



ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2026): 4.97
IJAFS 2026; 8(3): 01-07
www.agriculturaljournals.com
Received: 02-12-2025
Accepted: 15-01-2026

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Rice beyond staple food: Advances in value added rice products: A review

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DOI: <https://www.doi.org/10.33545/2664844X.2026.v8.i3a.1225>

Abstract

Rice (*Oryza sativa* L.) serves as a primary staple food for more than half of the global population, playing a crucial role in food security, nutrition, and cultural traditions, particularly across Asia. Rice has changed from being a traditional staple to a versatile raw material for a wide range of value added products due to rapid urbanisation, changes in lifestyle, and the growing need for convenience and functional foods. This review critically synthesises traditional knowledge and recent scientific advancements in value added rice products, including whole rice based foods, fermented products, extruded and fortified rice, rice based beverages, germinated brown rice, instant rice, and new uses like space nutrition. Processing technologies, nutritional and physicochemical changes, functional advantages, and public health significance are highlighted. The review emphasises how technological interventions including parboiling, fermentation, extrusion, germination, and fortification improve nutritional quality, shelf stability, and consumer acceptance. There is also discussion of future research goals and obstacles in the areas of functional food production, scalability, and the effectiveness of fortification.

Keywords: Rice, functional foods, fermentation, fortification, instant rice

1. Introduction

Rice has sustained human civilisation for thousands of years and is the main energy source for almost 3.5 billion people globally (FAO, 2022). Nutritional and socioeconomic significance of rice is shown by the fact that it accounts for up to 50% of daily calorie consumption in many Asian nations. Rice was once consumed as cooked whole grains, but industrialisation, globalisation, and advancements in food science and technology have significantly changed how rice is processed and used. The development of value added rice products has accelerated due to shifting customer preferences toward convenience, health conscious diets, and functional foods (Jin *et al.*, 2023) ^[13].

Value addition is the process of improving the nutritional, functional, sensory, or economic value of a raw material through innovation and processing. Physical processing (parboiling, puffing, flaking), biochemical alteration (fermentation, germination), structural transformation (extrusion), and nutritional enhancement (fortification) are examples of value addition in rice. These approaches address micronutrient shortages and new lifestyle related health issues in addition to increasing shelf life and palatability (Prinyawiwatkul, 2024) ^[28]. This review integrates the most recent information on value added rice products, connecting conventional methods with cutting edge technology developments.

2. Structure and nutritional composition of rice

The four main anatomical parts of rice are the husk, bran, germ, and endosperm. Because of its high cellulose and silica content and outer protective layer, the husk is unfit for direct human ingestion. The bran layer, which is nutritionally dense and contains dietary fibre, essential fatty acids, B-complex vitamins, minerals, and bioactive substances, is located beneath the husk. The endosperm makes up the majority of the grain and is mainly used as a

carbohydrate reserve, whereas the germ, despite its tiny size, is rich in vitamins, antioxidants, and lipids (Shafie and Esa, 2017) ^[29]. White rice with a lower micronutrient content is produced by milling and polishing to remove the bran and germ. Value addition techniques including parboiling, fortification, and using brown and germinated rice are necessary to improve nutritional quality, even if white rice has a higher digestibility and a longer shelf life due to nutrient losses during milling (Thomas *et al.*, 2023) ^[34].

Table 1: Nutritional composition of rice

Component	Amount (per 100 g)
Energy	345 kcal
Carbohydrates	78.2 g
Protein	6.8 g
Fat	0.5 g
Dietary Fibre	0.2 g
Calcium	10 mg
Phosphorus	160 mg
Iron	0.7 mg
Thiamine (Vit. B1)	0.06 mg
Riboflavin (Vit. B2)	0.06 mg
Niacin (Vit. B3)	1.9 mg

Source: NIN, 2017

3. Whole rice based value added products

3.1 Raw rice

Raw rice is rice that has been dehusked but not parboiled, and may be consumed as brown rice or further milled into white rice. It is a staple food valued for its mild flavour, versatility, and wide culinary use. Its processing involves harvesting, drying, dehusking, milling, grading, and storage to ensure quality and safety. Modern mechanised milling has replaced traditional methods, improving efficiency, hygiene, and uniform grain quality (Singh *et al.*, 2013) ^[30]. The processing of raw rice comprises a sequence of scientifically controlled post-harvest operations designed to preserve grain quality, safety, and market acceptability. Harvesting at physiological maturity minimizes grain damage, while drying reduces moisture to safe storage levels and prevents microbial spoilage. Grading and sorting ensure uniformity and purity, and controlled packaging and storage conditions preserve quality and extend shelf life. (Muller *et al.*, 2022) ^[23].

Raw rice recovery is an important indicator of milling efficiency and is influenced by factors such as paddy variety, grain maturity, moisture content during milling, and the degree of polishing. Proper drying and conditioning of paddy prior to milling help minimise kernel breakage and enhance milling performance, thereby improving the yield of marketable rice (Mihretu, 2025) ^[18]. Overall, efficient processing and optimized milling conditions are essential for maximizing raw rice quality and recovery, thereby ensuring its nutritional value, marketability, and suitability for large-scale consumption.

3.2 Parboiled rice

Parboiled rice is produced by subjecting paddy to a hydrothermal treatment involving soaking, steaming, and drying before milling. This process induces starch gelatinisation and facilitates the migration of water soluble nutrients from the bran into the endosperm, resulting in improved nutrient retention and altered grain characteristics (Bhattacharya, 2011) ^[4]. Beyond its basic hydrothermal processing, parboiling significantly modifies the

physicochemical and structural properties of rice kernels. During the treatment, partial starch gelatinisation strengthens the endosperm matrix, which enhances grain hardness and reduces fissuring during subsequent milling operations. This structural reinforcement contributes to higher head rice yield and lower breakage compared to non-parboiled rice. At the same time, the heat-moisture interaction promotes protein-starch interactions and lipid complex formation, resulting in a more compact granule arrangement and altered cooking behaviour. These changes account for the firmer texture, reduced stickiness, and increased cooking tolerance commonly observed in parboiled rice (Muchlisriyah *et al.*, 2023) ^[22]. Parboiled rice, which is generally less sticky than non-parboiled rice, is preferred by consumers in some South Asian regions because it matches their traditional taste expectations. Additionally, because of its superior nutritional qualities over non-parboiled rice, health conscious consumers favour it (Oli *et al.*, 2014) ^[26]. Studies have reported that consumption of parboiled brown rice is associated with reduced post-prandial blood glucose responses, highlighting its potential nutritional advantages (Bhar *et al.*, 2022) ^[3]. From a nutritional standpoint, parboiling modifies starch structure through the formation of retrograded starch and amylose-lipid complexes during cooling and drying, increasing slowly digestible and resistant starch fractions that reduce enzymatic hydrolysis and moderate post-prandial glycaemic response. Simultaneously, thermal inactivation of endogenous enzymes enhances storage stability by limiting lipid oxidation and microbial susceptibility, collectively conferring both nutritional and technological advantages to parboiled rice (Kumar *et al.*, 2022; Garg *et al.*, 2024) ^[14, 9].

3.3 Flaked, popped and puffed rice

Flaked, popped, and puffed rice are value added products obtained through the application of controlled heat, moisture, and mechanical forces that induce significant physical and structural transformations in rice grains. In the production of popped and puffed rice, grains are exposed to high temperatures and pressures, leading to rapid moisture evaporation and expansion of the starch matrix. This sudden pressure release causes the endosperm to inflate, producing a light, porous structure with low bulk density. Traditionally, these products were prepared using pan heating or sand roasting methods; however, modern industrial processes employ extrusion cooking and pressure-puffing technologies to achieve uniform expansion, improved hygiene, and consistent product quality (Mishra *et al.*, 2014) ^[19].

Flaked rice, commonly known as *poha*, is produced through a sequence of soaking, steaming, flattening, and drying operations. Soaking increases kernel moisture, while steaming induces partial starch gelatinisation, softening the grain structure and imparting flexibility. This structural modification allows the grains to be flattened without fracture during rolling. The subsequent drying step stabilizes the product by reducing moisture content, thereby enhancing shelf life. Owing to its thin structure and pre-gelatinised starch, flaked rice exhibits rapid rehydration, short cooking time, and easy digestibility, making it suitable for both traditional preparations and convenience foods (Kumar *et al.*, 2018) ^[16]. The presence of expanded, pre-gelatinised starch in popped, puffed, and flaked rice enhances

enzymatic accessibility and rapid digestibility, supporting quick energy release, while their light texture, shelf stability, and formulation versatility have promoted widespread use in ready to eat cereals and snack products, reflecting a convergence of traditional processing and modern food technologies.

4. Fermented rice products

Fermentation is one of the oldest and most effective value-addition techniques in rice processing. Effective fermentation improves nutrient bioavailability of rice and fosters greater health advantages. Fermented rice is preferred in many cultures due to its health benefits and delicious flavor. The fermentation process supports immune and gut health by enriching the food matrix with beneficial microorganisms, thereby imparting probiotic potential (Fitri *et al.*, 2025) ^[7].

Traditional fermented rice-based foods such as *idli*, *dosa* and *appam* rely on the synergistic metabolic activity of lactic acid bacteria and yeasts. These microorganisms hydrolyse complex carbohydrates and proteins, leading to improved protein quality, enhanced mineral bioavailability through phytate degradation, and increased levels of B-complex vitamins. The reduction in pH during fermentation not only contributes to characteristic sour notes and soft texture but also improves microbial safety and shelf stability. In addition, organic acids produced during fermentation enhance enzymatic activity and nutrient absorption in the gastrointestinal tract (Suryawanshi, 2018; Mishra *et al.*, 2022) ^[33, 20].

Beyond traditional foods, controlled saccharification and fermentation processes are employed in the production of rice-based alcoholic beverages and vinegars, where microbial conversion of starch-derived sugars into ethanol and organic acids contributes to flavour complexity and functional attributes. Fermentation of rice water has also gained attention for its antioxidant activity, probiotic potential, and traditional applications in digestive and skin health (Mishra *et al.*, 2022) ^[20]. Collectively, fermented rice products exemplify how microbial biotransformation can improve nutritional quality, sensory appeal and health functionality, bridging traditional dietary practices with emerging interest in functional and probiotic foods.

5. Extruded rice products

A high temperature, quick thermomechanical method called extrusion cooking turns broken rice or rice flour into a range of ready to eat and ready to cook goods. Starch gelatinisation, protein denaturation, and structural expansion take place during extrusion, producing porous products with improved rehydration and digestibility (Mishra *et al.*, 2014) ^[19]. These structural transformations also improve enzyme accessibility to starch, thereby influencing glycaemic response and nutrient bioavailability. Common extruded rice-based products include snacks, breakfast cereals, noodles, fortified rice kernels, and infant foods.

Thermo-mechanical extrusion involves processing rice flour, broken rice, or composite blends under controlled HTST conditions characterized by extreme shear forces, elevated barrel temperatures, and pressure gradients. These conditions promote the formation of lipid-starch complexes, amylose-amylopectin reorganization, and protein unfolding, followed by rapid expansion at the die exit due to sudden pressure release. The resulting cellular matrix and porosity

significantly affect textural attributes such as crispness, hardness, and bulk density. Product functionality is largely governed by feed moisture, extrusion temperature, screw configuration and speed and formulation, enabling precise tailoring of product quality, digestibility, and sensory acceptance (Dalbhagat and Mishra, 2019) ^[5].

Advancements in extrusion technology have enabled the incorporation of pulses, oilseed by-products, dietary fibre, and bioactive ingredients into rice based matrices, leading to the development of nutritionally enriched composite foods. Controlled extrusion conditions facilitate protein–starch interactions and fibre integration without compromising product expansion or palatability. Moreover, extrusion has been shown to reduce antinutritional factors such as phytates and enzyme inhibitors, thereby enhancing mineral bioavailability. Of particular public health significance are extruded fortified rice kernels, which serve as effective carriers for micronutrients such as iron, zinc, folic acid, and vitamin B-complex, contributing to the prevention of micronutrient deficiencies at the population level (Acharya *et al.*, 2025) ^[1].

6. Fortified rice and public health significance

According to FSSAI (2018) ^[8] rice fortification is a scientifically validated and cost-effective intervention for addressing widespread micronutrient deficiencies, particularly iron, folic acid, vitamin B₁₂, and zinc, among populations with high rice consumption. Fortified rice is typically produced by blending extruded fortified rice kernels (FRK) with conventional milled rice at standardized ratios, most commonly 1:100, depending on the target micronutrient levels and national regulatory guidelines. This blending approach ensures homogeneous micronutrient distribution across the rice batch while preserving the sensory, cooking, and textural attributes of native rice grains. The fortified rice kernels are engineered to closely mimic the size, shape, density, and cooking behaviour of natural rice, thereby preventing segregation during handling, storage, and transportation. In India, rice fortification has been strategically integrated into national nutrition programs such as the Public Distribution System (PDS), the Mid-Day Meal Scheme, and the Integrated Child Development Services (ICDS). Programmatic evaluations demonstrate significant improvements in haemoglobin levels, iron stores, and overall micronutrient status among children, adolescents, and women of reproductive age. From a public health perspective, the use of standardized blending ratios enables large-scale implementation without requiring changes in dietary habits, infrastructure, or cooking practices, thereby enhancing compliance and impact.

7. Instant rice

Over the past few decades, shifts in lifestyle patterns, rising per capita income, the expansion of nuclear family structures, and increased participation of women in the workforce have collectively reshaped global food consumption behaviour. These socio-economic transitions have led to a marked increase in the demand for convenient and ready to consume foods in recent years (Srinivasan and Shende, 2016) ^[32]. Instant rice is designed for rapid preparation and can be cooked and served within approximately 2 to 15 minutes (Herawat *et al.*, 2014) ^[12]. The soaking, cooking, and drying processes used to make instant rice have a significant impact on the cooked rice's

sensory attributes. Drying is an extremely important phase that can be done in a single step at a low temperature for a longer period of time or in multiple steps at a higher temperature for a shorter period of time to lessen the chance of case hardening (Mridula *et al.*, 2017) ^[21]. It is a dried and precooked rice product made to be quickly prepared without sacrificing flavour or nutrition. To gelatinize starch, premium rice is fully boiled after being soaked, occasionally with a salt pretreatment. After that, it is dried via freeze drying, air drying, or extrusion to produce a porous structure

that allows for rapid rehydration in three to five minutes. Instant rice is perfect for space missions, emergency use, and quick meals because of its low moisture content and barrier packaging, which guarantee long shelf life, safety, and convenience (Yadav *et al.*, 2024) ^[36]. Yu *et al.* (2017) ^[37] outlines the main stages in rice processing, including pre-cooking, cooking, and post-cooking operations shown in fig 1. It shows how controlled cooling, drying, and storage convert conventionally cooked rice into instant rice with rapid rehydration ability.

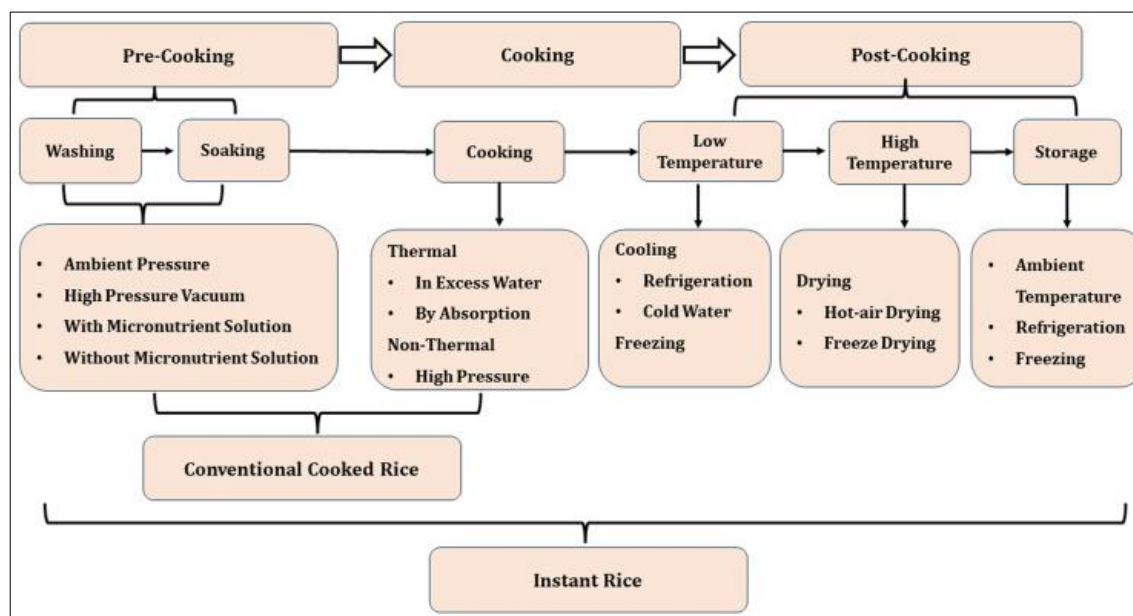


Fig 1: Processing of instant rice

Beyond terrestrial nutrition, rice-based foods also hold strategic importance in space and defence nutrition due to their high carbohydrate density, digestibility. In India, the Defence Food Research Laboratory (DFRL) has developed instant and shelf-stable rice based ready to eat meals using retort processing and dehydration technologies for space and high altitude applications. (Kumar and Gaikwad, 2023) ^[15].

8. Germinated brown rice

Germinated brown rice (GBR) is regarded as a whole food since only the outermost hull of the rice kernel is removed, thereby minimizing nutrient losses and preserving its inherent nutritional value. GBR is produced by soaking brown rice in water, typically at around 30 °C, for a defined duration to induce germination (Patil and Khan, 2011) ^[27].

According to Thomas *et al.* (2023) ^[34] germination in rice triggers metabolic processes that result in the production of bioactive substances like phenolics, antioxidants, and γ aminobutyric acid (GABA) shown in table 2. GABA protects diabetes, controls blood cholesterol, and stops leukemia and colon cancer cells from proliferating and migrating (Ngo and Vo, 2019) ^[24]. Texture and digestibility are improved, anti-nutritional factors are decreased, and mineral bioavailability is increased through controlled soaking and sprouting. Germination process enhances its nutritional value and antioxidant properties, transforming it into a high value functional food. The potential advantages of germinated brown rice as a functional diet for blood pressure control, brain function, and metabolic health are becoming more widely acknowledged (Thomas *et al.*, 2023) ^[34]

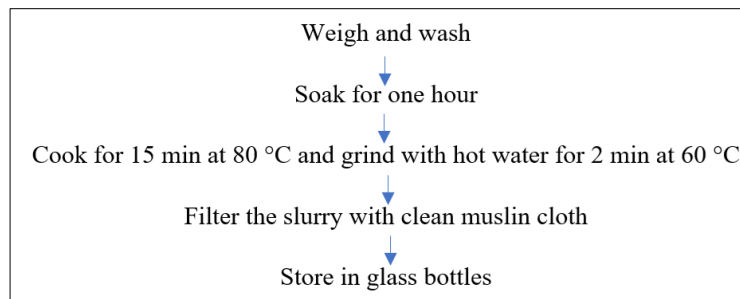
Table 2: GABA content of *Jyothi*, *Njavara*, and *Chitteni* rice varieties

Jyoti		Chitteni		Njavara	
Ungerminated (mg/kg)	Germinated (mg/kg)	Ungerminated (mg/kg)	Germinated (mg/kg)	Ungerminated (mg/kg)	Germinated (mg/kg)
19.18	116.89	26.67	127.97	26.63	130.29

8. Rice based beverages: rice milk

Soaking, heating, milling, enzymatic hydrolysis, filtration, and homogenisation are the processes used to create rice milk, a hypoallergenic plant based beverage. Enzymatic digestion and starch gelatinisation produce a stable colloidal

suspension and increase digestibility. For people who are lactose intolerant or vegan, rice milk is a good substitute. Its nutritional and functional qualities are further improved by fermentation and fortification techniques (Sreelakshmi *et al.*, 2024) ^[31].



Source: Sreelakshmi *et al.*, 2024 ^[31]

Fig 2: Optimised protocol for plain milk

Value added rice milk developed from the traditional *Suwendel* rice variety with clove, ginger, and garlic extracts shows improved functional properties and high consumer acceptability (Goonathilaka *et al.*, 2023) ^[10].

9. Rice flour

Rice flour is obtained by milling whole or polished rice and is a naturally gluten-free ingredient valued for its high starch content, bland flavour, and hypoallergenic nature. Depending on the processing method, rice flour may be produced as fine flour, steamed coarse flour, or roasted coarse flour, each exhibiting distinct functional properties such as water absorption capacity, pasting behaviour, and gelatinization characteristics, which determine their suitability for specific traditional and modern food applications. The starch in rice flour, predominantly composed of amylose and amylopectin, contributes to desirable textural attributes, including softness, cohesiveness, and gel formation (Tian *et al.*, 2023) ^[35].

From a technological perspective, rice flour exhibits excellent swelling power and digestibility, making it particularly suitable for bakery products, instant mixes, fortified foods, and extruded snacks. Pre-treatments such as soaking, parboiling, fermentation, or heat treatment can modify starch crystallinity, improve shelf stability, and enhance nutrient bioavailability. In traditional South Indian foods such as *puttu*, *idiyappam*, and *kozhukattai*, the particle size and degree of starch gelatinisation play a crucial role in determining product texture and sensory quality. Owing to its compatibility with composite formulations and its role as a carrier for functional ingredients, rice flour continues to gain importance in the development of gluten free and value added food products.

10. Rice bran based products

Rice bran is the nutrient dense outer layer of the rice grain removed during milling and represents a rich source of dietary fibre, high-quality proteins, essential fatty acids, γ -oryzanol, tocopherols, tocotrienols, B-complex vitamins, minerals, and phenolic antioxidants. The bioactive components of rice bran have been extensively associated with hypocholesterolemic, antioxidant, anti-inflammatory, and lipid metabolism-modulating effects, contributing to its growing recognition as a functional food ingredient (Gul *et al.*, 2015) ^[11].

Stabilized rice bran is widely incorporated into bakery products, breakfast cereals, extruded snacks, functional foods, and nutraceutical formulations due to its favourable water-holding capacity, emulsifying properties, and ability to enhance dietary fibre content. Rice bran oil, extracted from stabilized bran, is particularly valued for its balanced

fatty acid profile and high γ -oryzanol content, which collectively support cardiovascular health by improving lipid profiles and reducing oxidative stress. Advancements in processing and stabilization technologies have transformed rice bran from a milling by-product into a high-value ingredient with significant applications in health-oriented and value added food systems

11. Rice husk based products

The outer protective shell of the rice grain, a significant by-product of rice milling with little nutritional value but great industrial potential, is used in rice husk based goods. Because rice husk is fibrous and biodegradable, it has historically been used as fuel, animal bedding, and compost. Rice husk is currently valued as fuel briquettes, paper pulp, particle boards, activated carbon, and rice husk ash thanks to technical advancements. It is useful for cement, ceramics, insulation, and polymer composites due to its high silica concentration. Through these uses, rice husk is transformed from an agricultural waste into a valuable industrial resource that is both economically and environmentally beneficial (Kumar *et al.*, 2013) ^[17].

10. Rice based nutraceuticals

Bioactive substances found in rice bran, germ, and colored rice types are the source of rice based nutraceuticals. Among these are γ -oryzanol, phenolics, flavonoids, GABA, tocopherols, phytosterols, dietary fibre, and essential fatty acids, all of which have anti-inflammatory, lipid lowering, anti-diabetic, and cardioprotective properties. Commercial items for cardiovascular health, metabolic support, stress management, and plant based nutrition include rice bran oil capsules, gamma-oryzanol supplements, rice protein powders, rice extract capsules, and GABA capsules. Beyond supplements, rice derived bioactives for skin brightening, UV-protective, moisturizing, and anti-aging qualities have led to their growing use in cosmetic and personal care products such as creams, serums, shampoos, and powders (Dewan *et al.*, 2023) ^[6].

The *tridoshas* (humors) of *vata*, *pitta*, and *kapha*, whose imbalance in the human body causes a variety of ailments, can be relieved or subdued by rice, according to Ayurvedic treatises. In addition to correcting these imbalances, rice has the unique potential to enhance bodily components, eliminate harmful metabolism, control blood pressure, prevent skin conditions and early aging, and strengthen, renew, and energize the body (Ahuja *et al.*, 2008) ^[2]. In general, rice has changed from being a basic food to a valuable ingredient for cosmetic and nutraceutical uses. Overall, rice has evolved from a staple cereal into a multifunctional resource for nutraceutical, cosmeceutical,

and therapeutic applications, reflecting its expanding role in modern preventive and personalised nutrition

9. Challenges and future prospects

Optimising nutrient retention, sensory quality, and cost effectiveness of value-added rice products is still difficult despite tremendous progress. Future studies should concentrate on the creation of low glycemic rice products, the bioavailability of fortified nutrients, the sustainable use of byproducts, and consumer acceptability of functional rice foods. Sustainable innovation will depend on the integration of cutting edge processing technology with traditional expertise.

11. Conclusion

By adding value, rice has evolved from a basic staple to a multipurpose food supply that can meet contemporary dietary, technological, and economic needs. Rice based products today provide improved nutritional quality, convenience, and functional benefits because to processing methods such parboiling, fermentation, extrusion, germination, and fortification (Bhattacharya, 2011; Jin *et al.*, 2023) ^[4, 13].

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