want to eat them. In this way these foods remain important for strengthening nutritional security, adding dietary variety, and supporting sustainable food systems. Also, they give a solid starting point for building new functional food products that blend traditional wisdom with modern food processing practices (Anal et al., 2024; Siroha & Bangar, 2024).

6. INNOVATIVE FOOD PRODUCTS DEVELOPED FROM *Moringa oleifera* AND MALTED RAGI (*Eleusine coracana*)

Lately research on tacking functional ingredients onto the usual food, has really sped up, mostly because people everywhere now want nutrient dense, plant based, and more sustainable diets. Food companies have also been pushing out newer products with bioactive plant matter inside them , as consumers become more aware about lifestyle related illnesses, gluten sensitivity, and micronutrient shortfalls. Because Moringa oleifera and malted finger millet, also called *Eleusine coracona*, bring such nice complementary nutrition, a strong phytochemical load, and flexible processing options they've turned into pretty tempting functional ingredients (Sibanda, 2024). With improvements in how foods are prepared and handled, they can be blended into bakery goods, beverages, dairy style substitutes, gluten free items, extruded snacks, and complementary foods, even ready to eat formats. As a result, the nutritional value has gone up, plus the functional traits, and at the same time it fits the audience request for clean label products that still feel sustainable.

Innovative formulations, kinda in contrast with traditional food products, go for stronger sensory appeal, plus better shelf stability, more convenience, and also commercial scalability, along with nutritional upgrading (Njoroge et al., 2025).The production of value-added goods with improved nutritional bioavailability and desired physicochemical properties has been made easier by contemporary food technologies, such as extrusion cooking, fermentation, malting, encapsulation, spray drying, freeze drying, and composite flour technology. These developments have greatly increased the commercial uses of finger millet and moringa beyond home use into the functional and nutraceutical food sectors.

6.1 Bakery Products

As baked goods are popular among all age groups and offer a great means of nutritional fortification, they are among the most well studied uses of finger millet and moringa. In order to increase protein content, dietary fiber, mineral concentration, and antioxidant activity, researchers have effectively added finger millet flour and moringa leaf powder to bread, biscuits, cookies, muffins, cakes, crackers, and rusks. While finger millet adds resistant starch, slowly digesting carbs, and gluten-free functioning, fortification with moringa greatly increases the quantities of calcium, iron, β-carotene, and phenolic compounds (Deka et al., 2023).

Numerous studies have shown that substituting 10–30% finger millet flour for wheat flour enhances nutritional quality without negatively impacting dough handling or baking performance. In a similar vein, adding 2–10% moringa leaf powder significantly boosts nutritional density and antioxidant capability. However, adding too much moringa (more than 10%) might end up making the mixture look dark green, with an herbal vibe, plus maybe a subtle bitterness, and that could make the product less palatable for consumers. So in the end, finding the best replacement levels is still very crucial, to keep a proper balance between the sensory qualities people want and the nutritional advantage (Thobakgale, 2020).

6.2 Gluten-Free Products

The making of gluten-free functional foods has kind of been nudged along by the rising appearance of celiac disease and gluten sensitivity. In comparison with a lot of the store bought gluten-free cereals, finger millet seems to offer higher nutritional value and it is naturally gluten free, so that matters. Because of this, finger millet flour shows up in composite flour blends, gluten-free bread, cookies, pasta, morning cereals, and snack type items. When moringa is added, the micronutrient amount and protein quality are bumped up even more, which helps cover nutritional gaps that so often show up for people on gluten-free diets (Pandey, 2021).

From what recent studies say, hydrocolloids, enzymes, and composite flour techniques can step in for the missing gluten, mainly by making dough stability stronger, improving loaf volume, texture, and the overall quality of the final product. With that, customer acceptability of gluten-free finger millet goods should go up too (Rathnayake et al., 2018).

6.3 Extruded Snacks and Ready-to-Eat Products

One of the most significant technologies for creating nutrient-rich, shelf-stable ready-to-eat goods is extrusion cooking. In order to gelatinize starch, denature proteins, inactivate antinutritional substances, and increase digestibility while retaining high production efficiency, the method combines high temperature, pressure, and mechanical shear. Because of its dietary fiber content and starch composition, finger millet has shown outstanding extrusion capabilities. Finger millet based extruded treats tend to show better expansion, crispness, and in general more digestibility plus nutritional value (Yadav et al., 2022). And when moringa leaf powder is introduced, it just makes them even more interesting, like the snacks get additional antioxidants, vitamins, minerals and those bioactive phytochemicals kind of compounds (Trigo et al., 2023).

6.4 Functional Beverages

Functional drinks are one of the food industry’s fastest-growing corners. In a lot of cases, germination kicks up α-amylase activity, which lowers viscosity and makes it easier to produce nutrient-dense drinks that people can actually digest well. That’s why malted finger millet has been used for a long time to craft these kinds of nutrient-dense beverages. Modern formulations include dairy-based beverages, dairy-free plant beverages, fermented drinks, fast beverage powders, and probiotic formulations where malted finger millet is added in a more targeted way. Also, because moringa leaf powder or its aqueous extracts bring high micronutrient levels and antioxidant action, they have been used for herbal drinks and fortified drinks too. As per recent studies, if optimum formulations are used, then combining malted finger millet with moringa improves protein quality, raises calcium content, boosts antioxidant capacity, and increases overall functional value, while still keeping an acceptable taste profile (Sibanda et al., 2024).

6.5 Complementary and Therapeutic Foods

A pretty high nutritional density, a proper viscosity level, and digestion that is still acceptable are needful for complementary meals intended for newborns and young children. Malting helps with nutritional uptake and at the same time it significantly cuts down the viscosity of finger millet porridge, so the child can take in more nutrients per serving. Then, when moringa leaf powder is included, Protein shows better, and iron , calcium , provitamin A , carotenoids, and antioxidant content are all improved quite a lot. Because of that, these formulations have gotten quite a bit of attention as low cost supplemental foods that try to cover micronutrient gaps and protein energy malnutrition especially in low and middle income countries. If we compare complementary meals fortified with finger millet and moringa against older cereal based recipes, multiple studies report improved nutritional quality, better digestibility, and stronger functional properties (Khatiwada, 2026).

6.6 Pasta, Noodles, and Composite Flour Products

Finger millet is now being used in pasta, noodles, vermicelli, and even composite flour blends due to recent product development. When compared with refined wheat items, these kinds of foods have better mineral content, less glycaemic response, and more dietary fiber, which makes them feel more “supportive” for everyday choices. On top of that, the protein quality and antioxidant activity come up even further through moringa fortification, so overall they turn into better alternatives for frequent intake, not only once in a while (Malleshi et al., 2026).

According to research, modest replacement levels really can raise the nutritional content a lot, while still keeping the cooking quality, texture, and customer acceptance basically intact. So, using composite flour technology to weave both the elements in to staple meals, without making a major shift in the current production methods, is an effective choice, even if it sounds somewhat complicated at first (Poojara et al., 2025).

6.7 Current Challenges in Innovative Product Development

Even with a lot of progress there are still several hurdles when trying to make economically viable products that include malted finger millet along with moringa. With moringa, because of its chlorophyll concentration and that rather distinctive herbal flavor, using high amounts may end up affecting color, taste, and texture, kind of all at once. Also, products prepared from finger millet can come out harder and darker than products made from wheat. More work is still needed though, especially for standardizing processing conditions but also for tuning the ingredient proportions, then checking shelf life properly, doing consumer acceptability testing and figuring out how it performs in industrial-scale manufacturing. To boost nutritional quality while also keeping the sensory qualities people actually want, future work should lean on more advanced food processing methods, encapsulating bioactive substances in smart ways, precision formulation strategies, and AI assisted product optimization.

Table 2. Recent Studies (2020–2026) on Food Product Development Using *Moringa oleifera* and Malted Finger Millet

Authors (Year)	Product Developed	Ingredient(s)	Major Findings	Research Gap
Divya et al. (2024)	Functional foods (Review)	*Moringa oleifera*	Comprehensive evidence of nutritional and pharmacological properties	Limited human clinical studies
Kaur et al. (2024)	Food applications (Review)	Finger millet	High nutritional potential and broad food applications	Limited commercial-scale validation
Jaglan et al. (2025)	Industrial food applications (Review)	*Moringa oleifera*	Strong potential for functional food development	Need for formulation optimization
Gull et al. (2025)	Commercial food products (Review)	*Moringa oleifera*	Industrial and market potential highlighted	Shelf-life and consumer acceptance require further study
Siroha & Bangar (2024)	Millet-based food products (Review)	Finger millet	Diverse innovative products and processing methods	Limited comparative product evaluation
(Kumar, 2025)	Cookies, bread, muffins	Moringa + finger millet	Improved protein, fibre, antioxidant activity	Sensory optimization required
(Pongtong et al., 2026)	Extruded snacks	Finger millet	Enhanced digestibility and shelf stability	Scale-up studies lacking
(Patra et al., 2023)	Malt beverages	Malted finger millet + moringa	Improved nutrient density and antioxidant capacity	Clinical efficacy remains unclear
(Chiplonkar et al., 2022)	Infant formulations	Malted finger millet + moringa	Improved micronutrient density	Long-term intervention studies needed

Table 2 does a comparative summary, of the latest Scopus-indexed studies (2020–2026) about making food products with Moringa oleifera and malted finger millet. It kind of highlights how the formulations were made, what the main results were, and also where the research still kind of has missing parts or open questions. Overall it gives a, quick view of the directions taken, and the things that are not really settled yet.

7. PROCESSING TECHNOLOGIES FOR MORINGA AND MALTED RAGI-BASED FOOD PRODUCTS

The nutritional value, functional properties, sensory acceptability, safety, and the economic feasibility of food products prepared from Moringa oleifera and malted finger millet *(Eleusine coracana)* are heavily affected by processing methods, like for real. Besides making these nutrients more stable and easier to eat, careful processing also boosts nutrient absorption, reduces antinutritional components, and helps keep the bioactive chemicals in better condition. Even though traditional home style techniques such as soaking, germination, fermentation, roasting and drying are still widely used, more recent food engineering advances have introduced approaches like extrusion cooking, spray drying, freeze drying, encapsulation, and high-pressure processing. These newer methods help produce fresh functional foods with improved quality, plus longer shelf life (Kaur et al., 2024; Divya et al., 2024).

What matters most when selecting a processing method is the intended food use, the target consumer group, the nutritional objectives, and whether it actually makes economic sense. In general, contemporary processing is aiming to protect the desired sensory qualities, reduce processing losses that come along the way, and improve nutrient retention. So in order to commercialize functional foods made from finger millet and moringa, it's really important to understand how different processing techniques change the final product.

7.1 Malting (Germination)

One of the best ways to heighten finger millet's nutritional and functional edge is malting. During germination of the grain, then drying, plus a carefully regulated soaking step, the internal enzymes like α-amylase, proteases, and phytases start doing their job. In turn these enzymes make minerals more absorbable, protein digestion easier, and help carbohydrate utilization, because they cut up starch and storage proteins, while also chipping away phytates and other antinutritional compounds, even the plain ones you might not notice at first (Kaur et al., 2024). During germination, it turns out that the levels of free amino acids, B-complex vitamins, γ-aminobutyric acid (GABA) and also phenolic substances can go up, not only one thing. Then malting seems to reduce the viscosity of porridge, so it's easier to make nutrient-dense supplemental foods, which are fitting for clinical nutrition, for newborns and even for the elderly. In the meantime, malted finger millet has gained more and more weight as a component of quick drink blends, weaning meals, baked items, and health supplements, because of these nutritional as well as functional improvements (Sun Lee, 2025).

7.2 Fermentation

Through the metabolic processes of beneficial microorganisms, especially lactic acid bacteria and yeasts, fermentation is a classic bioprocess that improves food quality. When compared to unfermented goods, fermented finger millet products show better sensory qualities, higher B-group vitamins, decreased phytate levels, improved protein digestibility, and increased mineral bioavailability (Anal et al., 2024).

Additionally, fermentation helps produce volatile flavor compounds, bioactive peptides, and organic acids that enhance microbiological safety and product acceptance. Fermentation has demonstrated the capacity to lessen bitterness and increase the durability of several bioactive ingredients in moringa-based products, increasing its use in fermented meals and functional drinks (Divya et al., 2024).

7.3 Drying Technologies

Moringa leaves' high moisture content speeds up enzymatic and microbiological deterioration, hence drying is a crucial preservation technique. The preservation of nutrients, colour, fragrance, and antioxidant substances is greatly influenced by the drying process selected (Mehlomakulu & Emmambux, 2022). Although traditional sun drying is less expensive, it frequently leads to higher nutritional losses and contamination issues. Even though hot-air drying improves process control, heat-sensitive vitamins, like vitamin C, might get reduced anyway. Freeze drying, however, has shown a more favorable antioxidant activity with better carotenoids polyphenols and chlorophyll keeping. But then the thing is, its high operating cost keeps it from becoming widely used (Bhatta et al., 2020). To make moringa powders and beverage ingredients with improved dispersibility, and also longer storage durability, spray drying has in the last few years become more and more important (Divya et al., 2024 Jaglan et al., 2025).

7.4 Extrusion Cooking

Extrusion cooking makes ready-to-eat snacks, morning cereals and other quick bites by mixing really high temperature pressure plus mechanical shear together. It does not only support continuous, big-scale manufacturing but it also boosts starch gelatinization, knocks out harmful microbes, reduces antinutritional factors, and makes digestion easier (Isleroglu, 2025).

Since finger millet is rich in starch, it tends to work quite well for extrusion, while moringa brings along useful phytochemicals, and minerals too. For getting better product expansion and texture, but also keeping nutrients and satisfying customers, the extrusion settings like feed moisture, barrel temperature, screw speed and the ingredient ratio should really be tuned (Siroha & Bangar, 2024).

7.5 Composite Flour Technology

By mixing grains, legumes, fruits, vegetables, plus a few functional additives, composite flour technology seems to push nutrition higher while also reducing how much people lean on refined wheat flour (Akinwotu et al., 2025). In practice, breads, biscuits, cookies, cakes, noodles, pasta, and even the meals that go with them, all have been using composite flours built from finger millet together with moringa, and it works.

This approach also nudges the development of gluten-free products and at the same time it boosts protein quality, dietary fiber, calcium, iron, antioxidant output, and overall nutritional density. Still, if you add too much moringa it can shift the color, flavor, and texture, so formulation ratios should be tuned carefully (Gull et al., 2025).

7.6 Encapsulation of Bioactive Compounds

Encapsulation has kind of surfaced as a workable approach for protecting critical phytochemicals during processing and even storage. Bioactive substances from moringa, such as polyphenols, carotenoids, chlorophylls, and vitamins can be pretty easily damaged by oxygen, light, heat, and moisture (Zabot et al., 2022). So microencapsulation methods think spray drying, freeze drying, liposomes, or biopolymeric carriers can help make them more stable, enable a kind of controlled release, and also improve bioavailability for these compounds. Lately, research (Divya et al., 2024) has also been pointing out how encapsulated moringa extracts could fit into functional drinks, dairy alternatives, and nutraceutical items, especially in cases where keeping antioxidant activity intact is, like, the main concern .

7.7 Emerging Green Processing Technologies

Recent breakthroughs in sustainable food processing have developed a lot of non-thermal solutions that lower nutritional losses and at the same time improve food safety and overall quality. High pressure processing (HPP), pulsed electric fields (PEF), ultrasound assisted extraction, microwave assisted processing, and cold plasma therapy have shown promising uses for keeping bioactive compounds in place and extending shelf life, even when thermal damage is limited, or not substantial.

Even so, research that focuses on these technologies in moringa and finger millet based meals is still kinda restricted, but the early results are really encouraging: they suggest better processing efficiency, stronger nutritional retention, and improved industrial scalability. Moving forward, it would be wise to look at economic feasibility and how well these options actually fit commercial production, (Granato et al., 2020; Gull et al., 2025).

7.8 Processing Challenges and Future Technological Needs

Even with huge strides in technology, a lot of little and not so little hurdles still show up when trying to turn moringa and finger millet into really profitable, food products. There is variability in raw material quality, you know the seasonal swings in phytochemical composition, then the colour starts to shift in ways you don't want, and the flavour becomes a whole issue plus the

losses of heat-sensitive nutrients keep dragging down the end result. On top of that, industrial-scale standardization is often weak, processing parameters are not optimized well enough, and modern technologies cost way too much, so adoption stays limited.
For the future, research really should aim at bringing green processing methods together with careful process optimization, AI-supported formulation, predictive modeling, and sustainable manufacturing approaches. The goal is to improve nutritional quality while still keeping customer acceptability high and making sure the whole thing is economically feasible too.

8. CHALLENGES, RESEARCH GAPS, AND FUTURE PERSPECTIVES

The rising interest in Moringa oleifera as well as malted finger millet *(Eleusine coracana)* has led to big, kind of unexpected breakthroughs in producing functional and value-added food stuffs. A lot of studies have shown improvements in nutritional quality, better antioxidant activity, higher mineral content,and stronger functional qualities when these ingredients are blended into usual as well as newly made food blends. Still, even with all these promising findings, a bunch of scientific, technical, sensory, legal, and economic problems keep showing up, and they make wide adoption harder across the global food industry. In order to move lab-scale inventions into things that are commercially workable and also acceptable for everyday consumers, these obstacles have to be handled through multidisciplinary research (Divya et al., 2024; Kaur et al., 2024).
Even though there is an ever increasing amount of information available about *Moringa oleifera*, and about finger millet separately, most of the studies that got published tend to zoom in on nutrition, pharmacological effects, or on pretty standalone culinary habits. At the same time, a lot of earlier work seems to treat these materials like they should be used alone, and not really look at how they could work together, in a more complimentary way, especially when it comes to traditional plus creative food product making. As of now there still isn't a single, broad review that sort of pulls together and evaluates the nutritional quality, functional properties, processing methods, product development thinking, sensory impressions, commercialization opportunities, and the next research directions, all around the combined use of Moringa oleifera and malted finger millet in functional foods. This sort of missing piece is why an updated and comprehensive review is needed, so researchers can rely on stronger evidence and push forward more sustainable functional food innovation.

8.1 Standardization of Raw Materials

The notable variation in the nutritional profile of raw inputs is one of the principal obstacles, in building functional foods relying on finger millet and moringa, because it's not really stable. The level of proteins, minerals, vitamins, phenolic constituents and various bioactive materials can change, depending on cultivar, where the crop is grown, agronomic steps, weather conditions, the maturation period, harvesting season, and what happens after harvest during handling. Likewise, when germination situations shift, along with malting duration and drying practices, the nutritional quality of finger millet malt also moves around a bit.
So, future work should probably develop standardized methods for cultivation, harvesting, processing and quality assessment so that the nutritional composition and functional performance stay more uniform across the final food products (Jaglan et al., 2025).

8.2 Optimization of Processing Technologies

Even though standard processing steps like malting, fermentation, roasting, and drying tend to boost the nutritional value, there are still pretty big differences in how the processing parameters are set, and that keeps influencing product quality as well as nutrient retention. If the drying or baking stage gets too much heat, it can reduce heat sensitive vitamins, carotenoids, and phenolic compounds. On the other hand if the processing is too mild or incomplete, it may not remove the antinutritional elements strongly enough, and then the whole outcome feels less reliable. For the next studies, the focus should be on tuning those processing variables, perhaps using response surface methods, machine learning, and prediction tools powered by artificial intelligence. The goal would be to maximize nutrient retention while still keeping the sensory characteristics at a good level, plus not ruining industrial economic viability (Granato et al., 2020).

8.3 Sensory Acceptability and Consumer Preference

Consumer acceptability still is one of the major hurdles for commercializing goods that use moringa leaf powder. With high inclusion levels it can often show a dark green hue, a kind of herbal aroma, and a mildly bitter taste, and that can mess with overall take up. Also, products made with finger millet may show a darker color, a more dense texture, and reduced loaf volume, especially when they get swapped in at higher replacement levels for baking items.
Future research should dig into flavour masking tactics, and optimize ingredients and maybe use encapsulation technology in a more clever way, plus look at how consumers perceive it, via standardized sensory evaluation methods, with broad demographic groups included, too.
In addition, cross-cultural research are needed to identify regional differences in customer habits as well as readiness to purchase functional food products (Gull et al., 2025).

8.4 Limited Clinical Evidence

The antioxidant, antidiabetic, anti-inflammatory, antibacterial, and cardioprotective qualities of finger millet and moringa have been shown in a number of in vitro and animal studies; however, there are still few well-designed human clinical trials. As a result, nothing is known about these compounds' long-term effectiveness, ideal dose, bioavailability, and safety in various demographic groups.
In order to assess clinical outcomes pertaining to glycaemic management, cardiovascular health, and micronutrient status, cognitive function, immunological response, and metabolic diseases, future research should give priority to randomized controlled trials with sufficient sample sizes. Such proof would assist regulatory clearance for functional food applications and bolster health claims (Divya et al., 2024).

8.5 Bioavailability of Nutrients and Phytochemicals

The percentage of nutrients that the human body can absorb and use is not always reflected in a food product's nutritional content. While fermentation and malting significantly increase the bioavailability of minerals by lowering tannins and phytates, the absorption of a number of bioactive compounds has not been thoroughly studied.

To get a better understanding of nutrient bioaccessibility, absorption, metabolism, and physiological consequences, future research should use improved metabolomics, nutrigenomics, and simulated gastrointestinal digesting models. Instead of only increasing nutrient content, these methods will make it easier to create formulations with improved nutritional effectiveness (Kaur et al., 2024).

8.6 Shelf Life, Packaging, and Storage Stability

We still don't fully grasp how stable food items stay over long term when they're supplemented with malted finger millet and moringa. During storage, oxygen, light, temperature, and moisture exposure can slowly make bioactive chemicals, vitamins, carotenoids, and chlorophyll pigments start to break down. Because of that, future work should aim to boost product stability but also keep nutritional quality and consumer safety, so researchers may need to explore novel packaging techniques, active packaging materials, modified atmosphere packaging, biodegradable packaging, and natural preservatives. If shelf life gets modeled across different environmental conditions, then industrial commercialization would likely move forward more smoothly (Siroha & Bangar, 2024).

8.7 Regulatory and Commercialization Challenges

The legal frameworks that control functional food claims seem to differ a lot across nations, even though the scientific evidence keeps stacking up about the nutritional benefits of finger millet and mooring. On top of that, global commercialization is kind of slowed down by the absence of agreed upon benchmarks for ingredient quality, acceptable health claim wording, the labeling instructions, and also safety assessment procedures. So in practice, it feels like everything becomes harder, because there is no single standard everyone can point to.

To promote market expansion and customer trust, future initiatives should include harmonizing food rules, creating worldwide quality standards, and fostering cooperation between researchers, regulatory bodies, and the food business (Gull et al., 2025).

8.8 Sustainability and Future Food Systems

Interest in resilient and sustainable crops has increased due to climate change, population expansion, and growing strain on agricultural resources. While moringa exhibits quick growth, high biomass output, and the capacity to flourish in a variety of climatic situations, finger millet is known for its drought resistance, low water requirements, and adaptation to marginal areas. These qualities make both crops important contributions to global food security and sustainable food systems.

In order to maximize the benefits for the environment, money, and diet, upcoming studies really should bring in climate-smart farming techniques, life cycle assessment, a circular bioeconomy framework, and processing technologies that are sustainable. A few of the Sustainable Development Goals (SDGs) from the United Nations, especially SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-Being), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action), all seem to match the idea of weaving these crops into sustainable food systems (Anal et al., 2024; Kaur et al., 2024).

8.9 Future Research Priorities

Based on the evidence that is available right now, upcoming investigations should mostly focus on, a few priority angles, kind of:

- Using sophisticated modeling techniques, the malting, fermentation, extrusion, and drying processes are optimized.
- Standardizing the raw material quality along with the farming methods.
- Extensive randomized clinical studies to confirm health advantages.
- Extensive research in metabolomics, nutrigenomics, and nutritional bioavailability.
- AI-assisted functional food product optimization and formulation.
- The creation of customized, gluten-free, clean-label dietary products.
- Shelf-life extension technology and environmentally friendly packaging.
- Studies on industrial-scale commercialization and cost-effectiveness evaluations.
- Harmonization of global functional food regulations.
- An assessment of the life cycle effects and environmental sustainability of goods made from finger millet and moringa.

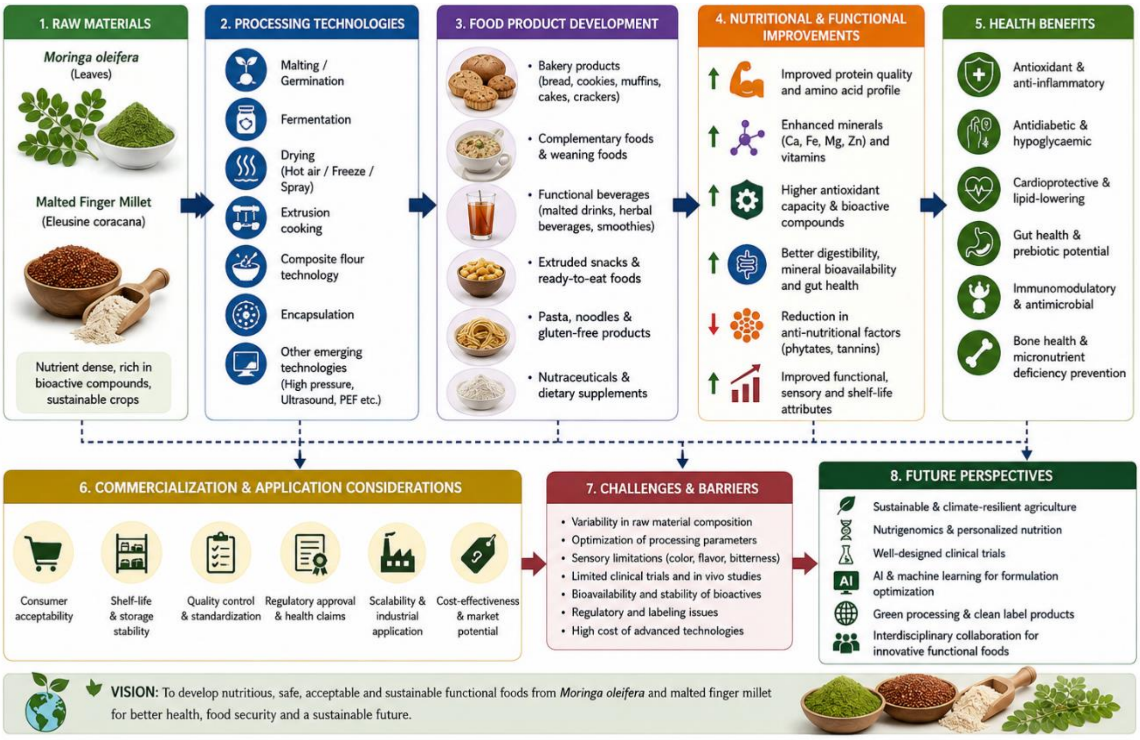

Figure 3. Integrated Framework for Development of Functional Foods from *Moringa oleifera* and Malted Finger Millet

Figure 3 lays out a kind of all-encompassing path for putting together beneficial meals with malted finger millet and Moringa oleifera. It sort of points at how these ingredients can support sustainable, and also health promoting food systems, by showing the whole journey, from the raw materials, through processing technologies and then into product development. After that it moves into nutritional enhancements and health benefits, then commercialization steps and even future research prospects. When taken as a whole, these research goals will improve the body of scientific knowledge, make commercialization easier, and encourage the incorporation of malted finger millet and Moringa oleifera into sustainable, health-promoting food systems.

9. CONCLUSION

The need for sustainable nutrient dense and functional food ingredients that can help maintain resilient food systems and also improve public health has really gone up, mostly because the global burden of non-communicable illnesses and malnutrition is increasing and on top of that we're seeing more environmental issues. In this area, Moringa oleifera along with malted finger millet, (Eleusine coracana) has become particularly appealing as functional ingredients, due to their kind of complementary nutritional make up, their wide selection of bioactive chemicals, and the fact they work in a broad range of uses both in everyday foods and in newer, less standard food items. This study kind of gives a wide view of how well these things can help with better, more sustainable food routines, by pulling together the newest findings on nutritional quality, their functional qualities, the processing methods, plus how food products get developed and what might happen next. It sorta connects the dots, even when the details get a bit scattered.

From the checked material, Moringa oleifera shows up as a pretty remarkable source of high quality protein, the essential amino acids, plus vitamins, minerals, carotenoids, polyphenols, glucosinolates, and flavonoids, too. It also seems to carry antioxidant, anti-inflammatory antimicrobial, antidiabetic, cardioprotective, and immunomodulatory properties, in a pretty broad sense. In a similar kind of way, finger millet is a crucial grain for backing metabolic health and helping fend off micronutrient shortfalls, mainly because it has high calcium, dietary fiber, resistant starch, carbs that digest more slowly, key minerals, and phenolic compounds. And when malting is used, the nutritional value of finger millet gets a strong boost. This happens by improving protein digestibility, increasing mineral bioavailability, reducing antinutritional factors and in parallel raising the levels of beneficial phytochemicals, which is kind of the main point overall.

A solid scientific base for building nutrient-enriched functional meals that can help with many types of malnutrition is given by the complementary nutritional characteristics of moringa and malted finger millet. Put together, they tend to boost protein quality, dietary fiber, mineral levels, antioxidant potential, and the overall nutritional worth in baked items, gluten free foods, complementary feeds, drinks, extruded snacks, pasta, composite flour blends, and ready to eat products. Still, how far these gains go really depends on the formulation ways that get refined, even while keeping acceptable technological performance, plus good sensory feel.

The analysis also show that the quality and usability of goods made from these ingredients are quite influenced by processing procedure. While newer technologies like extrusion cooking, encapsulation, spray drying, freeze drying, high-pressure processing, and other non-thermal approaches give chances to boost bioactive compound retention, product firmness, and industrial scaling, traditional methods like malting, fermentation, soaking, and drying are still effective, for raising nutrient availability and lowering anti nutrient compounds. To maximize nutritional benefit and keep customer acceptance steady, these technologies has to continue being optimized, or well adapted.

There are still a number of scientific and technical gaps, even with all the positive advancements. Big scale commercialization is still held back by variations in the content of raw materials, and by the fact that standardized processing techniques are not really there, plus a lack of clinical data, poor comprehension of nutritional bioavailability, and also the lack of unified regulatory

frameworks. On top of that, only a limited number of studies have looked at the use of malted finger millet together with moringa within functional food systems, which points to a crucial area for future interdisciplinary work. For strengthening the scientific backing for health claims and for industrial uses, more attention should be given to randomized clinical trials, metabolomics, nutrigenomics, artificial intelligence assisted product optimization, sustainable processing technologies, and life cycle assessment.
From a sustainability standpoint, both crops kinda fit with international initiatives to build resource-efficient and climate-resilient food systems. While moringa shows quick growth, high biomass output, and a quite remarkable nutritional density, finger millet is often recognized for drought resistance, low water needs, and the ability to adapt to marginal areas. So basically, bringing them into food systems creates some opportunities to boost food and nutrition security, diversify agricultural production, reduce dependence on resource-intensive crops, and back several Sustainable Development Goals of the United Nations, especially the ones linked to zero hunger, good health and well-being, responsible consumption and production, and climate action.
All in all, malted finger millet and Moringa oleifera feel like theyre complimentary functional ingredients, with real potential for making food that is more sustainable, reasonably priced, and honestly more nutritionally strong. Theres a decent basis for using them more often in both wealthier and low income nations, coming from a sort of overlap between long standing tradition, modern food processing know-how, and nutrition research that is actually evidence based. If the aim is to turn what science already knows into products that do well commercially, while also improving nutritional security, boosting everyday public health, and helping a more sustainable global food system, then future teamwork between researchers, food technologists, clinicians, policymakers, and people in the food industry will be key, really key.

References

[1] Akinwotu, K. O., Taiwo, K. A., & Ikujenlola, A. V. (2025). Advancements in Composite Flours: Applications, Nutritional Benefits and Processing Techniques. *Asian Food Science Journal*, *24*(6), 24-36.

[2] Alegbeleye, O. O. (2018). *How functional is Moringa oleifera? A review of its nutritive, medicinal, and socioeconomic potential*. *Food and Nutrition Bulletin, 39*(1), 149–170. https://doi.org/10.1177/0379572117749814

[3] Anal, A. K., Singh, R., Rice, D., Hazarika, U., Trivedi, D., & Karki, S. (2024). *Millets as supergrains: A holistic approach for sustainable and healthy food product development*. *Sustainable Food Technology, 2*, 908–925. https://doi.org/10.1039/D4FB00047A

[4] Anshu, Ladher, N., & Kumar, A. (2025). Innovation in functional bakery products: Formulation and analysis of moringa-fortified millet cookies. *Journal of Food Measurement and Characterization*. https://doi.org/10.1007/s11694-025-03665-0

[5] Ashoka, P., Raut, D., Sudeepthi, B., Gawande, K. N., Reddy, G. S. V., Padhan, S. R., & Panigrahi, C. K. (2023). Millet's role as a climate resilient staple for future food security: a review. *International Journal of Environment and Climate Change*, *13*(11), 4542-4552.

[6] Bhatta, S., Stevanovic Janezic, T., & Ratti, C. (2020). Freeze-drying of plant-based foods. *Foods*, *9*(1), 87.

[7] Chandra, D. (2022). Development Of Cereal Based Value Added Products Using Drumstick (Moringa Oleifera) & Flaxseed And Their Quality Assessment. *Agricultural Engineering (Process & Food Engineering)*.

[8] Chellappan, B. V., & Peramaiyan, R. (2024). Unleashing the potential of millets: a comprehensive review of its nutritional, therapeutic, and genomic attributes. *Journal of Biological Research*, *97*(1).

[9] Chiplonkar, S., Kajale, N. A., & Sanwalka, N. (2022). A Review of Food-Based Intervention Strategies for Improving Micronutrient Status and Health During Childhood. *Current Research in Nutrition & Food Science*, *10*(2), 407.

[10] Deka, G., Dutta, H., & Sharma, P. (2023). A review: Hydrothermal processing of millets and effect on techno-functional and nutritional properties. *Journal of Food Process Engineering*, *46*(9), e14408.

[11] Devi, P. B., Vijayabharathi, R., Sathyabama, S., Malleshi, N. G., & Priyadarisini, V. B. (2014). *Health benefits of finger millet (Eleusine coracana L.) polyphenols and dietary fiber: A review*. *Journal of Food Science and Technology, 51*(6), 1021–1040. https://doi.org/10.1007/s13197-011-0584-9

[12] Divya, S., Pandey, V. K., Dixit, R., Rustagi, S., Suthar, T., Atuahene, D., Nagy, V., Ungai, D., Ahmed, A. E. M., Kovács, B., & Shaikh, A. M. (2024). *Exploring the phytochemical, pharmacological and nutritional properties of Moringa oleifera: A comprehensive review*. *Nutrients, 16*(19), 3423. https://doi.org/10.3390/nu16193423

[13] Falowo, A. B., Mukumbo, F. E., Idamokoro, E. M., Lorenzo, J. M., Afolayan, A. J., & Muchenje, V. (2018). *Multi-functional application of Moringa oleifera Lam. in nutrition and animal food products: A review*. *Food Research International, 106*, 317–334. https://doi.org/10.1016/j.foodres.2017.12.079

[14] Fekete, M., Lehoczki, A., Kryczyk-Poprawa, A., Zábó, V., Varga, J. T., Bálint, M., ... & Varga, P. (2025). Functional foods in modern nutrition science: mechanisms, evidence, and public health implications. *Nutrients*, *17*(13), 2153.

[15] Gopalakrishnan, L., Doriya, K., & Kumar, D. S. (2016). *Moringa oleifera: A review on nutritive importance and its medicinal application*. *Food Science and Human Wellness, 5*(2), 49–56. https://doi.org/10.1016/j.fshw.2016.04.001

[16] Granato, D., Barba, F. J., Bursać Kovačević, D., Lorenzo, J. M., Cruz, A. G., & Putnik, P. (2020). *Functional foods: Product development, technological trends, efficacy testing, and safety*. *Annual Review of Food Science and Technology, 11*, 93–118. https://doi.org/10.1146/annurev-food-032519-051708

[17] Gull, T., Nouman, W., & Olson, M. E. (2025). *Industrial applications, toxicological impact and marketing trends of Moringa oleifera food products: A review*. *South African Journal of Botany, 176*, 141–157. https://doi.org/10.1016/j.sajb.2024.11.012

[18] Isleroglu, H. (2025). Hot-Extrusion Technology for Production of Cereal-Based Ready-to-Eat Snacks. In *Ready-to-Eat Snacks* (pp. 159-215). Apple Academic Press.

[19] Jagati, P., Mahapatra, I., & Dash, D. (2021). Finger millet (Ragi) as an essential dietary supplement with key health benefits: A review. *International Journal of Home Science*, *7*(2), 94-100.

[20] Jaglan, P., Kaushik, D., Kumar, M., Singh, J., Oz, F., Shubham, S., Bansal, V., Proestos, C., Kumar, V., & Rani, R. (2025). *A critical review on Moringa oleifera: Current status, physicochemical attributes, and food industrial applications*. *Natural Product Research, 39*(8), 2293–2307. https://doi.org/10.1080/14786419.2024.2387833

[21] Kaur, S., Kumari, A., Seem, K., et al. (2024). *Finger millet (Eleusine coracana L.): From staple to superfood—A comprehensive review on nutritional, bioactive, industrial, and climate resilience potential*. *Planta, 260*, 75. https://doi.org/10.1007/s00425-024-04502-2

[22] Khatiwada, R. (2026). *Optimization Of Weaning Food Using Locally Available Ingredients* (Doctoral Dissertation, Department Of Food Technology Central Campus Of Technology Institute Of Science And Technology Tribhuvan University, Nepal 2023).

[23] Kumar, A. (2025). Innovation in functional bakery products: formulation and analysis of moringa-fortified millet cookies. *Journal of Food Measurement and Characterization*, *19*(12), 10449-10467.

[24] Leone, A., Spada, A., Battezzati, A., Schiraldi, A., Aristil, J., & Bertoli, S. (2015). *Cultivation, genetic, ethnopharmacology, phytochemistry and pharmacology of Moringa oleifera leaves: An overview*. *International Journal of Molecular Sciences, 16*(6), 12791–12835. https://doi.org/10.3390/ijms160612791

[25] Malleshi, N., Kannan, S., Malleshi, S. N., & Manickavasagan, A. (2026). Finger millet (Eleusine coracana) malt: A comprehensive review of its preparation, and functional properties, nutritional benefits, and novel food product formulations. *Food Reviews International*, *42*(3), 1186-1213.

[26] Malleshi, N., Kannan, S., Malleshi, S. N., & Manickavasagan, A. (2026). Finger millet (Eleusine coracana) malt: A comprehensive review of its preparation, and functional properties, nutritional benefits, and novel food product formulations. *Food Reviews International*, *42*(3), 1186-1213.

[27] Mbikay, M. (2012). *Therapeutic potential of Moringa oleifera leaves in chronic hyperglycemia and dyslipidemia: A review*. *Frontiers in Pharmacology, 3*, 24. https://doi.org/10.3389/fphar.2012.00024

[28] Mehlomakulu, N. N., & Emmambux, M. N. (2022). Nutritional quality of wet and dry processed Moringa oleifera Lam. leaves: a review. *Food Reviews International*, *38*(8), 1635-1655.

[29] Mitra, S., et al. (2023). *Finger millet: Nutritional quality, processing technologies, health benefits and food applications—A review*. *Journal of Agriculture and Food Research, 13*, 100653.

[30] Njoroge, J. W., Phonphimai, P., Khatmorn, P., Ketnawa, S., Tonkla, P., Vong, V., ... & Donlao, N. (2025). Valorization of Sacha Inchi press cake: Technological advances, market, and regulatory considerations for sustainable food applications.

[31] Page, M. J., McKenzie, J. E., Bossuyt, P. M., et al. (2021). *The PRISMA 2020 statement: An updated guideline for reporting systematic reviews*. *BMJ, 372*, n71. https://doi.org/10.1136/bmj.n71

[32] Pandey, S. (2021). Nutritional aspects and health implications of gluten-free products. In *Challenges and Potential Solutions in Gluten Free Product Development* (pp. 17-34). Cham: Springer International Publishing.

[33] Patra, M., Bashir, O., Amin, T., Wani, A. W., Shams, R., Chaudhary, K. S., ... & Manzoor, S. (2023). A comprehensive review on functional beverages from cereal grains-characterization of nutraceutical potential, processing technologies and product types. *Heliyon*, *9*(6).

[34] Pongtong, K., Singh, R., Gamonpilas, C., & Anal, A. K. (2026). Advanced millet protein processing for designing plant-based whole foods: a review. *Journal of the Science of Food and Agriculture*, *106*(7), 3925-3937.

[35] Poojara, R. H., PS, S., Rose, A., & Somarajan, N. (2025). Composite flours for sustainable food systems: Integrating nutritional, environmental, and climate resilience strategies. *Journal of Environmental Science and Sustainable Development*, *8*(2), 490-522.

[36] Rathnayake, H. A., Navaratne, S. B., & Navaratne, C. M. (2018). Porous crumb structure of leavened baked products. *International journal of food science*, *2018*(1), 8187318.

[37] Roopashri, A. N., Savitha, J., Divyashree, M. S., Mamatha, B. S., Rani, K. U., & Kumar, A. (2023). Indian traditional fermented foods: the role of lactic acid bacteria. In *Lactobacillus-A multifunctional genus*. IntechOpen.

[38] Sadh, P. K., Kamboj, A., Kumar, S., Chawla, P., Kumar, R., Saharan, B. S., Kumar, D., Duhan, S., Nehra, M., Goyal, C., Brar, B., Joshi, S., & Duhan, J. S. (2024).

[39] Sahu, D. (2020). Studies On Drying Behaviour And Qualitative Analysis Of Moringa (Moringa Oleifera) Leaves.

[40] Shobana, S., Krishnaswamy, K., Sudha, V., Malleshi, N. G., Anjana, R. M., Palaniappan, L., & Mohan, V. (2013). *Finger millet (Eleusine coracana L.): A review of its nutritional properties, processing, and plausible health benefits*. *Advances in Food and Nutrition Research, 69*, 1–39. https://doi.org/10.1016/B978-0-12-410540-9.00001-6

[41] Sibanda, F. (2024). *Nutritional, biochemical and physicochemical properties of Pearl millet and moringa oleifera composite food products* (Doctoral dissertation, Cape Peninsula University of Technology).

[42] Sibanda, F., Jideani, V. A., & Obilana, A. O. (2024). Nutritional, biochemical, and functional properties of pearl millet and Moringa oleifera leaf powder composite meal powders. *Foods*, *13*(5), 743.

[43] Siroha, A. K., & Bangar, S. P. (2024). *Millet-based food products: An overview*. *Current Food Science and Technology Reports*, *2*, 213–220. https://doi.org/10.1007/s43555-024-00031-x

[44] Sun, Y., Li, C., & Lee, A. (2025). Sprouted grains as a source of bioactive compounds for modulating insulin resistance. *Applied Sciences*, *15*(15), 8574.

[45] Taylor, J. R. N., & Emmambux, M. N. (2008). *Gluten-free foods and beverages from millets*. In E. Arendt & F. Dal Bello (Eds.), *Gluten-Free Cereal Products and Beverages* (pp. 119–148). Academic Press.

[46] Thobakgale, M. R. (2020). *Quality characteristics of a functional beverage developed from Moringa oleifera and Aloe vera*. University of Johannesburg (South Africa).

[47] Trigo, C., Castelló, M. L., & Ortolá, M. D. (2023). Potentiality of Moringa oleifera as a nutritive ingredient in different food matrices. *Plant Foods for Human Nutrition*, *78*(1), 25-37.

[48] Van der Merwe, R. (2017). *Pearl millet porridge: improvement in iron and zinc bioaccessibilities through fortification with micronutrient-rich plant food components*. University of Pretoria (South Africa).

[49] Yadav, G. P., Dalbhagat, C. G., & Mishra, H. N. (2022). Effects of extrusion process parameters on cooking characteristics and physicochemical, textural, thermal, pasting, microstructure, and nutritional properties of millet-based extruded products: A review. *Journal of Food Process Engineering*, *45*(9), e14106.

[50] Zabot, G. L., Schaefer Rodrigues, F., Polano Ody, L., Vinícius Tres, M., Herrera, E., Palacin, H., ... & Olivera-Montenegro, L. (2022). Encapsulation of bioactive compounds for food and agricultural applications. *Polymers*, *14*(19), 4194.