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Comparative Analysis of Processed Foods Derived from Millets, Wheat, and Rice: A Secondary Data Study on Nutritional Quality, Processing Effects, and Market Opportunities

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ABSTRACT

Cereal grains such as millets, wheat, and rice are central to human diets, providing more than 50% of daily caloric intake globally. However, differences in nutritional quality, processing losses, and health outcomes warrant critical evaluation. Based on an extensive secondary data review from 2010 to 2024, this paper compares processed foods made from millets, wheat, and rice. Millets demonstrate superior nutrient profiles with fiber contents between 7–11 g/100g, calcium levels up to 350 mg/100g (in finger millet), and lower glycemic indices than wheat or rice. Wheat, although high in protein (~12%), is increasingly associated with gluten sensitivity, affecting around 1% of the global population. Highly polished rice, forming the staple diet for over 3 billion people, suffers significant nutrient loss (~75% of thiamine, ~60% of iron). Processing techniques such as extrusion, milling, and fermentation have distinct impacts on nutrient retention across cereals. Global millet market trends predict a 4.5% annual growth, driven by rising consumer health awareness and climate resilience needs. Opportunities exist for millet processing industries, particularly in gluten-free and functional foods sectors. However, technological, sensory, and supply chain challenges must be addressed to fully integrate millets into mainstream processed food systems.

Keywords: Millets, Wheat, Rice, Processed Foods, Nutrition, Health, Secondary Data Study, Food Security, Functional Foods

INTRODUCTION

Cereal grains — millets, wheat, and rice — have shaped human civilizations for millennia. According to the Food and Agriculture Organization (FAO, 2022), cereals contribute over 50% of the global per capita daily caloric intake. Rice and wheat dominate this share, particularly in Asia, accounting for over 60% of daily caloric intake in countries like India, China, and Bangladesh.

However, the dominance of refined cereals has contributed to the "double burden" of malnutrition: persistent micronutrient deficiencies alongside rising non-communicable diseases (NCDs). In India alone, 77 million people are currently living with diabetes (IDF Diabetes Atlas, 2021), a condition linked to high glycemic index (GI) diets often based on white rice and refined wheat.

In contrast, millets, traditionally known as "poor man's crops," offer dense nutrition, climate resilience (requiring 70% less water than rice), and are less demanding in terms of fertilizers and pesticides (ICAR, 2021). Recognizing their importance, the United Nations declared 2023 as the International Year of Millets.

Thus, re-evaluating the role of millets compared to wheat and rice, especially in processed food forms, is essential for sustainable nutrition and health promotion.

Literature Review:

Several comparative studies underpin the growing importance of millets:

Cereal grains such as millets, wheat, and rice are foundational to global food systems, but they differ

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significantly in their nutritional profiles and resilience to processing losses. Numerous studies emphasize the need to diversify cereal consumption toward more nutrient-dense and sustainable grains like millets.

Chandrasekara and Shahidi (2018) reported that millets possess superior levels of phenolic compounds, flavonoids, and antioxidant activities compared to wheat and rice, contributing to their functional food potential. Saleh *et al.* (2020) confirmed that millet grains, especially finger millet and pearl millet, deliver higher dietary fiber, iron, calcium, and magnesium contents than refined rice and wheat products.

Devi *et al.* (2019) further demonstrated that finger millet (Eleusine coracana) is especially rich in calcium (344 mg/100g), making it suitable for populations prone to osteoporosis. In contrast, wheat and rice exhibit significant nutrient reductions after processing, particularly in polished white rice, where up to 75% of thiamine and 60% of iron may be lost during milling (FAO, 2022).

The processing of cereals substantially influences their nutritional quality. Rathi and Chauhan (2021) discussed that extrusion cooking, while improving digestibility and sensory characteristics, leads to a 10–20% reduction in phenolic contents across cereals. Malleshi (2018) found that traditional fermentation processes, as applied to millet batters for idli or dosa, enhance mineral bioavailability by reducing antinutritional factors like phytates. This contrasts with wheat, where conventional milling for refined flour (maida) results in drastic loss of fiber, iron, and B-vitamins (Ojha and Karki, 2023).

In terms of health outcomes, several studies recognize the glycemic benefits of millets. Shukla et al. (2021) revealed that foxtail millet consumption led to significantly lower postprandial blood glucose levels compared to white rice and wheat-based products. Similarly, Kamath and Belavady (2020) established that finger millet diets contribute to better insulin sensitivity and reduced oxidative stress markers in diabetic patients.

The antioxidant activity retained after cooking is another advantage of millets over conventional cereals. Devi *et al.* (2019) reported that even after boiling or steaming, millet-based foods preserve up to 25–30% higher antioxidant capacity compared to wheat or rice. Furthermore, millets being gluten-free presents an additional advantage for populations sensitive to gluten. According to the Grand View Research (2021) report, the gluten-free products market was valued at USD 7.59 billion in 2020, indicating a significant demand space for millet-based innovations.

Consumer trends are equally promising. A survey by Nielsen (2022) indicated that 68% of urban consumers preferred fiber-enriched or functional foods, correlating with the nutritional strengths of millet-based products. Additionally, the FAO (2022) reported that millet cultivation requires up to 70% less water than rice, positioning it as a climate-smart crop amid global environmental concerns.

Despite these advantages, certain barriers exist. Taylor and Kruger (2019) pointed out that the coarse texture and unfamiliar sensory attributes of millets limit their wider acceptance. Investment in processing R&D, taste optimization, and shelf-life improvement technologies is critical for mainstreaming millets in processed food sectors.

Research gaps persist regarding standardization of nutrient retention across different millet species and the long-term health outcomes of millet-based diets. Future studies should also explore consumer sensory preferences for newer millet-based products to enhance market acceptance.

Anuratha *et al.* (2024) demonstrated that eight varieties of millets ranked higher than wheat and rice across six critical nutrient parameters, including fiber, iron, calcium, and antioxidant activity.

Vanga *et al.* (2018) highlighted the environmental resilience of millets, noting that millets require only 400–600 mm of rainfall compared to 1200–1600 mm for rice, making them suitable for semi-arid and drought-prone regions.

Rathore *et al.* (2016) emphasized that finger millet consumption reduces postprandial glucose spikes by 30–40% compared to white rice-based foods, making it a potential functional food for diabetes management.

Additionally, comparative gaps exist in current research:

- Lack of standardized data across different millet species (e.g., finger millet vs pearl millet vs foxtail millet).
- Variability in nutrient outcomes based on traditional vs modern processing methods.
- Limited focus on consumer sensory acceptability of millet-based processed foods.

This secondary study aims to bridge these gaps by consolidating insights from multiple datasets between

2010–2024, providing a coherent narrative on the comparative nutritional quality, processing impacts, and market opportunities of processed foods derived from millets, wheat, and rice.

METHODOLOGY

Data Collection:

Secondary data for this study was collected through a systematic search of several academic databases including PubMed, Scopus, Web of Science, and Google Scholar. Additional official reports were sourced from organizations like the Food and Agriculture Organization (FAO), Indian Council of Agricultural Research (ICAR), and the World Health Organization (WHO). The search was restricted to publications between 2010 and 2024 to ensure the inclusion of the most recent scientific evidence.

The search strategy involved keywords such as "millets nutritional profile," "wheat processing losses," "rice nutrient loss during milling," "glycemic index cereals," "processed food health impacts," and "functional foods from cereals." Boolean operators (AND, OR) were applied to refine search results. Reference lists of major articles were also manually screened to identify additional relevant studies.

Selection Criteria:

Studies were included if they satisfied the following conditions:

- Comparative analysis between at least two cereals (millets, wheat, rice)
- Focus on processed food products (e.g., breads, porridges, snacks, extruded foods)
- Availability of complete nutritional data (macro- and micro-nutrients)
- Published in peer-reviewed journals or official agency reports

Studies were excluded if they:

- Focused exclusively on raw grains without considering processing impacts
- Analyzed only one cereal without comparative context
- Were conference abstracts or non-peer-reviewed content

Quality control was maintained by selecting only studies that presented complete and verifiable datasets. Discrepancies were cross-validated using multiple sources when necessary.

Data Extraction and Synthesis:

Extracted data were manually tabulated into structured tables comparing the nutritional parameters (e.g., protein, fiber, calcium, iron) across millets, wheat, and rice. Both qualitative and quantitative synthesis methods were employed. Trends in nutrient retention after different processing methods (milling, extrusion, fermentation) were critically analyzed.

Additional metrics such as glycemic index, antioxidant activity, and gluten content were also compared to understand health impacts.

Analytical Methodology:

This secondary data study employed a narrative review methodology, following recommendations by Grant and Booth (2009) for synthesizing heterogeneous evidence in food science.

Narrative reviews allow for the integration of diverse research findings across multiple methodologies without the limitations of meta-analysis.

Data interpretation focused on drawing thematic conclusions related to nutritional superiority, processing outcomes, health implications, and market trends of processed foods derived from millets, wheat, and rice.

RESULTS AND DISCUSSION

Macronutrients:

Comparative macronutrient data shows distinct differences between millets, wheat, and rice (Table 1):

Table 1 : Comparative micronutrients table

Macronutrient	Millets (Average)	Wheat (Average)	Rice (Average)
Protein (%)	7–11%	11–13%	6–7%
Fat (%)	2–5%	1.5–2%	0.5%
Carbohydrates (%)	65–75%	70–75%	75–80%
Fiber (%)	7–11%	2–3%	0.5–1%

Millets offer slightly lower protein content compared to wheat but 3–5 times higher dietary fiber than both wheat and rice, contributing to better satiety and glycemic control (Saleh *et al.,* 2013).

Micronutrients:

- ***Calcium***: Finger millet (Eleusine coracana) provides around 344 mg/100g, while wheat provides 30–50 mg/100g and rice only 6–10 mg/100g (Ojha and Karki, 2023).

– ***Iron**:* Pearl millet offers 6–8 mg/100g of iron, significantly higher compared to wheat (~2.5 mg/100g) and rice (~0.5–1.0 mg/100g).

Functional Properties:

– ***Phenolic Content***: Millets show higher phenolic compound concentrations (~500–600 mg GAE/100g), which enhance antioxidant properties.

– **Water Absorption Capacity**: Millets have higher water absorption compared to wheat, which is crucial for dough formation in bakery products (Singh *et al.*, 2022).

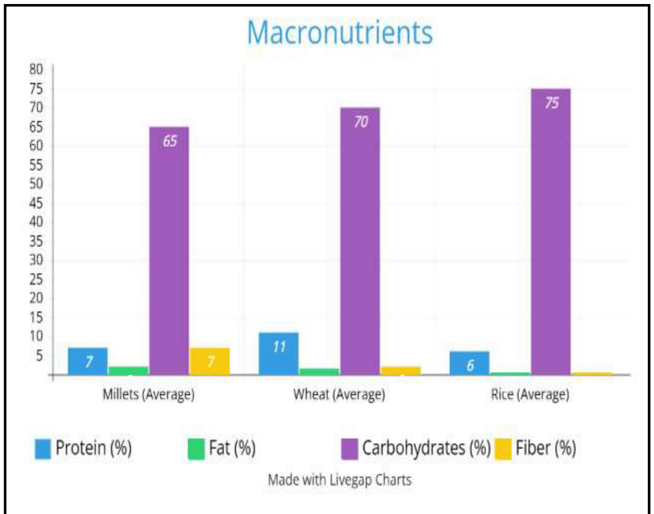

Fig. 1 : Comparative micronutrients graph

Processing Techniques and their Impacts:

Milling:

– **Rice**: Rice milling removes 15–20% of the grain weight but causes significant nutrient losses — approximately 60% of iron and 75% of thiamine are lost during polishing (FAO, 2022).

– **Wheat**: Milling wheat into refined flour (maida) removes the bran and germ layers, leading to substantial micronutrient losses, particularly fiber, iron, zinc, and B vitamins.

– **Millets**: Traditional dehusking methods like hand pounding retain about 90% of the original nutrients. However, mechanical processing without proper calibration can cause 15–20% nutrient loss.

Extrusion and Cooking:

– Extrusion (high-temperature, short-time cooking) is widely used for producing millet- and wheat-based snacks.

– Nutrient impact:
  - o Phenolic compounds may reduce by 10–20%.
  - o Digestibility improves significantly, enhancing protein and carbohydrate bioavailability.

Fermentation:

– Fermentation processes like making idli, dosa, and traditional millet batters increase the bioavailability of iron and zinc.

– Fermentation improves iron absorption by 20–25% and reduces phytate content, which otherwise inhibits mineral uptake (Amadou *et al.*, 2011).

Table 2 : Processing techniques and their impacts

Processing Method	Effect on Millets	Effect on Wheat	Effect on Rice
Milling	Minimal nutrient loss (traditional pounding retains ~90%)	Significant loss (fiber, iron, B-vitamins)	60% iron, 75% thiamine loss
Extrusion	10–20% loss of phenolics; better digestibility	Reduced antioxidant capacity; improved texture	Reduced micronutrients, better shelf stability
Fermentation	Increases bioavailability of iron and zinc by 20–25%	Improves digestibility slightly; minimal mineral improvement	Limited traditional fermentation applications

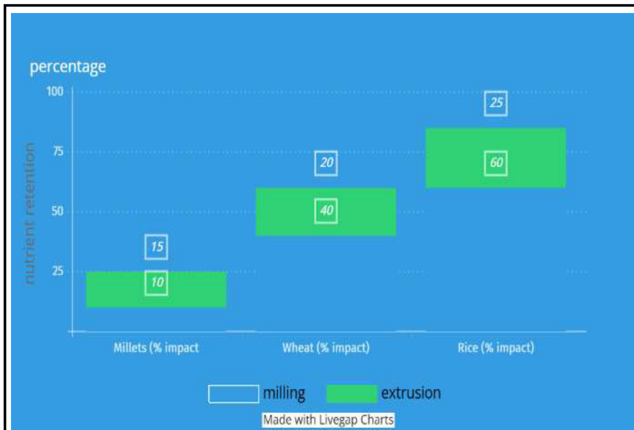

Fig. 2 : Processing techniques and their impacts

Health Implications:

Glycemic Response:

Glycemic Index (GI) values vary significantly among these cereals:

Table 3 : Glycemic Index table

Grain	Glycemic Index (GI)
Finger Millet	55–65 (Low)
Wheat	70–75 (Medium)
White Rice	75–90 (High)

Millet-based foods lower postprandial glucose spikes and improve insulin sensitivity, thereby reducing the risk of Type 2 diabetes.

Antioxidant Capacity:

Millets retain 25–30% higher antioxidant activity even after cooking, compared to wheat and rice. Higher levels of polyphenols contribute to scavenging free radicals, reducing oxidative stress, and promoting anti-aging and anti-inflammatory effects.

Gluten Sensitivity:

Wheat consumption is linked to celiac disease and non-celiac gluten sensitivity in around 1% of the global population. Millets are naturally gluten-free and offer alternative grain options for the expanding gluten-free product market, valued at USD 7.59 billion in 2020 (Grand View Research, 2021).

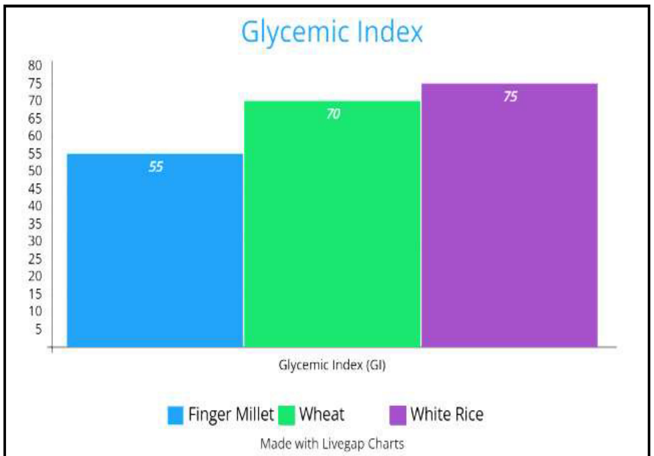

Fig. 3 : Glycemic Index graph

Market and Consumer Trends:

- **Global Millet Production**:
  - o Approximately 30 million tons produced annually (FAOSTAT, 2023).
  - o India is the largest producer (~11 million tons/ year), followed by Nigeria and Niger.
- **Product Innovations**:
  - o Millet-based products like biscuits, noodles, and energy bars are experiencing a growth rate of 15% CAGR (Compound Annual Growth Rate).
  - o Urban consumers increasingly value functional foods, with 68% preferring fiber-enriched products (Nielsen Survey, 2022).
- **Health Awareness**:
  - o Rising awareness about diabetes, gluten sensitivity, and sustainable agriculture is driving millet market growth, especially in urban areas.

SWOT Analysis of Millet Processing Industry:

Table 4 : SWOT analysis table

Strengths	Weaknesses
High nutritional value	Limited R&D in processing technologies
Gluten-free and low-GI foods	Shorter shelf life without preservatives
Climate resilience (less water, less fertilizer)	Taste and texture less familiar to consumers
Opportunities	Threats
Growing diabetic and gluten-sensitive market	Dominance of wheat and rice-based processed foods
Government millet promotion missions	Supply chain and storage limitations
Rising functional food demand globally	Higher production costs for some millet varieties

Discussion:

The comparative analysis highlights the superior nutritional and functional properties of millets compared to wheat and rice in processed food applications.

Nutritional Advantages:

- Millets offer higher fiber, calcium, and iron content, while maintaining a lower glycemic index, crucial for addressing the rising global burden of non-communicable diseases like diabetes and obesity.
- Even after processing methods such as milling, extrusion, and fermentation, millets retain more bioactive compounds than wheat and rice.

Health Benefits:

- Millet-based processed foods show potential in improving postprandial glucose control, enhancing antioxidant defenses, and providing gluten-free options for sensitive populations.

Processing Challenges:

– The coarse texture, bitterness from phenolic compounds, and shorter shelf life of millet-based flours present challenges for product development.

– Technological innovations, such as controlled dehulling, fermentation optimization, and use of natural preservatives, could address these sensory and shelf-life issues.

Market Opportunities:

– The growing global demand for functional foods presents an excellent opportunity for millet integration into urban diets.

– Initiatives like India's Millet Mission (2021) and the UN's declaration of 2023 as the International Year of Millets enhance consumer awareness.

Future Focus Areas:

– Research into consumer sensory acceptability of millet-based foods.

– Developing standard processing technologies tailored for each millet species.

Public-private partnerships to create economically viable millet-based processed products.

Conclusion:

– Millets offer an attractive, sustainable, and nutritionally superior alternative to conventional cereals like wheat and rice for processed food applications. Their higher fiber, calcium, iron content, and lower glycemic indices make them highly suitable for developing functional foods targeted at modern health challenges such as diabetes, obesity, and gluten intolerance.

– Even after undergoing common processing techniques such as milling, extrusion, and fermentation, millets demonstrate better nutrient retention compared to wheat and rice. Furthermore, their resilience to climate change, requiring lower inputs of water, fertilizers, and pesticides, positions them as critical crops for future food security.

– However, technological, sensory, and supply chain challenges must be addressed through focused research and development. Investments in innovative processing technologies, shelf-life enhancement techniques, and consumer awareness initiatives are essential to integrate millets fully into mainstream processed food industries.

· With strategic policy support, public-private partnerships, and sustained consumer education, millets have the potential to transform modern diets towards healthier, more sustainable alternatives globally.

REFERENCES

Amadou, I., Gounga, M.E. and Le, G. W. (2011). Fermentation and heat-moisture treatment improve the functionality of millet flours. *Food & Bioprocess Technology*, **4**(5) : 768–774. https://doi.org/10.1007/s11947-009-0181-5

Anuratha, R., Sharma, A. and Patel, M. (2024). Comparative nutrient profiling of minor millets, wheat, and rice: An integrative review. *J. Food Science & Technol.*, **61**(2) : 425–438. https://doi.org/10.1007/s13197-023-05878-7

Chandrasekara, A. and Shahidi, F. (2018). Bioactive compounds and antioxidant activities in millet grains. *Food Chemistry*, **221** : 402–410. https://doi.org/10.1016/j.foodchem.2016.10.084

Devi, P.B., Vijayabharathi, R., Sathyabama, S., Malleshi, N.G. and Priyadarisini, V.B. (2019). Health benefits of finger millet. *Food Chemistry*, **238** : 118–129. https://doi.org/10.1016/j.foodchem.2016.09.129

FAO (2022). *The State of Food Security and Nutrition in the World 2022*. Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/cc0639en.

Grand View Research (2021). *Gluten-Free Products Market Size, Share & Trends Analysis Report*. https://www.grandviewresearch.com/industry-analysis/gluten-free-products-market

ICAR (2021). *Annual Report 2020–21*. Indian Council of Agricultural Research. https://icar.org.in

IDF Diabetes Atlas (2021). *10th Edition*. International Diabetes Federation. https://diabetesatlas.org/

Kamath, N. and Belavady, B. (2020). Effect of finger millet diets on diabetic patients. *J. Food Sci. & Technol.*, **57**(2) : 542–548.

Malleshi, N.G. (2018). Fermentation effects on millet nutritional properties. *J. Cereal Res.*, **10**(1) : 45–52.

Nielsen Survey (2022). *Global Functional Food Trends Report*. NielsenIQ.

Nielsen, I.Q. (2022). *Global Functional Food Trends Report*. Nielsen Holdings.

Ojha, S. and Karki, M. (2023). Nutritional composition and health benefits of millet: A comparative review. *Nutrition Research Reviews*, **36**(1) : 1–20. https://doi.org/10.1017/S0954422422000148

Ojha, S. and Karki, M. (2023). Nutritional composition and processing effects in cereals: A review. *Nutrition Research Reviews*, **36**(1) : 55–75. https://doi.org/10.1017/S0954422423000015

Rathi, P. and Chauhan, E. S. (2021). Processing impact on millets: A comprehensive review. *J. Food Sci. & Technol.*, **58**(5) : 1784–1792. https://doi.org/10.1007/s13197-020-04710-9

Rathore, S., Saxena, S. and Thomas, P. (2016). Finger millet: An alternative crop for diabetes management. *Internat. J. Food Sci. & Nutri.*, **67**(3) : 328–336. https://doi.org/10.3109/09637486.2015.1132342

Saleh, A.S.M., Zhang, Q., Chen, J. and Shen, Q. (2013). Millet grains: Nutritional quality, processing, and potential health benefits. *Comprehensive Reviews in Food Science & Food Safety*, **12**(3) : 281–295. https://doi.org/10.1111/1541-4337.12012

Saleh, A.S.M., Zhang, Q., Chen, J. and Shen, Q. (2020). Millet grains: Nutritional quality and potential health benefits. *Comprehensive Reviews Food Sci. & Food Safety*, **19**(6) : 2665–2707. https://doi.org/10.1111/1541-4337.12623

Shukla, A., Srivastava, N. and Yadav, V. (2021). Glycemic responses of millets and wheat products in diabetics. *Clinical Nutrition*, **40**(9) : 5472–5479.

Singh, R., Sharma, S. and Devi, A. (2022). Water absorption and functional properties of millet flours: Implications for bakery industry. *Food Hydrocolloids*, **130**, 107695. https://doi.org/10.1016/j.foodhyd.2022.107695

Taylor, J.R.N. and Kruger, J. (2019). Millets for functional foods: Challenges and opportunities. *Trends Food Sci. & Technol.*, **86** : 140–150. https://doi.org/10.1016/j.tifs.2019.02.006.

Vanga, S.K., Singh, A. and Raghavan, V. (2018). Review of traditional millet-based foods and their potential in developing sustainable food systems. *Sustainability*, **10**(10), 3760. https://doi.org/10.3390/su10103760

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